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How Nature Deals with Waste

1.1. Introduction

1.1.1. *The wastewater problem*

Each day, approximately 1×10^6m^3 of domestic and 7×10^6m^3 of industrial wastewater is produced in the UK. This, along with surface runoff from paved areas and roads, and infiltration water, produces over 20×10^6m^3 of wastewater requiring treatment each day. To cope with this immense volume of wastewater there were, in 1999, some 9260 sewage treatment works serving about 95% of the population (Water UK 2001). The size of these plants varies from those serving small communities of < 100, to plants like the Crossness Sewage Treatment Works operated by Thames Water which treats the wastewater from over 1.7 million people living in a 240 km^2 area of London.

In terms of volume or weight, the quantity of wastewater treated annually in the UK far exceeds any other product (Table 1.1) including milk, steel or even beer (Wheatley 1985), with vast quantities of wastewater generated in the manufacture of most industrial products (Fig. 1.1). The cost of wastewater treatment and pollution control is high, and rising annually, not only due to inflation but to the continuous increase in environmental quality that is expected. During the period 1994–1999, the ten main water companies in England and Wales invested £16.55bn into its services. Over half of this was on wastewater provision. In the year 1998/1999, £1.9bn was spent on new wastewater treatment plants alone as compliance with the European Union Urban Wastewater Treatment Directive continues. The industry is extremely large, with the income for these water companies for

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Table 1.1. The quantity of sewage treated in the UK far exceeds the quantity of other industrial products processed. Comparative values are based on 1984 sterling values (Wheatley 1985).

Product	Tonnes/annum ($\times 10^6$)	Price (£/tonne)
Water as sewage	6500	0.10
Milk	16	25
Steel	12	300
Beer	6.6	280
Inorganic fertilizer	3.3	200
Sugar	1.0	350
Cheese	0.2	1300
Baker's yeast	0.1	460
Citric acid	0.015	700
Penicillin	0.003	45000

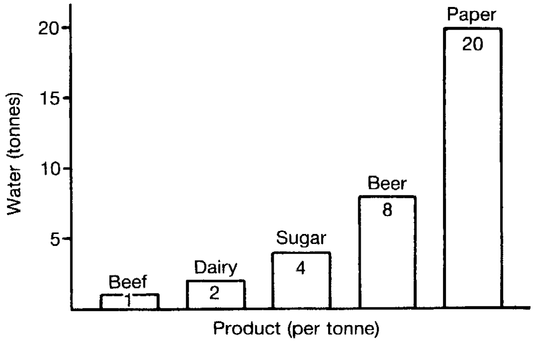

Fig. 1.1. Tonnes of water required in the manufacture of some products that produce organic effluents.

1998/1999 in excess of £6,000m with operating costs approaching £4,000m (Water UK 2001).

There are two fundamental reasons for treating wastewater: to prevent pollution, thereby protecting the environment; and, perhaps more importantly, protecting public health by safeguarding water supplies and preventing the spread of water-borne diseases (Sec. 2.1).

The safe disposal of human excreta is a pre-requisite for the supply of safe drinking water, as water supplies can only become contaminated where disposal is inadequate. There are many infectious diseases transmitted in excreta, the most important being the diarrhoeal diseases cholera, typhoid, and schistosomiasis. The faeces are the major source of such diseases with few infections, apart from schistsosomiasis, associated with urine. Among the most common infectious water-borne diseases are bacterial infections such as typhoid, cholera, bacillary dysentery, and gastro-enteritis; viral infections such as infectious hepatitis, poliomyelitis, and various diarrhoeal infections; the protozoal infections cryptosporidiosis, giardiasis, and amoebic dysentery, and the various helminth infections such as ascariasis, hookworm, and schistosomiasis (bilharzia). Although the provision of clean water supplies will reduce the levels of infection in the short term, in the long term it is vital that the environment is protected from faecal pollution (Feachem and Cairncross 1993; Mara 1996). Adequate wastewater treatment and the disinfection of water supplies has effectively eliminated these water-borne diseases from developed countries, but they remain endemic in many parts of the world, especially those regions where sanitation is poor or non-existent (Chap. 9). In developed countries where there are high population densities, such as the major European cities, vast quantities of treated water are required for a wide variety of purposes. All the water supplied needs to be of the highest quality possible, although only a small proportion is actually consumed. To meet this demand, it has become necessary to utilise lowland rivers and groundwaters to supplement the more traditional sources of potable water such as upland reservoirs (Gray 1997). Where the water is reused on numerous occasions, as is the case in the River Severn and the River Thames Sec. 10.2.2, adequate wastewater treatment is vital to ensure that the outbreaks of waterborne diseases that were so prevalent in the eighteenth and nineteenth centuries do not reoccur (Chap. 9).

