*Hupfer, M. & A. Kleeberg (2007): State and pollution of freshwater ecosystems - Warning signals of a changing environment. In: Lozán, J. L., H. Grassl, P. Hupfer, L.Menzel & C.-D. Schönwiese. Global Change: Enough water for all? Wissenschaftliche Auswertungen, Hamburg. 384 S. Online: www.klima-warnsignale.uni-hamburg.de*

# 2.9 State and pollution of freshwater ecosystems – Warning signals of a changing environment

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***SUMMARY:*** Inland waters are exposed to numerous natural and anthropogenic stress factors. Pollution by nutrients, harmful substances, and pathogens, the destruction of pristine habitats due to water way construction, changes in climate and invasion by non-indigenous species can lead to changes in biodiversity, a lowering of the self-cleaning capacity, and to serious restrictions in use. Major problems are eutrophication, atmospheric and geogenic acidification, salinisation and contamination by a huge number of xenobiotics. Especially in eutrophic waters an impairment of aquatic organisms can also be induced by algogenic substances. Some substances influence the 'critical equilibrium' of the sexual hormones of vertebrates, so that entire populations are threatened by the disturbance of reproduction. Precautionary water conservation, use of measures to reduce external loading sources and the application of ecotechnologies may reduce or reverse the impairments of freshwater ecosystems.

The characteristics of inland waters are sensitive indicators of environmental changes, since they reflect the state of the terrestrial surrounding, of the groundwater and of the atmosphere. In particular in industrial and agricultural landscapes waters are exposed to an intensive impact of utilisation which exceeds their pristine capacity thresholds and changes their state. Along with the strongly rising population growth, the intensive transformation of natural and cultural landscapes and the industrial development, the burden of inland waters have been experiencing a new dimension in the last two centuries.

*Fig. 2.9-1* shows the historical sequence of the appearance of different quality problems. The burden of waters with inorganic and organic trace matter, acidification, salinisation and eutrophication are in a similar way important for standing waters as for flowing waters. The type of water, the water retention time as well as the size, structure and land use within the catchment are determinants of the response to changes in loading. Since natural and anthropogenic burdens affect the ecological processes in a complex way, not all changes in rivers and lakes can be interpreted as warning signals of an environmental deterioration or climate change.

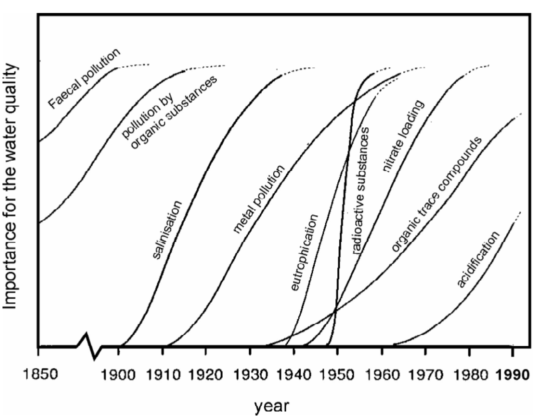


***Fig. 2.9-1:*** Temporal occurrence of supra-regional influences on the water quality in the industrialised world from 1850 to the present (modified from CHAPMAN 1992).

However, limnology has developed more and more detailed, trans-disciplinary methods to identify actual and historical stress reactions from the molecular to the population level to the ecosystem. This article gives an overview on known water burdens. Based on selected problems, it furthermore demonstrates how such signals look like and how they can be interpreted.

## Water quality problems

In earlier times, hygiene centred around the development of waters and the disposal of waste materials. Nowadays, in addition to these problems, global-acting factors represent a detrimental potential. Without considering possible ecological consequences rivers were straightened and regulated, impoundments built, wetlands dewatered, huge water masses were extracted from standing and flowing waters as well as from groundwater and discharged back – often polluted – at different locations. A notable problem at this juncture constitutes the water consumption by agriculture and industry as well as the water discharges from municipal and industrial effluents. World-wide only 5% of all waste waters undergo a purification process. The quality of water is closely related to its availability, so that in regions with water deficiency multiple usage of the water is coupled to correspondingly high burdens. Different stressors (*Table 2.9-1*) can directly happen as primary or secondary effects.

Globally, eutrophication, acidification and salinisation are probably the most common problems of waters that lead to the most serious water use restrictions (see *Table 2.9-1*).

