The Mersey Estuary – Back from the Dead? Solving a 150-Year Old Problem

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Abstract

The Mersey Estuary has suffered a legacy of abuse and neglect since the beginning of the Industrial Revolution. The discharge of effluents from manufacturing processes, together with wastewater from the burgeoning centres of population, resulted in the estuary gaining the unenviable reputation of being one of the most polluted rivers in Europe.

As a result of the long-awaited remedial action which has been implemented over the last fifteen years, there is now unequivocal evidence that the water quality of the river and the biology of the system have improved significantly and will continue to do so as further planned alleviation schemes are completed.

This paper reviews the achievements which have been made at the half-way stage in the 25-year multi-billion pound 'clean-up' campaign.

Key words: **Contaminants; dissolved oxygen; fish; Mersey Estuary; water quality.**

Introduction

The long-standing pollution of the Mersey Estuary was recognised and commented upon more than 150 years ago when, in 1848, James Newlands (the Borough Engineer) expressed his concern to the Liverpool City Council.

> 'The whole of the sewage is still thrown into the river, much of it, indeed into the basins, and all of it at such points as to act very prejudicially on the health of the town. It becomes therefore a consideration of vital importance how to relieve the river from its pollution.'

However, his concern was unheeded because it was generally believed that the large volume of water in the estuary, together with the strong tides, was capable of receiving almost unlimited volumes of untreated domestic and industrial effluents. Over the next 100 years, conditions became progressively worse as the population of the cities of Manchester and Liverpool and various towns in the catchment increased rapidly. This was coupled with a significant increase in the scale of manufacturing; many of the industries required large volumes of water for cooling and for processes such as bleaching and dyeing, tanning and metalworking.

Following the Second World War, there was a resurgence in manufacturing, particularly of petrochemicals and heavy chemicals based upon the chlor-alkali industry. Many of these new xenobiotic materials are more insidious in their effects on natural systems than the simple inorganic compounds and metals found in waste discharges at the beginning of the Industrial Revolution and expansion of the fledgling chemical industry.

The impact of the large volumes of effluent manifested itself in two principal ways:

(i) Beaches were heavily fouled by crude sewage and fatty material (mainly from edible-oil manufacturers); and
(ii) During the summer months, long reaches of the estuary were devoid of dissolved oxygen at all states of tide.

Unfortunately, water-quality data for the period prior to the 1960s are sparse, but it is likely that conditions were at their worst during the mid-1960s and that the estuary was also severely contaminated by a complex mixture of toxic inorganic and organic chemicals originating from the large number of factories. Likewise, there was only limited information about the biological status of the estuary. Anecdotal evidence asserted that, although the fishing was poor during the 1930s and 1940s, by the late 1950s there were no fish in the river and the system was effectively 'dead'. Whilst this is undoubtedly exaggerated, it is difficult to understand why the local community did not demand that urgent action should be taken.

Quantification of Problem

In the early 1960s, the pollution control authority instigated monthly water-quality surveys to establish the prevailing conditions at the time of sampling and, over a period of years, to detect any long-term trends. These surveys were carried out at high and low-water, with samples collected from eight bankside stations along the 46 km between the tidal limit (Howley weir) and the mouth of the estuary (Fig. 1).

The exercises focused on the basic parameters such as temperature, dissolved oxygen (DO), salinity, suspended solids (SS) and nutrients, and revealed long anoxic stretches (>25 km) during the summer months and high concentrations of amm. N (>12 mg/l) near the head of the estuary. Under these conditions, denitrification was significant and the concentration of oxidised nitrogen decreased to zero. The consequent reduction of sulphate (to maintain the oxidation of the large organic loads) had the potential for serious odour problems as hydrogen sulphide gas was released.

At the beginning of the 1970s, concern increased regarding the deleterious effects of heavy metals such as lead, cadmium and mercury. Reports produced by