In terms of environmental protection, rivers are receiving large quantities of treated effluent while estuaries and coastal waters have vast quantities of partially or completely untreated effluents discharged into them. Although in Europe, the Urban Wastewater Treatment Directive has caused the discharge of untreated wastewater to estuarine and coastal waters to be largely phased out. Apart from organic enrichment endangering the flora and fauna due to deoxygenation, treated effluents rich in oxidised nitrogen and phosphorus can result in eutrophication problems. Where this is a particular problem, advanced or tertiary wastewater treatment is required to remove these inorganic nutrients to protect rivers and lakes (Sec. 2.4). Environmental protection of surface waters is therefore a major function of wastewater treatment. In 1998, 30% of all rivers surveyed in England and Wales (12,241 km) were classified as having doubtful, or worse, quality (i.e. class D, E and F using the Environment Agency General

Table 1.2. The river quality in England and Wales based on the Environment Agency GQA systems.

	River length (%) in each quality grade						
	A	B	C	D	E	F	Total km
Chemical GQA							
1988–1990	17.7	30.1	22.8	14.4	12.7	2.3	34161
1993–1995	26.8	32.7	21.3	10.2	8.1	0.9	40227
1994–1996	27.1	31.5	21.2	10.4	8.8	1.0	40804
Biological GQA							
1990	24.0	31.6	21.6	9.8	7.3	5.7	30001
1995	34.6	31.6	18.4	8.1	5.4	1.9	37555
Nutrient GQA							
1990	8.0	17.7	10.2	13.1	28.0	22.9	23003
1993–1995	14.7	22.6	11.0	13.1	27.3	11.0	34864

Quality Assessment (GQA) chemical classification system) (Environment Agency 1998; Gray 1999; Water UK 2001) (Table 1.2). As in Ireland, there is an increasing trend in eutrophication of surface waters (EPA 2000). The cost of rehabilitating rivers, as was seen with the River Thames in the period 1960–1980, is immense. The River Mersey for example, now Britain's most polluted river, will cost an estimated £3,700m over the next quarter of a century to raise to a standard suitable for recreation (Department of the Environment 1984).

1.1.2. *Legislation*

Environmental legislation relating to wastewater treatment and receiving water quality is based largely on quality standards that are related to suitability of water for a specific use, the protection of receiving waters, or emission limits on discharges. Standards are usually mandatory with maximum permissible concentrations based on health criteria or environmental quality standards. Table 1.3 lists the key Directives concerning the aquatic environment that govern legislation in countries (Member States) comprising the European Union. The principal Directives are those dealing with Surface Water (75/440/EEC), Bathing Waters (76/160/EEC), Dangerous Substances (76/464/EEC; 86/280/EEC), Freshwater Fish (78/659/EEC), Ground Water (80/68/EEC), Drinking Water

Table 1.3. EU Directives concerning inland waters by year of introduction.

