See preceding article

Effluent treatment

Sulphide removal. The main problem was thought to be sulphide removal and a number of possible methods of treatment were considered. Sulphide can be removed by acidification and aeration but this method was discounted because it merely changes a water pollution problem into one of air pollution, unless very costly treatment of the gaseous hydrogen sulphide is practised.

Sulphide can be precipitated chemically using ferrous sulphate and lime but the resultant sludge is difficult to settle and dewater, and chemical costs are high. For these reasons chemical precipitation was not considered further.

Chlorination is also possible, oxidising sulphide to sulphate. However, large quantities of chlorine are needed to avoid the production of unsettleable colloidal sulphur and in consequence operating costs are high. Again this option was discounted.

The remaining option was catalytic oxidation. This technique was judged to be the most appropriate on both technical and cost grounds. The system proposed consisted of batch treatment by aerating the waste with 50-100mg/litre of manganese (as manganese chloride) at pH 10 to reduce sulphide to a negligible level. A manganese hydroxide precipitate requiring settlement and disposal was produced. The settlement of manganese hydroxide ensured that suspended solids concentrations were acceptable. pH had to be controlled after oxidation and achieving the pH limit presented no problems.

Sulphate and total dissolved solids. The treatment of the effluent to reduce sulphate and total dissolved solids concentrations was thought to be impracticable. It was proposed that sulphate should be reduced by introducing modifications to factory processes and that negotiations should be commenced to persuade the receiving Authority to relax the total dissolved solids standard.

The only remaining difficulty was the biological oxygen demand (BOD) limit but, after catalytic oxidation the effluent was biodegradable and therefore high-rate biological treatment was recommended to reduce the BOD to the required level. A schematic diagram of the treatment plant is given in Fig 9.

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Disposal to sea of toxic materials

John E Portmann and Michael G Norton

For many years, both industry and control authorities have thought that because of its size, the sea could accommodate vast quantities of waste material without any ill-effects. Experience in the wake of Minimata, the brown pelicans off California and the Eider ducks near Rotterdam has shown that this is not so. It is now recognised that although the sea does have a capacity to accept certain toxic materials without suffering any ill effects to its flora and fauna, it can only do so if due attention is paid to the method of disposal used, the rate of dilution and dispersion, and the possible mechanisms for aggregation of the waste or its reconcentration by biological systems. In the light of this, a number of control measures on what can be discharged to the sea have been introduced at both international and national level.

International controls

Dumping

In 1972 two Conventions were agreed to control pollution of the sea by dumping of wastes from vessels. The first was the Oslo Convention[1] which was signed by 13 states and applies to the North Sea and north-east Atlantic Ocean. Later, the London Convention[2] which applies to all the World's seas and oceans was signed by 60 states. Both Conventions are in force following their ratification by the required number of states.

The form of the two Conventions is similar, each listing substances for which dumping is prohibited and substances for which dumping is strictly controlled; the dumping of remaining substances must be controlled under licences, having regard to a number of factors including the composition and properties of the waste, the characteristics of the proposed dumping area and the method of disposal. These latter factors are listed in Annex III of the Conventions and must be considered in every permit application. Broadly speaking, they are a form of 'check list' to ensure that the national licensing authority considers all the relevant information necessary to estimate the environmental impact of the proposed disposal operation. Additionally, in considering the sea for the disposal of waste, states also undertook to take into account the practical availability of alternatives to sea disposal. The degree of consideration afforded to any of these factors varies according to the nature of the waste and the scale of the proposed dumping operation and it is not usually necessary to take all factors into account.

The Conventions list certain materials which require special care (Annex II) and others for which dumping is prohibited (Annex I). These latter materials, the so-called 'black list' substances, include: mercury and its compounds, cadmium and its compounds, organohalogen compounds, carcinogens, persistent floatable plastics and (in the Oslo Convention only) organo-silicon compounds other than polydimethylsiloxanes. The member states are required to prohibit the dumping of any waste containing these substances except where they are present in only 'trace' quantities or additionally, in the case of organohalogen or organosilicon compounds, when they are 'non-toxic' or are 'rapidly converted in the sea into substances which are 'biologically harmless'. Relaxation of the Annex I prohibitions is thus possible, provided that the discharge of the waste is not harmful to the marine environment. Where a licensing authority considers that a wast

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containing an Annex I compound can be so exempted and its disposal licensed therefore, agreed prior consultation procedures with the other member states must be followed before a permit can be issued.

