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# Water Quality Management in Major Cities

Case: The Water & Environment History of Copenhagen City

To Shanghai Int'l Environmental Conference on EXPO 2010

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## Abstract

History repeats itself. This goes for environmental history too. The development we now see in modern industrialised cities is a time-compressed view of the development cities like Copenhagen has been through over many centuries. History shows invariably, that urbanisation presents a huge benefit for the persons going to the cities and for the nations containing the big cities. However, at certain stages there are quite substantial health and environmental costs related to this development. Eventually the economic progress leads to a situation, where cities are getting very healthy and very clean, with clear skies and pure water for drinking and recreation and swimming.

This development from pristine nature over polluted cities to modern clean cities is a good example of the Environmental Kuznets Curve. In this paper, this will be illustrated by giving the water and environmental history of Copenhagen City since its foundation in 1167 by the most famous clergyman in Danish history: bishop Absalon. As a natural regional city centre connecting the Baltic Region with the North Sea region Copenhagen rapidly developed into an important major city. It made its living through fisheries of herring and shipping & trading, the name København meaning the "Merchants Harbour". However, for military reasons the city was constrained to small area, and the water and sanitation very poor. In the mid 1850's Copenhagen was one of the unhealthiest cities in Europe, and thousands of people died from Cholera.

From that point in time, a steady increase in environmental quality has taken place in Copenhagen. Firstly, a huge increase in healthy water supply from groundwater took place, substituting heavily polluted surface water. Secondly, after the 1970's a rapid increase in water use efficiency occurred to a level of 125 l/capita/day for private consumption. Sewerage were introduced in the late 1800's, the waste water taken off from the harbour in mid 1900, advanced waste water treatment introduced in the 1970's and finally storm sewer reservoirs introduced.

The water in Copenhagen is now so clean, that the environmental mayor of Copenhagen on June 1, 2001 could jump into the harbour for initiating the first swimming facility in Copenhagen in modern times. By using advanced technology and dynamic environmental information systems for air and water, and combining this with economic incentives, Copenhagen is continuously improving its environmental quality and efficiency to uphold its position as the Green Capital of Europe.

## Introduction

When the environmental mayor of Copenhagen, Mrs. Winnie Berndtson, jumped into the 15° cold water and initiated the bathing facility at Islands Brygge June 1. 2001, it was the culmination of a long history of water & environment for the capital city of Denmark. In this paper, I will highlight some of the most important events in this 1.000 year long story.

In the minds of the great and ancient Chinese people, who are known to well appreciate the long historic view, 1000 years may only be a glimpse in time. But there may still be lessons learned from

the urban development of a tiny group of Nordic barbarians, who were gathering oysters and hunting wisents<sup>1</sup> at a time, when the Chinese civilisation already were thousands of years old.

As two important lessons, I would like to emphasise:

- Solid management of water & environment makes a difference, particularly when including adaptive mechanisms like economically based regulation
- The long range outlook for water & environment in all major cities of the world are as good as for Copenhagen

In fact the development of the state of water and environment in Copenhagen city is a textbook example of the environmental Kuznets curve relationship. See figure 1 below.

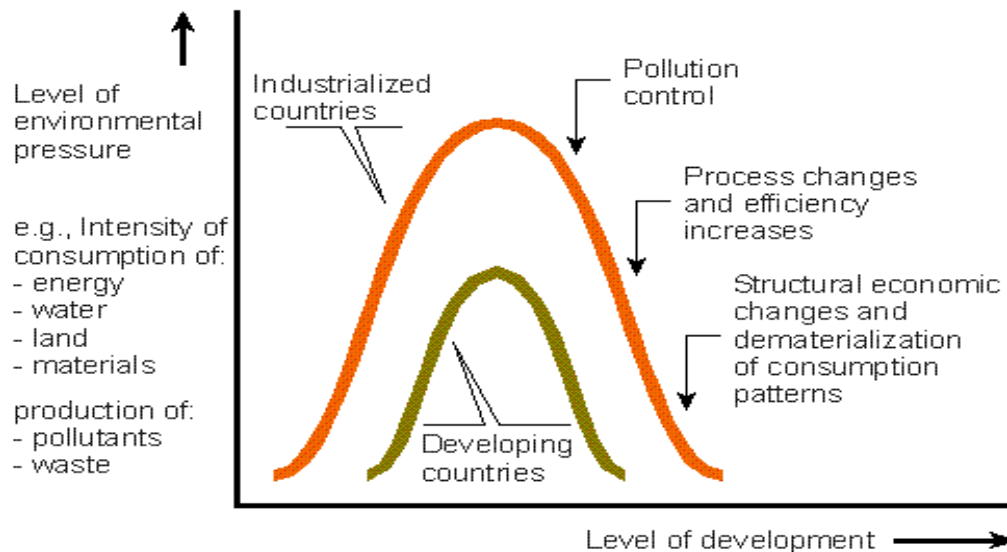


Figure (1) the environmental Kuznets curve, after UNEP<sup>2</sup>

The figure shows the relationship between environmental pressure and the level of development. For low levels of developments the environmental pressure is low. At intermediate levels of development the environmental pressure raises to a high level, then to decline again when the development continues. In a few words:

