THE ÖRSERUMSVIKEN PROJECT – *DECONTAMINATION*

Contents

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Örserumsviken transformed

This publication tells the story of how Örserumsviken, the bay outside Västervik, was transformed from a badly polluted arm of the sea to a reborn, pristine habitat as part of the national campaign for a non-toxic environment.

One of Sweden's biggest-ever clean-ups has rid the bay of 65 years' ecotoxic emissions from the Westervik papermill.

Work began in 1994, with the Västervik Environment and Health Protection Office commissioning a pilot study concerning possible after-treatment of the bay. The gigantic clean-up ended in the spring of 2004 with the planting of trees and shrubs up on the newly constructed retaining bank by which the ecotoxins of the industrial past will be kept under lock and key.

So there it lies, all the detritus which it took so many years to extract from off the seabed - relics of an industrial undertaking which began in 1915 and continued until 1980. Eventually the emissions formed a bottom layer which, together with the papermill's old fibre depot at the head of the bay, was estimated to include 750 kg mercury, 1,400 kg PCB and hundreds of kilos of other pollutants, polycyclic aromatic hydrocarbons (PAHs) among them.

The comprehensive environmental studies (2001-2003) preceding the clean-up showed that the ecotoxins from the papermaking period had slowly leeched out through the strait linking the bay with the Baltic, at a rate of some 200 g mercury and 400 g PCB annually. Given the amounts remaining on the seabed, Örserumsviken could go on polluting the Baltic for hundreds of years to come.

But most of the near-incomprehensible quantities of ecotoxins from the area have now been sealed beneath a protective layer of several different materials inside a stout retaining bank. PCB, mercury and PAHs, in other words, have been moved to a safer repository, and one of the most heavily polluted bays on the east coast of Sweden has been radically decontaminated and eliminated as a source of Baltic pollution.

Why was the clean-up undertaken? Was the MSEK 115 price tag justifiable? There are several answers to these questions.

The Västervik archipelago is designated an area of national interest in Sweden on account of its natural beauty, its scientific interest and its importance for outdoor recreation. Next to it, moreover, is the five-star Lysingbadet camping site, an oasis for thousands of summertime holidaymakers from near and far.

But above all we are talking about the future. Sweden's Riksdag (parliament) has resolved, as one of 15 national environmental quality objectives, that our common environment is not to be polluted by toxic substances.

For a long time Westerviks Pappersbruk AB was one of Västervik's biggest employers. The mill produced paper and cardboard from scrap paper brought in by rail. The goods trains passing through Västervik loaded with bales of paper were a familiar image of the 20th century's unqualified belief in the future. But there was an environmental price tag attached.

Unprocessed effluent

This 1960s air photo shows the papermill area and the inner part of the heavily polluted Örserumsviken. Insert: a picture of the scrap paper depot.
PHOTO COURTESY OF RIKETS ALLMANNA KARTVERK (THE GEOGRAPHICAL SURVEY OFFICE OF SWEDEN).

Wastepaper collecting was a regularly recurring and popular item on Västervik school timetables in the 1950s. Newspapers and magazines were proudly delivered to the papermill in Örserumsviken, and the school classes were then paid a few pence for every kilo collected.

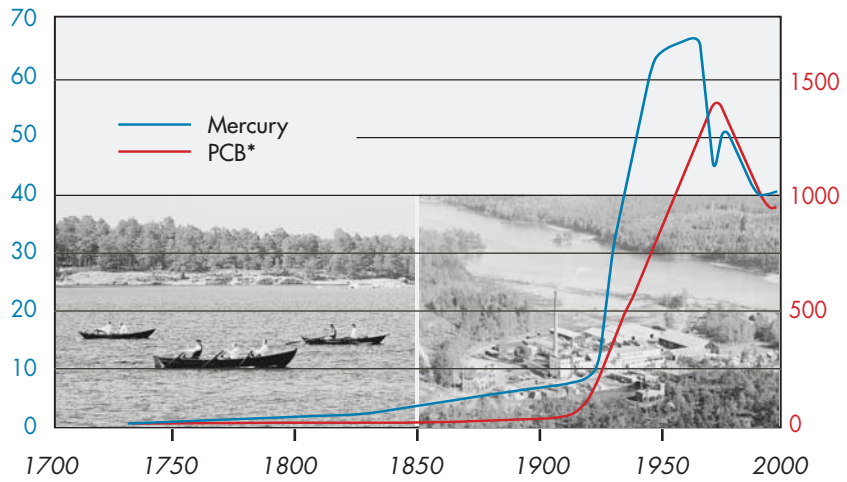
Few people, apart from the workers themselves, had ever been inside the factory perimeter. Otherwise they could have seen how raw effluent from the mill was being discharged straight into the bay. But few people in those days spared a thought for the environment.

The effluent contained paper fibres, and with the passing years these formed progressively thicker layers on the seabed. But the fibres also contained substances destined to be classified among the worst ecotoxins of our age - mercury and PCB, the latter denoting a group of chlorinated substances called polychlorinated biphenyls.