Substances listed in Annex II which are to be treated with 'special care' include potentially bioaccumulative and toxic substances (arsenic, lead, copper and zinc) and toxic substances (cyanides, fluorides, and those pesticides excluded from Annex I). For these substances, the licensing authority is not constrained in its judgement of what is environmentally acceptable and no prior reference of proposals to license need to be made to the Commissions. However, in cases where the concentration of these substances in the waste is 'significant' (defined as >0.1 per cent by weight), the authority is required to notify details of a licence immediately to the Commissions and hence to all parties to the Conventions, whereas under the general provisions of Annex III, licences are notified only every three months. The above circumstances are the only ones in which the Conventions require special action either before or after a licence is granted. In all cases, however, the decision to license is solely a matter for the national licensing authority.

Discharges

In 1974 the Paris Convention for the Prevention of Marine Pollution from Land Based Sources was concluded.[3] This Convention is an agreement between the states of Europe bordering the North Atlantic, on the measures they will individually and collectively take to prevent and combat pollution of the marine environment as a consequence of direct discharges to the sea. Just as the two Dumping Conventions include lists of substances, the Paris Convention has a so-called 'black list' which includes mercury and its compounds, cadmium and its compounds, persistent floatable plastics and persistent oils and hydrocarbons of petroleum origin. It also has a 'grey list' which includes organic compounds of phosphorus, silicon and tin, elemental phosphorus, non-persistent oils and hydrocarbons of petroleum origin and the following elements and their compounds: arsenic, chromium, copper, lead, nickel and zinc.

Thus, in many respects the Paris Convention is similar to those which seek to control dumping. However, there is one essential difference which stems from the fact that, while it may be practicable to cease certain types of dumping, it is often not practical to eliminate the discharge of a substance altogether. Thus, the countries which are party to the Paris Convention pledge themselves to eliminate, if necessary by stages, pollution by 'black list' substances and to limit strictly pollution by 'grey list' substances. There has been some difference of opinion on the interpretation of this objective, for pollution is defined in the Convention as a form of harmful effect or damage; some countries however, have interpreted the Convention to require the elimination of discharge of black list substances regardless of whether or not they cause any undesirable effect. The United Kingdom, however, has adopted the letter of the Convention and, although seeking actively to reduce inputs of the 'black list' substances, even where there is no detectable effect, regards itself as being under no obligation to eliminate all discharges of 'black list' substances, unless there is an undesirable effect.

In addition to the Paris Convention, those countries which are members of the European Community are bound by a Council Directive of May 1976 on Pollution Caused by Certain Dangerous Substances Discharged into the Aquatic Environment of the Community.[4] This is the so-called Dangerous Substances Directive (or ENV 131) and applies to both the freshwater and marine environments of the European Community. Apart from this and one or two minor differences in its 'black and grey lists', the effect of the Directive in terms of the control measures it seeks to impose on discharges to the maine environment, are essentially the same as those which are implied under the Paris Convention.

In practical terms there are a number of differences. The Directive is enacted in respect of particular substances by means of supplementary Directives dealing with each specific substance and usually specific routes of entry to the aquatic environment. Thus, at the present time, Directives are under consideration for mercury from chloralkali plants, cadmium from a variety of sources, dieldrin, endrin and aldrin from manufacturing sites and wool-treatment facilities and for PCBs. The other major difference from the Convention is that the Directive specifies that one of two methods of control should be adopted; either an emission standard applied to all discharges and based on what can be achieved by treatment methods etc or an environmental quality objective approach which permits variable levels of discharge according to the capacity and intended use of the receiving waters.

Annex III of the Oslo Convention: Provisions governing the issue of permits and approvals for the dumping of wastes at sea

Characteristics of the waste
- Amount and composition;
- Amount of substances and materials to be deposited per day (per week, per month);
- Form in which it is presented for dumping, i.e. whether as a solid, sludge or liquid;
- Physical (especially solubility and specific gravity), chemical, biochemical (oxygen demand, nutrient production) and biological properties (presence of viruses, bacteria, yeasts, parasites, etc);
- Toxicity;
- Persistence;
- Accumulation in biological materials or sediments
- Chemical and physical changes of the waste after release, including possible formation of new compounds;
- Probability of production of taints reducing marketability of resources (fish, shellfish, etc).