Eutrophication is the increasing intensity of primary production (trophy) of a water body, which is caused by an enhanced availability of nutrients. Due to the discharge of not sufficiently purified municipal waste water or due to

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***Table 2.9-1:*** Stressors for freshwater systems classified according to anthropogenic (A) and natural (N) causes as well as selected primary and secondary effects.

| ***Stressor type*** | ***Disturbing factor*** | | ***Causes (examples)*** | ***Water quality problem*** | ***Effects in freshwater ecosystems***<br>***Primary*** | ***Secondary*** |
|---|---|---|---|---|---|---|
| Chemical | Nutrients | A<br><br>N | Discharge of wastewater<br>Input from agricultural land use<br>Weathering, leaves | Eutrophication | Mass development of algae and macrophytes | Oxygen depletion<br>Toxic cyanobacteria<br>Increase of pH<br>Reed disease |
| | Organic material | A<br>N | Wastewater cellulose industry<br>Leaves | Saprobisation | Oxygen depletion | Fish kill |
| | Salts | A<br><br>N | Potash mining<br>Irrigation<br>Tide influenced salt gradients | Salinisation | Increase of salinity | Changes of species composition -<br>Decreased diversity |
| | Acids | A<br><br>N | $NO_x$, $SO_2$ from power stations<br>Pyrite oxidation in mining areas<br>Volcanism | Acidification | Decrease of pH | Increased mobility of toxic substances<br>Decreased diversity |
| | Suspended solids | A<br><br>N | Soil erosion due to deforestation and agriculture<br>Spring floods | Turbidity | Changes of water bottom | Reduced oxygen supply of sediments<br>Damage of fishes (gills) |
| | Harmful substances[1] | A<br><br><br><br><br><br><br><br>N | Organic and inorganic waste material and intermediates of industrial production (e.g., oil, tensides, heavy metals)<br>Treatment agents for plants and animals (e.g., pesticides, medicaments)<br>Waste water municipal<br>Biogenetic agents (e.g., cyanotoxins) | Contamination | Poisoning<br>Allergic reaction<br>Disturbance of reproduction | Decreased diversity |
| Physical | Thermic stress | A<br><br>N | Input of cooling waters<br>Climate change by $CO_2$ increase<br>Fair weather periods | Warming | Intensified decom-position processes | Oxygen depletion |
| | Radionuclides | A | Explosions of nuclear weapons | Radiation burden | Mutagenic effects | Decreased diversity |
| | UV-radiation | A | Destruction of ozone layer | | | |
| | Water flow conditions | A | Construction of dams<br><br>Upgrading of running waters | Manifold | Changes of water residence time<br>Destruction of natural habitats | Increased sedimentation and higher primary production |
| Biological | Parasites | N | | | Stress for organisms | Decreased fitness of population |
| | Non-indigenous species | A | Shipping lanes | Manifold | Displacement indi-genous species | Changed diversity |
| | Pathogenic bacteria | A | Waste water | Pathogens | Disease of humans and animals | |

[1] Approximately 5.000 to 10,000 of the roughly 50,000 chemical compounds, brought in by humans in the nature (xenobiotics) are toxically relevant .

drainage from agriculturally fertilised areas the extent of natural eutrophication processes has been extremely intensified since the mid of last century. This cultural eutrophication can clearly separated from the natural maturation of lakes which occurred over time spans of thousand of years. The increased algal and macrophyte growth as related to eutrophication leads to undesired and complex secondary effects in the structure and function of aquatic ecosystems. Despite the enhancement of productivity the fishery usage of those waters is restricted since high-value fishes are displaced by less valuable fish species, and even fish kill can occur.

Globally, 30 to 40% of all standing waters exhibit an unnaturally high trophy. In Germany, the levels of trophy show distinct regional differences. In the federal states Bavaria and Baden-Württemberg about less than 50% of the lakes are eutrophic or hypertrophic, whereas in Brandenburg and Mecklenburg-Western Pomerania 90% of about 1,500 lakes are classified as eutrophic or highly eutrophic.

This has natural causes since the pre-industrial, pristine state of the numerous shallow lakes of this region is eutrophic, but is enhanced by the previous and current loading from agriculture. Also running waters are affected by eutrophication. At a sufficiently long residence time, in particular in impoundments, algal mass developments are possible which can negatively influence the oxygen budget in the middle and downstream reaches of rivers. Hitherto predictions state that global warming will favour the turbid phytoplankton-dominated system and the cyanobacteria dominance (e.g. Mooij et al. 2005).

