From an Open Sewer to a Living Rhine River

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For many centuries, the Rhine has played an important role in the history and the social, political and economical development of Europe. The International Commission for the Protection of the Rhine (ICPR) was established in 1950 as the first intergovernmental body for the management of transboundary waters. Within the ICPR, Switzerland, France, Germany, Luxembourg and the Netherlands closely co-operate, while the European Economic Community co-operates in matters pertaining to water.

What started with the development of a joint monitoring strategy in the 50s and 60s of the last century, has become today a comprehensive integrated management strategy of the Rhine, comprising aspects of water quality, emission reduction, ecological restoration and flood prevention. This development was guided by a process of "learning by doing" and was influenced considerably by some major disasters.

This presentation illustrates how management approaches of the Rhine Commission have developed so far and it gives an outlook on the ongoing European Union water policy. Special attention will be paid to the prerequisites necessary for a successful water management strategy and to those factors that might be considered to be the success factors in the work of the Rhine Commission.

The Rhine River: uses and conflicts

The Rhine is one of the most well known and most important rivers in Europe (fig.1). For many centuries, it has not only been an important shipping lane, but also a source of food and valuable water, a crystallisation point for human settlements and a source of inspiration for poets and writers. Industrial development in North Western Europe mainly took place on the banks of the Rhine River. From its source in Switzerland and Italy, the Rhine flows via France, Germany and the Netherlands into the North Sea. The Rhine is 1.320 km long and has a catchment area of 200.000 km^2. After the Volga and the Danube the Rhine is Europe’s 3^{rd} largest river catchment. Nowadays, more than 58 million people live in 9 countries in the Rhine watershed. About 8% of the total surface is used for settlements, trade and industry. Here, Europe’s most important industrial and chemical companies’ annual production is worth some 550 billion Euros. More than 800 km of the Rhine are navigable with an annual load of almost 200 million tons of cargo crossing the Dutch-German border. Rhine water is used for industrial and agricultural purposes, for energy production, for the disposal of municipal wastewater and for the production of drinking water for more than 30 million people.

Furthermore, the Rhine is the natural habitat for a great variety of plants and many birds, fish and other species. It is obvious that the many different claims on the river must lead to conflicts or problems: water quality problems, problems in river ecology and flood-related problems.

Although water quality problems in the Rhine were already recognised in the 15th century, the deteriorating quality of the river was not really apparent before the end of the 1960s. By that time, the pollution of the Rhine with organic substances had led to acute oxygen problems in the river and almost all aquatic life had disappeared.