*Economic growth is the solution to environmental problems<sup>3</sup>*

The curve also shows that countries, which go through the development stages later, can learn from the experience of the on pioneering countries and by rational management decrease the environmental pressure at the intermediate development stage.

## The City by the Water

Copenhagen is a City by the Water, it is sometimes called the Venice of the North and it is partly built on water by using city waste to make landfills. Copenhagen means the Merchants Harbour. It is the cultural geographical centre of the Baltic region, and has finally come into its own again after the liberation of East Europe, and is now growing rapidly in importance.

<sup>1</sup> European Bison

<sup>2</sup> Global Environmental Outlook-1, UNEP 1997, <http://www-cger.nies.go.jp/geo1/>

<sup>3</sup> A Humane Environment: High Economic Growth is the Solution, not the problem. Karl Iver Dahl-Madsen. Proceedings of the 6. SERD/AIT seminar, Growth Unlimited, January 2000

Central Copenhagen is quite small with only 500.000 inhabitants; however in the Greater Copenhagen area on the Danish side of the Sound, there are about 1.5 million people. To this should be added about the same number of people on the Swedish side, which is the natural supporting region for Copenhagen and actually until “Roskildefreden<sup>4</sup>” in 1658 belonged to Denmark. After the establishment of the fixed link between Denmark and Sweden in year 2000, the regional activity around Copenhagen has increased, and it is now highly likely, that Copenhagen will take its rightful position as one the major regional city centres of Europe.

Copenhagen city has a special status in the environment and administration of Denmark. The Danish King Frederik III<sup>5</sup> gave Copenhagen these privileges because its brave people saved Denmark and the King himself from being conquered by the Swedes. Copenhagen became the Kings City. The city is since then ruled by a magistrate government.

The basic environmental administration in Denmark is generally divided into three levels:

- The municipalities, which gives environmental permits to industries and who monitor bathing water quality
- The counties, which oversee the municipality and are responsible for the environmental monitoring
- The environment ministry and the environmental protection agency, which makes the laws and the regulation, and which oversees the counties.

In Copenhagen city, however, the municipality and the county are merged together into one administratively level. This makes the administration streamlined and efficient, but may have some costs related to the lack of division of power. This tradeoff between efficiency and democratic public participation is an issue, which every country introducing environmental administration has to find fitting solutions for.

## The Original City

A small settlement was established more than thousand years ago in the area, which now constitutes the central part of Copenhagen. It gradually developed into a small town and was finally founded as a city by the most famous Danish clergymen Bishop Absalon in 1167. The first settlement was placed in a pristine natural setting with no environmental pressure at all. And the first settlers were a combination of farmers, merchants and fishermen.

## Herring Galore

In the period from to 1200 to 1500 the mainstay of the city's background for making a living was fisheries of herring. As described by the first Danish historian, Saxo Grammaticus:

*The density of herring in the Sound was so high that the ship's got stuck.*

The most likely explanation for this huge abundance of herring was periodic occurrences of very low oxygen concentrations in the deep water of the Baltic Sea, which caused high amounts of phosphorus to be released from the sediments. This again gave rise to much plankton production with a resulting high production of fish. This phenomena occurred long before human influenced input of nutrients became an important factor for the Baltic water quality conditions, which illustrates that oxygen deficit in the Baltic is partly a natural phenomena caused by specific hydrographic and meteorological conditions.

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<sup>4</sup> The Roskilde Peace Treaty

<sup>5</sup> "I want to die in my nest" which was Copenhagen

## **The Black Death**

In 1349 one of the worst disasters in the environmental history of Copenhagen City occurred: the Black Death. It was most likely caused by rats coming from the harbor and ships doing global trading, which already at that time was an important factor, however also at that time causing some risks.