The emission of sulphur and nitrogen containing gases leads to acid rain so that in areas deficient in lime, i.e. with a low buffer capacity, acidification of waters and soils occurs in a larger distance from the location of the emission. The affected waters are often clear and exhibit an apparently good quality. However, the decrease in pH causes extreme changes in the biocoenoses. Fishes and other higher organisms can neither survive nor reproduce. A further cause is the increased release of toxic metal ions (in particular aluminium, copper, cadmium, zinc and lead) from soils and sediments. Particularly affected by acidification are Scandinavia and the north-east of northern America. For example, 4,000 lakes in Norway and Sweden are strongly affected by acidification. In Germany, the acidification via atmospheric deposition constitutes a problem only in certain regions such as the »Bavarian Forest« or the »Black Forest«. An extreme acidification of waters can occur as a result of the extraction of natural resources. In Germany, in the medium-term approximately 500 lakes are going back to lignite mining. The majority of these lakes is severely acidified in their initial developing phase since lignite extraction produces acidity by the oxidisation of sulphur-containing minerals (pyrite, marcasite).

Declining groundwater levels, enhanced nitrate concentrations in the groundwater, the artificial drain of wetlands or long-lasting droughts in soils due to global warming can also enforce the oxidation of reduced sulphur compounds whereby the acid input into surface waters will be enhanced. Beside anthropogenic sources these oxidation processes can explain the increase in sulphate concentration in surface waters.

While globally the sulphate concentration in surface waters increased by a factor of 1.7 within the last 100 years, it increased by a factor of 4.3 to 5.7 in a couple of lakes in the federal state of Brandenburg (Germany) during 60 years (Kleeberg 2003). Due to an enhanced sulphate supply the importance of sulphate reduction in the sediment increases. The formation of insoluble iron sulphide can disrupt the iron-phosphorus cycle which results in an excessive mobilisation of phosphorus. Moreover, in waters poor in iron an accumulation of free hydrogen sulphide occurs more frequently above toxic levels in the sediment and in the anaerobic deep water layers.

The pollution by harmful substances can be caused by a broad variety of organic and inorganic materials, including toxic metals. Beside the release from ore smelting and metal industry, their use in pesticides is an important anthropogenic source. For example, pesticides, organic tensides, pharmaceutical and mineral oils belong to organic pollutants. Metals and organic compounds, such as polychlorinated biphenyles (PCB) that are accumulated in sediments and in food chains can increase to toxic concentrations.

The salinisation leads to radical changes in the bioceonoses, since freshwater organisms have typically only a small tolerance for enhanced salt concentrations. Causes of salinisation are changes in the hydrological regime e.g. due to enhanced evaporation or discharge of salt-rich water from mining, oil production and agricultural utilisation (see Chapter 2.7). As the water quality in most of the inland waters in Europe and northern America improved in the last decades, the burden of inland waters has been further increasing in most of the developing and newly industrialising countries.

The changes caused by anthropogenic burdens can be irreversible or reversible. Permanent changes in hydrology and the matter budget are caused by e.g. impoundments in rivers. Upstream of a dam the water retention time prolonged, so that this section becomes similar to a lake. This leads consequently to an accumulation of fine sediments, to oxygen depletion in the near bottom water and to enhanced phytoplankton growth.

Concurrently the dam acts as a barrier for organisms (e.g., hindered fish climb up) and separates originally connected habitats. In contrast, after the reduction of excessive nutrient inputs the enhanced primary production of a lake can in principle reach the former level before the loading. However, there exists no linear relationship between the nutrient concentration and the phytoplankton biomass since also other factors and feedback mechanisms (multiple control) determine the state of waters. Lakes often show a delayed response following the reduction of nutrient inputs and is typical particularly for many shallow lakes. Many of primarily macrophyte-dominated clear water lakes were transferred to a phytoplankton-rich turbid lake due to increasing nutrient concentrations. To restore the desired pristine state, however, nutrient concentrations have to fall below considerably lower threshold values as before and during the eutrophication process that led to the disappearance of macrophytes. Depending on the initial state the response behaviour differs compared to a changed nutrient loading (hysteresis effect), since different mechanisms cause a stabilisation of the corresponding state. Standing and running waters differ considerably in their reactions to material burden and the possibility of rehabilitation. The susceptibility to batch-wise burden of lakes is lower than for rivers. In contrast, the regeneration of running waters after the cessation of a pollution source is much faster than that of lakes because of the short water renewal time. Threats result not only from the cultivation and usage of waters and their respective catchments but can also have their origin in further-distant areas. For example, the atmosphere acts as transportation for emissions or certain physical burden factors, e.g. UV radiation or temperature. Relevant climatic factors which will alter freshwater ecosystems are described in detail in a review by MOOIJ et al. (2005).