Characteristics of dumping site and method of deposit
- Geographical position, depth and distance from coast;
- Location in relation to living resources in adult or juvenile phases;
- Location in relation to amenity areas;
- Methods of packing, if any;
- Initial dilution achieved by proposed method of release:
- Dispersal, horizontal transport and vertical mixing characteristics;
- Existence and effects of current and previous discharges and dumping in the area (including accumulative effects).

General considerations and conditions
- Interference with shipping, fishing, recreation, mineral extraction, desalination, fish and shellfish culture, areas of specific scientific importance and other legitimate uses of the sea;
- In applying these principles the practical availability of alternative means of disposal or elimination will be taken into consideration.

National control measures

Dumping

There has been a measure of control over dumping from the United Kingdom since the early 1960s, when the Ministry of Agriculture, Fisheries and Food and the Department of Agriculture and Fisheries for Scotland operated a voluntary control scheme. Under this scheme, companies or organisa-

Fig 1 Disposal of wastes at sea: the system to monitor

Stage		
Waste input →	Initial and long-term dispersal of soluble or suspended components →	Local or widespread settling of solid components
Parameters to monitor		
Pre-discharge	Water column	Sea bed
Composition of waste Toxicity and other properties	Acute toxic effects Water quality Productivity Chemical quality of marine life	Sediment composition Acute/chronic toxic effects Chemical quality of marine life Distribution of benthos and correlation with physical or chemical effects

tions involved in dumping wastes were invited to seek approval of their activities. Each proposal was considered individually taking due account of the waste, the method of disposal and site of disposal and, provided no significant adverse effects on the marine environment were expected, an approval for the disposal of the waste according to specified conditions was granted. This scheme was superseded in 1974 by enactment of the Dumping at Sea Act (1974),[5] following which the Oslo and London Conventions were ratified.

The Dumping at Sea Act makes it an offence to dump (or load for the purpose of dumping) any material in the sea, be that from a vehicle, ship, aircraft, hovercraft or other marine structure, without a licence from the relevant licensing authority, and except in accordance with the conditions of that licence. It is the responsibility of the licensing authority under the Act to 'have regard to the need to protect the marine environment, and the living resources which it supports, from any adverse consequences of dumping the substances or articles to which the licence, if granted, will relate, and the authority shall include such conditions in a licence as appear to be necessary or expedient for the protection of that environment, and those resources from any such consequences'. These provisions of the Act are thus effectively based on the philosophy of Annex III of the Conventions which requires that each proposal to dump a waste be assessed on its merits, having regard to the potential environmental impact. The detailed lists in Annexes I and II of the Conventions have not been specifically included in the UK legislation, although all the requirements of the Conventions are applied through the controls of the Act.

Discharges

Except for new or substantially altered discharges to controlled waters (i.e. estuaries), which are covered by the Clean Rivers (Estuaries and Tidal Waters) Act 1960,[6] discharges of effluents to coastal waters of England and Wales are not at present subject to statutory control by either central government or water authorities. However, some measure of control does exist under the bye-law powers of Sea Fisheries Committees, which allow them to prevent the discharge to coastal waters of substances which are likely to be either harmful to sea fishing interests or injurious to sea fish (or shellfish). In Scotland the situation is somewhat different and under the Rivers (Prevention of Pollution) (Scotland) Act 1965,[7] about 95 per cent of the discharges to tidal waters are controlled.

The Control of Pollution Act 1974,[8] provides much wider powers and when implemented will bring under water authority control all discharges to coastal waters including estuaries, regardless of whether the discharge is new or old, already licensed or locally unregulated. However, due to the economic situation and fears of possible increased costs, the relevant Part II of this Act has yet to be implemented and the UK is not in a position to meet all its obligations to either the Paris Convention or any sub-directive of the Dangerous Substances Directive. In practice, however, largely by virtue of good relations between the authorities and industry, where control measures are obviously necessary, controls and improvements can be and are instituted, as a number of examples cited later illustrate.