One third of Copenhagen's population died in that first epidemic. And at that time the population of Copenhagen was only about 40.000 people. An epidemic model was made to describe this Black Death disaster. These types of models are very dependent on the initial conditions, and it has been shown that if just a few more people had been living in Copenhagen an even bigger death toll could have been expected.

The Black Death continued to take its toll of the inhabitants of Copenhagen for about the next 400 years. The City eventually were able to eliminate the disease, most likely because the houses were changed from wooden houses to stone houses, which made the conditions for the rats harder.

## **Desertification & Deforestation in**

In the period from 1500 to 1750 Denmark was through a tough period of deforestation and desertification. Denmark had much use for wood for its great merchant and military navy and furthermore wood was used for producing salt by evaporation of salt water at some of the major Danish islands. The Danish hydrological cycles were thoroughly disturbed and the country was threatened by the imminent desertification. Denmark was only saved in the twelfth hour by a huge effort by the Danish farmers living in the threatened areas. All farmers had to use an hour per day for many years to roll the desertification back.

It is very fashionable for rich Europeans and Americans to go to developing countries and tell them, that they should not cut down the forests. In Denmark we have cut down our forests to less than 1% of the original forest cover, so maybe we should not preach too much to other people, about what they should do. And anyway it's difficult to argue that it's very harmful for a country to cut down its forests, as Denmark ended up being of the world's richest countries. In a development situation it may make a very good sense to take some inactive capital locked up in trees and convert it to active capital by investing in wealth-creating infrastructure: education, health services, production capacity etc.

## **Malaria in Denmark**

In the period from 1500 to 1800 malaria was widespread in Denmark. It was a very common disease in Denmark at that time and people called it: cold fever<sup>6</sup>. Most likely an increase in cattle farming broke the epidemic cycle and malaria went away from Denmark.

This goes to show that the distribution of malaria has very little to do with climatic conditions, but everything to do with institutions and management of the environment to make it healthy for people living in it. In the global climate change discussion Malaria and other infectious diseases are often used as a scare, with which to rush decision makers into untimely and possibly bad decisions.

## **Nitrogen & Agriculture**

As in any developing country the agriculture production of Denmark was severely nitrogen limited hundreds of years ago<sup>7</sup>. For this reason the waste from the citizens living in the city was seen as an important agricultural resource. And in 1650 we had the first examples of the use of Latrine or

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<sup>6</sup> koldfeber

<sup>7</sup> Danish Revolution, 1500 – 1800; An Ecohistorical Interpretation; By Kjaergaard, Thorkild//Translator: Hohenn, David; October 1994; Cambridge University Press

Night Soil for enhancing agricultural production. A rich agricultural community was established around Copenhagen, and at that time the Danish people learned much from the Dutch immigration to the island of Amager, a large flat island just outside the city walls of Copenhagen. Agriculture production was further developed in 1750, when nitrogen fixing crops were introduced. This was the start of Denmark developing into a major agricultural producing country, where the highly efficient farmers are now making food for 150 people, all in all fifteen million people are today (too well) fed by the Danish farmers. It was and is good for the Danish economy, but also adding a heavy load of nitrogen to the environment.

## **Extremely Polluted**

Population and production increase caused the environmental conditions in Copenhagen City to decline steadily. The environmental pressures were at the highest in 1850-60, where Copenhagen was an extremely polluted city<sup>8</sup>.

In Copenhagen at that time every person had 32 square meters available compared to London with 109. The average number of persons per house in Copenhagen was 38 compared to London with 7,4.

The reason for these horrible confined conditions was that the citizens of Copenhagen were not allowed to move outside the walls for military reasons. Consequently, Copenhagen was a very dirty and extremely dangerous city. The air pollution caused by burning of firewood for heating and cooking was in 1850 ten times higher than at the later highest level of industrialization.

50.000 persons lived in Copenhagen and 6.000 of these people died in the terrible cholera epidemics in 1853. Young pregnant women due to give birth did not want to go to a hospital. They would rather give birth on a staircase, which was much less dangerous than going to a hospital, where they would most likely die. The doctors went directly from a dinner party from one patient to another in their normal clothes without washing their hands and thereby systematically infecting all the patients along the way.

## **The Worst Was Over**

After 1860 the worst was over and the environmental conditions gradually started to improve. A main factor being that people were allowed to move out of the city to the fresh air and countryside. The first sewage systems were established in the early eighteen sixties. This was actually an example of a good use of the precautionary principle. To introduce sewage systems was the right decision for the wrong reasons. At that time it was believed that disease was caused by *Miasma*, described as a poisonous atmosphere thought to rise from swamps and putrid matter. But now we know that the diseases were caused by water polluted by human waste.