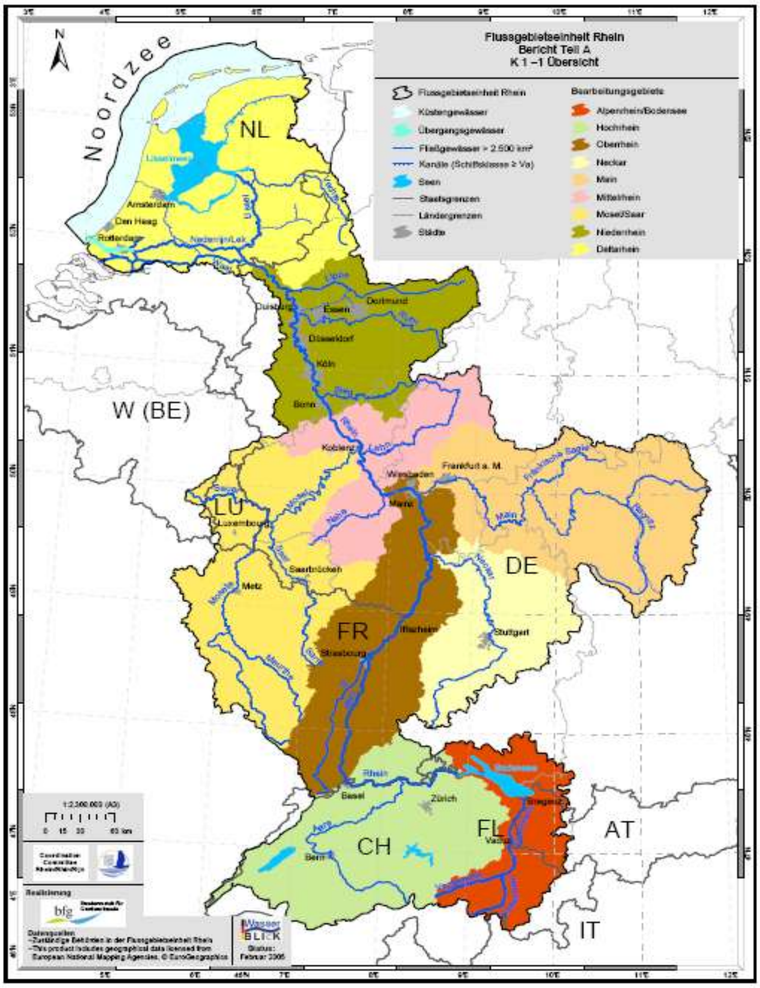

Fig. 1: The Rhine watershed with its sub-basins (total surface ~ 200.000 km²; Germany (~53%); Switzerland, France, Netherland (each ~13% - 18 %); Italy, Austria, Liechtenstein, Luxemburg, Belgium (together ~ 3%)

Other threats to the river ecosystem were the wastewater discharges of industries, agriculture, traffic and households. Large amounts of heavy metals, pesticides, hydrocarbons and organic chlorine compounds were discharged into the Rhine, causing further ecological problems: disappearance of indigenous species, deterioration of the water quality and sediment pollution. More and more efforts were needed to produce good quality drinking water, and by the end of the sixties the Rhine had the distressing reputation of being the sewer of Europe.

In 1986, the Sandoz accident clearly illustrated the disastrous impact accidental pollution can have on the whole river. Due to a fire in a Swiss factory producing chemical and pharmaceutical products, between ten and thirty tons of insecticides, fungicides and herbicides flushed into the river with the water needed to extinguish the fire and killed almost all river life between Basel and Koblenz (ca. 400 km).

Ecological problems

In the 19th century, the course of the Rhine was drastically altered in order to improve conditions for navigation and to enable the use of alluvial riverside areas for agriculture and other purposes. Further "corrections" in the river bed followed in the 20th century (fig. 2).

As a result, between Basel and Mainz the length of the river was reduced by more than 80 km and 85 % of the alluvial land was lost. Meanders and alluvial land were cut off, causing great changes in the river ecosystem. Other problems were the increase of flow velocity, the erosion of the river bed and the drop of groundwater levels.

Rhine 1838, source: Generallandesarchiv Karlsruhe

Rhine 1872, source: Generallandesarchiv Karlsruhe

Rhine 1980, source: Landesvermessungsamt Stuttgart

Fig. 2 Changes in river landscape: the Rhine at Breisach **1838, 1872 and 1980**: Only 160 years ago, the river freely moved through the floodplain; it topped the banks and changed its river bed. Today it is forced into a fixed bed and deprived of its natural dynamics.

Numerous dams and weirs serving hydropower production were constructed in the Rhine and its tributaries. Due to these physical barriers it was almost impossible for the most important fish species in the Rhine, the Atlantic salmon, and for other migratory species, to reach the spawning grounds. Catches of Rhine salmon decreased dramatically from more than 280.000 tons of fish around 1870 to zero in 1950.

Flood-related problems

Flood problems are as old as the river itself. Heavy rainfall or sudden snow melts and local ice-barriers have always caused high water levels in the Rhine basin. However, during the last two centuries, human activities in and along the river have strengthened the negative impact of higher water discharges. Changes in the course of the river and the riverbed, the increased use of the whole river basin, erosion, urbanisation and changes in the water flow seriously increased the risk of floods in the Rhine area. At the same time, more and more people and economic activities settled in endangered areas, thus increasing the potential damage resulting from high water levels.

The 1993 and 1995 floods in the middle and lower Rhine area clearly pointed out the need for a drastic change in both river management with respect to floods and the risk management policies in areas potentially at risk. During the last 10 years, the very same problems were repeatedly experienced in almost all European watersheds like the Odra, Elbe and Danube.