## Warning signals in freshwater ecosystems

In the following the effects of different stress factors on freshwater ecosystems are described and interpreted using three European research issues. Both the appearance of new species and chemical substances in terms of natural materials and contaminants can act as catalysts of stress reactions.

### Non-indigenoust animal and plant species

World-wide, a globalisation of flora and fauna occurs as the most outstanding change in biodiversity beside the extinction of species. Freshwater biodiversity is threatened by several mechanisms, of which the introduction of non-indigenous species and habitat alteration are the two most important. Exotic species act at various levels of organisation of macroinvertebrate communities, and are involved in different processes mediating their impacts on biodiversity, such as habitat modification or negative interactions with autochthonous fauna (DEVIN et al. 2005). The passive spreading of organisms (= diversion) can be facilitated by wind, water, animals and humans. In particular, along with the international networking of traffic and trade, natural spreading barriers as rivers, mountains and oceans are easier bridged over. Also global warming can increase the invasion potential of freshwater communities by imported species, as tested on alpine lakes (HOLZAPFEL & VINEBROOKE 2005).

Neobiota are non-indigenous organisms which have been reached, intended or unmeant by direct or indirect involvement of man, a previously not accessible area after 1492, the year of discovery of America. Neobiota are represented by animals (neozoa), plants (neophyta) and fungi species (neophyceta) which have been established potentially new populations or with at least three successful generations in the field.

The infiltration of aquatic neozoa in new habitats proceeds mainly by canalisation, by expansion via rivers as well as via irrigation and dewatering systems. Ships contribute considerably to the diversion of animals by their ballast water, fouling on their non-indigenous hulks or by their transportation charges. Prospects of utilisation, animal husbandry, aquaristic and fishery change likewise the indigenous fauna. The colonisation with neozoa partially occurs completely unnoticed – at different places there are already almost only exclusively non-indigenous species. There are many species, which were primary distributed by man. However, later they autonomously distributed themselves as e.g., the Zebra Mussel (*Dreissena polymorpha*). This species originates from the regions of the Caspian Sea and the Aral Sea and has been spreading throughout Europe for two centuries. Zebra mussel invasion into North American waters has resulted in profound ecological disturbances and large monetary losses (MAY et al. 2006).

Through the diversion of the North American crayfish (e.g., Spinycheek crayfish *Orconectes limosus*) to Germany the indigenous species were endangered not only through competition for food and habitat but also by acromycosis. The crawfish pest, which emerged first-time 1860 in Italy, kills the European crayfish species almost completely. Since the North American crayfish species do not fall ill, but can carry the disease, the crawfish pest has been distributed throughout Europe and Russia. The indigenous noble crayfish (European crayfish or Broad-fingered crayfish *Astacus astacus*) is thus strongly endangered.

Using the indigenous fish species of Germany one can demonstrate that the naturalisation of neozoa was purposefully carried out by man. So the »diversion« of a few – now regarded as indigenous species – had pure economic reasons. The Rainbow trout (*Oncorhynchus mykiss*), which originates from North America, came first-time around 1880 to Europe, since it was faster-growing and better-adapting than the Brown trout (*Salmo trutta fario*) to changing circumstances (pollutions, construction, straightening etc.). Two originally in China domiciled fish species, the Grass carp (*Ctenopharyngodon idella*) as well as the Silver carp (*Hypophthalmichthys molitrix*) were introduced from the 1960s into eutrophied waters since their herbivorous nutrition was hoped to serve as abatement of weeds and algal blooms.

The best known neophytes in European inland waters (since 1835) came from North America, the American waterweed (*Elodea canadensis*) and the Nuttall's waterweed (*E. nutallii*). Since the fast-growing plants soon hindered the inland navigation and fishery they were given the name »water pest«.