1973
Council Directive on the approximation of the laws of the Member States relating to detergents (73/404/EEC)
Council Directive on the control of biodegradability of anionic surfactants (73/405/EEC)
1975
Council Directive concerning the quality required of surface water intended for the abstraction of drinking water in the Member States (75/440/EEC)
1976
Council Directive concerning the quality of bathing waters (76/160/EEC)
Concil Directive on pollution caused by certain dangerous substances discharged into the aquatic environment (76/464/EEC)
1977
Council decision establishing a common procedure for the exchange of information on the quality of surface in the Community (77/795/EEC)
1978
Council Directive on titanium oxide waste (78/178/EEC)
Council Directive on quality of fresh waters needing protecting or improvement in order to support fish life (78/659/EEC)
1979
Council Directive concerning the methods of measurement and frequencies of sampling and analysis of surface water intended for the abstraction of drinking water in the Member States (79/869/EEC)
Council Directive in the quality required for shellfish wates (79/923/EEC)
1980
Council Directive on the protection of ground water against pollution caused by certain dangerous substances (80/68/EEC)
Council Directive on the approximation of the laws of the Member States relating to the exploitation and marketing of natural mineral waters (80/777/EEC)
Council Directive relating to the quality of water intended for human consumption (80/778/EEC)
1982
Council Directive on limit values and quality objectives for mercury discharges by the chlor-alkali electrolysis industry (82/176/EEC)
Council Directive on the testing of the biodegradability of non-ionic surfactants (82/883/EEC)
Council Directive on the monitoring of waste from the titanium oxide industry (82/883/EEC)
1983
Council Directive on limit values and quality objectives for cadmium discharges (83/513/EEC)
1984
Council Directive on limit values and quality objectives for discharges by sectors other than the chlor-alkali electrolysis industry (84/156/EEC)
Council Directive on limit values and quality objectives for discharges of hexachlorocyclohexane (84/491/EEC)
1985
Council Directive on the assessment of the effects of certain public and private projects on the environment (85/337/EEC)

Table 1.3. (*Continued*)

1986	Council Directive on the limit values and quality objectives for discharge of certain dangerous substances included in List I of the Annex to Directive 76/464/EEC (86/280/EEC)
1987	Council Directive on the preventation and reduction of environmental pollution by asbestos (87/217/EEC)
1988	Council Directive amending Annex II to the Directive 86/280/EEC on limit values and quality objectives for discharges of certain dangerous substances included in List I of the Annex to Directive 76/464/EEC (88/347/EEC)
1990	Council Directive amending Annex II to the Directive 86/280/EEC on limit values and quality objectives for discharges of certain dangerous substances included in List I of the Annex to Directive 76/464/EEC (90/415/EEC)
1991	Council Directive concerning urban waste water treatment (91/271/EEC)
	Council Directive concerning the protection of waters against pollution caused by nitrates from agricultural sources (91/676/EEC)
1992	Council Dirrective on pollution by waste from the titanium oxide industry (92/112/EEC)
1996	Council Directive on integrated pollution prevention control (96/61/EEC)
1998	Council Directive on the quality of water intended for human consumption (98/83/EEC)
2000	Council Directive establishing a framework for community action in the field of water policy (00/60/EC)

(80/778/EEC), Urban Waste Water Treatment (91/271/EEC), Nitrates (91/676/EEC), Integrated Pollution Prevention Control (96/61/EEC), and Water Framework (00/60/EEC). The Directive controlling sewage sludge disposal to agricultural land (86/278/EEC) is discussed in Chap. 8. In most Directives both guide (G) and imperative, or mandatory, (I) values are given. The G values are those which Member States should be working towards in the long term. In most cases, nationally adopted limit values are the I values although occasionally more stringent values are set.

The Dangerous Substances Directive (76/464/EEC) requires licensing, monitoring and control of a wide range of listed substances discharged to the aquatic environment. List I (Black List) substances have been selected mainly on the basis of their toxicity, persistence and potential for bioaccumulation. Those that are rapidly converted into substances that are biologically harmless are excluded. List II (Grey List) substances are considered to be less toxic, or the effects of which are confined to a limited area

Table 1.4. List I and List II substances defined by the EU Dangerous Substances Directive (76/464/EEC).