International co-operation

All the problems above mentioned have something in common: they can only be solved effectively in a basin-oriented international context. For example: the sediment quality in the downstream Rotterdam area is directly influenced by upstream discharges. Salmon cannot return to their upstream spawning areas when downstream barrages and weirs block their long way up and the magnitude of flood problems will be influenced by upstream and downstream riverbed conditions. Therefore, basin-wide co-operation is the first prerequisite for effective river management. Obviously, for the Rhine, this means international cooperation.

The first two decades of co-operation within the ICPR were dedicated to getting a common understanding of the Rhine problems and to creating a legal and institutional basis for co-operation. This first period of cooperation, just after World War II, was essential to create confidence, trust and understanding between the member states.

Joint monitoring programmes were developed, but the first joint measures to protect the river against the effects of organic pollution were only taken after 1970. Between 1970 and 1985, successful programmes were developed to reduce inputs of polluted municipal and industrial wastewater. Oxygen levels steadily rose. Some improvements could be observed in the situation with regard to pollutants. In this period, the main efforts focused on "end-of-pipe" techniques, i.e. wastewater treatment, rather than on preventive measures. During this period the Commission agreed upon several Conventions as legally binding instruments for the Contracting Parties. This situation lasted **until 1986**, and, as often is the case in environmental decision-making, **a serious disaster was needed to enable another step forward.**

Management by Disasters

Towards the end of 1986, an accident in a Swiss chemical warehouse painfully showed how vulnerable the Rhine ecosystem still was and how many threats still existed. Due to the disaster at the Sandoz-plant near Basel, 10 – 30 tons of toxic substances flowed into the river and caused the death of almost all aquatic life downstream as far as the Loreley near Coblence. The Sandoz incident triggered a wave of publicity in every state and country along the Rhine. Political attention was raised and in a very short time not less than 3 ministerial conferences addressed the issue of Rhine pollution, and finally resulted in the Rhine Action Programme (RAP) of 1987.

The Rhine Action Programme (RAP) clearly defined goals to be reached by the year 2000:

- to improve the ecosystem of the Rhine to such an extent that higher species, such as salmon and sea trout, again become indigenous.
- to guarantee the production of drinking water from the Rhine for the future.
- to reduce the pollution of river sediments to such an extent that sludge may at any time be used for land filling or be dumped at sea

- to improve the ecological state of the North Sea.

When adopting the Rhine Action Programme, the ministers agreed on some very challenging and ambitious targets like a 50% to 70% reduction of inputs of dangerous substances between 1985 and 1995 and the return of the salmon by the year 2000.

The Rhine Action Programme has been very successful. All along the river, measures have been taken to prevent pollution and as early as 1994 the ICPR could report that most of the reduction targets had been reached. In the field of industrial sources, the 50% target had been almost completely met. In particular, the discharges of noxious substances by municipalities and industry fell distinctly. Inputs of most priority substances were reduced by 70 -100% or were no longer detectable. In the year 2000, at the end of the implementation process, almost all reduction targets had been achieved (fig. 3).

Reduction of point source inputs between 1985 and 2000

30-49 %	50-69 %	70-100 %	No discharges**
total nitrogen (N)	1,1,1-trichloroethane*	ammonium	dioxins (1990-1992)
arsenic	2-chlorotoluene*	total phosphorous (P)	atrazin (2000)
	4-chlorotoluene*	lead	azinphos-ethyl (1990-1992)
	trichlorobenzenes*	cadmium	azinphos-methyl (1992-2000)
	hexachloro-	chromium	DDT (1990-1992)
	cyclohexane (HCH)*	copper	dichlorvos (2000)
		nickel	fenitrothion (1992-2000)
		mercury	malathion (1992-2000)
		zinc	parathion-ethyl (1992-2000)
		benzene*	parathion-methyl (1990-1992)
		1,2-dichloroethane*	simazine (1992-2000)
		tetrachlorethylene*	trifluralin (1990-2000)
		tetrachloromethan*	
		trichloroethylene*	
		trichloromethane (chloroform)*	
		aox	
		chloroanilines*	
		chloronitrobenzenes*	
		hexachlorobenzene (HCB)*	
		hexachlorobutadien*	
		polychlorinated biphenyls (PCB)*	
		azinphos-methyl	
Inventory from 2000 on		bentazon*	
benzo(a)pyren		drins*	
4-chloroaniline		endosulfan	
3,4, dichloroaniline		fenthion	
PAH		parathion-ethyl	
diuron		pentachlorophenol (PCP)*	
isoproturon		tinorganic compounds	