Environmental effects of waste disposal at sea

Although the controls ensure that a number of the properties of wastes are determined and an estimate is made of their likely environmental impact before the discharge is approved by the regulatory authority, a prudent authority will also monitor the marine environment for which it is responsible in order to establish the accuracy of its predictions as well as to improve its knowledge of environmental effects. Thus MAFF, as the licensing authority for dumping from England,* has included in its overall responsibilities on the control of marine pollution, a series of surveys of dumping grounds[9,10] to determine the physical, chemical and biological effects of large-scale disposal operations. Depending on the type of waste dumped and its probable site of impact, monitoring may be concentrated in the water column, at the sea bed or both (Fig 1). Because the potential impact of a waste entering the marine environment is similar whether it be dumped or discharged, the principles and conclusions of the dumping ground monitoring programmes are broadly applicable to pipeline discharges, if allowances are made for the different degrees of dilution and dispersion arising from the method and location of the discharge.

If the waste contains a substantial amount of suspended material, e.g. mine effluents, colliery waste, and fly ash, the sea bed may be substantially altered and deposits extended over several square kilometres. This may render the sea bed quite unsuitable for benthic organisms, even though the waste in itself is *not* actually toxic.[11] Recolonisation after such events is usually very slow. Additionally, and especially if the waste contains large pieces of mineral material, there may be interference with fishing operations, particularly potting for crabs and lobsters, although bottom trawling is also affected.

The settlement of organic particles from sewage and sewage sludges or from industrial wastes may result in ecological changes, although, in practice they are of a less serious nature than those due to colliery wastes and ash. Accumulation of

*The licensing authorities for Wales, Scotland and Northern Ireland are respectively, the Welsh Office, the Department of Agriculture and Fisheries for Scotland, and the Department of the Environment for Northern Ireland.

organic substances, often with associated metals, can lead to varying responses in different circumstances. Organic detritus may be utilised preferentially by some species and, following a modest increase in organic enrichment, biomass may be increased without seriously affecting species diversity. At higher levels of organic enrichment, only pollution-tolerant species may exist, although still at high biomass.[12] In extreme cases, the sea bed biota may be severely depleted in both species and number. Exceptions to this general response are found, however, and in some areas,[13] a slight enrichment of the sediment by organic particles from sewage sludge was accompanied by a reduction in the number of species without any increase in biomass being detected. Although these changes may be significant in local ecological terms, it is unlikely that they will significantly affect the productivity of commercial fisheries, providing that the receiving area is not one in which large numbers of the sensitive stages in the life histories of commercial fish and shellfish are present.

The large-scale input of certain forms of industrial waste and municipal sewage containing substantial proportions of industrial effluents may lead to an accumulation of metals and other persistent substances in sediments and biota. However, extensive monitoring of the quality of fish and shellfish caught around England and Wales has shown that on the whole this does not occur,[14,15] although there are notable exceptions. For example, in a number of the areas used for dumping of large quantities of sewage sludge there has been significant accumulation of certain metals, especially mercury, in fish. Similarly there has been an increase in the levels of metals such as zinc, lead and cadmium in intertidal shellfish in the Bristol Channel partly as a consequence of discharges to the Channel. Increased levels of certain other potentially

Fig 2 Sewage sludge dumping around the UK (1978)