*Cylindrospermopsis raciborskii*, a freshwater cyanobacterium of tropical origin, is not only increasingly found in (sub)tropical warm waters (> 25 °C) (MOLICA et al. 2005), but also in temperate regions. This species is of particular concern from a water quality perspective due to its known ability to produce a potent hepatotoxic alkaloid cylindrospermopsin (SAKER et al. 2003), and the neurotoxic PSP toxine (paralytic shellfish poisoning) (FASTNER et al. 2003). Cylindrospermopsin has been implicated in outbreaks of human sickness and cattle mortality resulting from consumption of water affected by *C. raciborskii* which was first reported almost 20 years ago from Palm Island, northern Queensland, Australia (GRIFFITHS & SAKER 2003). Currently this species appears to be spreading throughout temperate waters world-wide. It was reported for the first time in the 1990ies in NE Germany (FASTNER et al. 2003), in 1994 in France (BRIAND et al. 2002), in 2003 in New Zealand (RYAN & HAMILTON 2003), in 2004 in Canada, and at present spreading throughout temperate North America (HAMILTON et al. 2005). The encroachment of *Cylindrospermopsis* into the northern hemisphere was surprising because of its higher temperature demand. The immigrated strain, however, could probably adapt genetically to 5 °C lower temperatures. In NE Germany, until now C. raciborskii (at maximum biomass percentage of 20 %) could not accomplish adverse indigenous blue green algae species. However, a warming trend linked to climate change is likely to accelerate the spread and abundance of this potentially toxic species (HAMILTON et al. 2005).

By competition, grazing pressure, acting as disease or parasite vectors or also by hybridisation and cross breeding of extrinsic genetical material Neobiota can constitute a harassment of the original biological diversity, can influence the water quality and restrict the utilisation. However, not every alien species is »invasive« (fast-spreading, anxious). Many species are introduced, disappear soon after its appearance or intersperse into the ecosystem.

Some species intersperse apparently into the ecosystem in order to then disperse strongly within shortest periods of time. However, also in the future non-resident species will establish, which pollutant-tolerant, thermo and halophilic properties will have an advantage over species with a lower tolerance.

However, the scientific discussion is still controversial. Inshore waters of European coasts have accumulated a high share of non-indigenous species, where a changeable palaeoenvironment has caused low diversity in indigenous biota (REISE et al. 2006). Also strongly transformed modern coastal ecosystems seem to assimilate whatever species have been introduced and tolerate the physical regime. REISE et al. (2006) found no evidence that non-native species generally impair biodiversity and ecosystem functioning. However, the control of species that endanger indigenous species and habitats is necessary to protect autochthonous communities.

### *Cyanotoxins*

Generally, the discoloration, low secchi depth transparencies, flavourful deteriorations of the water, dissolved oxygen depletion and accumulation of toxic metabolism product, e.g. hydrogen sulphide, in deep waters and an enhanced occurrence of cyanobacteria (blue green algae) are regarded as warning signals of eutrophication. Increasingly, harmful algal blooms are being reported world-wide due to several factors, primarily eutrophication, climate change and more scientific monitoring (e.g., CARMICHAEL 2001). Cyanobacteria toxin poisonings occur in fresh and brackish waters throughout the world. Organisms responsible include 40 genera (CARMICHAEL 2001). Since cyanobacteria toxin poisonings have a risk to human health a few examples are given in the following.

Because of the ability to regulate their buoyancy by gas vacuoles and hence to regulate their light supply some cyanobacterial genera form dense anaesthetic »algal carpets« whereby the utilisation of the respective water bodies are considerably restricted. In addition, cyanobacteria may produce ecotoxicological effects. Already in 1878 the Australian scientist George Francis published the first article about acute poisoning of different domestic animals by cyanobacteria. Meanwhile the perishing of fishes, alligators and flamingos are attributed to cyanobacterial blooms. Also for human beings symptoms of diseases such as skin and eye inflammation, gastric and intestinal diseases, headaches as well as ague due to contact with cyanobacteria in drinking or bathing water are documented. The deleterious impacts of cyanobacteria are based upon the formation of toxic matter (hepato- and neurotoxins) out of different classes of substances (CHORUS 2001).

This way e.g., *Aphanizomenon flos aquae* can produce so-called anatoxins and saxitoxins which have a similar effect as the warfare agents Tabune and Sarine. They disable the nervous system of man and animal. Other cyanotoxines such as cylindrospermopsin, microcystins or nodularin exert an impact almost exclusively on the liver cells where they prevent the proteine phosphatase activity.