* = last inventory in 1992 or 1996 since the reduction target and ICPR target values were achieved
** = no discharges detected during inventory, year of inventory indicated in brackets

= nutrients
= volatile hydrocarbons
= metals
= non volatile hydrocarbons
= pesticides

Fig. 3: Reduction of point source inputs into the Rhine between 1985 and 2000

Annual loads of substances at Bimmen-Lobith

	Unity	1985	1995	2000
discharge	m³/s	1967	2773	2.500
ammonium nitrogen	t	37.000	14.000	6.800
total phosphorous	t	32.000	17.000	13.000
aox	t	4.700	1.300	1.100
zinc	t	3.600	3.000	1.400
chromium	t	500	530	150
copper	t	600	630	510
nickel	t	400	440	230
lead	t	550	500	250
arsenic	t		190	130
atrazine	kg	10.000	6.900	1.200
cadmium	kg	9.000	9.700	5.100
mercury	kg	6.000	3.500	1.600
sum PCB	kg	390	240	90
hexachlorobenzene	kg	240	200	100

Fig. 4: Reduction of annual loads of substances at the German-Dutch border at Bimmen-Lobith

Since the flow (m³/s) of the Rhine varies a lot from one year to the next, annual loads may only be estimated. In spite of these reasons for inaccuracy, fig. 4 is rather reliable: between 1985 and 2000, the annual amount of discharges fell for most priority substances. In addition, between 1985 and 2005 the total load of nitrogen at the German-Dutch border fell by 30%.

In 2005, about 96% of the population in the Rhine catchment are connected to municipal waste water treatment plants. In 1985, no more than 85 % had been connected.

Nowadays there are still inappropriate amounts of a few substances which flow down the Rhine into the North Sea, especially nitrogen or some heavy metals like copper and zinc. These mainly come from diffuse inputs into waters and not from pinpointed sources. Other problems still remaining are due to former inputs, the so-called historic contaminations (for example PCP). Recently, other substances have become the focus of attention, such as pharmaceuticals and certain substances with hormonal effects. These are the issues to be discussed today or in the near future.

As a result, the Rhine water quality has considerably improved in the last decades. From being the sewer of Europe in 1970, the Rhine River has developed into one of the cleanest international rivers in Europe.