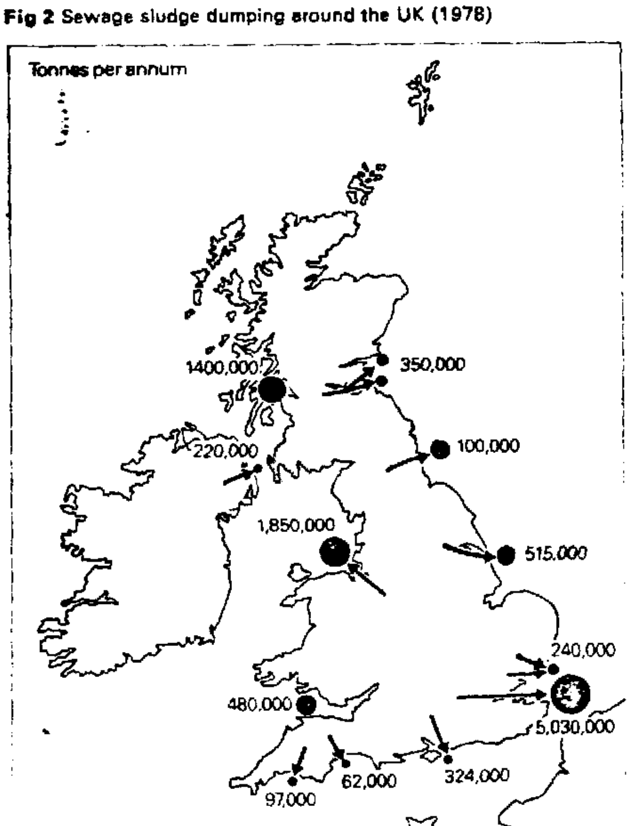

Table 1 **Dumping inputs by UK 1976–79 (10^3 t/a)**

	1976	1977	1978	1979
Sewage sludge	7 010	7 500	7 844	7 920
Industrial waste	453	588	508	628
Colliery waste/fly ash	2 226	1 816	2 173	2 280
Dredged spoil	32,092	27,740	34,630	34,780

Table 2 **Estimated input to coastal waters, England and Wales 1975**

	Domestic sewage	Industrial effluent	Rivers
Volume (m^3/a x 10^6)	2 810	1 270	54,500
Total N (t/a x 10^3)	80	40	190
Total P (t/a x 10^3)	24.5	21.5	9.5
Suspended solids (t/a x 10^3)	365	1 970	1 650
Cadmium (t/a)	30	25	120
Mercury (t/a)	12.8	4.7	2.2

harmful substances, e.g. dieldrin and PCBs have also been found in areas where inputs are higher than normal.

Where the waste contains substances which are highly toxic but which are readily degradable or neutralised in the sea, e.g. strong acids or alkali, disposal into the water column may have little or no impact and the effect may be difficult to monitor. This will be especially so if the waste is disposed of from a moving vessel as the dilution achieved can be as much as 10,000 fold within the first 5–10 minutes. The most important precaution is to ensure that one effluent does not contain, as a minor constituent, a persistent substance which may be reconcentrated up a marine food chain, and that in areas of limited water exchange and a continuous or regular discharge, effects do not result from exposure to low concentrations over long periods of time.

UK practice in the control of dumping at sea

Sewage sludge

Figure 2 shows the location of sewage sludge dumping sites around the UK and the quantities licensed for dumping in 1978. Substantial quantities of sewage sludge are disposed of to sea and the quantity is rising steadily – at present about 30 per cent of the sludge produced in the UK goes for sea disposal. In granting a licence for the disposal of sewage sludge to sea, the licensing authorities take account of the nature of the receiving environment, the possibility of other suitable means of disposal and the other interests in the area of proposed disposal. Accumulation of organic matter on the sea bed is less likely if a site can be chosen which has strong tidal currents. In areas where current movements are small, accumulation of organic matter and associated toxic materials may ensue and fishing interests may be affected.[16,17]

If certain metals, especially those listed in the 'black and grey lists' of the Conventions, are present, constraints may be imposed by the need to restrict concentrations of 'black list' substances to 'trace' levels. In practice this means that sewage sludges which contain higher concentrations of metals than the normal range may not be licensed. This has also led to severe constraints being applied to the inputs allowed from a number of industrial concerns which had previously discharged relatively high concentrations of cadmium or mercury to sewers.

Industrial waste

Figure 3 shows the location and scale of industrial waste dumped from England and Wales during 1978. As can be seen from Table 1 the quantity of industrial waste licensed for sea disposal has increased steadily in recent years. Part of this increase has been the result of pressure placed on industrialists and contractors through the closure of some landfill sites and the restrictions placed on others as to the type of wastes they can accept. However, a substantial number of applications for sea disposal licences are received which have to be refused owing to the unsuitable nature of the waste.

Industrial wastes which are suitable for dumping at sea are mainly those with a high organic content and consequently oxygen demand, or those which may have a high acute toxicity but without lasting effects. In both cases, the effects of high BOD and undesirable acute tocixity of the waste can be overcome by dilution. In the latter case, threshold toxicity levels can be determined by bioassay and the likely environmental effect predicted from the estimated dilution of the waste in the wake of the vessel.[18,19] A judgement can then be made on whether or not discharge will cause any significant effects on marine life in the wake of the vessel, and if necessary, the dilutions achieved may be increased by a reduction of the discharge rate.