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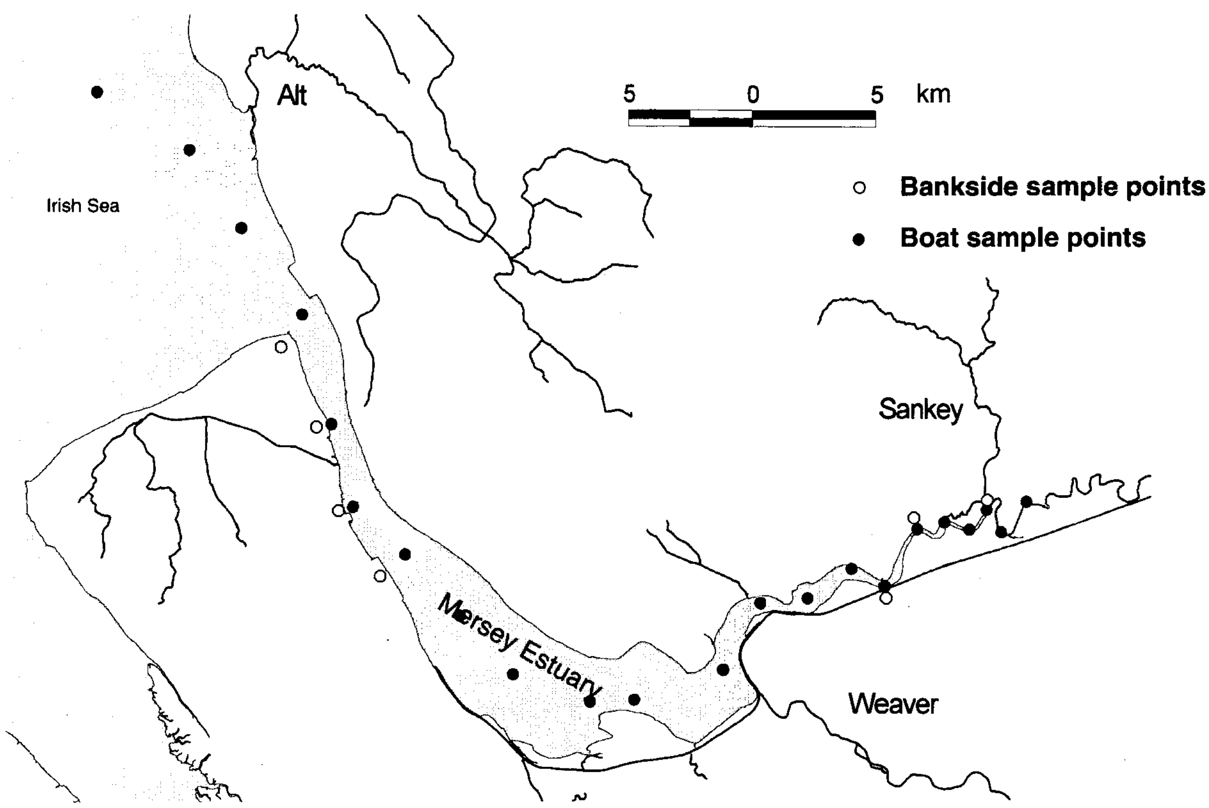

Fig. 1. Mersey Estuary: sampling points

Government laboratories[1,2,3] revealed that fish which were caught in Liverpool Bay had elevated tissue levels of these metals – almost certainly as a consequence of the combined effects of the contaminated runoff from the Mersey and the disposal of sewage sludge and industrial wastes in the bay. Unfortunately, analytical methods for trace contaminants were not available in the laboratories of the River Authority. Consequently, ambient concentrations of metals or organic compounds in the estuary at this time were not known. This lack of information generated a number of research projects at Liverpool University to rectify the situation[4,5,6,7].

In 1974, responsibility for pollution control was transferred to the newly established regional water authorities. This involved collecting, treating and supplying potable water; providing the infrastructure for the treatment and disposal of domestic and industrial wastes; and protecting lakes, rivers, estuaries and coastal waters and their associated flora and fauna. The fundamental change in management from a 'parochial' to a 'regional' view provided an ideal opportunity to rationalise and improve the monitoring programmes for all the watercourses in the North West.

In the Mersey, monthly samples from the seven bankside sites were supplemented by up to twenty-three mid-stream samples collected initially by helicopter (at high and low-water), and latterly at high water using a fast launch. These programmes have continued and are now carried out by the Environment Agency. They provide a 25-year data set against which to judge the effectiveness of the large capital-intensive schemes required to clean up the river.

From 1980, trace contaminant analyses were added to the programme which continued to evolve as new analytical methods became available and new substances of concern were recognised. Nowadays, sampling for a comprehensive suite of determinants is undertaken at several of the stations to monitor compliance with the current 'environmental quality standards' (EQSs)[8].

