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A Pilot Study of Collective Action and the Environmental Kuznets Curve 1895-2000

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Abstract: Because of a growing population and industrialization, total pollution levels in many water-courses around the world have increased considerably for hundreds, if not thousands, of years. In the last few decades, however, the trend of increasing water pollution has been turned in many industrialized countries, delinking economic growth from environmental pollution. This is in essence one aspect of what many environmental economists call an 'environmental Kuznets curve'. The research question of this project is why there is such a pattern to water quality in many countries? Much previous literature on the topic studies only the positive impact of environmental legislation. This study, focusing upon the case of the river Göta in Sweden, undertakes a more thorough analysis, including other crucial factors as well such as industrial transformation and decline, as well as stakeholder associations. The project utilizes a very long series of data on the water quality in the river Göta, covering more than 100 years of data for crucial indicators, in order to establish what factors were contributing to reducing levels of pollution. Analyzing the driving factors of this 'Environmental Kuznets Curve' can give us crucial insights into how a sustainable development might be achieved in the future.

JEL: N53, N54, N73, N74, Q25, Q28, Q57

Keywords: Economic History, Environmental history, Environmental pollution, Water quality, Environmental Kuznets curve, Sweden, Göta älv

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1. Introduction

Water pollution is one of mankind's oldest environmental problems. Solutions to the pollution of a common pool resource such as water have been sought in a variety of ways throughout history. One of the most common 'solutions' historically have been to transfer the problem geographically – away from a city, for example – often by the use of flowing water (rivers or constructed canals or sewers). This is however at best solving the environmental problem locally. Because of a growing population and industrialization, total pollution levels in many water-courses around the world have increased considerably for hundreds, if not thousands, of years. With growing pollution levels in total, just moving the problem geographically became increasingly unsustainable. In the last few decades, however, the trend of increasing water pollution has been turned in many countries. The environmental quality of many water-courses around the world has improved considerably in the last few decades, in sharp contrast to the historical experience before that.

Analyzing this shift – what many environmental economists call an 'environmental Kuznets curve' – can give us crucial insights into how a sustainable development might be achieved. The theoretical argument behind the existence of an 'environmental Kuznets curve' concerns a process developing over time. Applying a historical method therefore seems most proper, rather than the method of cross-country regressions used by most economists studying the topic. By an historical analysis, we are able to discern the timing of events, and might thus more clearly come to understand the causalities involved in the process of environmental degradation and/or improvement. The historical experience might thus teach us lessons for the future.

In this study, we focus upon one case in particular, and a perfectly clear case of an 'environmental Kuznets curve' at that. The case is the pollution of the Göta River, the biggest and most industrialized river in Sweden. Many of Sweden's most important industrial establishments – including several pulp- and paper-mills, metallurgical and chemical industries and the car manufacturing complex – have been connected to this river in particular. There is in this case furthermore a long series of continuous data on environmental quality, starting in the late 19th century. Such a long series of continuous data might be unique in the world. The data shows clearly that environmental pollution increased significantly during the process of industrialization in the region. From the 1970s, however, the trends for many pollution indicators have turned. Whereas many previous studies have emphasized the positive impact of institutions (most importantly environmental legislation), we want to broaden the picture, including many other variables into the equation, including not the least industrial transformation and decline.

2. Previous studies

The conflicts over water, and the (un-)sustainable use of the ecosystem-services that lakes and watercourses can provide, has been one of the popular themes in environmental history. Many scholars have for example studied how regulation and damming of rivers, for the purpose of irrigation or the production of hydroelectric power, have impacted the environment (Worster 1985; White 1995; Jakobsson 1996; McCully 1998; Tvedt 2004; Coopey and Tvedt 2006; Tvedt and Jakobsson 2006; Barca 2007).

The pollution of lakes and watercourses is also a popular field of research in environmental history – including nutrient-based, chemical or thermal pollution (Cioc 2004). A number of studies have shown how scientific progress (most importantly in the fields of epidemiology and bacteriology – the so-called 'bacteriological revolution') and development of technology to treat sewage emissions contributed to considerable improvements in water quality in many watercourses during the late 19th and early 20th century. Much of the initial focus lay upon dealing with the well-known problem of human organic waste, for example by investing in sewerage and (later) in sewage treatment (Lundgren 1974; Cain 1977; Luckin 1986; Goubert 1986; Steinberg 1991; Clapp 1994: ch. 4; Sheail 1998; Gumpbrecht 1999; Lundgren 1999; Ogle 1999; Hill 2000; Melosi 2000; Olsson 2001; Cioc 2002; Tarr 2001; Mallea 2002; Sheail 2002: ch. 3; Tal 2002: ch. 7; Tarr 2002; Andreen 2003a; Andreen 2003b; Dolin 2004; Keeling 2004; Tarr 2004; Tarr and Josie 2006; Barles and Lestel 2007; Benidickson 2007; Closmann 2007; Neri Serneri 2007; Wennersten 2008; Bernes and Lundgren 2009).

Industrial pollution would generally not be dealt with until much later, during the second half of the 20th century. A long range of scholars have emphasized how in particular regulations and legislation limiting the industrial emissions of pollutants contributed to improving the environmental quality of industrialized rivers and other water-courses around the world (or how the weak regulations has delayed any progress). Particularly in the 1960s and 1970s, a growing environmental consciousness in many industrialized countries led to an increased attention to preventing and/or minimizing industrial pollution, rather than just treating the problem after pollution had occurred (Tarr and Ayres 1990; Brüggemeier 1990; Cumbler 1991; Steinberg 1991; Sheail 1993; Brüggemeier 1994; Clapp 1994: ch. 4; Outwater 1996; Sheail 1997; Sheail 1998; Lundgren 1999; Gustavsson 2000; Simmons 2001; Söderholm 2001; Tarr 2001; Cioc 2002; Tal 2002: ch. 7; Andreen 2003a; Andreen 2003b; Gustafson 2003; Gustavsson 2003; Andreen 2004; Björk 2004; Tarr 2004; Söderholm 2005; Bergquist 2007; Closmann 2007; Adams et al 2008; Closmann 2008; Collins et al 2008; Lekan 2008; Wennersten 2008; Bernes and Lundgren 2009; Wegner 2009; Kinneryd 2010). Introducing and enforcing such legislation would however often prove to be controversial. Lars Lundgren has for example studied the political debate about water pollution in Sweden during the early period of Swedish industrialization – 1890 to 1921. His findings show that many important industrial interests successfully opposed legislation restricting the emission of waste during this period. At this time, Lundgren summarizes, "increased material standards were more important than clean rivers and lakes." In the 1960s, on the other hand, popular perception regarding the environment and environmental problems had changed, largely due to increasing welfare (so that more basic needs were satisfied). At this time, pollution therefore started to be seen as a threat and problem that ought to be dealt with. A very similar process seems to have occurred in the German Ruhr-region, in Britain as well as in the United States, with many polluters successfully opposing any form of binding legislation. The enforcement of the same legislation, once it had been introduced, also became controversial in many cases, with polluters trying to avoid having to take action, or directly challenging the enforcement through legal proceedings (Lundgren 1974: quote on p. 237; Brüggemeier 1990; Sheail 1993; Brüggemeier 1994; Lundgren 1999; Tal 2002: ch. 7; Andreen 2003a; Andreen 2003b; Dolin 2004; Lewis 2005, ch. 9; Wennersten 2008; Bernes and Lundgren 2009). The role and impact of voluntary created watershed associations, or river committees, (Vattenkommittéer, Vattenvårdförbund, Vattendragsgrupper) in managing water resources has been analyzed in several investigations and reports (Lundqvist 2004:36; Gustafsson 1996; SOU 1997; SOU 2002; Galaz 2005).

Regulations in the form of legislation, or other institutions, is however not the only variable effecting the level of environmental pollution in a watershed. A few scholars have for example noted how regional industrial transformation contributed to improvements in the water quality in certain rivers, such as the Hudson or the Elbe, and how shifts in the methods of production also had a crucial influence on the amounts as well as forms of environmental pollution (Adams et al 1996; Tarr 2001; Stradling and Stradling 2008). A further factor contributing to the level of pollution in a river is whether the pollutants could be used as resource, such as the nitrogen from sewage to be used as fertilizer, or sulfuric acid from ore. If this could be the case, there was a clear economic incentive to minimize the emissions. Lower levels of pollution then became a positive, albeit not necessarily intended, side-effect (Brüggemeier 1994; Barles 2005; Barles and Lestel 2007; Bergquist 2007)

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3. Theoretical considerations

Institutional analysis has become most crucial for the study of ecological economics as well. This is the case not the least when the issue is one of the sustainability of the use of open access- and common pool resources, such as a river. In an often-cited article, Garrett Hardin argued that one important reason behind environmental degradation was an institutional failure, the famous 'tragedy of the commons' (Hardin 1968). Common responses from economists were thus to call either for governmental regulation of, or for the privatization and establishment of private property rights over, the commons around the world. Many scholars, perhaps most importantly Elinor Ostrom, has since shown that there are many examples of successful institutions for governing the commons, such as communal tenure or irrigation water management schemes. In these examples, robust institutions have been in place for decades or even centuries (Ostrom 1990; Ostrom et al 1999; Ostrom 2008). Based on her research, Ostrom has suggested eight "design principles" that she believes are helpful for sustaining a common pool resource over the long run. The eight principles are: 1) clearly defined boundaries for the CPR, 2) congruence between appropriation and provision rules and local conditions, 3) collective-choice arrangements (so that most individuals affected can participate in modifying the rules), 4) monitoring of CPR conditions, 5) graduated sanctions if violation of rules occur, 6) low-cost conflict-resolution mechanisms, 7) minimal recognition of rights to organize by external governmental authorities, and 8) nested enterprises (Ostrom 1990:table 3.1).

Following the third point of Ostrom's principles social science models have emphasized the importance of continuous social interaction to relive societies from the commons dilemma. In game theoretical, rational choice based, models this could be accomplished by repeated bids in a negotiation game where the actors continuously could restate their bids considering expected reactions from their counterparts until a mutually optimal solution is found. The possibility for such solutions is often considered to stand in proportion to social equality between the actors and to the existence of working external institutions for the monitoring of agreements (Galaz 2005; Knight 1992, 1995). Other scholars, rejecting a strict assumption of rational choice, stresses the readiness of actors to make what John Rawls has defined as reasonable choices and strategies, when they continuously meet and interact with their counterparts in many social situations. Individual costs and benefits could then be counterbalanced by established conceptions of fairness and reason (Rawls 1993 pp 11-15 & 48-54; Elster 2000; Steele 1991; Bromley 1991:_159-60).

The socio-economic impact of pollution could vary significantly. One rapidly growing field of research is the so-called 'environmental justice' school, where the uneven social distribution of impacts from pollution is in focus (for river-related studies in this field, see for example Williams 2001; Allen 2003; Stroud 2003; Lerner 2005; Loo 2007; Wennersten 2008; Price 2008).

In the literature on environmental economics, the idea of an 'environmental Kuznets curve' has received a lot of attention. In their by now classic study, Gene Grossman and Alan Krueger examined the relationship between per capita income and environmental quality. The pollution of rivers is one of the factors that they include in their study. Their findings showed that there was an initial phase of environmental deterioration, as per capita income increased, followed by a subsequent phase of improvements of environmental quality (Grossman and Krueger 1995). Following Grossman and Krueger, a number of scholars have since devoted their attention to studying in what (if any) areas such 'environmental Kuznets curves' can be found, experimenting with different specifications of cross-country regressions. Still, there is so far little consensus on the issue. The empirical support for a more general existence of EKC-patterns has been put in question by many scholars. Some economists, as well as some involved in the popular debate, have interpreted the findings of an EKC-pattern as showing that economic growth is good for the environment (in stark opposition to the more pessimistic message of for example the Club of Rome's Limits to Growth (Meadows et al 1972)). Many scholars – including some of the proponents of an EKC - have however noted that the reduced-form model that most often has been estimated econometrically in analyses is highly incomplete, since it does not take into consideration crucial factors such as technology, environmental regulation or industrial composition. It has therefore, not surprisingly, proven difficult for many previous studies to show solid support for a causal mechanism that could explain an EKC-pattern. The role of institutions and environmental regulations has however often been emphasized (Grossman and Krueger 1995; Lindmark 1998; Dasgupta et al 2002; Stern 2003, 2004; Dinda 2004; Levinson 2008; Carson 2010).

4. Aim of this project

As will be shown in this paper, there is no doubt that the pattern of environmental quality of the Göta River follows an 'environmental Kuznets curve' for many of the most important water pollution indicators. The aim of this research project is to study why there is such a pattern in this case? In other words, why were previous trends of increasing pollution of the river halted in the 1970s, and later also reversed? In order to do this, we need to study the environmental history of the river.

Institutions of various sorts – most importantly environmental legislation – can have played, and probably did play, a key role in this process. As was noted in the previous section, many scholars of environmental river history have emphasized the importance of such regulations and legislation. Few studies have however also looked at competing hypotheses (one important exception being Tarr 2001). Whereas it in specific case-studies might be clear that legislation has influenced the choice of technology of production in a certain plant or company (see for example Söderholm 2001; Gustavsson 2003; Söderholm 2005; Bergquist 2007), we cannot automatically assume that what is true on the micro-level also is true in the aggregate for a whole watershed, region or country. In many cases, the improving environmental quality in a specific river does not only match the timing of the introduction of environmental legislation, but also the timing of major industrial transformation. The improvement in water quality in the Rhine from the 1970s onwards might, for example, be due not only to the German environmental legislation (studied by Cioc 2002 and Lekan 2008), but also due to the major industrial decline taking place in traditional industrial regions such as the Ruhr around the same time (van Winden et al 2010:333). At the same time, the environmental legacy of many industrial operations has to be remembered, and can constitute a serious source of pollution long after the industrial establishment has ceased operations (Newman 2003; High 2003:161-2).

One of the core aspects in this project will certainly be to focus upon the contribution of institutions. There are two main institutions that will be explored. Firstly, national environmental legislation (and regional/local implementation of the legislation). Over the period, national environmental legislation developed considerably, as will be shown in the paper. Secondly, a number of specific Watershed Conservation Associations (vattenvårdsförbund) were also established during the middle of the 20th century, all around the country, including one covering the lake Vänern, and one covering the Göta River (Pettersson 2009). These were stakeholder associations, incorporating local municipalities, private corporations and representatives of the county administrative boards, in one institution. We thus have examples of both formal (governmental) institutions, in the form of environmental regulation, and regional, common/stakeholder institution, in the form of the water conservation associations, which might have been influential in the process.