The microcystins, termed after the most common genus *Microcystis*, are cylindrical hepatotoxines which consist of a ring of seven amino acids. Similar to the Death cap mushroom (*Amanita phalloides*) the liver cells dissolve within a few hours after poisoning. The cynotoxins remain for the most part in the algal cells and will be released into the water only at lysis.

Aquatic organisms have developed strategies to protect themselves against this stress. In water plants an activation of detoxifying enzymes has been observed under the influence of cyanotoxins, which turn the toxin more water soluble by coupling with cell molecules, which facilitates its exudation or decomposition (*Pflugmacher* 2004).

For water fleas (*Daphnia* spec.) it seems that more resistant genotypes prevail. To prove this, 40 year old eggs of these small crustaceans have been isolated and revived from the sediment of Lake Constance, which can be assigned to the period before, during and after eutrophication (Hairston et al. 1999). The growth in the presence of microcystin was tested under laboratory conditions. During eutrophication the sensitive genotypes disappeared and the resistant ones became dominant in the lake. It reveals how aquatic organisms can adapt to changed environmental conditions by means of a »quick evolution«. Why the cyanobacteria produce the extremely effective and dangerous toxins is so far not known. It is assumed that theses toxins are a matter of a »bioweapon« – but it is not clear so far. As yet it was assumed that one can circumvent mass developments of cyanobacteria by a reduction of nutrient loading.

Along with the construction of the ring canalisation in the 1980s the nutrient loading and productivity of Lake Ammersee, Bavaria, Germany, reduced. However, due to the deeper penetration of light an ideal ecological niche resulted for the »Burgunder blood algae« *Planktothrix rubescens*. This species was already described in 1825 after a mass development in Lake Murtensee, Switzerland, where it coloured the water blood-red. One believed that the colour resulted from the upwelling blood of the Burgundies (former tribe) killed here in 1476. Due to its special cell construction this species is able to survive also in deeper water layers between 7 and 15 m. At the same time a decline in the population of the European Whitefish (*Coregonus lavaretus*) of more than 90% was noticed which led to severe fishery problems. The Whitefish showed a deviant behaviour. They evaded into deeper layers with barely food and oxygen. Much is indicated to the fact that this behaviour is related to the occurrence of the toxic cyanobacteria (Ernst et al. 2001).

For acute threats by cyanotoxines recommendations of the WHO exist in respect to the threshold of drinking water (see Chorus 2001). For bathing purposes, health warnings (freshwaters warning notices) range from urgent measures to prohibition of bathing. The probability of mass developments of cyanobacteria decreases generally along with the reduction of the growth-limiting phosphorus concentration.

### Hormone-active substances

There are a multitude of »stress signals« in the aquatic environment which cannot be explained by the common toxic effects of environmental relevant harmful substances. For more than 40 years ago it was found that the American Bald Eagle (*Haliaeetus leucocephalus*) was threatened with extinction since its eggshells became increasingly thinner and more fragile, and this coincided with a dramatically decreasing number of hatched offspring.

In another case the population of alligators in Lake Apopka, Florida, USA, decreased despite of protection measures. An abnormal high mortality of embryos and deformation of reproduction organs resulted in a lowered fertility. Furthermore, there are a couple of observations about the shift of the sexual ratio for waterfowl, water snails and fishes. In Great Britain scientists found fish which showed hermaphrodites (bisexualism) in the outlet of many waste water treatment plants. Also from rivers and shallow lakes around Berlin, Germany, observations exist that there are deviations to the normal sexual ratio in favour of the females. It could be demonstrated that substances discharged from waste water treatment plants cause the synthesis of the egg yolk precursor proteine vitellogenin in male rainbow trout. This formation is usually exclusively induced by the specific female hormone Oestradiol (Hansen et al. 1998). The different effects mentioned are attributed to substances which can dramatically disturb the reproduction and development processes in vertebrates. The effectiveness of those substances is based on the fact that they substitute natural hormones in the organisms and act as pseudo hormones. They can block the effect of hormones or influence the hormone economy. These substances are designated as hormone-active substances or »endocrine disruptors« (Norris & Carr 2005). Most of the more than 50 known endocrinic-effective substances have oestrogene effects, i.e. they act similar to the female sexual hormone 17ß-oestradiol. The concentrations of natural and synthetic oestrogenes determined at the outlets of waste water treatments plants, however, are near to a dose effect relationship for fishes and amphibians (Opitz et al. 2002).