Monitoring is very demanding in terms of staff and financial resources; consequently the programmes are a delicate balance between what is desirable and the resources available. The determination of trace contaminants requires sophisticated instrumentation and skilled analysts, and is considerably more expensive than the simple sanitary parameters. Therefore careful consideration has to be given to the locations and number of sites that can be sampled and the appropriate frequency of the surveys for any given determinant. It should be noted, however, that the results serve more than one purpose, for example to:

(a) Define the water quality at each point between the tidal limit and the open sea, under a variety of ambient conditions (e.g. temperature regime, freshwater runoff, tidal-range, wind strength);
(b) Investigate local problems (e.g. 1979–80 bird mortalities[9], endocrine disruption in fish[10]);
(c) Discern long-term changes (particularly by monitoring trends in biota and sediments);
(d) Classify the system using national protocols;
(e) Provide data to determine compliance or otherwise with EU Directives (e.g. chlor-alkali, dangerous substances); and
(f) Provide data for the development and validation of mathematical models.

Restoration Planning

The discharge of crude sewage into the River Mersey has caused concern for more than a century. During this period, fears were expressed in terms of (a) the potential damage to public health, (b) the decline in the inshore fishery[11,12], and (c) the possible detrimental impact on the integrity of the navigation[13,14].

In 1971, the Mersey and Weaver River Authority published a report detailing the conditions prevailing in the estuary and on the adjacent foreshores accessible to the public[15]. Shortly thereafter, a steering committee with representatives from local government, industry and the River Authority was convened with the brief of bringing about, within a period of ten years, an 'effective and lasting improvement in the condition of the Mersey'[16]. The committee opted to tackle the problem by:

(i) Appointing consultants to consider the re-sewerage of Merseyside and the construction of appropriate wastewater-treatment facilities[17]; and
(ii) Commissioning the former Water Pollution Research Laboratory (WPRL) to develop a mathematical model of the estuary which would enable the effects of polluting discharges to be assessed, and the likely improvements resulting from the proposed remedial works to be predicted[18].

In 1974, the newly formed North West Water Authority inherited the results of these studies together with the responsibility of implementing their recommendations, and adopted the following objectives for the estuary outlined in the 1971 report[19]:

(a) The estuary should, at all times, contain dissolved oxygen to obviate odour nuisance (of primary importance in the upper estuary); and
(b) The foreshore and beaches should not be subject to fouling by crude sewage or fats from industrial effluents (of primary importance in the lower estuary).

By modern standards, these criteria appear to be extremely lax. With the benefit of hindsight, it should be borne in mind that they were only 'short-term' objectives to rectify what was reasonably considered to be an abominable situation. At that time, the general public were much less aware of environmental matters, their aspirations not so demanding, and (moreover) their willingness to pay for the necessary 'first-time' effluent treatment was by no means certain. Following liaison with the major industrialists, it was resolved that it would be unreasonable for the Private Sector to bear a disproportionate part of the costs and that they should work to reduce their loads at a pace similar to the reductions scheduled by the Water Authority's capital-expenditure programme.

Two decades ago, the Authority had many other pressing water-quality problems to investigate and resolve. In 1980, the North West had a greater length of polluted rivers and canals (214 km in Class 4) and estuaries (36 km in Class D) than any other region. Moreover, most of the polluted rivers were in the Mersey Basin where 40% of the river length was seriously polluted[20]. The politically sensitive business of deciding on priorities was as complex an issue as finding the optimum technical solutions[19].

The interim objectives were not intended to protect or improve the estuarine fauna. The biological status of the estuary was only vaguely known (but contrary to popular myth it was definitely not dead); endeavouring to protect the indigenous organisms from the impact of toxic substances was not, at the time, a high priority. Ensuring their survival was of concern, but evaluating and minimising any chronic effects from the complex mixture of dangerous substances undoubtedly present, was an issue to be tackled at a later date.

Evaluation of Options

Estuaries are much more complex systems than inland rivers because waters of different compositions meet and mix as they are advected back and forth. A considerable effort is required to gain even a rudimentary understanding of the dynamic physical, chemical and biological processes taking place. Without this knowledge it is difficult to assess, with confidence, the impact and fate of contaminants discharged to the watercourse. Attempting to rationalise the large body of data collected in the course of such studies without recourse to a mathematical model, however simple, would likewise be onerous. The type of model[21,22] which was used to plan the remedial works on the Thames Estuary[23,24] was adapted for the Mersey and played a key role in the planning process.