In contrast to many previous studies, we do not assume from the start that legislation was the most important – let alone the only – factor explaining the pattern that the environmental quality of the river describes over time. By correlating the development of the environmental quality of the river, with indicators of economic activity in the individual companies as well as generally in the region, together with an analysis of legal and institutional development, we hope to be able to analyze in depth the causal mechanisms behind the 'environmental Kuznets curve' in the river in question.

One core contribution of this project is thus to undertake a theoretically more systematic analysis of the history of the pollution of a river than we believe has been done previously. There are a number of possible hypothesis that the project will attempt to test:

- One first hypothesis is that polluting industries and other activities simply are migrating geographically, so that there is a change in industrial composition in the region studied. This might happen for a number of different reasons, including a change in goods or factor markets, but also environmental legislation increasing the cost of polluting the river. If this is the case, the problem of pollution would be solved locally, but not globally.
- A second hypothesis is that there is no change in industrial composition but that the industries changed their production processes to less polluting ones, or invested in sewage/emissions treatment. This could also happen for a number of different reasons: change in demand for goods produced, stiffer environmental regulation driving

technological development of less polluting technologies, or technological improvements driven by other (exogenous) factors.

- A third hypothesis is that the substances polluting the river become a valuable asset. Pulp- and paper mills did for example for a long time dump waste fiber into the river. This is nowadays used as a source of energy for the plants, and is thus a valuable resource. The plants might for that reason invest money in technology to collect waste fiber from their production process. That waste might become an asset might be due to a number of different reasons: technological improvement, changing market demand for various substances, or stiffer environmental regulation increasing the cost of polluting, thus making other usage more competitive.
- A fourth hypothesis is that the preferences of the population lead to higher marginal value of a clean environment over time. This could be the case for example if people's preferences generally are structured so that there is a hierarchy of needs or demands, for example in line with Maslow's theory where physiological needs have primacy over safety needs (including the need for a safe environment), in which case the effective demand for a clean environment would increase when more basic needs have become satisfied (i.e. with economic growth). This could also be the case if preferences are changing over time in favor of less environmental pollution, for example as an effect of increasing knowledge of the negative consequences of pollution. In the first case, the incentives to invest in pollution abatement would increase with increasing GDP/capita (and thus over time in this case, since Sweden experienced a steady growth in GDP/capita throughout the period of study). In the second case, incentives to invest in pollution abatement would increase as scientific knowledge accumulates something it presumably does over time.

The project is a case study of a single river. As such, the results are of course not generalizable in the sense that the history of the Göta River is representative of other cases in history. The case is however generalizable in another sense: by learning from history, we are able to make better informed decisions for the future. Much of the discussion of environmental problems is focused upon the problems of environmental degradation and destruction. In this case, we want to focus on the potentially successful solution – or at least improvement – of an environmental problem. Understanding how water pollution was dealt with successfully in this case can be highly useful for policy-making and the legislative process in other settings in the future, specifically in the case of water-resource management, but potentially also in other cases of common-pool resources.Brödtext utan indrag,

5. Geography and demography of the Göta River Valley

5.1. Geography

In a global comparison, the Göta River is a quite small river (for comparative data, see Czaya 1983:52-4). The size of the watershed – 50,233 km^2 – is for example considerably larger than the Hudson River (with a watershed covering some 35,000 km^2, studied by Tarr 2001) and almost four times the size of the watershed of the river Thames in England (watershed of 13,000 km^2, studied by Luckin 1986 among others), but only a quarter of the size of the watershed of the river Rhine in continental Europe (watershed of 224,000 km^2, studied by Brüggemeier 1994 and Cioc 2002) or roughly a tenth of the size of the Rio Grande (570,000 km^2). Göta is however the most important river in Scandinavia. It has by far the largest watershed of all rivers in the region (most of it in Sweden, but a small part of the watershed also in neighboring Norway). It is also the largest river in the region if measured by discharge – on average 550 m^3/s.

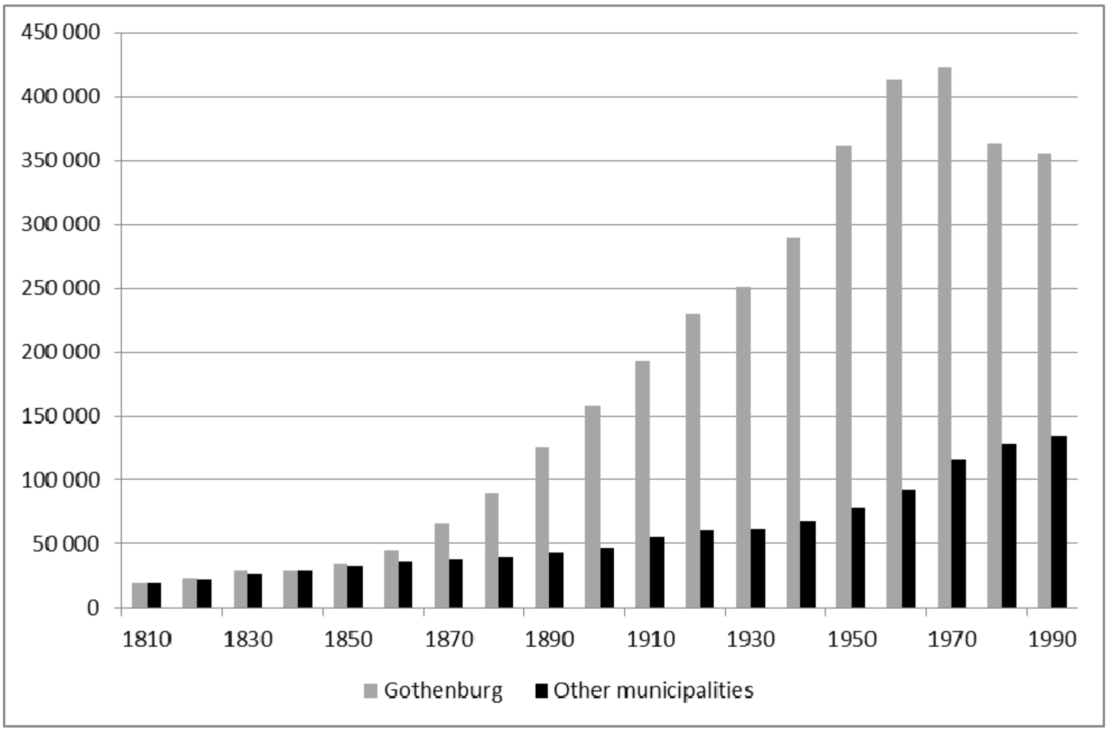
The river leads from lake Vänern (5,655 km^2, the third largest lake in Europe) to the ocean at Kattegatt (connected to the North Sea/Atlantic ocean). The river is comparatively short– only 93 kilometers. The main tributary to lake Vänern, Trysilelva/Klarälven (the water from this river feeds into the Göta River) is considerably longer – 460 kilometers –

and is often included when reporting the length of the Göta River (Göta Älvs Vattenvårdsförbund 2005:13-17).

5.2 Demography

On the way to the ocean, the river passes through a couple of cities, most importantly Gothenburg, Sweden's second largest city. Many of these cities use the river as a source for drinking water, and as a sink for sewage emissions. Graph 1 shows data on the population in the parishes connected to the Göta River. There is a considerable growth in population in this region from the late 19th century, until the 1970s. In the 1980s, population levels dropped somewhat in the city of Gothenburg, whereas the population in other parishes continued to grow (for most of the data on environmental quality, reported in later sections of this paper, the latter data-series is the most important, since the sewage emissions from the city of Gothenburg are located downstream from the point of measurement of the quality of the water). Since the 1990s, population growth has recurred in the region.

GRAPH 1. *Population around Göta River, 1810-1990*



Source: Folkmängdsdatabasen, Umeå Universitet. Available online [http://rystad.ddb.umu.se:8080/FolkNet/index.jsp]. Accessed 2011-03-04.200

A growing population naturally entails growing production of human organic waste in the region. The introduction of water closets, as well as investments in sewerage, contributed to increasing amounts of sewage reaching the Göta River. Sanitary problems related to human organic waste were thus moved from away from cities, but instead contributed to a new and growing problem of water pollution (Bernes and Lundberg 2009:67-71). The epidemic spread of water-transmitted diseases also became a growing problem – particularly large epidemics hit Sweden in the 1880s and the 1910s (Andersson 1992: table 3). The 'bacteriological revolution' did however contribute to an increasing awareness of not only the problem, but also how to deal with it.

6. **The industrialization of the river**

6.1. Prehistory - the river before hydroelectricity

Direct use of hydropower from the river in combination with its transport facilities was an important factor behind industry localization at the river streams long before the area could be considered industrialized. Waterwheels supplying energy for grain- and saw mills were established around the smaller streams at Vargön and Lilla Edet and in connection to the large falls at Trollhättan. Before electrification there was no technology that could master more than a small fraction of the energy capacity of the river, and there were no industries or other human activities that could have utilized its full energy flows. The grain mills produced for local markets, and growth of this industry was therefore somewhat limited. The sawmill industry was in contrast growing substantially, in production as well as in unit sizes, from the beginning of the nineteenth century, in response to increasing export demand. The timber was shipped over the lake Vänern from forests on the North and West sides of the lake. Sawn timber could continue down the river to the harbor of Gothenburg. From the 1850's onwards, sawmills were beginning to be supplemented and replaced by wood based paper and pulp production. The production was initially based on mechanical grinding of wood to produce what is known as mechanical pulp, producing a low quality rough paper for packing and newsprint. Later on, the production of mechanical pulp was supplemented with the production of bleached durable papers from so called chemical pulp, depending on chemical inputs and emissions. This production was much more energy intensive, using not only mechanical but also thermal energy (Särlvik 1992, Hylander 1992).

6.2. Domesticating the stream; establishing large scale hydroelectricity.

In the 1880s, small scale electric hydropower was established in connection to industries and urban areas, for lighting and specific mechanical use. A couple of such plants were set up in connection to the falls at Trollhättan, used for mechanical industries, carbide production and zinc melting. None of them produced more than a couple of hundred kW. In 1890 the state decided to investigate how the power resources at Trollhättan could be put to the most efficient use. Until this investigation was finished no more water rights would be leased to small scale use. The only exception from this was the Malöga station established in 1903, producing 460 kW for the Trollhättan canal locks and for local electric lighting (Hansson 1992b: 18).

By then the plans for establishing a large scale, state-owned, multipurpose hydropower plant in Trollhättan was well developed. The investigators had visited plants in Canada and the United States – the Schoelkopf plant by the Niagara Falls was a particularly important model. With a height of fall of 33 meters, an average flow of 550 m3 per second and a gigantic water store situated close to urban centers and good logistic conditions for large scale export industries, Trollhättan seemed to be an ideal location for hydropower. There were however many institutional obstacles to overcome before the construction could begin. The first obstacle concerned property rights. A verdict in the Supreme Court in 1901 concluded that the state owned the water rights in the Trollhättan falls, even though large parts of river banks were owned by private companies. The largest of these companies, the Canal Company, was bought by the state in 1905 and transformed into the Royal Waterfall Board (Kungliga vattenfallsstyrelsen). The Waterfall Board has since been a dominating actor in Swedish electric power production and -distribution (Hansson 1992a). The other companies located around the falls parted with their land rights in exchange for financial compensation and alternative sites. (Early on, the Waterfall Board realized that owning the rights to the smaller falls at Vargön and Lilla Edet also was necessary to utilize the full potential of the river. Here, the Board had to negotiate with paper plants that held the established water rights, as well the property rights over riverbanks on both sides of the river. To obtain these rights the Waterfall Board had to pay relatively high prices. This was especially so in the Vargön case, where they had to exceed competing offers from a large private power producer (Hansson 1992b:69-78, 94-100, Hansson 1992a).

As part of these deals the companies and the Waterfall Board made mutual contracts for long-term supply of electricity at fixed prices. At this stage such contacts was considered favorable for the Waterfall Board since one of their main considerations was how to find a market large enough for the very energy supply that their plans anticipated. In the long run, however, these fixed deliveries to comparably low prices would primarily turn out to be very profitable for the electricity-purchasing companies (Hansson 1992a).

The building of the power plant Olidan began in 1907 and the first stage was finished in 1910 when they could produce almost 40 MW (40,000 kW) from four generators. Until 1919 this capacity expanded to 120 MW from 13 generators. Today the capacity has increased to 135 MW. The next step in this expansion was the construction of a power station at Lilla Edet, started in 1918 but not finished until 1926, due to economic depression and technical problems in utilizing large water flows in a rather low fall height. In 1973 this plant was expanded with a fourth generator giving it a capacity of 43 MW. In 1934 a power station at Vargön was completed. Today it has three generators and an effect of 34 MW. After 1934 the workforce from Vargön was transferred to a new project at the falls in Trollhättan, aiming at utilizing their full production capacity. After constructing some new canals and dams they started to build a new large plant at the site of the old small scale plant at Malöga. This plant that was to be named Hojum and vas equipped with two large generators that together delivered 100 MW. In 1992 this station was extended with a third generator, adding 72 MW to its capacity. Altogether the power plants along the river now form a cluster with an aggregated effect of 388 MW that could deliver 1,635 GWh per year (Ahltin 1947, Hansson 1992a, www vattenfall.se).

6.3. Hydropower as a factor for localization of industry

TABLE 1 *Distribution of electricity from the Trollhättan hydropower plant 1920. Quantity and price divided between areas of distribution*

Areas of distribution	GWh	%	Milj. SEK	%	SEK/GWh
Stallbacka & Vargön	237	65	2.7	43	11,672
Gothenburg	84	23	1.8	28	21,761
Other	42	12	1.8	29	43,873
Σ	363	100	6.4	100	17,773

Source: Official statistics of Sweden, Royal Waterfall Board

In the 1920s the infrastructure and technique for long-distance, high-voltage electricity transmission was still not developed, hence costs and energy losses increased substantially with distance. To find, or establish, sufficient demand for electricity within reasonable distance from the power plants was therefore a major concern for the Waterfall Board. Selling electricity to the city of Gothenburg was from the beginning an important part of the plan, but it was even more important to establish electricity-consuming industries in close connection to the power plants, and along the power line to Gothenburg.

By setting up an industrial park at Stallbacka, some kilometers upstream from the power plant in Trollhättan, the Waterfall Board could offer replacement sites for the industries that had to be moved to give room for the plant and its dams. Sites could here also be offered to new electricity-intensive industries that were encouraged to establish in close connection to the plant. These were industries that also could benefit from the transport capacity of the river, and in many cases use its water for industrial processes. For most of these industries the river also served as an important recipient of liquid industrial waste and pollution. Today, Stallbacka is one of Sweden's most dense industrial zones (Särlvik 1992).

