See previous article

particularly for small-to-medium sized works in rural areas, the expectation is that sludge disposal to land will continue, albeit perhaps in a modified form.

This continuation is conditional upon the containment of potential problems associated with micro-pollutants. Sludging has increased the amount of certain heavy metals to levels greater than the original natural background concentration. Whether or not these increases are significant in terms of contaminating food chains is less certain. More research is required, full consultation is essential and limits must have regard for the economic implications as well as the risks. Only in this way will realistic limits emerge which while protecting the environment, do not unnecessarily penalise either those responsible for disposing of sludge or their customers.

Acknowledgements. While this paper is published with the permission of the Director of Planning, the views expressed are those of the author and not necessarily of Thames Water.

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Amounts and effects of toxic materials discharged to sewers

Robin Chalmers

An assessment of the effects of toxic materials discharged to sewers is complicated by the fact that the toxicity of materials varies not only according to the nature and concentrations of the materials themselves, but also according to the nature of the receiving environment. Sewers may discharge to treatment works or directly to surface waters or the sea.

Manufacturing operations vary with the nature of the product made, the size of the manufacturing operation, the degree of application of good practice in minimising discharges and the extent of water recycle or re-use adopted. The amounts of wastes then discharged to sewers is further influenced by the extent of pre-treatment prior to discharge, which is dictated by the standards required for those effluents, which vary from location to location.

In practice however, the amount of toxic materials actually discharged by an industry, is determined in most countries by the limits prescribed by the sewerage authorities. These limits are derived either from an approach of using the 'best available technology economically achievable' for elimination of pollutants by pre-treatment of the wastes (the USA's aim for 1983) or from an assessment of the amounts of a substance which can be accepted into sewers without damage to a sewage treatment system or to the ultimate receiving environment. This approach, based upon environmental quality objectives, is the one currently adopted in the UK and some other European countries. It is therefore the effects of toxic materials which should, and generally does, determine their amounts in discharges to sewers, and examples of these are given later. According to recent WHO estimates (1979) about 60,000 chemicals are frequently used in daily life, and this number increases at the rate of some 200 to 1000 new chemicals per year. Knowledge of their toxicity, particularly chronic toxicity, is not always complete and limits have to be framed with some factor of safety.

Some interplay exists between what is achievable and what is desirable in limiting discharges to sewers. It is therefore important to know how wastes arise and how effectively they can be minimised at their points of origin. Limits can then be determined more or less realistically and where this is desirable, as in some developing countries, introduced in phased stages. For this reason, some attention is given to the amounts of wastes, and their variability, as they arise.

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What is toxic?

Toxicity may be defined as the ability of a chemical molecule or substance to produce injury once it reaches a susceptible site in or on an organism. The word is derived from the Greek *Toxikon* – poison for arrows. Toxicity is a chemical phen[illegible] [illegible]

Toxicity may also be selective, even though the laws of genetics apply almost universally. A practically universal biochemistry of mitosis can be inferred from evidence that toxic agents such as colchicine arrest the process of mitosis at one particular stage in all species.[1] However, despite the common basis for living matter there are marked biochemical differences between the various species and in the biochemistry of various tissues within any one species. Selective weed killers and pharmacological agents are well known.

The question of what is toxic must therefore be examined carefully. Not only does the toxicity of a substance vary with the nature of the chemical itself and of the substrate upon which it acts, but also with its concentration, e.g. common salt may be toxic in some circumstances. It is therefore a matter of degree as well as of kind, and it is important that when considering 'toxic' wastes, one should also bear in mind the nature and volume of the waste in relation to the receiving environment. This bears upon the acceptability of the wastes for discharge to sewers, pre-treatment requirements if any, and the standard required, which should be relevant and scientifically based.[2]

The position is complicated further by the tremendous difference in the response of test organisms towards toxic substances, depending upon temperature, aeration, hardness of water, age and condition of the test organism, and the conditions under which the test is carried out. There may be a thousand-fold difference in the toxic concentration of the same substance quoted by different authors.[3]

Apart from direct toxic effects, trade effluent discharges may be objectionable for other reasons. The phrase 'Poisonous, noxious or polluting' recurs in the UK water pollution control legislation, although its definition is left to the courts. For the present purpose, toxic substances are taken to include those which impair or inhibit treatment processes.

Variability in trade effluent discharges

Sources of trade effluent discharges should be critically examined because action at this stage can significantly reduce toxic effects and simplify subsequent treatment. Variations in the quality of trade effluents at the sources may be classified into:

● *Cyclic variations*
Discharges from electro-plating and similar cyclical processes; Discharges of phosphating and body pre-treatment from automobile manufacturers; Brewery and largescale food manufacture discharges, with a regular production cycle.

● *Seasonal variations*
Discharges from food processing, canning and freezing which vary with crops available and fish caught.

● *Variations associated with discharge of strong spent 'dumping' solutions*
Aircraft engine manufacture, with strong discharges contained for pre-treatment; Automobile manufacture with strong discharges metered into running swills flows.

● *Variations due to irregular process changes*
Random variations in multiple products produced at organic dye works; Variations in production by herbicide manufacturers, due to market requirements; Variations in tannery operations.

● *Variations resulting from modifications to production processes in pollution control programmes*
The elimination of dumping strong solutions by in-plant treatment; Alterations to the nature of the solutions in use by elimination of, e.g. cyanides from some plating operations or introduction of 'low-cyanide' processes; The introduction of re-use and re-cycle procedures.