The model is a one-dimensional, steady-state, Lagrangian type which calculates the average concentrations of substances throughout a tidal cycle and presents the values as a function of the distance along the estuary. Accordingly, the estuary is sub-divided into a number of uniformly mixed segments of fixed volume which move to and fro with the tide. Effluents from individual outfalls contribute to several segments, depending upon their location and the tidal excursion. Non-conservative pollutants are assumed to decay in accordance with known relationships, and the resultant oxygen balance is calculated.

In order to validate the model, it was necessary to compare the calculated distributions of key parameters, i.e. DO, amm. N and total oxidised nitrogen, with those observed in the field. Generally, satisfactory agreement was obtained for a wide range of freshwater flows and summer and winter temperatures. The severe conditions which were encountered on 30 June 1976 (at the beginning of a drought with unusually high water temperatures) were chosen as the 'yardstick' against which future predicted improvements were to be assessed[25].

Having established that the model could produce an 'adequate' simulation of water quality, it was used extensively to provide information about:

(i) The contribution of various components of the total load (non-tidal Mersey, tributaries, industrial discharges, crude sewage etc.) on the distribution of DO and other key parameters (Fig. 2);
(ii) The anticipated effect of implementing the various sewerage and sewage-treatment options under consideration; and

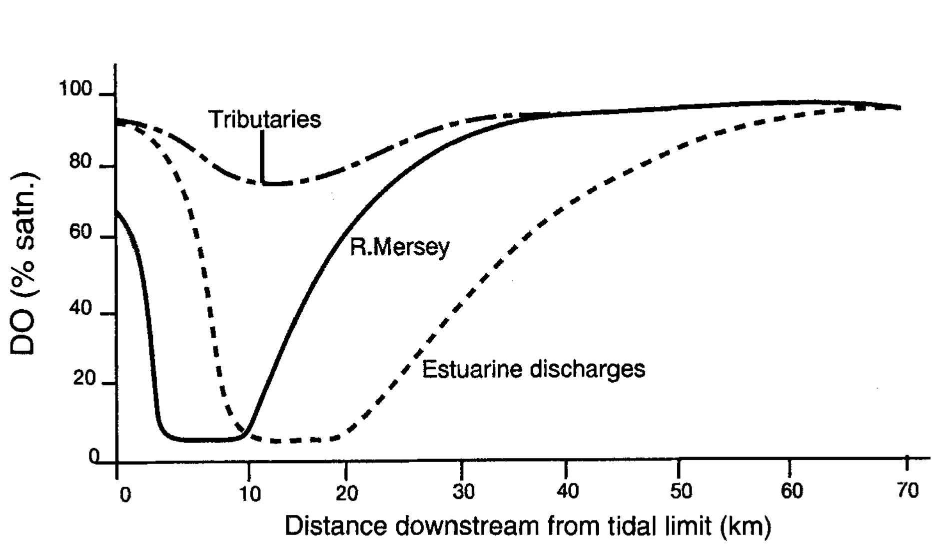

Fig. 2. Components of DO sag (extreme summer conditions) (polluting load discharged by River Mersey exerts its effect mainly in upper estuary, whereas loads from tributaries and estuarine industrial and domestic sources have an effect further downstream)

(iii) The implementation of schemes for the direct industrial discharges.

More than eighty predictive runs were carried out, and some examples of the results of these investigations have been published[17,20,26].

Mersey Pollution Alleviation Scheme

Having discussed the political and technical problems, in 1980 North West Water embarked upon a 15-year programme costing £90 million to achieve the relatively modest objectives set out in the 1971 study[27]. Twenty years later, it is interesting to note that this initiative did not meet with universal approval, and a dissenting minority questioned the merits of spending such large amounts of money.

Perhaps the most significant milestone in the history of the restoration of the estuary took place in 1981. The problems of the region were brought into sharp political focus by public disorder and riots in Toxteth (an area of Liverpool), which resulted in direct intervention by the Secretary of State for the Environment. Problems associated with Merseyside were highlighted, including the longstanding pollution of the estuary.

Subsequently, in November 1982, the Department of the Environment published 'A consultation paper on tackling the water pollution in the rivers and canals of the Mersey catchment and improving the appearance of their banks' and, in the spring of 1983, convened a Mersey Conference to pursue the issues. In his foreword to the paper, the Secretary of State declared:

> 'But today the river is an affront to the standards a civilised society should demand of its environment. Untreated sewage, pollutants, noxious discharges all contribute to water conditions and environmental standards that are perhaps the single most deplorable feature of this critical part of England.'