The early construction of a power line to supply the city of Gothenburg with electricity encouraged similar industries to establish and expand on many other sites downstream along the river.

In the sections that follow, the establishment of electricity-intensive industries in the Göta River Valley is divided into four sectors (Olsson 1984).

1. The *pulp and paper mills* have been the largest industrial consumers of electricity in Sweden at least since the early twentieth century.
2. The second largest consumer was the *metallurgical industry* which became increasingly dependent on electricity with the introduction of electrometallurgy as well as electric smelters and furnaces. In Sweden this development in combination with hydropower was a crucial component in the industrial strategy to modernize the old charcoal-based iron industry without becoming too dependent on imported coal and coke.
3. The third important sector was the *electrochemical industry* producing chemicals such as potassium, chloride, hydrogen gas, lye, soda, Hydrogen peroxide, etc. and lead-acid batteries for industrial and vehicle use.
4. Finally an expanding and diversified *mechanical engineering industry* could also utilize cheap electricity

TABLE 2 *Table 2. Electricity consumption in some industrial sectors of Sweden. Quantities (Megawatt hours) and relative shares 1940-1980*

Sectors	1940		1960		1980
	GWh	%	GWh	%	GWh
Metalworks	1,546	28	5,282	25	7,386
Paper and pulp industries	1,780	32	7,689	37	14,207
Chemical industries	487	9	2,579	12	5,474

Source: Official statistics of Sweden, Royal Waterfall Board

6.4. Paper and Pulp Mills

The production of mechanical paper pulp through grinding of wood at Vargön started already in the late 1860s. The pulp vas the sold to paper several paper plants that lacked sufficient waterpower to produce their own pulp with this technique. In 1873, the company completed this production by building their own paper plant, starting a rapid expansion of the company.

Already in 1888, as one of the first paper producers in Sweden, the company Wargöns Bruk added a factory by the Göta River, close to the inflow from Lake Vänern. In this factory chemical pulp was produced, using the so-called sulfite process (Hermelin 1950: p 64). In this process, the lignin and the cellulose in the wood is separated chemically by using salts of sulfurous acid and other chemicals like magnesium or potassium. This produces almost pure cellulose that is much whiter than the mechanical pulp. Yet, until the beginning of the 1990s the sulfite pulp was in most cases bleached using chlorine, emitting large amounts of chlorinated dioxins and other organic compounds with the waste water (Bierman 1993; Kinneryd 2010: Bernes & Lundgren 2009:79). Wargöns Bruk had contracted for large electricity deliveries for a period of forty years. The cheap supply of electricity facilitated the expansion and conversion of the production from mechanical into chemical pulp and paper. However, even though the latter technology in particular was very energy intensive, the company could not utilize all of the contracted supply of electricity. In 1913, Wargön therefore diversified into a new activity by establishing an electrometallurgical smelter for the production of ferroalloys with metals such as chrome, silicon, manganese and aluminum (see more on this below). The paper production also experienced swift growth under these conditions. During the first half of the century paper production at the Vargön factories grew from about 6,000 to 35,000 tons, mechanical pulp from 4,000 to 23,000 tons and chemical pulp from 3,000 to 21,000 tons (Hermelin 1950: p. 136 f). During the same period, Wargön as a company transformed into a global corporation by buying, and merging with, companies and enterprises in the fields of mining, forestry, paper and metallurgy. Through this vertical integration they could control a complete supply chain for the production of paper, pulp and ferroalloys for an international market. In 1968, the company was taken over by the American corporation Airco. Airco then sold the paper and pulp branches and the forest estates to the Swedish corporation Holmen AB. In 2009 when Holmen was consolidating its paper production to fewer and larger units, the closeness to the Trollhättan power plant was no longer a significant advantage and the paper production at Vargön was closed down.

A cluster of paper industries were localized in connection to the streams at Lilla Edet. The first was Lilla Edets Pappersbruk AB, founded in 1881, when it started to produce mechanical pulp that was reprocessed into rough paper. In 1900, a factory producing chemical pulp and paper was completed. The sulfurous acid needed for the sulfite process was also produced in-house at the Lilla Edet factory. In 1918, the buildings and the factory site where sold to the Waterfall Board, giving room for a new power plant. The financial capital from this sale was invested in a new larger factory completed 1926, with a production capacity of 18,000 ton paper per year (about 3.5 % of the total Swedish paper production at the time). An even larger factory replaced this in 1957. By then the company had specialized in soft paper products for hygienic use. Today, the factory is owned by the multinational corporation SCA (Swedish Cellulose AB) (Hylander 1992).

The second paper industry to be established in Lilla Edet was the Inland cardboard factory that started production in 1896. They came to specialize in packing material. Today Inland are owned by the global corporation Knauf Danogips and produces the packing for their plasterboard products. (Hylander 1992)

In Göta immediately South of Lilla Edet a factory for production of paper pulp, using the sulfite process, vas started in 1905. The factory expanded continuously for many decades, reaching a production capacity of 14,000 tons in 1914, 35,000 tons in 1930 and 43,000 tons in 1957. The customers of the Göta factory were mainly Swedish and German paper mills, among them the Lilla Edet and Inland companies. In 1957 this factory was destroyed in a large landslide. A new plant for sulfite pulp was erected in 1958 along with a large grindery for mechanical pulp production. The production of chemical pulp was closed down in the late 1970s partly because of ecological complaints. In the early 1980s, the whole factory was shut down after a couple of years of heavy financial losses (Hylander 1992).

Finally the water in the Göta River has also been affected by a large paper mill by its tributary Mölndalsån. The Papyrus Company was founded in 1893 but paper production on the site of a high waterfall had traditions from the first half of the eighteenth century. The production at Papyrus expanded from 4,000 tons in 1900 to 40,000 in 1939. Originally Papyrus produced its own electricity from the falls in Mölndalsån. The water flow was however too small and too uneven to secure the production process. Instead of connecting to the Waterfall Board lines, Papyrus became part owner (later on majority owner) in Yngeredsfors Kraft, a privately owned hydropower station situated by a smaller river some 100 km to the south. Mölndalsån was of course still used for process water and as recipient of waste that ended up in the Göta River (Hallén 2010; Ahltin 1945).

6.4.1. Environmental effects of paper production

The production of paper and pulp affected the water in many ways. Firstly, the plants emit organic matter such as waste fibers. The dissolution of these in fresh water reduces the oxygen level and hence the biological living conditions. This effect is measured by Biological Oxygen Demand (BOD) or Chemical Oxygen Demand (COD). Secondly, the waste water contains nutrients such as nitrogen and phosphorus, causing eutrophication.

Thirdly, in the chemical processes the pulp is generally bleached. The reason is partly aesthetical but the bleaching also enhances the paper's adequacy for printing and improves the readability. It has also positive effects on the papers aging properties. Basically the bleaching separates the traces of resin and lignin and lye that remain after the boiling process. These are the organic compounds that cause the brown or yellow color and the roughness of the paper. Conventional bleaching was done with elemental chloride and releases dioxins and other chlorinated organic compounds into the waste water. Dioxins are highly toxic, if the concentrations are high enough, it has severe effects on the marine fauna and on human health, causing reproductive, hormonal and immunity problems (Svärd 1990) Göta Älvs Vattenvårdsförbund 1996, 2005)During the late eighties, after successful campaigns by Greenpeace and other environmentalists, researchers developed new bleaching methods using les degrading, non-elemental chlorides (ECF-elemental chloride free) or completely chloride free methods (TCF) using ozone, oxygen peroxide etc. The Swedish and Finnish paper industry has been forerunners in this transition. Today there is no pulp produced in Sweden that uses elemental chloride. Getting rid of chloride in the process also made it possible to separate most of the lignin from the wastewater and use it as a bio-fuel (Bierman 1993; Kinneryd 20 Bernes & Lundgren 2009:79).

6.5. Metallurgy

Smelters for the manufacturing of alloys were well suited for a location in connection to hydropower plants with high variation in their electricity productions. They had high energy demands, but could at the same time adapt their production to the variations in electricity supply. There were at least six such companies established in Trollhättan between 1913 and 1918. Three of them lasted only for a couple of years. One larger plant survived until 1932, producing foremost ferrosilicon. Two plants where taken over by Wargöns Bruk in 1929 and 1942. After that, they were used for manufacturing ferrochrome (Ericsson 1987).

As mentioned above, the old paper mill run by Wargön diversified its production in 1912, to utilize their long run contract for electricity. A new electric smelter was taken into operation this year. In 1920, the smelter was the largest construction of its kind in Sweden. At this time, the production of ferroalloys with silicon and manganese (FeSi, SiMa, FeMa) at Wargön reached 14,000 metric tons per year. In 1950, the smelters produced more than 30,000 metric tons of alloys (Hermelin 1950 p. 136 f.) When the metallurgical branch of Wargön in 1968 was consolidated as a daughter company under Airco with the name Vargön Alloys, the production of manganese alloys came to an end. Instead, a new smelter for ferrochrome (FeCr) was built in 1972. At that time, it was the largest in the world. Today the company is owned by the Turkish Ylderim Group. It has a yearly capacity of 25,000 metric tons of ferrosilicon and 160-200,000 tons of ferrochrome and is considered to be one of the most energy and electricity intensive enterprises in Sweden.

Finally, one large alloy plant, AB Ferrolegeringar, was established in Trollhättan 1913. In the 1920's and 1930's they were the largest producers in Europe of low carbon ferrochrome (LC FeCr). After 1939, they diversified their production into ferroalloys made with molybdenum (FeMo), vanadium (FeV) and tungsten (FeW). (Ericsson 1987)The production continued in large scale until the late 1980s when it was gradually phased out, only to be completely shut down in the early 1990s (Särlvik 1992).

6.5.1. Environmental effects of electrometallurgyRubriknivå 2

The most severe effects of these activities have been caused by emissions of metals into the air. Metals have also tended to leak into the water from this production, both directly from the production process and indirectly from old dumps of metallic waste along the riverbank. The most problematic of these metals is chrome, and especially hexavalent chrome which has been a common component in ferrochromium alloy products (Bernes & Lundgren 2009: 80 ff; Svärd 1990: Göta Älvs Vattenvårdsförbund 1996, 2005).

6.6. Electrochemical industry

Another highly electricity-intensive activity was the electrochemical industry, where base chemicals are produced through electrolysis and other electrical processes, or where electricity is stored chemically in batteries. Electrochemical production was well suited for a location in connection to hydropower plants. Since they had a large, but not constant, demand for electricity they could in particular utilize surplus capacity at nighttime for their chemical processes. The electrochemical industry along the river became well integrated with the local metallurgical and paper industries, but they also produced for larger markets on the national and global level.

The first example of this type of industry appeared already before the large scale electrification, as mentioned above: a small factory in Trollhättan produced carbide with electricity from a small generator (Särlvik 1992).

In 1916 Stockholms Superfosfatfabrik AB, which for a long period was Sweden's largest electrochemical company, later under the name Kema Nord, localized the most electricity consuming segments of its production to Trollhättan. They came to specialize in production of chlorates and perchlorates, especially sodium chlorates that were used foremost for production of herbicides and for the bleaching of paper pulp. They had also a large production of carbides until the late 1940s. In the 1970s this production had difficulties with profitability, increased competition, high energy costs and environmental complaints, and the electrochemical production was closed down. Today all that remains is a production of wax for the paper industry (Särlvik 1992, Glete 1987: 81-82).

The largest electrochemical industry along the river is EKA Chemicals, situated in Bohus about 25 km from the southern river mouth in Gothenburg. This company relocated its production to this site in 1924 in search of good supplies of electricity and process water. This plant produced varieties of chloride mostly for bleaching in textile and paper production. They also produced a large spectrum of other base chemicals – such as potassium, alkaline lye, potassium chloride, soda, peroxide chloride and hydrochloric acid – and metallic salts and other substances for galvanizing and metal-plating. Today EKA

Chemicals has grown into a global subsidiary within the Akzo Nobel Corporation specializing in chemicals for the production and bleaching of paper pulp and for water treatment (Alexandersson 1992; Elektrokemiska 1936).

In Nol, some five kilometers upstream from Bohus, the German company AFA started production of lead-acid batteries in 1914. In this case, it was also the electricity supply in combination with good transport facilities that motivated the localization. Tudor produced batteries for machines and vehicles until 1999. Today, the plant has been taken over by Battery and Fuel Cells Sweden AB, a company that develops new technology in the fields of batteries and fuel cells (Alexandersson 1992).

6.6.1. Environmental effects of the electrochemical industries

Obviously such a diversified chemical production as this makes it hard to evaluate all possible effects on water quality and water safety. Among the emissions that seemed to have caused the most worries are metallic salts, mercury, chloride and cyanide. The battery production has over the years caused environmental pollution; primarily regarding emissions of lead into the water and depositions along the riverbanks (Svärd 1990; Göta Älvs Vattenvårdsförbund 1996, 2005).

6.7. Mechanical engineering

Measured in turnover and employees, mechanical engineering has to be considered the most important industrial sector in the river valley. In general, this activity has not been as dependent on intense electricity use as the ones discussed above. However, in areas where cheap electricity was available, electrification could be an important factor of rationalization and development in this sector as well. In the early days, companies in the mechanical engineering sector were also well integrated with the electricity-producing and -consuming cluster, both as consumers of energy and metallurgical products and as supplier of machinery and other equipment.

The oldest of these companies that came to reach large scale production was NOHAB Industries. Founded already 1847 it was a diversified mechanical workshop producing a large variety of engines, machinery and vehicles. They started as a producer of agricultural machinery and water turbines. Later, they became a large producer of locomotives, engines and printing presses. During the Second World War, arms and other military equipment came to dominate their production. During the 1960s and 1970s they also delivered equipment for nuclear power plants.

Two other large industries could be regarded as spin-offs from the NOHAB Company. Volvo Aero started producing aircraft engines in 1940, as subsidiary to NOHAB. In 1941 the majority ownership was transferred to the Volvo Corporation. Today Volvo aero is a world leading producer and developer of some advanced jet engine components that they deliver to companies such as Rolls-Royce, Pratt & Whitney and General Electric; they also deliver specialized equipment for commercial spacecrafts and the European space program.