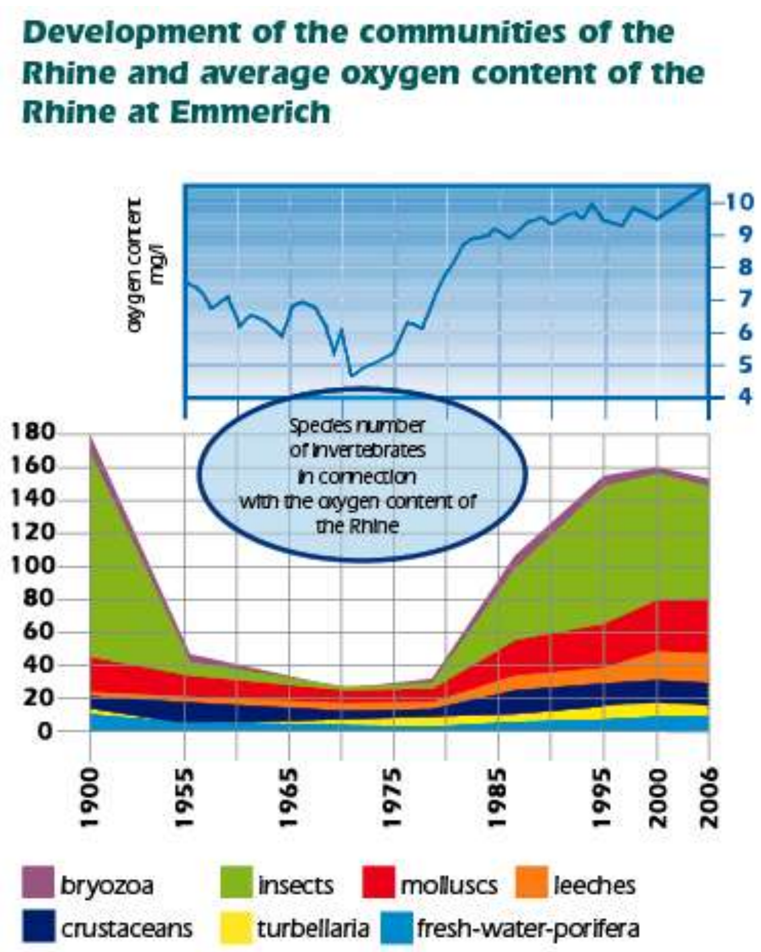

Fig. 5: Development of the species number of invertebrates between 1900 and 2006 and of the oxygen contents of the Rhine at the German-Dutch border.

The rise of the average annual oxygen content of Rhine water at the German-Dutch border reflects the pleasing success in the field of wastewater treatment in the period 1955 -2006 (cp. fig. 5). Parallel to improved oxygen contents, the number of invertebrate species like insects, molluscs, leeches etc. has distinctly increased, even though river straightening has clearly changed the species composition and little demanding immigrant species prevail (in some sections by up to 90%). Since 1995, the species number has more or less remained constant, however, many insect species abundant more than 100 years ago, such as the Ephemera *Oligoneuriella rhenana* are still missing. Presumably, this is also due to the monotonous structure of river banks caused by waterworks improving conditions for navigation.

Salmon 2000, the ecological dimension of the Rhine Action Programme

The most challenging objective of the Rhine Action Programme was the return of the salmon - as flagship species - to the Rhine by the year 2000. Extensive programmes were developed and implemented to enable salmon to return to their spawning grounds. Fish passages were built by-passing many physical barriers in the Rhine and its tributaries. At the same time, habitat improvement measures were taken in many tributaries in order to restore spawning grounds. Parallel action aimed at creating a new stock of Rhine salmon was required.