This consultation process resulted in the creation of the Mersey Basin Campaign, the aims of which are to harness the efforts of the public authorities, private investors and voluntary organisations to revitalise the area by concentrating efforts on water quality and bankside redevelopment. The campaign was formally launched in 1985 and adopted the water-quality objectives as determined by North West Water at an estimated cost of £4 billion for the 25-year programme – about half this sum being scheduled for the restoration of the rivers. In addition, the Government-sponsored campaign had an objective to remove bankside dereliction and encourage attractive waterside developments as a stimulus for economic regeneration.

With Government backing, many of the potential schemes which were evaluated by the Authority could now be programmed at an accelerated pace. Comprehensive details of the necessary large-scale engineering projects, together with anticipated costs and timings, have been reviewed by several authors[25,26,27].

Indicators of Water-Quality Improvements

By the end of the 1980s, early signs of improving water quality and biological diversity were beginning to become apparent[28]. Nearly ten years later, there is an increasingly large amount of data demonstrating that the expenditure is having the desired effect.

Aesthetics

Probably the most frequently asked question over the last few years has been: 'Is the Mersey getting cleaner?'

The answer must be an unequivocal 'yes'. However, macro-tidal estuaries are highly energetic systems and, consequently, the water will always be brown and muddy because of the high concentrations of material which is continually being re-suspended by the strong currents. Also, there have been significant changes in the aesthetic appearance of the river, as crude-sewage discharges have ceased and higher proportions of industrial effluent are treated prior to discharge or have been diverted to sewer. In addition, the amenity value of the Mersey is being exploited as increasing numbers of people are enjoying water-based or water-side recreation.

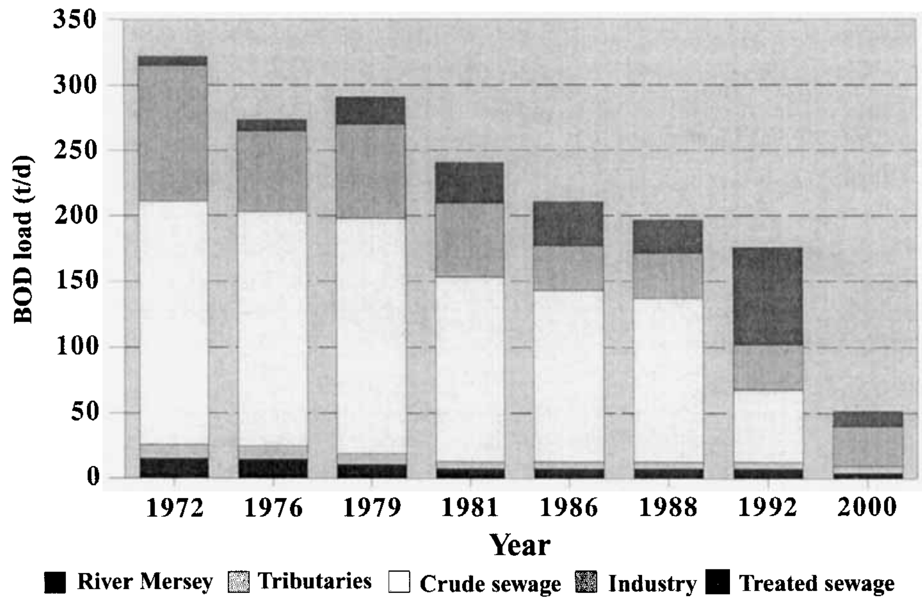

Fig. 3. Reduction in BOD loading

Dissolved Oxygen

Treatment schemes which have been completed to date have had a substantial impact on the organic loading – the BOD load having been reduced from more than 300 t/day in 1972 to just over 50 t/day by the Millennium (Fig.3). The BOD load from crude sewage will have been almost eliminated and the demand from treated effluents attenuated by the installation of secondary treatment to comply with the standards laid down in the EU urban waste water treatment Directive[29]. There have also been improvements in the condition of all the watercourses in the catchment – the changes over the last thirty or so years at Howley weir often being quoted (Fig. 4).