Natural sources of oestrogenic substances are ingredients of plants (phyto oestrogenes) and fungi (myko oestrogenes) as well as sexual hormones and their metabolites in urine of human and animal. Synthetic hormone-active substances with oestrogenic effect are contained in pharmaceutics and industrial chemicals (e.g., organo chloride pesticides, polychlorinated biphenyles, decomposition products of tensides, phthalates). Synthetic oestrogenes reach the environment via waste water as a result of the usage of agents for contraception and the increasing hormonal treatment after menopause. The steroid hormones are not completely decomposed in waste water treatment plants so that in urban waters effective concentrations can be high. Excessive concentrations of endocrine-active substances were also found surprisingly in high mountain lakes far away of any sources. In the Austrian Lake Gossenkölle the insecticide DDT accumulated in the fat tissue of trouts and the reproduction organs dwarf. As the only explanation it is assumed that the distribution of these toxins proceeds via the atmosphere (GRIMALT et al. 2001). Although many laboratory findings exist that natural and synthetic substances can influence the hormone system of animals, the causal relationship between the observed phenomenon in nature and the exposition to these substances is not easy to document.

Documentation is especially difficult since the effects can depend on other classes of substances and non-chemical changes in the habitat. Currently, urgent needs in research exist for a better evaluation of the importance of hormone-active substances onto man and environment. Hence, precaution in water protection commands to avoid the environmental burden by hormon-active chemicals.

## Avoidance strategies and remediation designs

As manifold the types and causes of waters burden may be, as different are also the strategies to restore the functions of degraded aquatic ecosystems. Therefore, only general principles can be introduced here. Under optimal conditions waters are able to compensate external burden by biological self purification and buffer mechanisms or chemical and physical reactions. The capacity thresholds of an aquatic ecosystem are determined by its structure and that of its environment. Helpful for reaching certain quality targets are so called »critical load« models which describe qualitative changes in the ecosystems in dependence of the supply of one or more matters of burden and to describe contrariwise different characteristics of waters. In this way it is possible to assess a necessary limit of nutrients and harmful substances as concentrations at the location of emissions and also with respect to their effect in the water itself.

If utilisation or the habitat functions are affected according to the site of application external or in-waters counteractive measures are considered. External techniques are aimed at the reduction of sources in the catchment area. These inputs become restricted as the terrestrial matter cycles are being closed widely. To these measures belong the construction of sewage treatment plants for the purification of municipal and industrial waste waters, extensification measures in agriculture and the recycling of industrial wastes. Along with the construction of buffer ecosystems as pre-reservoirs, polishing ponds or plant belts primarily the nutrient input into the waters can be restricted. A further strategy in this respect therein consists to re-actuate original sinks for nutrients such as fens. *In-situ*-measures – also called as ecotechnologies – are considered if disaster situations occur or the symptoms of a waters burden, such as oxygen depletion, have to be reduced. They are also meaningful if the attainment of the target is not possible by external measures alone or the effect is to be expected with a huge time lag. Ecotechnologies are the large-scale utilisation of ecological effect principles via controlling intervention which change the ecosystem in that way that the management target is being maximally supported.

The ecotechnology of running waters aims mainly at the maintenance of the natural morphological state of the water or at the restoration after its damage by measures of river development towards a preferably nature-oriented morphology (renaturation). A nature-oriented water structure leads via the enlargement of the running time, the fouling areas for biofilms and habitats for filtering organisms (mussels, sponges etc.) to an enhancement of the self purification potential.

Thanks to the application of ecotechnologies in lakes and reservoirs a broad spectrum of possibilities is applied today. Most of the measures were developed for the control of eutrophication.

The nutrient concentration can be influenced by chemical treatment, the oxygen household by aeration aggregates, the under water light climate by destratification and food webs by a so-called »top-down« control (biomanipulation). The manipulation of the food web »from top« results from the declining of planktivorous fishes. Thus, the algal-filtering zooplankton (small crustaceans) in turn are conserved and consequently an enhanced grazing pressure is borne onto the not-desired phytoplankton. This leads to a reduced turbidity of the water.

Anthropogenic burden of waters are only conditionally avoidable.

Preventive water conservation presupposes the definition of critical thresholds for physical, chemical and biotic burden in dependence of the respective properties of water. The formulation of sustainable developing targets for inland waters should, therefore, orientate not on the pristine state but should consider the actual usage and colonisation of the landscape by man, the current knowledge of ecology and the technical progress ♦