In modern times the precautionary principle is unfortunately often misused. It is not used as a principle for action in an obviously dangerous situation even if not all is known. On the contrary the principle is used to postpone important decisions on new technology, even if there is a very slight risk for a bad outcome, or to make premature resource allocations for preventing a problem, where there is a small risk for something bad occurring far in the future. What we need to counteract this misuse is a bravery principle, which states that a small risk should not prevent obviously good things from happening now. A good example would be the introduction of GMO crops, which have obvious and immediate benefits, among other for the environment, and at very low risks.

## **Good & Efficient Water Supply**

A major good development for the people in Copenhagen City was the increase of healthy water supply. Before 1850 most people were drinking untreated surface water polluted with their own

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<sup>8</sup> Det Heles Vel. By Jens Engberg. Published by Copenhagen City in 1999 (In Danish)

wastes, exactly as we still see now in many poorly developed countries. However, in 1859 the first water works were introduced and from now on there was a steady increase in the supply of high quality drinking water to the happy citizens of Copenhagen.

In 1860 the water supply was very low: 1 million cubic meters per year, then it increased to its maximum level in 1970, where hundred million cubic meters were supplied per year. After that the water supply has gradually decreased down to 60 million cubic meters per year, not because there is fewer people and lower demand for the services provided by water, but because there has been established a steady increase in water use efficiency. The waste from leaky water supply pipes has been reduced to a very low level and people are not wasting water at home mainly because the water price has been increased to make a dent in the your pocket if you use water without a good reason. Before economy incentives were introduced it was normal to cool your beer by letting the cold tap water run freely.

### Industrialization & Mercury

Copenhagen passed through a heavy industrialization phase in the mid nineteen hundreds. Among other there was a chlorine factory situated exactly, where the new swimming facility now is located. This factory discharged about 50 tons of mercury during its operation; sixteen tons of these are still left in the harbor sediments of Copenhagen. See figure (2).

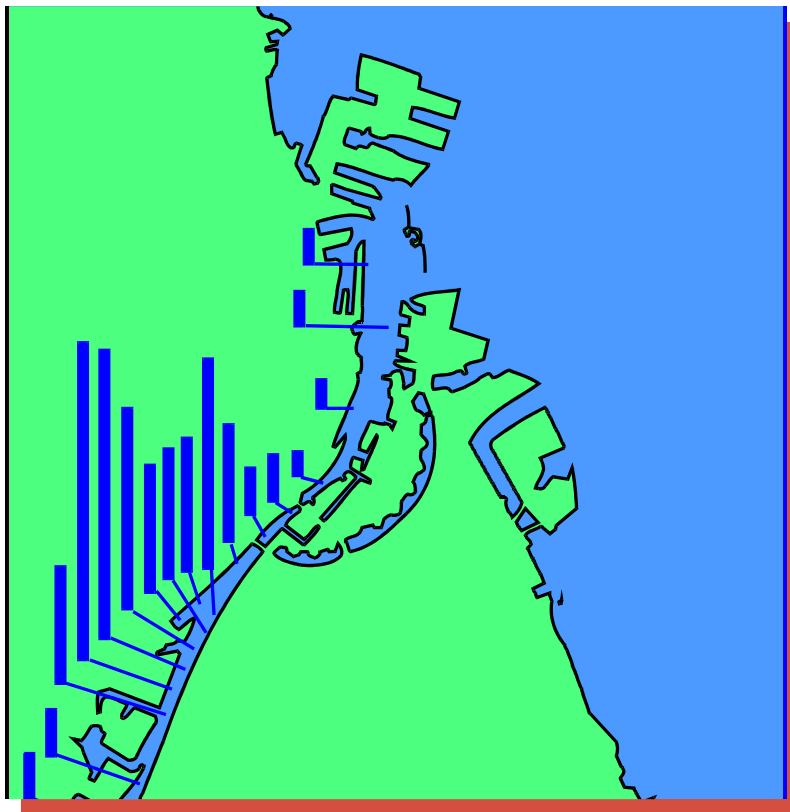


Figure (2) Mercury concentrations in Copenhagen harbor. Highest column is 100 mg Mercury/kg DW

This is more or less the same amount of mercury which was discharged to the Minamata Bay in Japan, one of the well known environmental disasters of the world. Copenhagen did however not have a health problem from the mercury, because people in Copenhagen were not eating fish on a daily basis as the Japanese at the bay, and anyway there was no fish at all in the harbor as the water quality was too bad for the fish to survive.