These reductions in loadings have had a corresponding effect on the DO regime which has been observed during routine boat surveys. In 1997 and 1998, the minimum measured values were 6% and 46% saturation respectively. It is still possible for the DO concentration to fall below 20% saturation, but this is the exception rather than the norm and would occur over a restricted length of river, rather than the considerable reaches of former times.

Dangerous Substances

The NRA report[8] cites several examples of reductions in the discharges of some metals and organic compounds. Perhaps the case of mercury is most worthy of mention.

Following concern about contamination of fish in Liverpool Bay[1,3], in 1975 ICI invested £25 million in new plant to remove the element from the waste-brine

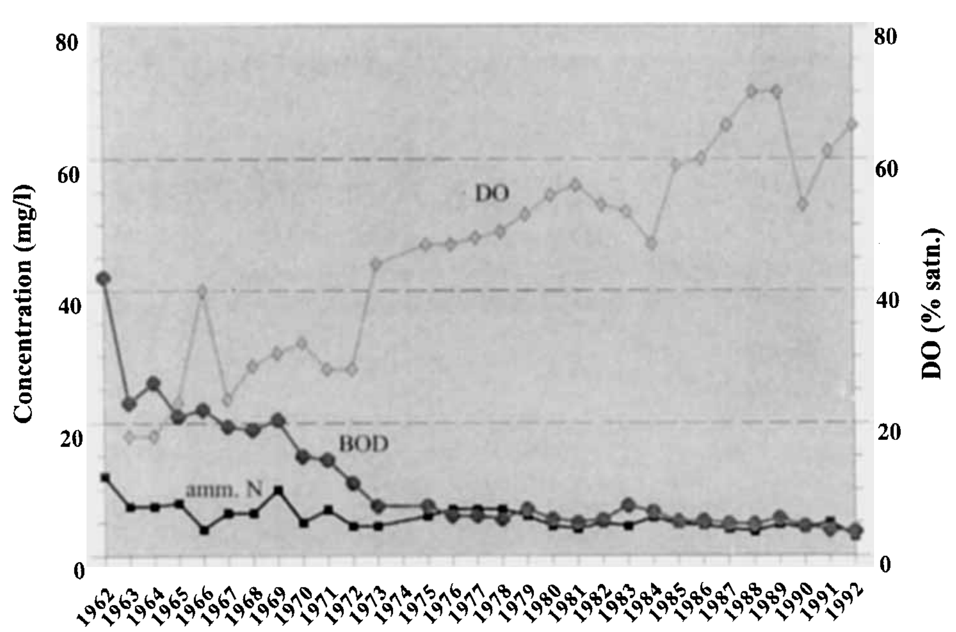

Fig. 4. Improvement in water quality at Howley weir (mean annual values)

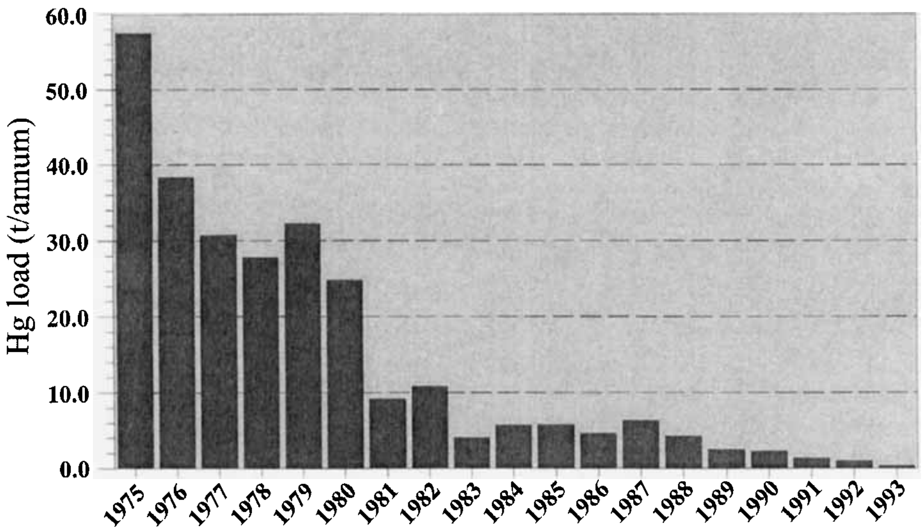

Fig. 5. Reduction in mercury discharges from chlor-alkali plants

streams from the electrolytic production of chlorine. This led to a reduction in losses of the metal from approximately 60 t/annum in the mid-1970s to less than 1 t/annum at present (Fig. 5). At another chlor-alkali plant £10 million were invested in a mercury-free process using membrane cells[8]. The benefits of these positive measures have been reflected in lower concentrations found in sediments[8,30] and mussels[8] (EU Directive requirements). The concentrations found in angler-caught fish have also shown statistically significant reductions between 1992 and 1996[31].