The second large spin-off, SAAB, started as an aircraft producer 1937 in cooperation between NOHAB and some other large Swedish defense contractors and investors. NOHAB soon lost active ownership control over this enterprise. With the end of the Second World War the demand for this production decreased sharply. To utilize established capacity, the company started to produce motorcars in its Trollhättan factories. Together with the large production of Volvo cars and trucks in Gothenburg this sector formed an industrial cluster where many sub-contractors have been established in Trollhättan, Gothenburg and the surrounding area. In 1990, the car division of SAAB, including all production facilities in Trollhättan, was bought by General motors. Today, after the GM restructuring in 2010, SAAB is a comparably small independent car producer owned by the Dutch company Spyker cars.

Another large business of this type with effects on the river is the SKF (Svenska Kullagerfabriken) ball-bearing factory in Gothenburg, situated by the tributary Säveån just before its mouth in Göta River. This factory vas founded 1907 and is today the headquarters of the largest ball-bearing manufacturer in the world, with more than 100 factories around the world (Fritz & Karlsson 2007).

Historically shipbuilding has been an important economic activity in the river valley. During the 20th century, this industry came to be concentrated to the river mouth in the Gothenburg harbor with three large shipyards. In 1965 two of them, Götaverken and Eriksberg, had grown to be the two largest shipyards in the world (measured in tonnage production) outside of Japan (Olsson 1996:221). In the 1970s, the global shipbuilding industry experienced a large crisis and restructuring that resulted in a rapid decline of the industry in Gothenburg and Sweden. The last ships where built in the late 1980s. Today, there are only repair- and renovating activities in Gothenburg. These shipyards were also large mechanical workshops producing large engines, engine parts and other mechanical equipment. In the early years of the 20th century, there were several smaller such combined shipyards producing engines and smaller tonnage of ships. Only one of them survived into the second half of the century. That was the Lödöse shipyard, situated about five km south of Lilla Edet. They produced smaller tonnage trawlers, ferries, towboats and ships for costal transports. In the early 1970s they peaked in size employing a workforce of about 350. In 1985 this production was closed down. (Olsson 1992).

6.7.1. Environmental effects of Mechanical engineering

In relation to its large production, the effects of the engineering and shipbuilding sector on water quality seems (according to our present knowledge) to have been smaller than the electricity intensive activities presented above. In absolute numbers it has however emitted significant amounts of oils, metal traces and toxic solvents into the water (Svärd 1990, Göta Älvs Vattenvårdsförbund 1996, 2005).

6.8. Pollution before the outflow from Lake Vänern

As described above the river valley from Lake Vänern to the sea is short but heavily industrialized. Most of the environmental impact that could be measured at the river mouth derives from this stretch.

The water is however not unaffected by human economic activity when it leaves Vänern. To the south the lake is bordering one of Sweden's most intensely cultivated agricultural districts. Here pesticides, herbicides and nutrients from fertilizers has been leaking into the lake through streams and smaller rivers.

The larger tributaries to the north and west and especially the largest river, Klarälven, runs through large forests that has been subject to silvicultural practices such as chemical weed control and fertilization. In these forested areas one could also find several large paper plants, metalwork's and mining activities (Kardell 2004 p77 ff., Bernes & Lundgren 2009). The mere size of the lake and the watershed also means that it has been receiving large amounts of acid rain and other forms of polluting atmospheric fallout.

The environmental quality of the water in Lake Vänern has at times been severely affected by these factors, even though the improvements have been significant in the last 25 years. The environmental character and capacity of a large lake like Vänern is substantially different from that of a streaming river. While it takes 1-5 full days for the water to flow from Lake Vänern to the sea, the average turnover of the water stores in the lake is approximately eight years. Accordingly the lake has a restoring capacity, where many pollutants sink to the bottom and is stored in the seabed sediments and oxygen levels could be re-established. The large water store has also a higher capacity to disperse many forms of pollutants. Still, for many forms of pollution, such as phosphor, nitrogen, COD and zinc, the initial contribution from Lake Vänern constitutes a significant addition to the ones emitted in the river valley (Gustavsson 2000, Svärd 1990: p. 11).

6.9. Conclusions

The most important factor influencing the localization of industries in the river valley was the abundant supply of electricity from the hydropower plants during the first four decades of the 20th century. After that, the infrastructure for long distance electricity was fully developed and an integrated national market with converging prices was created. There was no longer any particular advantage in localizing energy intensive industries to this area. But the river also supplied industries with other facilities such as process water and transport facilities, and the location in close connection to Gothenburg and its harbor was still often advantageous for these exporting industries. The heavy industry character of the area was maintained for a long time, and to a significant extent it has survived until this day, partly as an example of path dependency. However, large sections of this industry has disappeared during the last forty years. Some companies have not been able to compete on globalized markets. Other plants have been closed down when corporations have consolidated their production in fewer and larger units of production. To what extent this structural transformation has contributed to the improvement of the river environment remains to be investigated.

Another obvious conclusion is that the technical development within these sectors has made it possible to reduce many forms of emissions to comparably low costs. This is most obvious when one considers the paper and pulp industries where new technology has developed, often in response to high political pressure. It became possible to separate and recycle much more of the organic waste and to bleach pulp and paper with none, or less damaging, forms of chloride.

A similar development (but with less direct consumer pressure involved) in the chemical and metallurgical industries has made it possible to substitute the most environmentally harmful elements and to refine cleaning processes without too large costs.

The expansion of shopping malls, warehouses and other distributional activities is another important change that follows the general trend of transition towards a post-industrial and service-oriented economy. Many of the previously industrial sites in the River Valley have now been taken over by commerce and distribution.

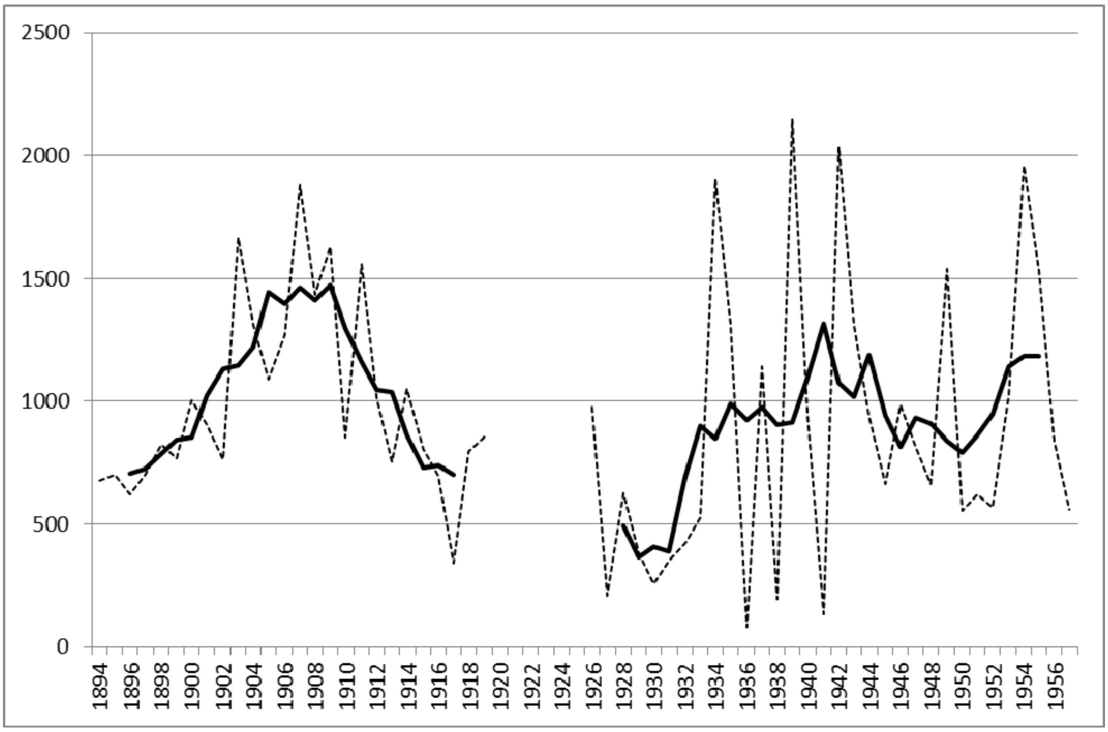
7. The pollution of the river

Since the river is the source of drinking water for the whole city of Gothenburg, there has been continuous and regular sampling of the water quality since 1895 at the inlet of the main water purification plant in Gothenburg, Alelyckan. Other cities and towns, such as Lilla Edet and Trollhättan further upstream, have also used the river as a source of drinking water. There is therefore similar sampling from a number of places, although the data-series is not as long for some of these places. In the 1950s, a watershed association was established, with the task of monitoring water quality in the river (see section 7.2 below). This association has ever since undertaken regular testing of the water quality at a number of different locations along the river. What the samples are tested for has varied over time. During the early years, the samples from the Gothenburg water plant inlet were only tested for a small number of substances – including sludge, acids, pH-value, earth metals and chemical oxygen demand. As time passes, the samples were tested for an increasingly longer list of substances, also including nitrogen and phosphorus, sulphate and a number of heavy metals.

In the graphs below, we use data from two points along the river – firstly upstream from the inlet at the water purification plant in Trollhättan. There are only a few industries situated along the Göta River prior to this inlet. The data from this point thus largely measures the quality of the water flowing from Lake Vänern. This is in turn to a large extent a reflection of environmental pollution of the water taking place prior to it entering the Göta River proper. Much of the pollution showing up in these tests reflect the pollution from industries along many of the tributaries to lake Vänern. The second point of data is downstream in the Göta River, at the inlet of the water purification plant Alelyckan in Gothenburg. While there are a couple of important industries (including petrochemical industries, and the sewage treatment plant of Gothenburg) situated further downstream from Alelyckan, the data from this point does to a large extent reflect the total environmental load of pollution in the river, which is then fed into the ocean.

The data on actual pollution in the river is presented relative to modern-day benchmark levels from the Swedish Environmental Protection Agency (Naturvårdsverket), on what modern science considers very low (below dashed green line), low (green line), medium (yellow line), high (orange line) or very high (red line) levels of pollution (for these environmental assessment benchmark values, see Naturvårdsverket 1999).

Graph 2. *Bacterial colonies (annual average, per ml water, 20^{0}C, 48 hours) in the water in the Göta River, 1894-1957 (annual data and 5-year moving average)*



Sources: Årsredovisning Göteborgs vattenverk, Kommunfullmäktiges handlingar Göteborgs Stad [Annual report of the Water treatment plant, Documents of the City Council, City of Gothenburg], 1894-1957

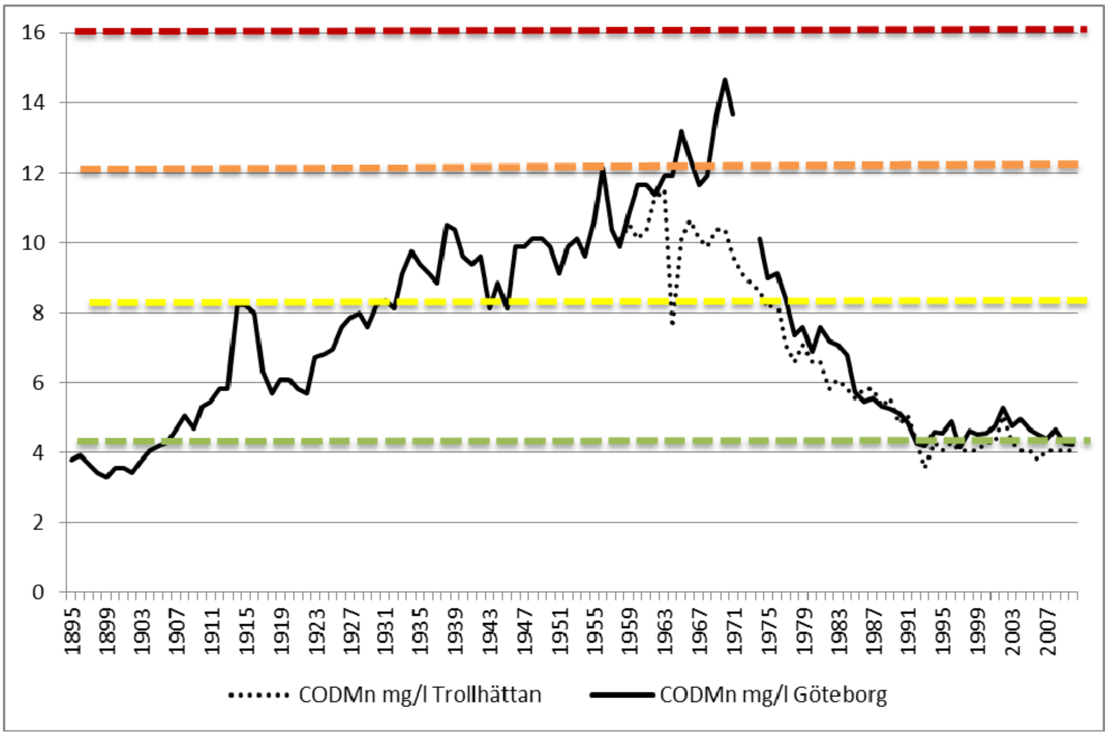
Graph 2 shows data on the amounts of bacteria in the untreated river water, used as drinking water. Though all bacterial colonies are not necessarily dangerous for humans, the amounts of bacteria in a body of water is an indicator of the risk that dangerous epidemic diseases – such as cholera or typhoid – might be transmitted through the water.

As can be seen in the graph, levels of bacteria seem to have increased in the 1890s, and the first years of the 20th century. During the two following decades, however, the amount of bacteria in the river is reduced. From the 1920s to the 1950s, there is substantial fluctuation in the annual average data on bacteria in the river, but there is no upwards trend – despite a growing population in the region throughout the whole of this period. The positive relationship between economic (or, in this case, population) growth and environmental pollution does therefore seem to have been turned around at quite an early date, when it comes to levels of bacteria.

Further investments were made to deal with other aspects of the pollution from sewage. In the 1930s, mechanical treatment of sewage increasingly came into use around the country. In the 1950s, biological treatment of sewage also started to come into use in

Sweden. The city of Gothenburg did however not introduce the latter until in the 1970s (Bernes and Lundberg 2009:186-8).