## **Sewage Bypassing & Treatment**

All the sewage was discharged directly to the consequently much polluted harbor. In 1950's it was decided to move the sewage discharge from the harbor to the Sound. This decision immediately produced a much better situation in the Harbor. This actually goes to show that bypassing and dilution of sewage can be a good solution for a country at a certain stage of its development before it can afford advanced wastewater treatment.

In the seventies the public pressure for getting a much better water environment paved the ground for introducing advanced wastewater treatment. Organic removal was introduced in the seventies and nutrient removal at the end of the century. However, this was not necessarily a very optimal process, as some of the treatment, particularly for phosphorus, has shown up to have very little effect. The background for taking these decisions was the BAT principle: Best Available Technology. This can be viewed as a BAD principle, as it does not take into account which kind of receiving water body actually is influenced by the sewage discharge. And secondly it's not very operational as there are technologies available for treating water to any quality level. So at the very least the BAT principle is worthless without economic considerations.

The impact of the modern Danish society on the water environment is now regulated by the EU water frame directive. This directive uses the natural condition as the reference state for describing good and high ecological quality. This is a basically a good thing as it fixes the reference states to a scientific technical issue, which cannot be influenced by political maneuvering. Furthermore, the directive asks the European countries to establish a relationship between the loadings of substances and the resulting ecological states. The situation is not ideal, however because the water frame directive is too ambitious in its aim is to obtain good or high ecological quality in most of the European waters. This is obviously not possible in a relatively small region with 350 million people and large tracts of land being used for agriculture production.

Many ideas in the European water frame directive may be a good inspiration to other countries. However, it should not be copied fully as it does not to a sufficient degree allow for human beings to be an integral part of the ecological system.

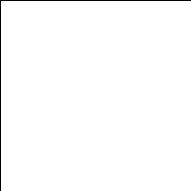
## **Fixed Links & Renewable Energy**

In the late part of the twentieth century Copenhagen has solved many of its primary environmental problems. And the City can now afford worry about secondary problems like for instance the impact of fixed links and sea wind mills. None of these secondary problems are pushing the health and safety of human beings at any serious risks, and the effect on the ecosystems are marginal if the constructions are planned sensibly. However these problems are still getting as much attention and as many resources for accessing their impacts, as if it were serious primary environmental problems. It just goes to show that the number of problems for human beings never changes and that human beings tend to be continually worried.

One of the most advanced environmental impact assessment studies in the world was made before and during the construction of the bridge over the Sound. During this project were developed the powerful techniques, which are supporting modern data collection for the environmental impact assessment process.

## **The Virtual Water World**

Modern environmental information systems must fully integrate modeling and monitoring. Models without data are guesswork; however data without models is wasted effort. So both parts of the environmental information system must be seen as equally important. To combine the two parts methods like data assimilation can produce a system with online access to a fully integrated set of data for decision support. This is leading on to the perfect water information system: the Virtual Water world, where a steady and high bandwidth stream of data is merged with powerful 3-



dimensional modeling to give a nearly perfect mirror of the state of the water world. In the words of Tolkien from the Lord of the Rings:

*Galadriels mirror shows many things, sometimes it is what you want to see, but sometimes it can show many different things that is hard to explain, and often can be a possible near future.*

In Denmark DHI has together with Copenhagen City taking the first steps to establish a virtual water world in the form of a water forecast<sup>9</sup>, which is for water, what the weather forecast is for weather.

## **The Green Cities of the World**

Copenhagen is now aiming to be the green capital of Europe. It has used hundreds of millions of U.S. dollars to renew its sewage systems and to prevent storm water overflows to the harbor by building storage reservoirs. Since 1. juni 2001 the harbor is now ready for swimming among other because the Copenhagen city is using the DHI water forecast early warning system for bathing water quality to secure health and safety for the public using the swimming facility.

Copenhagen has already come very far in securing a good environment. There's still more to do but it seems safe to say, that getting rich is surely good for the environment.

Other major cities in all parts of the world can do the same thing. They need to learn the lessons from a city like Copenhagen, and they need to use sensible management principles. But first of all they need the self-confidence, which is the basic requisite for daring to do the right thing. Copenhagen has done it. This means all the other cities in the world can do it too.

Obviously the great Chinese nation is on the right track and will be able to create beautiful and clean mega cities. Even if there are some growing pains<sup>10</sup> along the way, continued high economic growth is the right prerequisite for quickly creating a good state of water and environment.

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<sup>9</sup> [www.waterforecast.com](http://www.waterforecast.com)

<sup>10</sup> Economist, August 21 2004