It was not known at first how hazardous these substances were. They were simply part of the papermaking process. For a couple of decades, many papermills used mercury to clear their piping and machinery of algae and other contaminants which might otherwise cause breakdowns. PCB entered the mill with recycled paper. For a long time it was used, for example, in printing inks and self-copy paper (aka carbonless copy paper). With one or two brief intermissions, the papermill remained in operation till 1980, by which time Örserumsviken, in terms of ecotoxin quantities, was one of the most heavily polluted bays on the east coast of Sweden. Environmental stipulations during the mill's active history were not very demanding by present-day standards. Only in 1954 was temporary purification of the mill's effluent introduced, with the construction of a primitive retaining wall, and even this had an opening through which, when the pond was full up, effluent could escape into the bay; the pond filled up in about ten years. This untenable situation eventually led to the papermill being ordered to clean up the badly polluted bay.

The clean-up, however, was a long time coming. A water court judgement in 1970 allowed the papermill to go on discharging effluent into the bay "during a three-year trial period", but by 1976 there could be no more stalling. A new water court judgement ordered the papermill to clean up the inner part of the bay, and work began in 1978.

PCB and mercury in the bottom sediment of Örserumsviken



Industrialisation triggered an accumulation of ecotoxins in the environment. The PCB and mercury concentrations in the above diagram are given in nanograms per gram of total solids, but with different scales for the two substances. The visible growth of concentrations already from the 1920s onwards, is due to a certain remixing in the sediments.
* The study included five types of PCB, which means that concentrations of all known types taken together are roughly four times greater.

PCB

PCB is the collective name for a large group of chlorinated substances (about 200 in all) formerly used in many branches of industry and technology, e.g. in glue, jointing compound, oils, glazing putty, paints and certain kinds of paper. Although PCB had been used industrially ever since the 1930s, as a pollutant it went unnoticed till 1970.

Salvage paper was used in Västervik throughout the papermill's lifetime, but the fact of its containing PCB was only discovered in the 1980s.

Detailed investigations have shown PCB to be a highly potent ecotoxin, and it has been given much of the blame for the severe decline in otter and seal reproduction rates in the Baltic during the 1980s.

Use of PCB was already banned in 1972, but most of the 1.5 million tonnes of it manufactured worldwide are still loose in the environment or in the components made with it. International surveys, however, have indicated diminishing PCB concentrations in the Baltic Sea, thanks no doubt to the banning of the substance.

Kvicksilver

Mercury is an element which was widely used, e.g. as a chemical pesticide. Farmers in the 1950s used seed which had been mercury-treated to make it resistant to fungus and insect pests. In the 1960s the mercury content of dressed seed was found to be the cause of widespread death, due to mercury poisoning, among wild birds.

Phenyl mercury was used in the paper and pulp industry to prevent algal growth in piping and machinery, and mercury was used as a pulp preservative. Mercury began to be used at the Westervik papermill in the 1950s, and the practice probably lasted until the end of the 1960s.

Mercury, being an element, cannot be destroyed but has to be isolated to prevent it spreading further. One serious problem is that mercury can be turned into methyl mercury. This happens when oxygen is lacking where the mercury has accumulated, e.g. in fibre banks on the seabed.

Bay water damaged fish fry

PCB and mercury were not the whole legacy of the papermill in Örserumsviken. The studies also revealed large quantities of substances belonging to a group of chemical compounds collectively known as PAHs. This is one of the latest and most important environmental research findings.

Laboratory experiments showed water from Örserumsviken to cause deformities and increased mortality among fish fry. This picture shows fry with spinal deformities.

PHOTO COURTESY OF AQUATIC TOXICOLOGY LABORATORY, STOCKHOLM UNIVERSITY.

PAHs is short for polycyclic aromatic hydrocarbons. These substances are formed, for example, through incomplete combustion of fossil fuels like oil and coal, inefficient wood firing and smelting of aluminium. Diesel-powered traffic and wood firing are the main emission sources. Creosote, which for a long time was used for impregnating wood, also contains large quantities of PAHs.

Not all PAHs are toxic, but a considerable number of them contain benzene, which is carcinogenic.

When fish fry in a laboratory environment were exposed to water from Örserumsviken, deformities and increased mortality resulted. Studies in the Emån river and elsewhere have yielded similar results, and PAHs are suspected as part of the reason for some fish species having difficulty in reproducing in certain areas along the east coast of Sweden. How did Örserumsviken come to contain such large amounts of PAH, probably something like 550 kilos? Studies of the bay and of the archipelago beyond revealed much heavier PAH concentrations in the bay, which can only mean that the papermill was responsible for at least part of the widespread propagation of PAHs.

These relatively large quantities may be due to ash from a coal-fired central heating plant at the papermill, and perhaps also to non-recyclable asphalt paper, but a great deal emanates from outside sources. Concentrations are often just as high in the waters round big towns and cities.

The Institute of Applied Environmental Research, Stockholm University, analysed a total of 18 different PAH compounds in Örserumsviken, but a lot of research still remains to be done where PAHs and their environmental effects are concerned.

The old clean-up...