Unfortunately, many of the characteristics which make a toxic material unsuitable for land disposal also render it unsuitable for dumping at sea. Thus, wastes which are persistent or which tend to be accumulated by marine organisms are usually unacceptable for sea disposal. The 'black and grey' lists of the Oslo and London Conventions provide some guidance on what is unlikely to be accepted, but these lists are not comprehensive, and it is essential that each waste is considered individually on its merits.

Control of discharges and actual problems

An exercise has recently been undertaken in this country to establish which substances were of real concern to water authorities. At the same time attention has been paid to those substances which are currently of interest in the context of the European Community Dangerous Substances Directive.

Fig 3 Industrial waste dumping around England and Wales (1978)

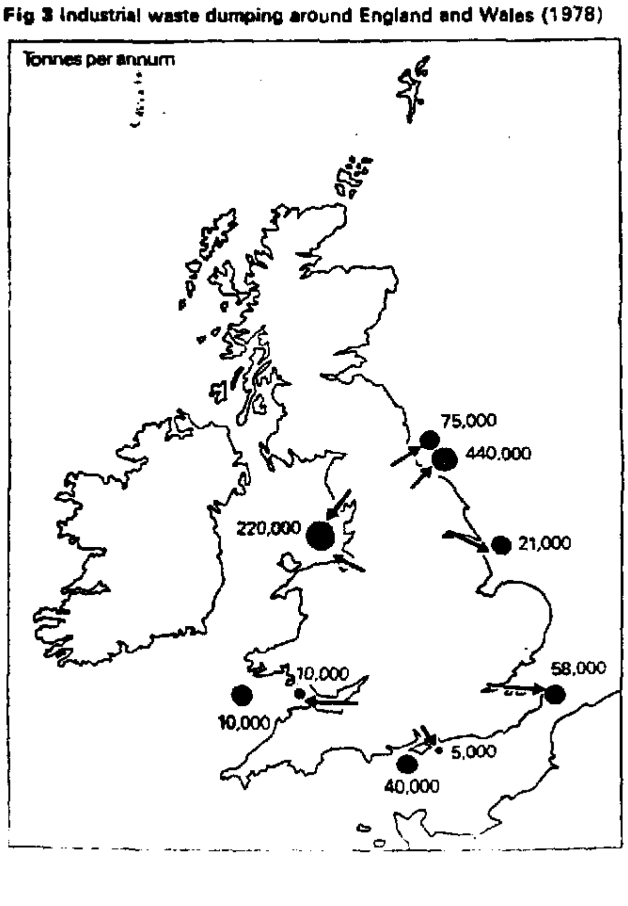

Table 3 Mercury input to two areas off UK coast (kg/d)

	Liverpool Bay 1972	Liverpool Bay 1979	Outer Thames Estuary 1971	Outer Thames Estuary 1979
Direct river input	1.0	1.0	0.6	0.6
Sewage effluents	0.8	0.8	6.8	1.7
Dumping	3.0*	2.2	18.0	4.1
Dredged spoil	1.6	0.9	–	–
Industrial input direct	16.0	5.0	–	–
	22.4	9.9	25.4	6.4

*Subsequently rose to a peak of 7.4 in 1976

Table 4 Cadmium in two species of intertidal shellfish from selected sites in the Bristol Channel (mg/kg wet weight)

Site	Limpets 1971	Limpets 1977	Winkles 1971	Winkles 1977
Portishead	50	44	–	–
Black Nore	64	40	26	2.0
Clevedon	49	38	–	–
Weston super Mare	93	12	19	1.5
Black Point	26	–		
Cardiff	14	32	–	0.7
Penarth	–	32		
Barry Island	65	–	8.6	4.0
Col Huw Pt	15	10	5.3	1.3

The results of the two exercises give considerable food for thought. The first exercise related particularly to discharge, but the second has included all routes of input including dumping.

The three groups of substances which were considered at a purely local level to be the most common cause of concern or gave rise to actual problems in coastal and estuarine waters were: organic matter (especially sewage), nutrients (especially ammonia – usually again arising from sewage) and toxic substances, (e.g. cyanides and phenols). Mercury, cadmium and dieldrin were acknowledged to cause significant problems in particular areas but neither PCBs nor petroleum hydrocarbons were thought to cause any problem of significance. From the surveys, it also appears most unlikely that any of the substances presently being considered by the European Community as potential 'black list' substances (HCB, HCBD, DDT, HCH, endosulfan, pentachlorophenol or trichlorophenol) cause any problems in freshwaters, let alone the marine environment. Thus, few of the problems encountered by the water authorities are due to substances included in the 'black list'.