GRAPH 3. *Chemical Oxygen Demand (COD) in the Göta River, 1895-2010*

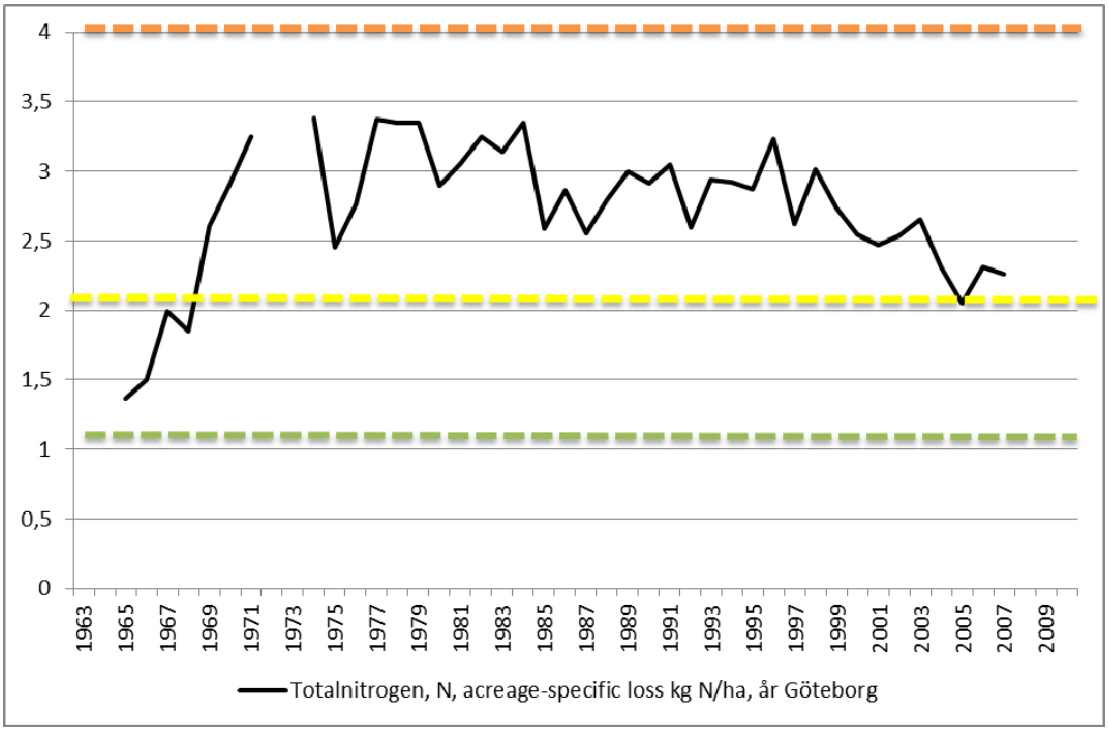


Sources: Gothenburg 1895-1971: Årsredovisning Göteborgs vattenverk, Kommunfullmäktiges handlingar Göteborgs Stad [Annual report of the Water treatment plant, Documents of the City Council, City of Gothenburg]; Gothenburg 1974-1985: Göta Älvs Vattenvårdsförbund, Recipientkontroll; Trollhättan 1965-2010 and Gothenburg 1985-2010: Miljöövervakningsdata – Sjöar och vattendrag, Naturvårdsverket och SLU [Environmental Surveillance Data – Lakes and rivers, Swedish Environmental Protection Agency and SLU]. Available online at: http://info1.ma.slu.se/IMA/dv_program.html. Accessed 2011-01-13.
Note: Pollution benchmark levels from Naturvårdsverket 1999: table 11.

Graph 3 shows data on Chemical Oxygen Demand (COD) in the river. The Chemical Oxygen Demand shows the amount of oxygen necessary to decompose organic material. A high level of COD leads to oxygen depletion, i.e. loss of oxygen for the aquatic life in the river, thus impacting the biological diversity in the river directly. Brödtext utan indrag

The levels of COD increased drastically in the Göta River during the first seven decades of the 20th century, reaching what the Swedish Environmental Protection Agency considers high levels in the 1950s and 1960s, and approaching very high levels by the late 1960s. The levels of COD peaked in 1970, at 15 mg/l (some of the samples from this year showed even higher levels, with a maximum of 21,5 mg/l, thus reaching very high levels of pollution according the EPA-benchmark). The increase is directly related to the growth of industrial production, not the least pulp- and paper production, along the tributaries to lake Vänern (thus the high levels of COD of the water feeding into Göta River) as well as runoff from agriculture in the region. From the 1970s, until the early 1990s, the levels of COD drop considerably, so that the levels returned to low or even very low levels. Judging from this indicator, the river is today as unpolluted as it was at the beginning of the 20th century.

GRAPH 4. *Acreage-specific loss of nitrogen to the Göta River (kg N/hectare and year), 1965-2010*



Sources: Gothenburg 1895-19711965-1971: Årsredovisning Göteborgs vattenverk, Kommunfullmäktiges handlingar Göteborgs Stad [Annual report of the Water treatment plant, Documents of the City Council, City of Gothenburg]; 1974-1985: Göta Älvs Vattenvårdsförbund, Recipientkontroll; 1985-2010: Miljööver-vakningsdata – Sjöar och vattendrag, Naturvårdsverket och SLU [Environmental Surveillance Data – Lakes and rivers, Swedish Environmental Protection Agency and SLU]. Available online at: http://info1.ma.slu.se/IMA/dv_program.html. Accessed 2011-01-13.
Note: Pollution benchmark levels from Naturvårdsverket 1999: table 5.1.

In graph 4, we plot the acreage-specific loss of nitrogen to the river. High levels nitrogen in water contributes to eutrophication, which in turn can contribute to the growth of cyanobacteria and oxygen depletion, among other effects.

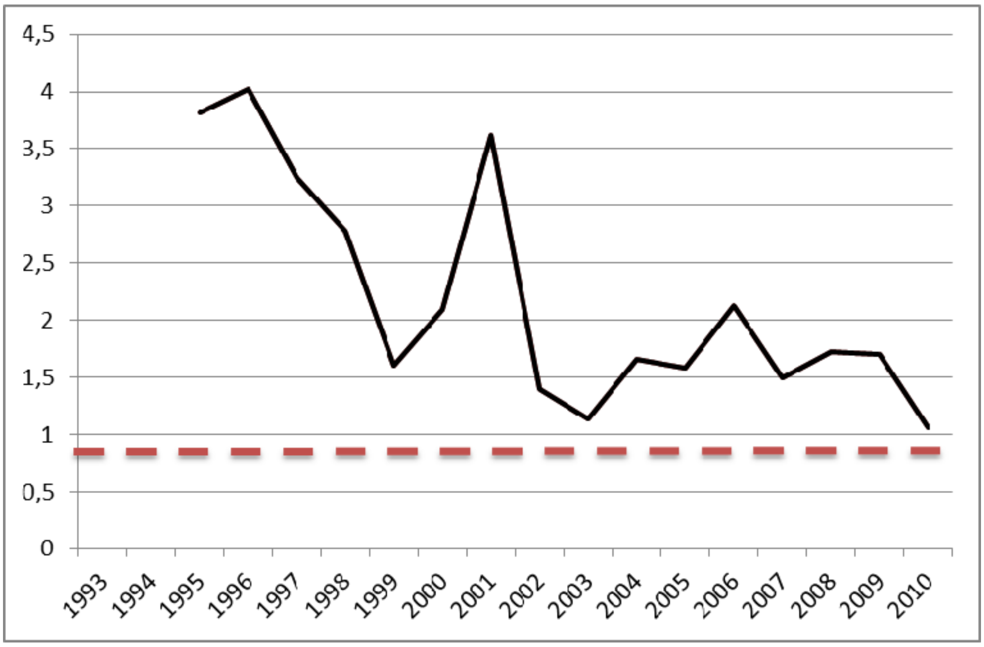
In this case, the development was not as dramatic as in the case of COD – the total levels of nitrogen increased from low to medium levels in the 1960s (when the data-series so far begins) and approached but never reached high levels of nitrogen loss from the watershed. With medium levels in lakes, the growth of cyanobacteria is probable, and with high levels such growth is very probable. Levels of nitrogen then stagnated, and started to decrease slowly in the 1980s. Today, the levels are still of medium level, but the trend is still one of decreasing pollution.

Both COD and nitrogen thus increased in the river until the 1970s. The trend has however turned, and pollution levels have now decreased since then. The trends are similar for other substances tested for in the water samples, including total phosphorus and sulphate. We thus have solid evidence of an 'environmental Kuznets curve' in the case of these pollutants of the Göta River.

For yet other chemicals, such as many heavy metals, the data-series available so far is only quite short – stretching back to the 1980s at best. One of the heavy metals – mercury – was of particular importance in the case of the Göta River, since there was considerably emissions from the chemical industry along the river. Mercury is highly toxic, and the concentrations found in the river when pollutions were at their peak far exceeded the benchmark values required for drinking water (1 μg/l), according to Swedish law (SLVFS 2001:30). Mercury pollution was thus a key concern not the least for the city of Gothenburg, in order to secure a safe drinking water in large enough amounts to sustain the population of the city. Graph 5 shows data for concentration of mercury in the river water from the middle of the 1990s, when systematic testing became more reliable. At this time, the concentration was four times higher than what was considered safe in drinking water, but the pollution decreased significantly during the period.

For some of the other heavy metals, including nickel and zinc, pollution levels in the river have also dropped since testing begun in the 1980s (or somewhat later in some cases), even though the pollution in these cases never was as problematic as in the case of mercury. Since it seems reasonable to assume that the emission-levels of these pollutants have risen to reach the levels found when testing began, the data also suggest the existence of an 'environmental Kuznets curve' in the case of these pollutants as well.

GRAPH 5. *Levels of mercury in the Göta River (µg/l)*



Sources Miljöövervakningsdata – Sjöar och vattendrag, Naturvårdsverket och SLU [Environmental Surveillance Data – Lakes and rivers, Swedish Environmental Protection Agency and SLU]. Available online at: http://info1.ma.slu.se/IMA/dv_program.html. Accessed 2011-01-13.
Note: Benchmark level for safe drinking water from SLVFS 2001:30.

8. **Institutions**

8.1. National environmental legislation

Environmental legislation in Sweden has developed along a number of different lines. Concerning the pollution of water, one first debate was whether to restrict or prohibit environmental pollution in general or not. A second issue concerned governmental supervision of environmental quality, and a third issue concerned obligatory prior notification to or approval from the authorities in order to establish environmentally hazardous plants.

In the Water Rights Ordinance of 1880 (Vattenrättsförordningen, SFS 1880:57), one specific paragraph relates to the pollution of rivers, prohibiting the emission of garbage in rivers if it can lead to shallowing of the river "or other nuisances" (eller andra olägenheter). The law did thus leave some leeway for interpretation regarding pollution of rivers, but was far from clear and specific on the topic, so there were debates and motions in parliament in the 1890s and the early 1900s on how to deal with the slowly growing issue of pollution of rivers. In response to the debates, the government in 1903 assigned a specific committee (dikningslagskommittén) the task of investigating the issue thoroughly. In the meanwhile, no legislative action was taken by the government. The committee would need twelve years of work to come up with a proposal, but in 1915, they presented a draft for a new Water Act to the parliament. The proposal included imposing an obligatory requirement to acquire governmental concession before establishing any enterprise that might cause environmental pollution. The new Water Act came into being in 1918, but all proposals concerning pollution were omitted from the new law (SFS 1918:523). Three years later, in 1921, parliament decided to not take any action on the issue of environmental pollution, but to leave it be for the time being (Lundgren 1974).

In 1936, the issue of pollution was raised in parliament yet again. A new committee was formed and given the task to look into the issue anew. Waiting for the results of the work of the committee, the government made a temporary announcement (kungörelse) in 1937. The announcement stipulated that a new authority – the Fisheries Supervision Authority (fiskeritillsynsmyndigheten) – was given the task of supervising the state of environmental quality in watercourses and lakes. The authority was given the right of access to any property they required for conducting their supervision. If necessary, they could issue advice or instructions to individuals or enterprises in order to counteract pollution of water. If these instructions were not followed, the authority could bring charges before the county administrative board for violation of the Water Rights Ordinance of 1880. The announcement furthermore stipulated that the establishment of a number of different types of factories required prior notification to the Fisheries Supervision Authority. If there was a risk of considerable damage to fisheries in specific premises, the authority could prohibit the emission of pollution entirely (SFS 1937:598).

In 1939, the committee on environmental pollution established just a few years back presented a report to parliament. It would take parliament two years to come to a decision on the proposals in the report, but in 1941, the Water Act (of 1918) was amended to incorporate the issue of environmental pollution. In the amended law, chapter 8 on the emission of pollutants, was considerably improved upon. The law now stipulated that people responsible for any plant – be it private or public – were required to undertake "reasonable" (skäliga) actions to counteract pollution from the emission of sewage or industrial waste water. The law also stipulated that private enterprises were prohibited to emit pollutants in lakes or streams, unless it was unreasonable to require any countervailing action. The burden of proof that any action counteracting pollution was unreasonable was thus to a large extent put upon the private enterprises. If fisheries were hurt by pollution, the responsible plant owner could be forced to pay substantial damages. The government was also entitled to prohibit the establishment of specific plants, until it had been shown that necessary precautions would be taken to counteract the pollution of rivers. The government could finally also prohibit any emission of pollutions in specific premises in the interest of nature conservation in general (SFS 1941:614).

The same year, 1941, also saw a specific ordinance detailing the requirement to notify the authorities of the planned establishment of specific sorts of plants. The ordinance enumerated a list of types of plants – including concentrators, sulphite- and sulphate-cellulose plants, papermills and others – that required prior approval, i.e. they could not be established until it had been shown that necessary precautions to counteract environmental pollution would be undertaken. The ordinance enumerated a further list of types of plants that just would require prior notification to (but not necessarily prior approval from) the authorities before establishment (SFS 1941:843; SFS 1946:684; SFS 1956:583).

1941 also saw the birth of a law which stipulated that drinking water delivered in conduits from a water treatment plant had to be tested regularly, both physically-chemically (at least once every year) and bacteriologically (weekly or monthly, depending on the size of the water treatment plant) (SFS 1941:654). At the same time, in a specific ordinance, the previously temporary Fisheries Supervision Authority was made permanent. In 1948, the tasks of this authority were transferred to the then newly established Fisheries Board (Fiskeristyrelsen), and in 1956 transferred yet again – now to the newly established Government Water Inspection (Statens Vatteninspektion). In 1967, the task of supervision was transferred to the then newly established Environmental Protection Agency (Naturvårdsverket), together with the county administrative boards. The paragraphs regulating the practicalities of supervision remained largely unchanged throughout the period (SFS 1941:615; SFS 1948:482; SFS 1956:582; SFS 1967:371).