A – by the standards of its time – comprehensive decontamination of the inner part of Örserumsviken began in 1978, the State having obtained a water court judgement ordering the new owner, PLM, to clean up the bay after it had been made clear that the fibre banks contained heavy concentrations of mercury.

Apart from the important environmental objective of collecting the mercury, another aim was if possible to recover the paper fibres.

The clean-up carried out in 1978 was similar in certain respects to the major and definitive decontamination of Örserumsviken completed in 2004. The technique employed on the earlier occasion involved dredging 200,000 cu. m. of fibre banks from the inner part of the bay and pumping it onto dry land, where it went through several processing stages. The water was centrifuged off and the fibres deposited inside the enclosure constructed in the 1950s.

This technique was successful in several respects: the fibres and mud pumped ashore proved to retain more than 90 per cent of the mercury, thus achieving the environmental target inscribed in the water court judgement. In addition, more than 600 kg PCB were trapped as well, though nobody knew it at the time – this environmental problem only became known a couple of years later. Altogether, dredging operations in the bay during 1978 and 1979 covered 15 hectares out of a total of 37. The first step had thus been taken towards a full reinstatement of the whole bay, but it would take until 2001 for a new generation of decontamination equipment to be wheeled onto the site of the old papermill.

PLM, the papermill's last owner, had advanced plans for trying to recycle the "used" fibres in the dredging spoil, but in 1980 the company decided to close the plant down.

The fibres, and their ecotoxic contents, remained on the shore of the bay. Years passed, and the fibre depot was forgotten as it disappeared under a pine and birch wood which could evidently flourish in the midst of the pollutants. Slowly but surely, however, large quantities of fibres slid into the old pond, aggravating the problem of leeching toxins.

The old tank at the papermill contained a morass, several metres thick, of paper fibres from the whole of the papermill's productive career and from the 1978-1979 clean-up.

Thus far but no further. Entering the fibre tank at the papermill could have fatal consequences.

Some of the equipment used for the first clean-up operation was still lying around in 1998.

...and the model for the new one

A clean-up project the size of Örserumsviken is much more than just a clean-up. The preparations are every bit as time-consuming. Under the new Environmental Code which entered into force in 1999, a dredging project on this scale has to be examined by an environmental court and rules of conduct laid down for it. The Code also requires information to be supplied to everyone affected.

A public hearing about the clean-up plans took place in Västervik on 11th October 1999, to meet the statutory requirement of everyone affected being kept informed by means of "extended consultation". Accordingly, a number of public authorities and NGOs (Non-Governmental Organisations) were among those invited to attend the Västervik meeting. They included such central authorities as the National Board of Fisheries, the Swedish Environmental Protection Agency, the Swedish Maritime Administration and the National Heritage Board. Local organisations such as yachting and boat clubs, fishing associations, birdwatching clubs and archipelago associations were also invited to attend.

It was not until after this consultation that the Municipality of Västervik filed its application with the Environmental Court in Växjö, on 13th March 2000 in the form of a massive volume containing detailed accounts of the quantities of ecotoxins to be disposed of and the decontamination procedure to be followed. Schedules to the application contained an environmental impact assessment and accounts of control programmes, describing the environmental monitoring procedure to be followed as work progressed. Altogether the application ran to over a hundred pages. On 20th November 2000 the Environmental Court in Växjö, in its capacity as Water Court, delivered judgement and defined the terms to which the clean-up would be subject. Briefly, the judgement permitted the Municipality of Västervik to dredge 200,000 cu. m. sediment and deposit the spoil on the old papermill site inside a new, reinforced retaining wall. The judgement also required the bay to be blocked with a special textile screen at the point where it debouched into the archipelago. The screen serves as a filter, trapping the particles in the water.

Simultaneously with the Water Court's judgement, a general contractor was appointed for the clean-up. The contract went to Vägverket Produktion Syd, which in turn engaged a number of subcontractors for different parts of the work.

Sequence of operations in a decontamination project	Örserumsviken project year
PILOT STUDY Studies of maps and records General field studies, with risk classification Investigation of responsibilities and funding	1994
MAIN STUDY Detailed fields studies Simplified or in-depth risk assessment Investigation of responsibilities and funding Investigation of measures and options Risk evaluation, with overarching objectives and action requirements. Investigation with a view to planning/detailed planning. Revision of action requirements, if needed.	1995-1998
PREPARATION Planning Application for permits etc Award of contracts	1998-2000
IMPLEMENTATION Actions and ongoing environmental surveillance	2001-2004
FOLLOW-UP Surveillance programme Evaluation of work Experience feedback	2004-

Ecotoxin collection technically complicated

The landfill site built up for the new clean-up operation was covered with bentonite, plastic film, sand and gravel.

The clean-up operation which started in Västervik in the summer of 2001 was the biggest Sweden had ever seen. Work began with the construction of a stout new retaining wall, five metres high and completely impervious, out towards Örserumsviken, at the same time as the bay was cordoned off with a textile screen to trap the particles present in the water. A control station was also established outside the screen, to ensure that no ecotoxins escaped into the bay.