To put this 'good news' into perspective, a cautionary note would not be amiss. There is a vast array of potentially harmful organic compounds to be found in the estuary. Some, such as PCBs, PAHs, DDT and its degradation products, have a reasonably well-established impact on the biota. For numerous other substances the picture is much less clear – only about 100 out of a total of approximately 300 compounds found in water samples have been positively identified, and the biological effects of these materials remain an enigma.

Recent work[10] has indicated that, whilst significant progress has been made in restoring the estuary, there is no room for complacency. Studies of endocrine disruption in flounder have revealed that, of all the UK estuaries investigated, these effects were most profound in the Mersey – in contrast to the adjacent Dee estuary where there was apparently no such problem. Several compounds are being investigated as causative agents, and a four-year national programme to address this problem has just commenced.

Summary of Major Improvements

Achievements to date include:

(a) Over £1 billion have been invested in the Mersey Basin clean-up and more is planned;

(b) Increasingly stringent controls have been applied to both direct industrial and sewage-effluent discharges to the estuary and rivers within the Mersey catchment;

(c) Liverpool's first water-side wastewater-treatment works, costing £40 million, has been operational for nearly ten years;

(d) All discharges on the Liverpool bank of the river are now connected to the interceptor sewer for treatment at the Sandon Dock site;

(e) Additional capital works are in progress at Liverpool, Birkenhead and Bromborough to meet the higher standards of the urban waste water treatment Directive[29];

(f) Industry has been encouraged to reduce the discharge of biodegradable waste water to the river, either by installing suitable treatment plant or diverting the flows to sewage-treatment works;

(g) There has been major involvement by industry in environmental improvement projects, particularly with respect to dangerous substances;

(h) Over the last 25 years, the organic pollution load of the rivers flowing into the estuary has been reduced by more than 80%;

(i) Nitrification at the main Manchester sewage-treatment works has resulted in a major reduction in the load of amm. N discharged to the Manchester Ship Canal and hence to the upper estuary;

(j) Mercury discharges have been reduced by more than 90% over the last twenty years;

(k) The concentrations of heavy metals deposited in salt-marsh sediments bordering the estuary, which have been dated by radiometric techniques, have reduced significantly – in some instances to near pre-industrial levels[32];

(l) The concentrations of lead and mercury in eels and flounder decreased significantly between 1992 and 1996;

(m) The River Mersey has become a haven for wildfowl and waders, with numbers increasing by more than 60% over the last decade. The estuary is designated as internationally and nationally important for some species; and

(n) Increasing numbers of fish are now returning to the estuary with more than forty species having been recorded since detailed surveys began – about ten of these species being fairly common.

However, much remains to be carried out to ensure that the objectives which are outlined in the Mersey Estuary Management Plan[33] are achieved.

A very encouraging start has been made: perhaps the progress which has been seen, at just past the half-way stage in a 25-year programme, will come as a pleasant surprise to those who remember the daunting challenge of the early 1970s. The restoration of the North-West's major watercourse is testimony to what can be carried out with modern technology, coupled with the whole-hearted support of the local community.

Conclusions

1. The benefits of the Mersey Basin clean-up are playing an integral part in (i) promoting water-side development, (ii) regenerating urban areas, and (iii) significantly enhancing the tourism potential of the region. The River Mersey is now regarded as the 'jewel in the crown' of Merseyside, and is celebrated in the increasingly popular annual Mersey Festival.
2. Over the last twenty years, considerable effort has been made by the public, private and voluntary sectors to change the Mersey from an embarrassing liability into the focus for the regeneration of the region which bears its name.

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Footnote

On 29 September 1999, the Mersey Basin Campaign won the Inaugural Prize as the World's best river-management initiative. This was held in Brisbane, Australia, and the £40 000 prize was awarded in the face of fierce competition from around the world. The Mersey Basin is now the acknowledged leader in river-management strategy. This victory would not have been possible without the financial support of North West Water and the Environment Agency and the wholehearted commitment of the many partners in the campaign.