List no. 1 ('*black list*')
Organohalogen compounds and substances which may form such compounds in the aquatic environment
Organophosphorus compounds
Organotin compounds
Substances, the carcinogenic activity of which is exhibited in or by the equatic environment (substances in List 2 which are carcinogenic are included here)
Mercury and its compounds
Cadmium and its compounds
Persistent mineral oils and hydrocarbons of petroleum
Persistent synthetic substances

List no. 2 ('*grey list*')
The following metalloids/metals and their compounds:
Zinc, copper, nickel, chromium, lead, selenium, arsenic, antimony, molybdenum, titanium, tin, barium, beryllium, boron, uranium, vanadium, cobalt, thalium, tellurium, silver
Biocides and their derivatives not appearing in List 1
Substances which have a deleterious effect on the taste and/or smell of products for human consumption derived from the aquatic environment and compounds liable to give rise to such substances in water
Toxic or persistent organic compounds of silicon and substances which may give rise to such compounds in water, excluding those which are biologically harmless or are rapidly converted in water to harmless substances
Inorganic compounds of phosphorus and elemental phosphorus
Non-persistent mineral oils and hydrocarbons of petroleum origin
Cyanides, fluorides
Certain substances which may have an adverse effect on the oxygen balance, particularly ammonia and nitrites

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which is dependent on the characteristics and location of the water into which they are discharged (Table 1.4). Member States are in the process of establishing environmental quality standards (EQS) for surface and ground waters. These will be used as maximum permissible concentrations in waters receiving discharges containing such compounds (Table 1.5).

Water policy in the EU has recently been rationalized into three key Directives: Drinking Water (80/778/EEC), Urban Waste Water Treatment (91/271/EEC), and the Water Framework Directive (2000/60/EEC).

The Water Framework Directive (2000/60/EEC) brings together the existing Directives on water quality of surface fresh water, estuaries, coastal waters and ground water. It covers all aspects of aquatic ecology and water quality, including the protection of unique and valuable habitats, the protection of drinking water resources and the protection of bathing waters. It achieves this by managing all water resources within River Basin

Table 1.5. Environmental quality standards for List I and List II substances in England and Wales (Environment Agency 1998).

List I substances	Statutory EQS[a] (μg/l)	Number of discharges
Mercury and compounds	1	752
Cadmium and compounds	5	2196
Hexachlorocyclohexane (all isomers)	0.1	123
DDT (all isomers)	0.025	15
DDT (pp isomers)	0.01	1
Pentachlorophenol	2	88
Carbon tetrachloride	12	51
Aldrin	0.01	35
Dieldrin	0.01	58
Endrin	0.005	37
Isodrin	0.005	7
Hexachlorobenzene	0.03	20
Hexachlorobutadience	0.1	14
Chloroform	12	73
Trichloroethylene	10	48
Tetrachloroethylene	10	51
Trichlorobenzene	0.4	31
1,2-dichloroethane	10	87

[a]Standards are all annual mean concentrations

List II substances	Operational EQS[a] (μg/l)	Measured as
Lead	10	AD
Chromium	20	AD
Zinc	75	AT
Copper	10	AD
Nickel	150	AD
Arsenic[b]	50	AD
Boron	2000	AT
Iron	1000	AD
pH	6.0–9.0	P
Vanadium	20	AT
Tributyltin[b]	0.02	MT
Triphenyltin[b]	0.02	MT
PCSD	0.05	PT
Cyfluthrin	0.001	PT

Table 1.5. (*Continued*)

List II substances	Operational EQS[a] (μg/l)	Measured as
Sulcofuron	25	PT
Flucofuron	1	PT
Permethrin	0.01	PT
Atrazine and simazine[b]	2	A
Azinphos-methyl[b]	0.01	A
Dichlorvos[b]	0.001	A
Endosulphan[b]	0.003	A
Fenitrothion[b]	0.01	A
Malathion[b]	0.01	A
Trifluralin[b]	0.1	A
Diazinon	0.01	A
Propetamphos	0.01	A
Cypermethrin	0.0001	A
Isoproturon	2.0	A

A = annual average, P = 95% of samples, D = dissolved, T = total, M = maximum.

[a] Standards quoted for metals are for the protection of sensitive aquatic life at hardness 100–150 mg/l $CaCO_3$, alternative standards may be found in DoE circular 7/89.

[b] Standards for these substances are from the Surface Waters (Dangerous Substances) (Classification) Regulations 1997, Sl 2560 in which case these are now statutory.