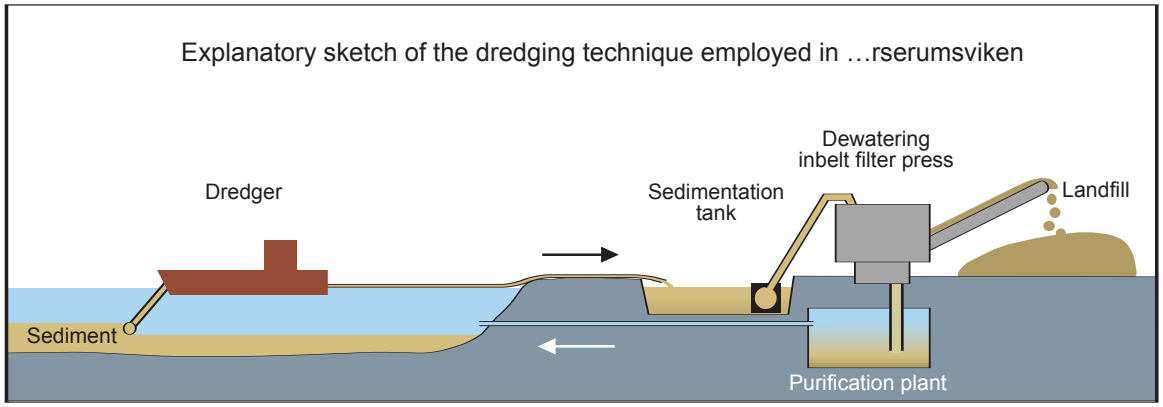
The Örserumsviken clean-up was based on removing the uppermost stratum of the bay's benthic sediment. This meant extracting an 0.8 metre thick layer of mud and fibres with a dredger armed with a helical suction nozzle. The dredger was held in position by hawsers from on shore and its position monitored with GPS satellite navigation equipment. From the dredger the slurry was pumped ashore through a floating pipeline and put through several processing stages, in which it was dewatered with the aid of cyclones and belt filter presses. Finally the water passed through a purifying plant and was assayed before being released back into the bay. The dewatered dredging spoil in turn was mixed with thickener and cement to a suitable consistency before being driven to its terminal landfill repository inside the newly constructed retaining wall. Admixture of a small proportion of cement created a more stable landfill site with less risk of subsidence.

In this way, during the years that followed, kilo upon kilo of ecotoxins from the bay was successively put under lock and key. At peak efficiency, the benthic slurry removal rate was something like 500 cu. m. hourly. To maintain a consistently high dredging rate, a sedimentation tank was constructed ashore to receive the spoil whenever the belt filter presses malfunctioned or became overloaded.

Turbidity warning

All the time work was in progress, a check was maintained in case the turbidity of the water became so high that ecotoxins might

The dredger (above, left) in action in the bay. Below it is a sedimentation tank for the dredging spoil. The picture above shows the dewatered screenings being laid up inside the newly constructed retaining wall.



be escaping from the bay. All data were stored at a special gauging station which was always directly accessible from the municipal environment protection office. The station had an in-built warning system which sounded the alarm if dredging was causing excessive turbidity. All the time dredging was in progress, water samples were taken and analysed for toxin content.

Dredging was not confined to the bottom of the bay. Special shallow-draught machines were used to clear the shores of reeds and contaminated sediment, and a small channel was excavated to reinstate the little island, Karins Holme, off the southern shore of the bay.

The project suffered serious delays, for many reasons, but dredging operations were successfully concluded in the summer of 2003, by which time almost 200,000 cu. m. contaminated benthic sediment had been removed from the bay. Later, in the autumn, the inlet screen was removed and work concentrated on properly covering over the dredging spoil. The whole operation ended in spring 2004 with the planting of trees and shrubs on top of the new retaining wall.

Many problems along the way

The Örserumsviken clean-up operation presented many technical problems which had to be solved as and when they arose. The main difficulty was the inadequate capacity, or inefficiency, of various parts of the decontamination equipment.

In October 2002, therefore, the Municipality of Västervik applied to the Government for an extension of the project period. Even so, the clean-up turned into a race against time.

The difficulties of coping with pollution in the bay began early on. The Swiss company chosen as subcontractor for the dredging operation suffered constant reverses in the matter of getting personnel and plant to the bay on time. Among other things, a host of permits had to be obtained for transporting heavy plant across Europe. The equipment itself, when finally in position, either broke down or proved to have insufficient capacity. These problems led the general contractor to appoint a new subcontractor for the dredging.

From beginning to end, the project was beset with numerous technical problems. The first dredger had too little capacity. The belt filter presses for dewatering the spoil were also affected by repeated malfunctions and were found to have insufficient capacity. More and more machines were therefore successively deployed.