In 1956, the Water Act was amended again. This time, some of the paragraphs concerning pollution of water were made more stringent. It was for example now totally prohibited to emit untreated sewage water, and emissions of sewage were not allowed if it caused public nuisance (SFS 1956:581). The next step would however wait until 1969, when a new Environmental Protection Act (Miljöskyddslagen, SFS 1969:387) along with a more detailed Environmental Protection Ordinance (Miljöskyddskungörelse, SFS 1969:388, later replaced by SFS 1981:574) was put in place. The law tightened up many of the previous regulations on environmental pollution, not only to water but also to air. The law stipulated that plants that might be environmentally hazardous had to be located in such a place that the activity could be conducted with a minimum of public nuisance. Plant owners were still required to undertake 'reasonable' measures to protect the environment, including prevention and cleaning up after pollution has occurred. If something was 'reasonable' or not was to be determined by the contemporary technical possibilities, taking the common good into consideration, and the gain from an activity was to be weighed against the damage to the environment from the pollution in question. If the environmental pollution from an activity would lead to 'considerable nuisance', it was to be allowed only if 'particular circumstances' (särskilda skäl) were at hand. If environmental pollution from an activity considerably impaired living standards for a large number of people, it was not to be allowed at all (exceptions were made for road-, railroad- or airport construction). Just as in previous legislation, the authorities could prohibit emissions completely in a specific premises, in the interest of nature conservation or – a new amendment in the Environmental Protection Act – in the interest of the common good. The new Act also incorporated the previous legislation on notification about and/or prior approval from the government before establishing potentially hazardous plants. A special Board of Concessions for Environmental Protection (Koncessionsnämnden för miljöskydd) was set up to oversee this process and decide on applications. The Act furthermore included the previous legislation on the supervision of environmental quality. The task was still assigned to the Environmental Protection Agency, just as it had been in 1967 (SFS 1969:387).

The Environmental Protection Act thus assembled all the three major strands of legislation that previously had been introduced: the general restrictions against environmental pollution (including the obligation to undertake reasonable action to counteract it), the governmental supervision of environmental quality, and the requirement to notify and/or get prior approval from the authorities before establishing new plants. The new Act contributed with few new elements regarding the pollution of water. Most of the elements in the Act were just taken over from previous legislation (Hydén 1978:323).

The Environmental Protection Act did initially not include any sanctions against environmental pollution per se. Not even serious environmental degradation could in itself be punished under the law. Sanctions could only be administered in the case of an agent failing to acquire approval for emitting pollutants, violating a license granted, or failing to provide the authorities with correct information. The aim of the policy-makers was, as

Andreas Duit has put it, to construct a system that could produce compromises between environmental considerations and economic growth (Duit 2002:235). The authorities did therefore largely focus their work on consultation and advice to agents undertaking environmentally hazardous activities rather than direct enforcement of the legislation, thus taking a cooperative rather than confrontational approach. The Environmental Protection Agency was even criticized for using "police methods" when suing the city of Umeå in court after having tried in vain for many years to get them to decrease emissions from the local sewage treatment plant. "Environmental crime" (miljöbrott) was only included in the Swedish Criminal Code (Brottsbalken) in 1981 (Mårald 2007:28-29, 136). Because of budget constraints, the environmental protection institutions became highly dysfunctional from the start, Duit has argued: supervision by the authorities was in reality very rare. The polluters were instead expected to supervise themselves. The Board of Concessions was furthermore very accommodating towards industrial establishment. Even though a long list of industrial establishment required prior approval, virtually all applications – 99.5 per cent in one study – were approved. The Board of Concessions normally chose to apply conditions to an approval, rather than reject an application (Duit 2002:147-152).

In the same spirit of cooperation, state grants to reduce emissions from industries were introduced the same year as the Environmental Protection Act (1969). The grants were targeted towards older (industrial) plants. An establishment could receive at most 25 per cent of the costs of an investment that was made in order to reduce pollution. The Environmental Protection Agency was put in charge, together with the Labor Market Board, of administering the grants (SFS 1969:356).

During the 1950s and the 1960s, a number of watershed conservation associations had been established in Sweden on a voluntary basis by parties interested in the environmental quality of the watershed, including one concerned with the Göta River (see section 7.2 below). In 1976, new national legislation was put in place that required that any agent that had received permission under the Environmental Protection Act to emit hazardous waste into a watercourse, also had to be a member of the relevant watershed conservation association (SFS 1976:997).

In 1983, a new Water Act came into effect. In the first paragraph, the act laid down that water was to be protected and conserved as a common natural resource. At the same time, the Act did not cover water pollution, except for in the case of drinking-water. In the latter case, the new Water Act stipulated that any agent who might harm the source of a drinking-water supply was obligated to take pre-cautionary measures in order to prevent and – if it occurred – treat pollution of the water (SFS 1983:291).

In the 1980s and 1990s, a number of amendments to previous legislation were enacted, along with the introduction of a number of new acts regarding the conservation of and care for the environment. In 1986, for example, a new Environmental Damages Act (Miljöskadelag, SFS 1986:225) was introduced, detailing the damages to be paid in the case of environmental pollution. The following year, a new Economizing with Natural Resources Act (Lag om hushållning med naturresurser, SFS 1987:12) was passed. The law stipulated that land and water resources were to be used in a long-term sustainable way. Especially sensitive land or water areas were to be protected as far as possible. In 1988, the supervision and enforcement of the Environmental Protection Act was partly decentralized to the local municipalities. The Environmental Protection Agency and the County Administrative Boards continued to have an important role in the process (SFS 1988:924). In 1989, a new ordinance on Environmental Damages Insurance (Förordning om miljöskadeförsäkring, SFS 1989:365) was introduced, in order to secure funding from polluters in order to pay for environmental damages to agents hurt by the pollution in question. In 1991, a number of older acts were amended so that any application for the permission to emit pollutants had to include an Environmental Impact Assessment (miljökonsekvensbeskrivning, MKB, SFS 1991:648; SFS 1991:649; SFS 1991:650).

The next major step in the development of environmental law in Sweden came with the passing of the comprehensive Environmental Code in 1998, after almost a decade of discussions and political wrangling (Miljöbalk, SFS 1998:808). The new Code incorporated many of the older environmental protection acts – including the Environmental Protection Act with all its amendments, the Act on Economizing with Natural Resources and parts of the old Water Act, and the paragraphs on environmental crime from the Criminal Code – together in one piece of legislation. New developments in the act included formulations in the introductory chapter. The first paragraph of the Code stipulated that the aim of the legislation was to further a sustainable development, which included securing a healthy environment for current and future generations. All agents involved in economic activity were now required to have the necessary knowledge, and undertake necessary precautions, in order to protect the health of humans and the environment from harm or nuisance. All agents were also required to use best available technology to the same purpose (unless it could be shown to be unreasonable to do so). Facilities were to be located so as to minimize the infringement on and nuisance for people and the environment (again with the possible exception if this requirement was shown to be unreasonable). Other new developments in the law included the introduction of environmental quality norms (miljökvalitetsnormer), which were specified thresholds of pollution which could not be exceeded. For the purpose of supervision of the quality of water sources, the country was divided into five separate Water Districts. Göta River and the surrounding region was included in the district of the Western Sea (Västerhavets vattendistrikt).

Following the passing of the new Environmental Code, a long list of new ordinances were stipulated, specifying in detail many of the paragraphs of the Code. The list included specifications concerning environmental quality norms, supervision of the legislation, environmental impact assessments, environmental damages insurance and others (SFS 1998:897; SFS 1998:899; SFS 1998:900; SFS 1998:901; SFS 1998:905; SFS 1998:915; SFS 1998:930; SFS 1998:940; SFS 1998:950; SFS 1998:1252; SFS 1998:1473).

In 2004, a new ordinance was introduced concerning the quality of water environments. The ordinance stipulated that the regional Water Districts were to decide on environmental quality norms in the case of water, so that there is no deterioration in the environmental quality, and so that the standards set by the European Union might be met in the future (SFS 2004:660).

To conclude, this section has studied how environmental legislation has developed in Sweden regarding the pollution of water. During the first phase of industrialization, no action was taken to limit or prohibit pollution from industrial plants. As Lars Lundgren has shown, this was to a large extent due to the influence from industrial interests. The situation was portrayed as if choice had to be made between economic growth or clean water. In this context, interests in favor of economic growth held the upper hand during the first decades of the 20th century. A most important step was taken in the late 1930s and early 1940s. Water pollution had by this time become so sever a problem that many felt action must be taken to abate the problem. New laws were introduced putting some limits on the right to emit pollutants in watercourses (requiring agents to undertake 'reasonable' action to prevent and abate pollution), and establishing some basic institutions for the supervision and enforcement of the legislation. Judging from the environmental quality indices reported in the previous section of this paper, however, the new legislation does not seem to have been very successful initially. Pollution continued to increase for many decades after these new laws were introduced.

In 1969, the first comprehensive Environmental Protection Act came into force. Regarding water pollution, the new act didn't introduce any substantially new elements, but just incorporated formulations from older pieces of legislation. The Environmental Protection Act of 1969 would in 1998 be replaced by the Environmental Code. In the meanwhile, a number of minor new acts were introduced, complementing the Environmental Protection Act on many specific issues – for example the introduction of environmental impact assessments or statutory environmental damages insurance. Most of the core paragraphs regarding the limitation of pollution of water would however remain quite unchanged throughout the last decades of the century.

The preliminary overview of water-related environmental legislation in Sweden thus shows that there is no clear-cut evidence that the introduction of legislation alone can explain why pollution in the Göta River started to decrease during the 1970s (and thus the pattern of an 'Environmental Kuznets Curve'). The essential elements related to the pollution of water in the Environmental Protection Act of 1969 had been put in place already some two to three decades earlier, seemingly without much impact upon the development of pollution in the river. The legislation did however for a long time give considerable leeway for interpretation, since agents were required to undertake pollution-abating action only if this was considered 'reasonable'. How to judge whether something was 'reasonable' or not was somewhat specified in the Environmental Protection Act of 1969, but the issue still remained unclear just judging from the wording in the legislation. Some of the amendments or clarifications in the Environmental Protection Act, or the political climate the legislators and administrators were working in at the time, might thus have opened up for a more stringent application of environmental law in praxis, tilting the balance in favor of environmental conservation. In a research project (undertaken in 1986), two legal scholars studied the regional implementation of the Environmental Protection Act in the west of Sweden, after it had become stricter in 1981. In the five years from 1981 to 1986, the regional County Administrative Board only submitted five cases for investigation of environmental crime, to the local prosecutors. One of these cases concerned pollution in the Göta River, by the chemical company EKA. Of the five cases, the public prosecutor dismissed four of them on varying grounds (including the pollution from EKA). In the fifth case, the polluter was sentenced to a very lenient fine. The researchers concluded that the chain of control by the middle of the 1980s still required serious reinforcement in order for the legislation to become effective (Rossing and Malmqvist 1986).

8.2. The Göta River Watershed Conservation Association

(This whole section is based upon Pettersson 2009)

In 1958, a Watershed Conservation Association (Göta Älvs Vattenvårdsförbund) was established in the Göta River proper. A number of similar associations had already been established some years earlier in parts of the watershed covering, or upstream of, lake Vänern, and others would be established in the following years. The geographical reach of the Association was clearly demarcated to the stretch of the river from the outflow at lake Vänern, to the outflow in the ocean, i.e. to Göta River proper. The Association was a cooperative one, including both municipalities/cities and industries as members. In the first year, 20 municipalities and 16 industrial companies constituted the membership of the Association. The aim was to create a chain of cooperating associations covering the whole watershed. The statutes of the Association established that it would study the pollution of the river water, and promote conservation of the water quality.

In focus during the 1960s was pollution from oil spills, as well as leakage from waste dumps along the river. New issues that became of greater importance during the second half of the 1960s and throughout the 1970s were oxygen depletion in the river, as well as mercury pollution and acidification. Efforts to reduce the emission of pollutants were intensified during the early 1970s. In the 1980s, municipal sewage treatment plants came into focus again, especially the problem of sewage overflow.

In the late 1960s and early 1970s, the Association increased its cooperation with a number of other watershed associations, as well as other agents. Repeatedly during this time, the association noted in its publications that industries and sewage treatment plants had much to do to reach what was legally required of them regarding pollution control. During this period, the membership of the Association also increased considerably.

One important role for the Association was education: the association arranged field trips and lectures, established special working groups, and alternated the location of board meetings, in order to let the members learn more about specific pollutions. Cooperation with other associations, as well as researchers at the University of Gothenburg and Chalmers Technical High School in Gothenburg, was further developed, also in order to increase the knowledge of the members about the environmental status of the river.

Even though there were some proposals to widen the agenda of the association, conservation of the watershed remained the core concern throughout the period. The association also managed, as one member put it, to avoid the trap of protecting the pollution of the members that the association was supposed to supervise:

> "Since the association always have remained impartial to environmental opinions and specific interests, and have had as a goal the joint interests of its membership to protect the watershed, the situation has never risen that the association could be suspected of representing any other interest than the watershed." (Petterson 2009:25-26, translation and italics by the authors of this paper)

When studying the development of the watershed conservation association, Maria Pettersson draws the conclusion that, on its own, it constituted a fragile institution, according to Elinor Ostrom's model for successful institutions for managing common pool resources such as a river. The Association was however not established in an institutional vacuum. On the contrary, as was shown in the previous section, there was already at the time of the birth of the Association some national environmental legislation in place, along with institutions (such as the County Administrative Board) that were in charge of enforcing it. The association was therefore set up in order to meet just a handful of Ostrom's design principles: primarily monitoring of the environmental status of the river (design principle 4), in a clearly defined geographical area (design principle 1). That the government not only accepted the establishment of the Watershed Conservation Associations, but also legislated about mandatory membership for polluting agents (see SFS 1976:997 in the section above), show that the right of organization also was recognized (design principle 7). There was by design, however, no way for the Association to impose sanctions on its members, and no mechanism to resolve conflicts (design principles 5-6). These factors were however dealt with through other institutions – through various supervision authorities and in courts, respectively (see section on legislation above). In effect, the Watershed Conservation Association became one of a series of nested enterprises (design principle 8).

The crucial role and impact of watershed associations, or river committees, in managing water resources and in some smaller has been analyzed from a game theory perspective by

Victor Galaz, in a political science thesis investigating the development and efficiency of Swedish and Chilean water management institutions (Galaz 2005).