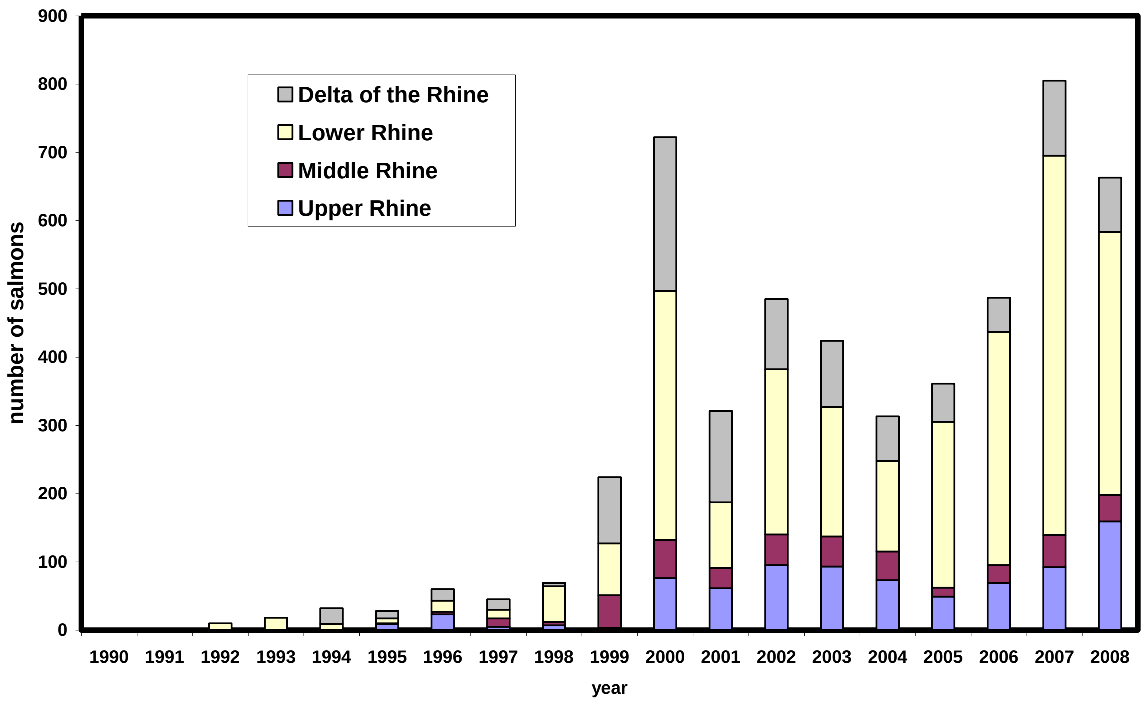

Fig. 6: Number of salmons returning to the Rhine and its tributaries (cumulative) for natural reproduction (1990 – 2008).

The success of the so-called "Salmon 2000" Programme is evident. Since 1990, salmon has returned from the sea to the Rhine and its tributaries and, since 1992, natural reproduction has been recorded. Ambitious political goals at international level have been translated into concrete measures and activities at local level. The programme continued after 2000 as “Salmon 2020”. There is evidence that, by the end of 2008, more than 5.000 adult salmons had returned to the Rhine basin to spawn in the tributaries of the Rhine (fig. 6). With the construction of three fish passages on the Nederrijn / Lek in the Netherlands (2001 – 2004) and two large fish passages in the Upper Rhine (Germany / France, 2000 and 2006) the objective “Improve the continuity of the main stream” has been achieved in some sections. Further measures are required and are currently under discussion between the states in the Rhine watershed. According to a careful estimation, a population of some 7.000 to 21.000 salmon will annually migrate upstream by the year 2020.

This concept of further integration of policies received an extra impetus and even more political commitment after the extreme floods in the middle and lower sections of the Rhine in 1993 and 1995. **Like in 1987, after the Sandoz disaster, it is evident that serious problems were needed to convince the Rhine states that measures had to be taken.** Although prevention and precaution were basic principles for the management of the Rhine, two enormous floods with even greater consequences for many people seemed to be necessary before adequate measures were taken. The ICPR drafted an “Action Plan on Floods” including the target of ecological improvement of the Rhine and its floodplain and, in 1998, the Rhine Ministers decided to implement this plan until 2020 (cost estimation 12.3 billion Euros).

The action targets are:

- Reduce damage risks by 10% in 2005 and by 25% by 2020
- Reduce gauges by 30 cm in 2005 and by 70 cm in 2020
- Increase awareness of floods by drafting risks maps (ICPR Rhine atlas 2001)
- Improve the flood forecasting system

By 2005, important action targets had been achieved, as different measures entailing costs of 4.5 billion Euros were implemented. The riparian states have for example created great retention areas for 77 million m³ of flood water along the main stream, as they are most effective in order to reduce extreme flood stages. In order to increase flood awareness the ICPR published a Rhine atlas in 2001.

Reflections

The successful co-operation in the framework of the ICPR has been an example for many other river basin organisations. It is of course not possible to simply project the Rhine approach on any other river in the world. Therefore, it is very important to take good notice of the process steps made in the Rhine Commission and to learn from both positive and negative experience in the ICPR. In the same way, the ICPR can learn from experience made on other international rivers.

Based on the experiences and achievements of the ICPR, it could be argued that a process driven by political commitments is more effective and flexible than an approach using legally binding measures. This could be illustrated by the rapid success of the implementation of the Rhine Action Program - a political commitment - following a period of a slow but steady improvement resulting from a series of binding measures on wastewater treatment. However, both elements are required and finding a good balance between political commitment and legal enforceability is a continuous and iterative process.

The achievements of the Rhine Commission have also triggered and guided further development at EU level, such as the Water Framework Directive of December 2000 and the Directive on the assessment and management of floods (2007). These directives do not only legally underpin the implementation of measures by EU Member States; they have also strengthened the importance of river basin commissions in Europe, because they oblige Member States to coordinate measures at the international river basin level.
All these developments can be seen as a fruitful output from many interactive processes in river commissions as well as in their Member States and at a European level. Co-operation in river basin management has to be based on mutual confidence of all parties involved. The negative and positive lessons learnt from co-operation in the International Commission for the Protection of the Rhine may serve as an example for other (international) water management authorities all over the world.

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