Progressively greater resources were mobilised as it became clear that time margins for the operation were diminishing. Necessity being the mother of invention, innovative solutions were found to many problems. For example, a piste machine was rented from a ski slope in the autumn of 2002, after several days monsoon rain had made it impossible for the dewatered dredging spoil to be moved out with ordinary dumpers and wheel loaders. Other solutions included dredging the shores with a specially equipped, shallow-draught working boat from Flatholmen in the archipelago. A long-reach excavator with an 18-metre arm became another conspicuous ingredient of the Örserumsviken plant line-up.

A special shallow-draught boat was used for inshore operations.

Eco-monitoring continues

The rehabilitation of Örserumsviken is being followed by a comprehensive monitoring programme. Kalmar University will be studying the recovery of life in the bay following the dredging operations, and the landfill side containing the dredging spoil will be kept under close surveillance for several years to come.

The dredging operations in Örserumsviken meant the removal of several hundred kilos of ecotoxins in the old, fibrous sediments. But how will Nature respond to this clean-up? Will mercury concentrations in pike decline rapidly or slowly, and what will happen to all the different small creatures?

Kalmar University already had divers in position to examine the bay when dredging operations ended in the autumn of 2003. Several algal species were found to be "moving in" on the newly remediated beds. Small perch and various other small creatures were also present. But the fish population was considerably smaller than before the clean-up.

Natural conditions in Örserumsviken made it a highly productive fishing ground. Historical documents show that fishing rights in the 18th century belonged to the Crown, suggesting that the fishing here was important.

The University will be studying the bay for 6 or 7 years after the clean-up. Two other bays in the municipality are being studied at the same time, for purposes of comparison.

Many field trips occurred during the project. Here visitors are being shown over the gauging station for monitoring the bay's turbidity.

Groundwater control

The large fibre landfill site will also be kept under close observation. Given the importance of preventing any contaminant leakage, a special monitoring programme has been designed for this purpose. For the period ending in 2008, the groundwater will be checked in five different places on and around the site of the former papermill. In addition, several drinking water wells in the neighbourhood will be investigated. Figures from these studies can then be compared with samples taken before the clean-up.

Up on the actual landfill site, where the ecotoxins are now shrouded in bentonite, plastic film, sand and other covering layers, a number of pipes project from the ground. These can be used for studying what is going on down inside the landfill site, whether water is seeping in and whether the gas which will form beneath the cover contains mercury or PCB. These checks will also continue until 2008. The environmental quality objectives defined in the water court judgement for the clean-up require transport of PCB and mercury from the bay to the coast outside to diminish by 90 and 70 per cent respectively. The judgement also requires atmospheric immissions of these substances to be reduced by no less than 99 per cent. The checks carried out in the next few years will show whether or not the target is achieved.

Developments down among the paper fibres can be studied through a well and through a number of pipes in the landfill site. Items for measurement include gaseous emissions and subsidence.

Christer Ramström, sub-project leader for environmental control, sounds the depth of the water after dredging operations in the inner bay.

Kalmar University will be studying the recovery of flora and fauna in the bay following the clean-up.

National environmental objectives demanded rehabilitation

The reinstatement of Örserumsviken is a further step towards achieving Sweden's environmental quality objectives. In 1999 the Swedish Riksdag (parliament) adopted 15 such national quality objectives for environmental quality. The decontamination of Örserumsviken touches on several of these, and above all on the creation of a non-toxic environment.

The spending of taxation revenue on environmental remediation often comes in for criticism, one widespread view being that toxins are "best left alone". But this is out of keeping with the 15 national environmental quality objectives resolved on by the Riksdag, which in turn form part of a wider European perspective.

All three of the environmental clean-ups so far undertaken in the county have virtually halted the spread of ecotoxins into the Baltic Sea from the sources concerned. Every year, between 3 and 5 kg PCB – containing, moreover, the extremely hazardous substance dioxin – was escaping from Järnsjön lake in the Municipality of Hultsfred. Decontamination of the Jungnerholmarna islands has curbed seepage of cadmium, lead and nickel into Kalmarsund. And the Örserumsviken clean-up has ended escapes of mercury and PCB, as well as a large number of PAHs (polycyclic aromatic hydrocarbons).

"Environmental clean-ups have to be viewed in the longer term," says Tommy Hammar, the County Administrative Board's expert adviser on decontamination operations, with reference to the long-term return on expenditure.

"We know today that, with every day that passes, toxic substances are being dissipated in our habitat and are also reaching humans.

"So catching hold of the toxins while they remain in large quantities in limited areas, like Örserumsviken, is a race against time.

"Time will show the big clean-ups to have been money well spent.

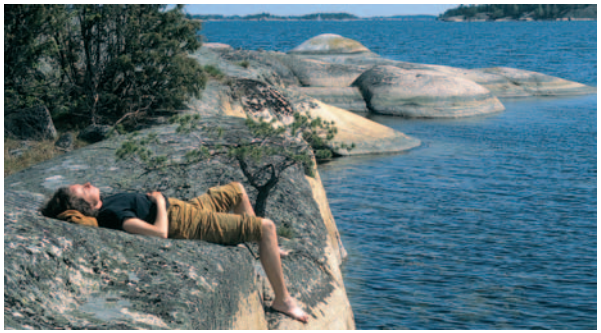
"At the end of the day, we're talking about creating the sustainable society, which means the achievement of quality of life for our own and future generations."