Districts for which management plans will be drawn up using environmental quality standards (EQSs) (Table 1.5). The Directive sets clear monitoring procedures and lists specific biological, hydromorphological and physico-chemical parameters to be used for rivers, lakes, estuaries and coastal waters. For each of these resource groups, definitions of high, good and fair ecological quality are given for each specified parameter.

The Urban Waste Water Treatment Directive (91/271/EEC) makes secondary treatment mandatory for sewered domestic waste waters and also all biodegradable industrial (e.g. food processing) waste waters. Minimum effluent standards have been set at BOD 25 mg l^{-1}, COD 125 mg l^{-1} and suspended solids 35 mg l^{-1}. Those receiving waters that are considered to be at risk from eutrophication are classified as sensitive so that discharges require more stringent treatment to bring nutrient concentrations of final effluents down to a maximum total phosphorus concentration of 2 mg l^{-1} for P and a total nitrogen concentration of 10–15 mg l^{-1} for N (Table 1.6). Due to the cost of nutrient removal, the designation of receiving waters as sensitive has significant cost implications for Member States.

Table 1.6. The Urban Wastewater Treatment Directive (91/271/EEC) sets discharge limits for wastewater treatment plants. Values for total phosphorus and nitrogen only apply to discharges $> 10,000$ population equivalents (PE) discharging to surface waters classed as sensitive (e.g. those subject to eutrophication).

Parameter	Minimum concentration	Minimum percentage reduction
BOD_5	25 mg O_2 l^{-1}	70–90
COD	125 mg O_2 l^{-1}	75
Suspended solids	35 mg l^{-1}	90
Total phosphorus	1 mg P l$^{-1\text{a}}$	80
	2 mg P l$^{-1\text{b}}$	80
Total nitrogen	10 mg N l$^{-1\text{a}}$	70–80
	15 mg N l^{-1b}	70–80

[a] 10000–100000 PE.
[b] >100000 PE.

Strict completion dates have been set by the Commission for the provision of minimum treatment for waste waters entering freshwater, estuaries and coastal waters. For example, full secondary treatment (Sec. 2.1) including nutrient removal for all discharges to sensitive waters with a population equivalent (PE) >10,000 must be completed by the end of 1998. By 31 December 2005 all waste waters from population centres <2,000 PE discharged to freshwaters, and <10,000 PE to coastal waters must have sufficient treatment to allow receiving waters to meet environmental quality standards, while populations centres larger than these require secondary treatment (Fig. 1.2). The Directive also requires significant changes in the disposal of sewage sludge including:

(i) That sludge arising from waste water treatment shall be reused whenever possible and that disposal routes shall minimise adverse effects on the environment
(ii) Competent authorities shall ensure that before 31 December 1998, the disposal of sludge from waste water treatment plants is subject to general rules (i.e. Codes of Practice) or legislation
(iii) The disposal of sludge to surface waters by dumping from ships or discharge from pipelines or other means shall be phased out by 31 December 1998
(iv) That the total amount of toxic, persistent or bioaccumable material in sewage sludge is progressively reduced

This wide scoping legislation is considered in more detail in Chap. 8. The disposal options for sewage sludge are further limited if it contains