9. Discussion

During the early phase of industrialization in Sweden, pollution was treated as an unwanted but necessary price to pay for economic growth. The choice, as Lars Lundberg has shown, was thus one between economic growth or clean water. Just as in many other cases of water pollution, fisheries was one of the sectors that felt a direct negative economic impact from the pollution, and from an early stage tried to get polluters to reduce their effluents (Lundgren 1974:ch. 9.8; see also Wheeler 1979; Luckin 1986:163-172; Cumbler 1991; Tarr 2001 for the experience in other countries). Some of the earliest pieces of legislation in Sweden were also concerned with the situation for fisheries in particular (see section 7).

As has been shown in this paper (see section 6), there is solid evidence that many of the environmental quality indicators – including COD and nitrogen loss – in the case of the Göta River describe what environmental economists call an ‘environmental Kuznets curve’. In a first phase, until the late 1960s or early 1970s, pollution levels increase along with economic growth. From the 1970s onwards, however, the positive relationship between economic growth and environmental pollution was turned over. While the economy continued to grow both in Sweden in general, and in this region in particular, the environmental quality of the river started to improve. By the early 2000s, some of the environmental quality indicators were showing pre-industrial levels of pollution. It thus became possible to combine economic growth and clean water.

The records of improvement are however limited to the indicators that actually are measured. One possible critique against much of the empirical support for EKC-trends is that we usually measure well-known indicators, where there is a well-established consensus on the effects. However, the environmental history shows many examples of how new knowledge and new technology have the effect that society has to start paying attention to environmental indicators that earlier have been unknown or highly disputed. This is evident in the case of Göta River as well: during the early 20th century, the main indicators of environmental quality of the river are the levels of bacteria, as well as the amounts of oxygen in the river. Other indicators, such as the amounts of phosphorus or heavy metals, only start to be measured much later in time. In the future, we might perhaps be able to observe indicators such as micro-plastics, brominated flame retardant or pharmaceuticals.

With data on these pollutants, the picture of a general improvement of the water quality in Göta River might have to be adjusted. In the meanwhile, available data points to this conclusion. The aim of this study has been to analyze why this is so.

In order to understand this development we need to study the historical development of the environmental pollution in the river. According to Grossman and Kreuger, the environmental pollutions they study peaked when a country had reached a per capita income level of $8,000 dollars (1985 dollars, Grossman and Kreuger 1995). In those cases where Nemat Shafik found an EKC-pattern, the pollution peaked at approximately this level of income as well, or somewhat earlier in some cases (Shafik 1994). In the case studied in this paper, the peak seem to occur much later, at the time when the early-industrializer Sweden had an average GDP per capita of approximately $10,700 (1985 dollars). This supports Dasgupta et al's proposal that it might be possible for late developing countries to follow a lower and flatter Environmental Kuznets Curve than countries that developed economically earlier (Dasgupta 2002:151-158).

There is nothing automatic in this turning trend. On the contrary, reducing the environmental pollution required a lot of conscious effort by a number of agents. As was shown in the background to this paper, a long line of previous case-studies – most importantly from the United States, but also from Britain and Germany – have argued that improved environmental legislation largely can explain similar 'environmental Kuznets curves'. This does not seem to be the case in the Göta River, at least not on its own. As was shown in this paper (see section 7), the introduction of legislation is per se not enough to explain the 'environmental Kuznets curve'. The turning of the trend certainly coincided in time with the introduction of the Environmental Protection Act. Most of the crucial pieces of legislation regarding water pollution were however introduced in Sweden already by the early 1940s. The Environmental Protection Act entailed nothing essentially new concerning water pollution, but only incorporated a couple of previous acts and ordinances into one single piece of legislation. Whereas the introduction of legislation therefore is unsatisfactory as an explanation to the turning trend, enforcement of the legislation might however have changed. This will be one of the areas for future research in this project.

What must also be taken into consideration is the considerable industrial transformation taking place in the region. The establishment of heavy industries producing paper products, batteries, base chemicals, ferrous alloys and of mechanical engineering industries contributes during the first half of the 20th century contributes to a deteriorating environmental quality. An important driving force behind this industrialization is the abundant supply of electricity on from hydropower on a local/regional market. When this market for electricity distribution was integrated on a national and subsequently a European level this local advantage no longer existed. In combination with a considerable concentration of the paper and metallurgical industries into fewer and larger units of production this convergence in energy prices resulted in a decline of these industrial sectors in the river valley. Some part of the environmental improvements in the river could probably be explained by this decline. Other could be attributed to the technical change within these industries; allowing emissions to be reduced without inflicting high cost on producers and consumers. The tendency for maturing economies to transfer from industrial production to services has been one of the arguments behind an Environmental Kuznets curve relation between economic development and environmental deterioration. This argument has been criticized for underestimating the environmental impact of services. Travelling and transport, for example, are often severely polluting activities. However in this particular case, measuring the impact on a streaming river, it is reasonable to expect a positive effect of such a restructuring of the economic landscape in the river valley. This is though no valid argument for a general EKC since the improvements on water emissions might have been counterbalanced with increased air emissions and other transportation effects.

10. Plan for future research

As was mentioned in section 3 of this paper, we work with four main hypotheses: industrial transformation, changing production processes, effluents becoming resources, and changing preferences. All of these factors could in turn be driven by a number of variables – including legislation (and its enforcement), development of factor- and goods markets, and technological progress. In order to test for these hypotheses, we need to undertake a number of more detailed studies. Plans for future research therefore include:

- The enforcement of environmental legislation. The enforcement of the legislation will be studied using the archives of the County Administration Board, as well as the Board of Concessions for Environmental Protection, where the decisions on prior approval (and conditions for the approvals) were made. Can any qualitative change in monitoring, supervision or enforcement of the legislation in cases related to the Göta

River be found in these archives, which might explain the turning trend? The question is thus related to several of the hypotheses.

- Stakeholder institutions. Whereas environmental crime is not a victimless crime, negative consequences might be complex and diffuse. Supervision and monitoring is thus of the essence. This was one of the key tasks of the Göta River Watershed Conservation Association. Can the work of this association contribute to explaining the turning trend, and if so, what was the positive contribution from this institution? This question, too, is related to several of the hypotheses.
- The supply of drinking water. Because of the geographical location of Gothenburg, the citizens more or less became a 'hostage' that could be used by regional authorities to enforce stringent conditions on polluters. To what extent was the cost of purifying the water a factor in the equation? The question is related to the enforcement of legislation, and thus to several of the hypotheses.
- Sewage treatment. Population continued to increase throughout the period, with a short fall during the 1980s in the city of Gothenburg. Human organic waste ought therefore to have increased over the period. At the same time, investments in sewerage and treatment of the sewage most probably reduced the pollution load actually reaching the river. Why were these investments undertaken, and to what extent can this explain the improving environmental quality of the river? The question is thus mostly related to the second hypothesis.
- Industrial transformation. A more in-depth study of the industrial transformation of the region will be undertaken, in order to test in particular for the first hypothesis of this paper. To what extent can this transformation contribute to explaining the turning trend?
- Key polluters. In-close study of some of the key polluters of the river, such as EKA Chemicals or the paper mill Lilla Edet, and the transformation of their pollution throughout the period, in order to test for the second and third hypothesis of this paper in particular. The issue to be studied is: can factors related to the markets and production structure of the companies explain any reduction in pollution? The impact of legislation on the specific companies will also be studied in this context.

- The impact of garbage dumps and industrial waste depots. The effects of leaking dumps and depots have not been treated in this paper. The effects have probably been high and the problem is a pivotal example of an upstream-downstream conflict. There is also a long and diffuse time lag between technical change and structural transformation on one hand, and of environmental impact on the other. Many industrial waste depots remain on sites where the industries that dumped them have disappeared. Some of them are also unregistered. Many of these depots are placed in connection to the river banks. Landslides have been quiet common in the river valley. If such a slide should occur in the wrong place, the continuous leakage of polluting substances could turn into a rapid deterioration.
- The role of agri- and silviculture. Again, a core issue will be to study whether factors related to the market and production structure, as well as legislation, contributed to a reduction in emissions of pollution? The question is thus related to hypotheses 1-3.

Sources and literature

Unprinted sources

Printed sources and literature

Adams, Michael, Hartmut Kausch, Thomas Gaumert and Karl-Ernst Krüger (1996), "The Effect of the Reunification of Germany on the Water Chemistry and Ecology of Selected Rivers", Environmental Conservation 23(1):35-43.

Adams, M.S., B. Hale, T. Gaumert, M. Bergemann, B. Ohm and C. D'Elia (2008), "Environmental History of the German Elbe River - Interactions among the ecological, economic, and political environments", Proceedings of the 2008 Trans-Atlantic Institutional Environmental Policy in Relation to Environmental Education (TIES) Workshop, Madison, Wisconsin USA.

Alexandersson, Erik (1992) "Två stora industrier i Ale" Kring Göta älv. Studier i en dalgång. Tre böcker: Göteborg

Althin, Torsten (1945) Papyrus 1895-1945: -På traditionsrik grund- Minnesskrift til Aktiebolaget Åaåyrud femtioårsjubileum, Mölndal

Althin, Torsten (1947) Vattenbyggnadsbyrån 1897-1947: historic Stockholm

Allen, Barbara (2003), Uneasy Alchemy: Citizens and Experts in Louisiana's Chemical Corridor Disputes. Cambridge: MIT Press.

Andersson, Yvonne (1992), Dricksvattenburna sjukdomsutbrott I Sverige – i ett historiskt, hygieniskt och tekniskt perspektiv. Gothenburg: unpublished masters thesis, University of Gothenburg.

Andreen, William (2003a), "The Evolution of Water Pollution Control in the United States - State, Local, and Federal Efforts, 1789-1972: Part I", Stanford Environmental Law Journal 22: 145-200.

Andreen, William (2003b), "The Evolution of Water Pollution Control in the United States - State, Local, and Federal Efforts, 1789-1972: Part II", Stanford Environmental Law Journal 22: 215-294.

Andreen, William (2004), "Water Quality Today - Has the Clean Water Act Been a Success?", Alabama Law Review 55:537-593.

Barca, Stefania (2007), "Enclosing the River: Industrialisation and the 'Property Rights' Discourse in the Liri Valley (South of Italy), 1806-1916", Environment and History 13:3-23.

Barles, Sabine (2005), "A Metabolic Approach to the City: Nineteenth and Twentieth Century Paris" in Dieter Schott, Bill Luckin and Geneviève Massard-Guilbaud (eds.), Resources of the City: Contributions to an Environmental History of Modern Europe. Aldershot: Ashgate.

Barles, Sabine and Laurence Lestel (2007), "The Nitrogen Question: Urbanization, Industrialization and River Quality in Paris, 1830-1939", Journal of Urban History 33:794-812.

Biermann, Christopher J. (1996) Handbook of pulping and papermaking San Diego : Academic Press

Benidickson, Jamie (2007), The Culture of Flushing: A Social and Legal History of Sewage. Vancouver: UBC press.

Bergquist, Ann-Kristin (2007), Guld och Gröna Skogar? Miljöanpassningen av Rönnskärsverken 1960-2000. Umeå: Umeå Universitet, Ekonomisk-historiska institutionen.

Bernes, Claes and Lars Lundgren (2009), Use and Misuse of Nature's Resources: An Environmental History of Sweden. Stockholm: Naturvårdsverket.

Björk, Fredrik (2004), "Sockerindustri, döda fiskar och en envis ryttmästare", in Nils Andersson et al (eds), Sociala konflikter och kulturella processer: historia med människor i centrum. Malmö: Malmö högskola.

Bromley; Daniel W. (1991) Environment and economy. Property rights & public policy. Oxford: Blackwell.

Brüggemeier, Franz-Josef (1990), "The Ruhr Basin 1850-1980: A Case of Large-Scale Environmental Pollution", in P. Brimblecombe and C. Pfister (eds.), The Silent Countdown. Essays in European Environmental History. Berlin: Springer Verlag.

Brüggemeier, Franz-Josef (1994), "A Nature Fit for Industry: The Environmental History of the Ruhr Basin, 1840-1990", Environmental History Review 18(1):35-54.

Cain, Louis (1977), "An Economic History of Urban Location and Sanitation", Research in Economic History 2:337-389.

Carson, Richard (2010), "The Environmental Kuznets Curve: Seeking Empirical Regularity and Theoretical Structure", Review of Environmental Economics and Policy 4(1):3-23.

Cioc, Mark (2002), The Rhine: An eco-biography 1815-2000. Seattle: University of Washington Press.

Cioc, Mark (2004), "Rivers" in Shepard Kreich, J.R. McNeill and Carolyn Merchant (eds.), Encyclopedia of World Environmental History. New York: Routledge.

Clapp, B.W. (1994), An Environmental History of Britain since the Industrial Revolution. London: Longman.

Closmann, Charles (2007), "Chaos and Contamination: Water Pollution and Economic Upheaval in Hamburg, 1919-1923", Journal of Urban History 33:828-847.

Closmann, Charles (2008), "Holding the Line: Pollution, Power, and Rivers in Yorkshire and the Ruhr, 1850-1990" in Christof Mauch and Thomas Zeller (eds.), Rivers in History: Perspectives on Waterways in Europe and North America. Pittsburgh: University of Pittsburgh Press.

Collins, Timothy and Edward Muller and Joel Tarr (2008), "Pittsburgh's Three Rivers: From Industrial Infrastructure to Environmental Asset", in Christof Mauch and Thomas Zeller (eds.), Rivers in History: Perspectives on Waterways in Europe and North America. Pittsburgh: University of Pittsburgh Press.

Coopey, Richard and Terje Tvedt (2006), A history of Water. Vol. 2. The Political Economy of Water. London: I.B. Tauris.

Cumbler, John (1991), "The Early Making of an Environmental Consciousness: Fish, Fisheries Commissions and the Connecticut River", Environmental History Review 15(4):73-91.

Czaya, Eberhard (1983), Rivers of the World. Cambridge: Cambridge University Press.

Dasgupta, Susmita et al (2002), "Confronting the Environmental Kuznets Curve", Journal of Economic Perspectives 16(1):147-168.

Dinda, Soumyananda (2004), "Environmental Kuznets Curve Hypothesis: A Survey", Ecological Economics 49:431-455.

Dolin, Eric Jay (2004), Political Waters: The Long, Dirty, Contentious, Incredibly Expensive but Eventually Triumphant History of Boston Harbor - A Unique Environmental Success Story. Boston: University of Massachusetts Press.

Duit, Andreas (2002), Tragedins institutioner: Svenskt offentligt miljöskydd under trettio år. Stockholm: Stockholms Universitet, Statsvetenskapliga institutionen.