The national environmental quality objectives

At least five of Sweden's 15 national environmental quality objectives (underscored below) are touched on by clean-up operations in the county. Briefly, the environmental quality objectives are as follows.

1. Reduced Climate Impact
2. Clean Air
3. Natural Acidification Only
4. A Non-Toxic Environment
5. A Protective Ozone Layer
6. A Safe Radiation Environment
7. Zero Eutrophication
8. Flourishing Lakes and Streams
9. Good-Quality Groundwater
10. A Balanced Marine Environment,
11. Thriving Wetlands
12. Sustainable Forests
13. A Varied Agricultural Landscape
14. A Magnificent Mountain Landscape
15. A Good Built Environment

The Jungnerholmarna islands in the Municipality of Mönsterås were transformed from contaminated industrial land to beautiful walking country.



The environmental quality objectives are concerned with quality of life.

The rehabilitation of Örserumsviken constitutes a new step towards a cleaner environment in an area classed among places of national interest for natural beauty/scientific interest, culture and recreation. Lysingsbadet and the Korpaholmarna islands, with one of Sweden's biggest five-star camping sites, are right next to Örserumsviken.

The decontamination of Örserumsviken serves to enhance the water quality of an archipelago area with Lysingebadet at its centre.

Cleansing a national asset

In the County Administrative Board's conspectus of areas of outstanding scientific interest and natural beauty, the Västervik archipelago comes among the highest-classified (class 1) areas in the County of Kalmar. The publication *Natur i östra Småland* contains the following description of the archipelago:

> *"The archipelago is extremely manifold and varied, blessed with natural beauty and attraction and offering excellent opportunities for boating, bathing, canoeing, fishing and studies of the natural and man-made environment. Every year the archipelago is visited by boat tourists in their tens of thousands, especially along the very busy shipping lane off the east coast. There are also many suitable places for land-based outdoor recreation."*

Geologically, too, the Västervik archipelago is of outstanding interest because of its mixture of younger and very old rocks, the oldest being quartzites which have existed for nearly 2.5 billion years. The archipelago also bears distinct traces of the retreating ice cap, in the form of smooth slabs of rock and glacial striations. And in past millennia the sea has formed remarkable end moraines and shingle fields.

Hunting and fishing

The archipelago is also of great antiquity as a settlement and source of livelihood for the coastal population. The oldest signs of human presence date from the Stone Age, when people lived by hunting and fishing. To this day, the archipelago and inlets of the Tjust area remain dotted with Bronze Age burial cairns.

The Västervik archipelago has been traversed by important shipping routes ever since medieval times. Spårö is mentioned in a shipping route description from the 13th century. The whitewashed beacon at Spårösund still guards this ancient shipping lane.

Right down to the second half of the 20th century, the archipelago still had a large permanent population living by archipelagic farming and fishing. Many islands have been continuously inhabited since the 16th century and, with their archipelago villages, rank today among the jewels of the east coast heritage.

The worst century

For a long time, however, the quality of the water in this archipelago has been gradually deteriorating, owing to large-scale changes of human lifestyle - more specifically, to industrialisation, migration to the towns and cities, agricultural mechanisation and the growth of motorism in the countries surrounding the Baltic Sea.

Purple loose-strife and white sticky catchfly (Silene viscosa) *flourish in Stora Betskäret, one of the outposts of the Västervik archipelago.*

The rare narrow-leaved helleborine orchid grows on several of the archipelago islands.

The Västervik archipelago was already traversed by shipping lanes in medieval times. Spårö Beacon overlooks a shipping lane dating from the 13th century.

The Västervik archipelago is a geology textbook come to life. Picture: *veined gneiss in the outer archipelago.*

Örserumsviken has an abundance of birdlife. The great crested grebe, for example, is very much at home here.

Kalmar County – an ecological big spender

Kalmar County is going through a purging bath on the grand scale. The environmental situation has been improved through a succession of major clean-up projects of which Örserumsviken is the latest to have been accomplished. But the map of buried ecotoxins shows how much remains to be done in an old industrial county. Thirty of the most heavily contaminated areas will together cost between MSEK 2,000 and 3,000 to decontaminate.

One of Sweden's first big clean-up projects began in 1993-1994, when Järnsjön lake in the Municipality of Hultsfred was cleansed of 400 kg PCB from the Nyboholm papermill in the County of Jönköping. This was done by means of suction dredging, and the contaminated spoil was deposited on a landfill site near the lake.

The results of the clean-up quickly became noticeable. Two years afterwards, PCB concentrations in fish from the lake had fallen by half. Järnsjön being part of the great Emån river network, the clean-up also helped to reduce emissions of mercury and PCB into the coastal waters of Kalmarsund.