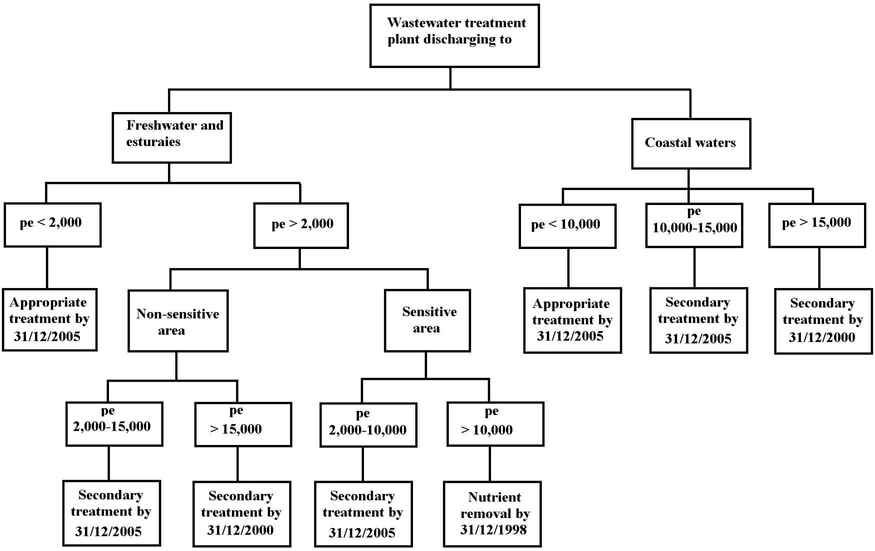

Fig. 1.2. The implementation of the EU Urban Wastewater Directive, with dates for compliance by Member States.

metals or listed substances which may categorise it as a hazardous waste under the EU Directive on Hazardous Waste (91/689/EEC).

Industrial effluents have in the past been a major cause of pollution. The discharge of industrial effluents is generally governed by two objectives: (1) the protection of environmental water quality, and (2) the need to protect sewers and wastewater treatment plants (Table 1.7). To meet these objectives, discharge standards are required that are a compromise between what is needed to protect and improve the environment and the demands of industrial development. Most industrialists accept that the application of the *best practical technology* (i.e. effluent treatment using the best of current technology to meet local environmental requirements at the lowest financial cost) is a reasonable way to comply with the effluent discharge standards set. However, where discharges contain dangerous or toxic pollutants which need to be minimised, then the application of the *best available technology* is required (i.e. effluent treatment using the best of current technology to minimise local environmental change, especially the accumulation of toxic materials, where financial implications are secondary considerations). Where effluent standards are necessary that are even unobtainable using the best available technology, then of course industries can no longer continue at that location.

Table 1.7. Typical effluent standards for discharges to sewers (Gledhill 1986).

Parameter	Standard	Reasons
pH	6 to 10	Protection of sewer and sewage works fabric from corrosion.
Suspended solids	200–400 mg l^{-1}	Protection from sewer blockages and extra load on sludge disposal system.
BOD_5	No general limit	Local authorities would be concerned with large loads on small sewage works and balancing of flows may be required in order not to overload treatment units.
Oils/fats/grease	100 mg l^{-1}	Prevention of fouling of working equipment and safety of men. Soluble fats, etc. can be allowed at ambient temperature.
Inflammables, hydrocarbons, etc.	Prohibited	Prevention of hazards from vapours in sewers.
Temperature	43°C	Various reasons — promotes corrosion, increases solubility of other pollutants, etc.
Toxic metals	10 mg l^{-1}	Prevention of treatment inhibition. The soluble metal is more toxic and different metals can be troublesome. Total loads with a limit on soluble metals more realistic.
Sulphate	500–1000 mg l^{-1}	Protection of sewer from sulphate corrosion.
Cyanides	0–1 mg l^{-1}	Prevention of treatment inhibition. Much higher levels can also cause hazardous working conditions due to HCN gas accumulation in sewer.

The integrated pollution prevention and control (IPPC) Directive (96/61/EEC) was adopted in September 1996. Integrated pollution prevention and control is a major advance in pollution control in that all discharges and environmental effects to water, air and land are considered, together with the *Best Practicable Environmental Option* (BPEO) selected for disposal. In this way, pollution problems are solved rather than transferred from one part of the environment to another. In the past, licensing of one environmental media (i.e. air, water or land) created an incentive to release emissions to another. Integrated pollution prevention and control also minimises the risk of emissions crossing over into other environmental media after discharge (e.g. acid rain, landfill leachate). There is only one licence issued under IPPC covering all aspects of gaseous, liquid, solid waste and noise emissions, so that the operator only has to make one application as well as ensuring consistency between conditions attached to the licence in relation to the different environmental media. In Europe, IPPC applies to the most complex and polluting industries and substances (e.g. large chemical works, power stations, etc.). In England and Wales, the Environment