Elektrokemiska (1936) 1895-1935 Elektrokemiska aktiebolaget Bohus Malmö: Förlag svensk storindustri

Elster, Jon (2000) "Rational choise history: A case of excessive ambition" The American political science review 94(3):685-695.

Ericsson, Curt (1987) "Den Svenska ferrolegeringsindustrins pionjärskede" Daedalus: 56 pp. 75-87

Fritz, Martin & Karlsson, Birgitt (2007) SKF – A Global story 1907-2007. Informationsförlaget: Stockholm

Galaz, Victor (2005) Power in the commons. The politics of water management institutions in Sweden and Chile. Department of political science, Gothenburg University: Gothenburg

Glete, Jan (1987) Ägande och industriell omvandling. Ägargrupper, skogsindustri, verkstadsindustri 1850-1950)

Goubert, Jean-Pierre (1986), The Conquest of Water: The Advent of Health in the Industrial Age. Oxford: Polity Press.

Grossman, Gene and Alan Krueger (1995), "Economic growth and the environment". Quarterly Journal of Economics 110:353-377.

Gumprecht, Blake (1999), The Los Angeles River: Its Life, Death, and Possible Rebirth. Baltimore: The Johns Hopkins University Press.

Gustafsson J-E. (1996) Avrinningsbaserade organisationer som aktiva planeringsaktörer. Solna: Svenska vatten- och avloppsverksföreningen VAV:64

Gustafson, Jörgen (2003), "Naturens värde: Debatter kring en planerad industrietablering vid Mälaren 1959 och 1966" in Erland Mårald and Christer Nordlund (eds.), Värna, vårda, värdera: Miljöhistoriska aspekter och aspekter på miljöhistoria. N.d.: Forskningsprogrammet Landskapet som arena.

Gustavsson, Ann-Kristin (2003), "Reningsvärk när svensk industri möter miljöskyddslagen: Fallet Rönnskärsverken" in Erland Mårald and Christer Nordlund (eds.), Värna, vårda, värdera: Miljöhistoriska aspekter och aspekter på miljöhistoria. N.d.: Forskningsprogrammet Landskapet som arena.

Gustavsson, Eva (2000), "Sjön som slasktratt - Ett bidrag till Vänerns miljöhistoria", Vid Vänern - Årsskrift Vänermuseet år 2000. Lidköping: Vänermuseet, pp. 12-16.

Göta Älvs Vattenvårdsförbund (2005), Fakta om Göta Älv – En beskrivning av Göta Älv och dess omgivning 2005. Göteborg: Göta Älvs Vattenvårdsförbund.

Göta Älvs Vattenvårdsförbund (1996) Fakta om Göta Älv Göteborg: Göta Älvs Vattenvårdsförbund.

Hallén, Per (2010): "Papyrus – Specialisering och nytänkande", in Det stora fallet.

En historia om Mölndals kvarnby och kraften i fallet (Hallén, P. & Olsson, K. eds.). Göteborg: Sekel bokförlag,pp. 306-320

Hansson, Lars-Erik (1992a) "Kraften från Göta älv" Kring Göta älv. Studier i en dalgång. Tre böcker: Göteborg pp. 164-170

Hansson, Lars-Erik (1992b) Kungl. Trollhätte kanal- och vattenverk. Trollhätte kraftverk. Del 1 Trollhättan: Vattenfall

Hardin, Garrett (1968), "The Tragedy of the Commons", Science 162(3859):1243-1248.

Hermelin, Per G. (1950) Wargöns aktiebolag 1847-1949. En historik Göteborg

High, Steven (2003), Industrial Sunset: The Making of North America's Rust Belt, 1969-1984. Toronto: University of Toronto Press.

Hill, Libby (2000), The Chicago River: A Natural and Unnatural History. Chicago: Lake Claremont press.

Hydén, Håkan (1978), Rättens samhälleliga funktioner. Lund: Studentlitteratur.

Hylander, Carl (1992) "Pappersframställningen" Kring Göta älv. Studier i en dalgång. Tre böcker: Göteborg

Jakobsson, Eva (1996), Industrialisering av älvar: studier kring svensk vattenkraftutbyggnad 1900-1918. Göteborg: Historiska institutionen, Göteborgs universitet.

Kardell, Lars (2004) Svenskarna och skogen. Del 2. Från baggböleri till naturvård.

Keeling, Arn (2004), "'Sink or swim': Water Pollution and Environmental Politics in Vancouver, 1889-1975" BC Studies 142/143:69-101.

Kinneryd, Hanna (2010), "Environmental Adaptation does not Happen Over Night: The Swedish Path to Chlorine Free Bleaching of Paper", unpublished workingpaper, Luleå Tekniska Universitet.

Knight, J. (1992) Institutions and Social conflicts. Cambridge: Cambridge University Press.

Lekan, Thomas (2008), "Saving the Rhine: Water, Ecology, and Heimat in Post-World War II Germany" in Christof Mauch and Thomas Zeller (eds.), Rivers in History: Perspectives on Waterways in Europe and North America. Pittsburgh: University of Pittsburgh Press.

Lerner, Steve (2005), Diamond: A Struggle for Environmental Justice in Louisiana's Chemical Corridor. Cambridge: MIT press.

Levinson, Arik (2008), "Environmental Kuznets curve", The New Palgrave Dictionary of Economics, Second Edition. New York: Palgrave Macmillan.

Lewis, Tom (2005), The Hudson: A History. New Haven: Yale University Press.

Lindmark, Magnus (1998), Towards Environmental Historical National Accounts for Sweden: Methodological Considerations and Estimates for the 19th and 20th Centuries. Umeå: Umeå Universitet.

Loo, Tina (2007), "Disturbing the Peace: Environmental Change and the Scales of Justice on a Northern River", Environmental History 12:895-919.

Luckin, Bill (1986), Pollution and Control: A Social History of the Thames in the Nineteenth Century. Bristol: Adam Hilger.

Lundgren, Lars (1974), Vattenförorening: Debatten i Sverige 1890-1921. Lund: Gleerups.

Lundgren, Lars (1999), "Från miljöproblem till miljövård: Ett genombrott med fördröjning", Daedalus 67:229-248.

Lundqvist, Lennart J. (2004) Sweden and ecological governance – Straddling the fence. New York: Manchester University Press

Mallea, Amahia (2002), "Downstreamers: Public Health and Relationships on the Missouri River", Agricultural History 76(2):393-404.

McCully, Patrick (1998), Silenced Rivers: The Ecology and Politics of Large Dams. London: Zed Books.

Meadows, Donella et al (1972), The Limits to Growth: a report for the Club of Rome's Project on the Predicament of Mankind. London: Earth Island.

Melosi, Martin (2000), The Sanitary City: Urban Infrastructure in America from Colonial Times to the Present. Baltimore: Johns Hopkins University Press.

Mårald, Erland (2007), Svenska miljöbrott och miljöskandaler 1960-2000. Möklinta: Gidlunds.

Naturvårdsverket (1999: Bedömningsgrunder för miljökvalitet – Sjöar och vattendrag [Basis for an assessment of environmental quality – Lakes and watercourses]. Rapport 4913. Stockholm: Naturvårdsverket.

Neri Serneri, Simone (2007), "The Construction of the Modern City and the Management of Water Resources in Italy, 1880-1920", Journal of Urban History 33(5):813-827.

Newman, Richard (2003), "From Love's Canal to Love Canal: Reckoning with the Environmental Legacy of an Industrial Dream" in Jefferson Cowie and Joseph Heathcott (eds.), Beyond the Ruins: The Meanings of Deindustrialization. Ithaca: Cornell University Press.

Ogle, Maureen (1999), "Water Supply, Waste Disposal, and the Culture of Privatism in the Mid-Nineteenth Century American City", Journal of Urban History 25:321-347.

Olsson, Göran (2001), "The Struggle for a Cleaner Urban Environment: Water Pollution in Malmö 1850-1911", Ambio 30 (4-5): 287-291.

Olsson, Kent (1992) "Älvdalens varvsindustri" Kring Göta älv. Studier i en dalgång. Tre böcker: Göteborg

Olsson, Kent (1996) Göteborgs historia, näringsliv och samhällsutveckling. Från industristad till tjänstestad 1920-1995.

Olsson, Sven-Olof (1984) "Elektrifieringen ur avnämarsynpunkt. Användningsområden och distributionssystem" När elektriciteten kom. Tretton uppsatser om elkraftens historia, (Daedalus: 53): 59-87.Ostrom, Elinor (1990) Governing the Common: The Evolution of Institutions for Collective Action. Cambridge: Cambridge University Press.

Ostrom, Elinor, et al (1999), "Revisiting the Commons: Local Lessons, Global Challenges", Science 284(5412):278-282.

Ostrom, Elinor (2008), "Institutions and the Environment", Economic Affairs 28(3):24-31.

Outwater, Alice (1996), Water: A Natural History. New York: Basic Books.

Pettersson, Maria (2009), Göta Älvs Vattenvårdsförbund: En välfungerande institution för att hantera en gemensam resurspool? Gothenburg: Unpublished bachelor's thesis, University of Gothenburg.

Price, Jenny (2008), "Remaking American Environmentalism: On the Banks of the L.A. River", Environmental History 13:536-55.

Rossing, Ylva and Ulf Malmqvist (1986), Brott mot Miljöskyddslagen? Rapport från ett kontaktforskarprojekt vid rättsvetenskapliga institutionen. Göteborg: Göteborgs Universitet.

SFS (Svensk Författningssamling [Swedish Statute Book]). Stockholm: Svensk Författningssamling.

Shafik, Nemat (1994), "Development and Environmental Quality: An Econometric Analysis", Oxford Economic Papers 46:757-773.

Sheail, John (1993), "Public interest and self-interest: The Disposal of Trade Effluent in Interwar England", Twentieth-Century British History 4(2):149-70.

Sheail, John (1997), "The Sustainable Management of Industrial Watercourses: An English Historical Perspective", Environmental History 2:197-215.

Sheail, John (1998), "'Never Again': Pollution and the Management of Watercourses in Postwar Britain", Journal of Contemporary History 33(1):117-133.

Sheail, John (2002), An Environmental History of Twentieth-Century Britain. Basingstoke: Palgrave.

Simmons, I.G. (2001), An Environmental History of Great Britain from 10,000 Years Ago to the Present. Edinburgh: Edinburgh University Press.

SLVFS (2001:30), Livsmedelsverkets föreskrifter om dricksvatten [The Food Administration's Regulations on Drinking Water]. Stockholm: Livsmedelsverket.

SOU (1997:155) Miljösamverkan i vattenvården. Stockholm: Fritzes

SOU (2002:105) Klart som Vatten – Betänkande om utredningen svensk vattenadministration. Stockholm: Fritzes

Steele, Scott R. (1991) "Property Regimes as Information Regimes: Efficiency and Economies of Joint Production" Environmental and Resource Economics 18(3):317-337.

Steinberg, Theodore (1991), Nature Incorporated: Industrialization and the Waters of New England. Amherst: University of Massachusetts Press.

Stern, David (2003), "The Environmental Kuznets Curve", Online Ecological Economics Encyclopedia [http://www.ecoeco.org/education_encyclopedia.php]. Accessed 2011-01-21.

Stern, David (2004) "The Rise and Fall of the Environmental Kuznets Curve". World Development, 32, 1419-1439.

Stradling, David and Richard Stradling (2008), "Perceptions of the Burning River: Cleveland's Cuyahoga River", Environmental History 13:515-35.

Stroud, Ellen (2003), "Troubled Waters in Ecotopia: Environmental Racism in Portland, Oregon" in Louis S. Warren (ed, 2003), American Environmental History. Malden: Blackwell publishing, pp. 299-318.

Svärd Bo (1990) Göta älv – påverkan & vattenkvalitet. En samlad beskrivning av situationen i och kring Göta älv. Göteborgs stad, miljö- och hälsoskydd.

Särlvik, Ingegärd (1992) "Industrierna kring fallet" Kring Göta älv. Studier i en dalgång. Tre böcker: Göteborg pp. 187-194.

Söderholm, Kristina (2001), Lukten från Örebro pappersbruk: Föroreningsmotstånd och teknikval under tidigt 1900-tal. Luleå: Luleå tekniska universitet.

Söderholm, Kristina (2005), Tekniken som problem och lösning – Föroreningsmotstånd och teknikval I 1900-talets svenska pappersmassaindustri. Luleå: Luleå Tekniska Universitet, Institutionen för industriell ekonomi och samhällsvetenskap.

Tal, Alon (2002), Pollution in a Promised Land: An Environmental History of Israel. Berkeley: University of California Press.

Tarr, Joel and Robert Ayres (1990), "The Hudson-Raritan Basin" in Robert Turner et al (eds.), The Earth as Transformed by Human Action: Global and Regional Changesin the Biosphere over the Past 300 Years. Cambridge: Cambridge University press.

Tarr, Joel and T.F. Josie (2006), "Critical Decisions in Pittsburgh Water and Wastewater Treatment" in Terje Tvedt and Eva Jakobsson (eds.), A history of Water, vol. 1: Water Control and River Biographies. London: I.B. Lauris.

Tarr, Joel (2001), The Search for the Ultimate Sink: Urban Pollution in Historical Perspective. Akron: University of Akron press.

Tarr, Joel (2002), "The Metabolism of the Industrial City: the Case of Pittsburgh", Journal of Urban History 28:511-545.

Tarr, Joel (2004), "Water Pollution" in Shepard Kreich, J.R. McNeill and Carolyn Merchant (eds.), Encyclopedia of World Environmental History. New York: Routledge.

Tvedt, Terje (2004), The River Nile in the Age of the British: Political Ecology and the Quest for Economic Power. London: I.B. Tauris.

Tvedt, Terje and Eva Jakobsson (eds. 2006), A history of water. Vol. 1. Water control and river biographies. London: I.B. Tauris.

Wegner, Jan (2009), "Sludge on Tap: Queensland's First Water Pollution Legislation, 1944-1985", Environment and History 15:199-216.

Wennersten, John (2008), Anacostia: The Death & Life of an American River. Baltimore: Chesapeake Book Co.

White, Richard (1995), The Organic Machine: The Remaking of the Columbia River. New York: Hill and Wang.

Williams, Brett (2001), "A River Runs Through Us", American Anthropologist 103(2):409-431.

van Winden, Willem, Leo van den Berg and Luis Carvalho (2010), Manufacturing in the New Urban Economy. Hoboken: Taylor & Francis.

Worster, Donald (1985), Rivers of Empire: Water, Aridity, and the Growth of the American West. New York: Pantheon.

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