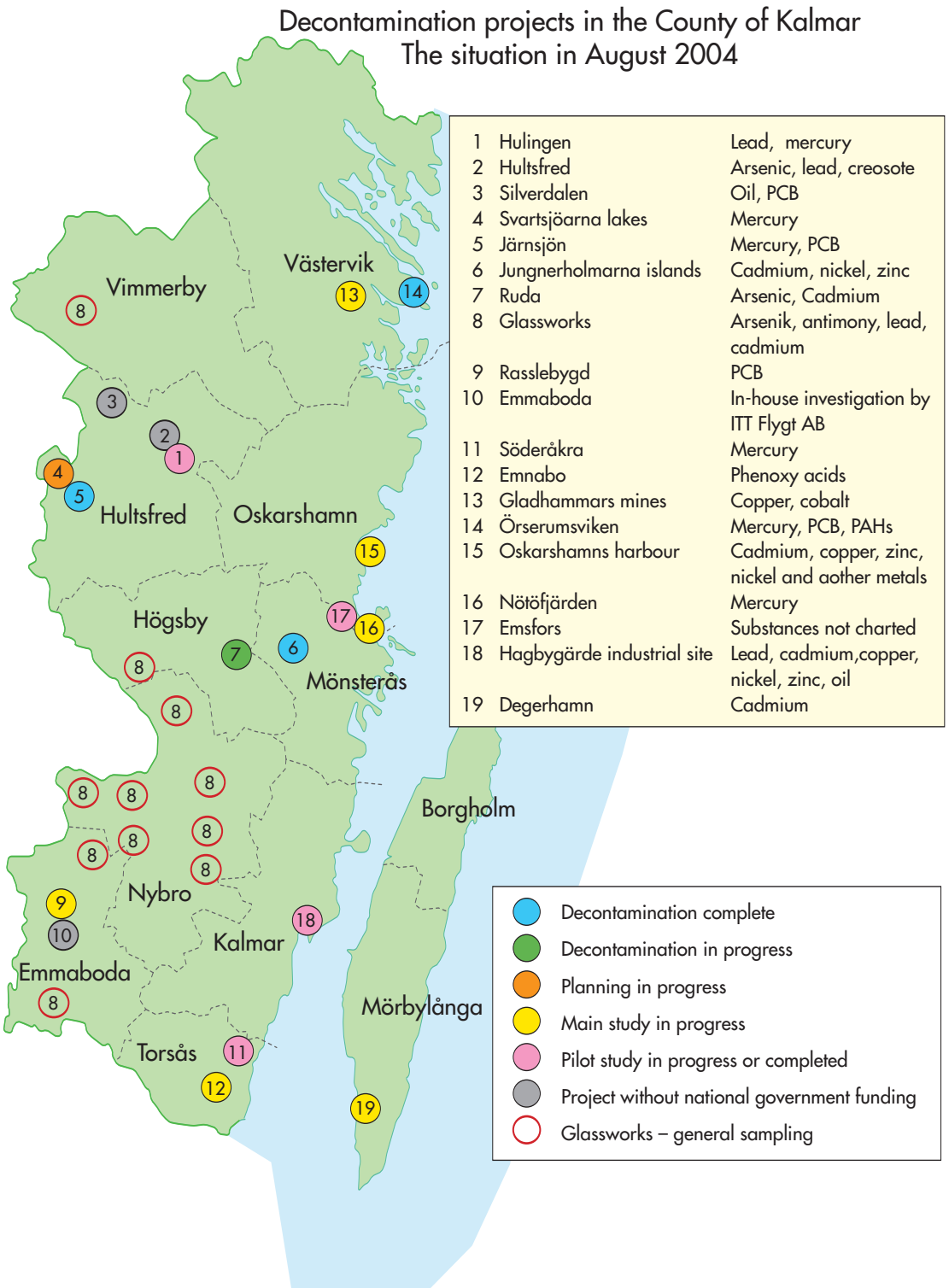
Another big step towards decontaminating the Emån river and Kalmarsund was taken in the next major decontamination project, starting in 1999. On the Jungnerholmarna islands in Fliseryd, production of battery paste for rechargeable accumulators and the melting-down of old lead batteries had left its mark on the environment. Environmental surveys indicated above all the presence of very large quantities of cadmium, nickel and lead, both in the river and on the factory site.

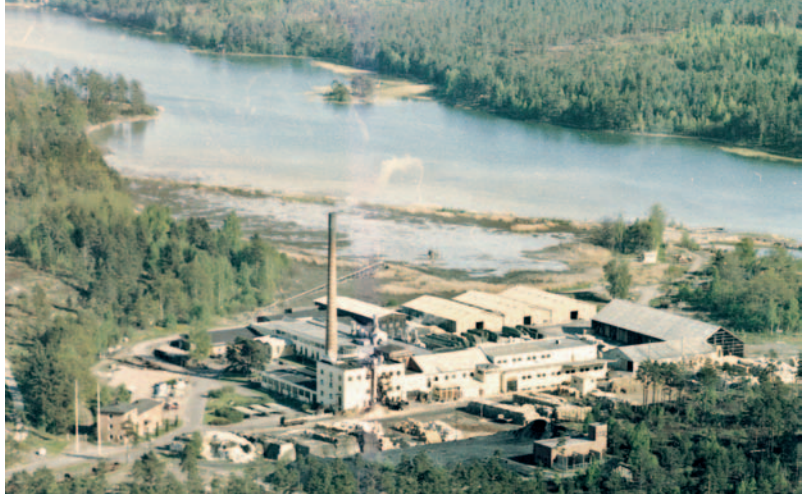
As a result of the clean-up operation, more than 90 per cent of the 35 tonnes of cadmium and 900 tonnes of lead in the area were disposed of. This was a technically demanding operation, due among other things to all the old and heavily contaminated industrial buildings on the site being classed as environmentally hazardous waste.