Agency issues guidance for such processes to ensure that the BPEO is carried out. The aim of IPPC is to minimise the release of listed substances and to render substances that are released harmless using *Best Available Techniques Not Entailing Excessive Cost* (BATNEEC). The objective of the guidance notes is to identify the types of techniques that will be used by the Agency to define BATNEEC for a particular process. The BATNEEC identified is then used as a base for setting emission limit values (ELVs). Unlike previous practice in the identification of BATNEEC, emphasis is placed on pollution prevention techniques such as cleaner technologies and waste minimisation rather than end-of-pipe treatment. Other factors for improving emission quality include in-plant changes, raw material substitution, process recycling, improved material handling and storage practices. Apart from the installation of equipment and new operational procedures to reduce emissions, BATNEEC also necessitates the adoption of an ongoing programme of environmental management and control which should focus on continuing improvements aimed at prevention, elimination and progressive reduction of emissions.

The selection of BATNEEC for a particular process takes into account (i) the current state of technical knowledge, (ii) the requirements of environmental protection, and (iii) the application of measures for these purposes which do not entail excessive costs, having regard to the risk of significant environmental pollution. For existing facilities, the Agency considers (i) the nature, extent and effect of the emissions concerned, (ii) the nature and age of the existing facilities connected with the activity and the period during which the facilities are likely to be used or to continue in operation, and (iii) the costs, which would be incurred in improving or replacing these existing facilities in relation to the economic situation of the industrial sector of the process considered. Thus, while BATNEEC guidelines are the basis for setting licence emission standards, other factors such as site-specific environmental and technical data as well as plant financial data are also taken into account. In Ireland, similar IPPC licensing procedures are operated by the Environmental Protection Agency (EPA 1994), and like the Environment Agency in England and Wales, public registers of all licences are maintained.

The introduction of the polluter which pays charging system throughout Europe and the USA is an attempt to achieve such environmental objectives, at least in terms of the cost to the community, by reinforcing the philosophy that the polluter is responsible for all aspects of pollution control in relation to its own effluent (Deering and Gray 1987). Two distinct types of charges exist: *effluent charges* are levied by local authorities for discharges directly to surface waters, whereas *user charges* are levied for the use of the authority's collective treatment system (Table 1.16). By charging industry for treating their effluents in terms of strength and volume, it encourages them to optimise production efficiency by reducing the volume and strength of their effluent. Most important of all, such charging systems ensure that effluent disposal and treatment costs are taken into account by manufacturers in the overall production costs, so that the cost of the final product reflects the true cost of production (Deering and Gray 1986).

Wastewater treatment is not solely a physical phenomena controlled by engineers, it also involves a complex series of biochemical reactions involving a wide range of micro-organisms. The same micro-organisms that occur naturally in rivers and streams are utilised, under controlled conditions, to rapidly oxidise the organic matter in wastewater to innocuous end products that can be safely discharged to surface waters. Compared with other industries which also use micro-organisms, such as brewing or baking, wastewater treatment is by far the largest industrial use of micro-organisms using specially constructed reactors. As treatment plants that were constructed during the early expansion of wastewater treatment in the late nineteenth and early twentieth centuries now near the end of their useful lives, it is clear that the opportunities for the biotechnologists to apply new technologies, such as genetic manipulation combined with new reactor designs, to pollution control are enormous (Chap. 10). In the future, cheaper, more efficient, and more compact processes will be developed, with the traditional aims of removing organic matter and pathogens to prevent water pollution and protect public health replaced with a philosophy of environmental protection linked with conservation of resources and by-product recovery (Chap. 11).

Natural scientists, whether they are trained as microbiologists, biochemists, biologists, biotechnologists, environmental scientists or any other allied discipline, have an important role in all aspects of public health engineering. They already have a significant function in the operation and monitoring of treatment plants, but their expertise is also needed in the optimisation of existing plants and in the design of the next generation of wastewater treatment systems.

1.2. Nature of Wastewater

Although there has been a steady increase in the discharge of toxic inorganic and organic materials, it is still the biodegradable organic wastes