This finding may reflect a failure however, to identify the cause of current problems, and the level of information on inputs of some of these substances leaves much to be desired. The relative importance of the 'black list' substances, mercury and cadmium, in the national league table makes more sense when the scale of input is considered. Table 2 shows the 1975 estimates of input of these two substances by the three major routes to coastal waters of England and Wales relative to those of nitrogen, phosphorus and suspended solids of high BOD.

Nevertheless, cadmium and mercury have been a cause for local concern in those areas where one or two sources have led to concentrations in food species higher than normally considered desirable. For example, in Liverpool Bay and in the Thames Estuary in the 1970s, the content of mercury in fish flesh was such that people who ate more than the usual quantity of fish could well have exceeded the recognised tolerable weekly intake.[20] Table 3 shows the level of daily input to these two areas between 1972 and 1979. In 1972-73 dumping of sewage sludge was a significant route, and measures were taken by the control authority to reduce the input of mercury into sewage systems from which these sludges were derived. In Liverpool Bay the other main source was industrial effluent and again measures were taken, this time as a result of voluntary action by industry and persuasion by the water authority, to reduce the amount of mercury discharged. The inputs of mercury into Liverpool Bay and the Thames Estuary are now less than 40 and 25 per cent respectively of those in the early 1970s, and show how successful these measures have been. The major problem with cadmium occurred in the Bristol Channel but again controls applied voluntarily at the major industrial source were successful in bringing down the level of cadmium in intertidal shellfish from the area (Table 4).

Relationships between sea and land disposal

Restrictions on land-fill facilities or the lack of availability of treatment often lead to increased pressure to provide an outlet for wastes either by dumping or discharge into the sea. While the overall objectives of safe land and sea disposal are the same (i.e. to avoid significantly detrimental effects on the environment) the means of achieving this common objective are quite different. Sea disposal exploits the sea's ability to dilute and disperse a waste, and in some cases to neutralise, degrade or even to absorb it. On the other hand, land tipping seeks to contain a waste within the confines of the tip, either totally in the case of Class 1 tips or with an acceptable rate of escape via leaching in other cases. Some wastes (e.g. sewage sludge) are capable of productive use on agricultural land provided that the concentrations of toxic metals and other substances are below harmful concentrations.

Other differences arise because the discharge of a waste to sea is a direct injection of a substance into a living ecosystem, the health of which it is desired to protect, whereas the use of a site for landfill disposal involves the sacrifice of its other uses during its life as a tip, although reclamation may take place afterwards. Treatment or incineration destroys some or all of a waste's toxic components, thus removing the environmental hazard. A further point of difference is that land disposal can be considered purely from a national standpoint, whereas discharge of wastes in the sea may affect the interests of countries sharing the same sea area, thus leading to international regulations.

With these major differences of ultimate effect, it is clear that many wastes are not equally suitable for land and sea disposal. Wastes are likely to be environmentally acceptable for disposal to sea if they have the following characteristics:

- They should be readily dispersible into the water column;
- They should not give rise to biologically significant effects whether these are due to acute or chronic toxicity, are effects on the quality of marine species, or are due to ecological disturbances;
- They should not compromise other legitimate uses of the sea for recreation, fisheries, transport, mineral extraction, etc.

Among the wastes which are especially suitable for sea disposal are the predominantly aqueous wastes which come from a number of industries and sewage treatment plants and which are contaminated with components of acceptable toxicity and persistence; these make up a large proportion of wastes licensed for dumping and also those discharged by pipeline. The less suitable wastes include many solid wastes, sludges which often contain unacceptable levels of persistent metals, and liquid wastes which are toxic, immiscible or contain unacceptable levels of persistent or bioaccumulative substances. Such wastes, which include the 'black list' susbtances referred to earlier, are not normally dumped at sea and their discharge to the marine environment may be subject to increased restriction as more regulations are enforced. Other methods of land disposal will thus continue to be necessary for many types of waste even though the quantity of wastes discharged to the marine environment will continue to be large.

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