Today the islands make beautiful walking country.

Arsenic and mercury

A big decontamination operation started in Ruda, in the Municipality of Högsby, in 2004, aimed at saving a municipal water source from arse-





Production at the Westervik papermill started in 1915 and continued until 1980. This air photo, taken in 1963, shows the mill's location on Örserumsviken.

PHOTO COURTESY OF KULBACKEN MUSEUM ARCHIVES.

Industrial emissions from the Pauliström papermill have contaminated the Upper and Lower Svartsjöarna lakes in the Municipality of Hultsfred.

AIR PHOTO COURTESY OF MUNICIPALITY OF HULTSFRED.

Hulingen, near Hultsfred, is a well-known lake for bird-watching, but there is mercury present here, e.g. from papermills further upstream in the Emån river network.

nic, a highly toxic element. Arsenic is present in the ground as a legacy from an impregnating plant and a glassworks. Here again, some of the toxic substances were able to seep out into the Emån river through a smaller watercourse.

Further upstream in the Emån system is a tributary called Pauliströmsån. This passes through a stretch of unspoiled Småland countryside but has nevertheless been heavily polluted by emissions. The emissions came from further upstream, from the Pauliström papermill, which used mercury in its production processes. As a result, two small lakes downstream, Svartsjöarna ("the Black Lakes"), have received about 250,000 cu. m. mercury-contaminated paper fibre, and the mercury has slowly migrated further to the Emån river.

There are also many areas along the county coast which have been heavily polluted by industrial activity. Örserumsviken was one of them. Things were even worse in the pool of Oskarshamn harbour, which contains nearly all of the most notorious heavy metals. Ships entering and leaving the harbour are helping to spread these metals out to sea.

Race against time

Each county has been tasked by the Environmental Protection Agency with listing the 30 areas which it considers most urgently in need of remediation. The cost of the clean-ups hitherto accomplished and planned in the County of Kalmar is now estimated at between MSEK 2,000 and 3,000.

"This is not to say that the County of Kalmar is more polluted than other counties," says Tommy Hammar of the Kalmar County Administrative Board, "but we have a longer coastline and our watercourses pick up pollutants from inland."

"Then again, we were early starters at identifying our environmental problems."

"Our county has made quite considerable headway, because we started with really heavy assignments like Järnsjön lake, the Jungnerholmarna islands, Örserumsviken and the Ruda industrial site."

Many steps to be taken

• In 1994 the Västervik Municipal Environment and Health Protection Office carried out a pilot study of possible methods for after-treatment of the benthic sediment of Örserumsviken. The pilot study was sent to the County Administrative Board, which in turn gave priority to Örserumsviken in the conspectus it forwarded to the Environmental Protection Agency concerning important after-treatment projects in the County of Kalmar.

• In 1995 the Kalmar County Administrative Board received a grant of MSEK 3 from the Environmental Protection Agency, partly for an investigation of responsibility for the pollution and an assessment of the risk of PCB and mercury spreading into the surroundings. The County Administrative Board invited the Municipality of Västervik to take over the grant from the Environmental Protection Agency and run the project. The Municipal Executive Board appointed a steering committee and project group whose members included representatives of the Environmental Protection Agency and the County Administrative Board as well as the Municipality. A succession of reports and surveys was compiled between 1996 and 1998.

• In the autumn of 1998 the Municipality of Västervik applied to the Ministry of the Environment for a State grant under the local investment programme. The Municipality's request for MSEK 68 in State aid towards the clean-up was granted by the Government on 8th April 1999.

• On 31st May 1999 the Municipal Executive Board resolved to go ahead with the Örserumsviken project and appointed a steering group to decide how the project was to be organised and to allocate the necessary resources. A host of surveys were inaugurated in the autumn of 1999, aimed at charting the environmental situation in the bay, and a comprehensive progress of planning and investigation was started. The 1999 studies showed the ecotoxins to be more widely distributed than had previously been known, and the project also proved more expensive than anticipated. An additional grant of MSEK 40 was therefore made by the Environmental Protection Agency.

• Dredging and landfill contracts were awarded in the summer of 2000. The main contract was signed in November 2000.

• The practical task of decontamination began in the spring of 2001 and was completed in the autumn of 2003. Certain supplementary works were undertaken in the spring of 2004. These included the planting of trees and shrubs on the landfill site.

Summer evening in the Västervik archipelago. Stora Björkskär.

PROJEKT
ÖRSERUMSVIKEN
VÄSTERVIK

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MUNICIPALITY OF VÄSTERVIK