Examples of the extent of such variations, which have been met in a busy consulting practice, have been published elsewhere.[4] Discharges from large-scale automatic electroplating showed fluctuations where none were expected, and indicated pre-treatment design parameters. Variations in brewery discharges showed the gain possible from balancing the strongest discharge flows and of programming discharges for night-time or slack periods.

Table 1 Water demand of some major industries

Industry	Water demand
Leyland Cars, at 43 plants	2 x $10^5 m^3$ each week
ICI Billingham	2 x $10^5 m^3$ each day
British Steel Corporation	2 x $10^5 m^3$ each half-hour
The Central Electricity Generating Board at [illegible] output	2 x $10^5 m^3$ each minute

Variability in industrial water requirements

Table 1 compares, on a time basis, the water demand of some major industries.[5,6] Of more practical interest is the use of water per production unit as shown in Table 2. The large variation of water consumption is significant; lower water usage is an indication of good management and better production control and is usually accompanied by a lower wastage of the product. The South African figure of $5 m^3/t$ of steel is one of the lowest in the world,[7] and much can be learnt from a study of good practice in such hot developed countries where water is scarce.

Amounts of wastes from manufacturing operations

Amounts of wastes vary according to manufacturing operations. In the Netherlands pollution coefficients are ascribed to a large number of industrial wastes, based upon a population-equivalent (pe):

$$1 \text{ pe} = \frac{\text{grams COD} + 4.57 \text{ grams}N}{180}$$

The coefficients vary from 0.5 per employee for textile spinning and weaving to 20 for chemicals manufacture.

In a very broad classification of industrial effluents, UK authorities listed:[8]

● Effluents from food and drink manufacture;
● Other organic effluents, including those from paper, leather and wool industries;
● Effluents containing metals and cyanides;
● Chemical effluents.

Effluents in the final two categories are potentially toxic,[9] and some data can be derived from examination of production sources.

Metal finishing wastes

Approximate annual consumptions of chemicals by the UK metal-finishing industry in 1973 were listed by Mattock.[10] The losses to effluent were assessed as 10-20 per cent of the cadmium, copper, tin and zinc consumed; 50 per cent of the nickel, and 70 per cent of the chromic acid; and virtually 100 per cent of the cyanides.

Toxic organic chemicals

A number of valuable development documents for effluent limitations guidelines have been produced for the US Environmental Protection Agency (EPA). That for the 'significant organic products segment' of organic chemical manufacturing,[11] includes extensive tables of manufacturing

Table 2 **Order of magnitude of water consumptions associated with different industries**

Industry	Water intake per unit
Brewing	8- 25m^3/t
Dairies	1- 13m^3/t
Electroplating, galvanising	10- 50litres/m^2 surface
Fruit processing	4- 7m^3/t
Motor cars	10-100m^3/car
Paper making	5-260m^3/t
Potato processing	15- 65m^3/t
Poultry processing	30- 35m^3/1000 chickens
Power generation	3-100litres/kWh
Slaughter houses	1- 20m^3/cattle unit
Rolling mills	2- 16m^3/t
Steel	4-300m^3/t
Sugar beet	5- 20m^3/t
Tanning	74- 88m^3/t
Textile processing	80-600m^3/t
Yeast manufacture	90-150m^3/t

process raw waste loads from which the list in Table 3 has been abstracted. The sections correspond to:

- Continuous vapour phase processes where contact process water is used as diluent, quench or vent gas absorbent;
- Continuous aqueous liquid-phase reaction systems;
- Batch and semi-continuous processes.

There is a large variation in flows, loading, and concentrations. The BOD and COD concentrations shown are based on wastewaters coming directly from the process, and do not necessarily represent the waste concentrations which a typical single-state biological waste treatment plant would accept. In most cases the concentrated wastewater would be diluted with less concentrated wastes from other processes or with slightly contaminated waters. The best available technology economically achievable, (BATEA, 1983 Standard) is based on the addition of activated carbon treatment, following biological treatment.

Polychlorinated biphenyls

The PCBs form a classic case of a refractory organic substance that resists degradation in the environment by all means. They should not occur in discharges to sewers. In the USA the EPA has banned all manufacturing discharges of PCBs, but care is still required in the disposal of surviving PCB sources – principally in dielectric insulating and cooling fluids in capacitors and transformers.

In the mid-1970s the waste load of PCBs discharged to waterways or sewers in the USA was assessed as less than 5kg/d – principally from the capacitor industries. Much greater quantities were discharged to land or in scrap oils to incineration – those from the capacitor industries were estimated to be 2000 and 1800kg/d respectively.

Pesticides

There are more than 500 individual pesticides of commercial importance, and as many as 34,000 distinct major formulated products.[12] In a major study[13] the EPA classified the waste loads from the three principal types of pesticides produced as shown in Table 4. This Table illustrates clearly that the wastes produced by an industry may be substantially reduced by pre-treatment before discharge to sewers or disposal by other routes.

Amounts discharged to sewers

In addition to variations inherent in the manufacturing processes and the extent to which good practice is adopted in minimising the discharges, pre-treatment will often substantially reduce the amounts of wastes involved. The extent of pre-treatment applied is determined either by quality conditions imposed by regulatory agencies or by the economic advantages in pre-treating to minimise acceptance charges. The weights of toxic substances which may be discharged to sewers is therefore substantially determined by what the receiving sewage disposal works, if any, can receive and treat or dispose of satisfactorily. In developed countries, and many developing countries, concentrations which determine these amounts are prescribed by law.

In Great Britain, approximately half of the flow of sewage received at treatment works in 1970 was composed of industrial effluent.[9] This amounts to 6.8 x 10^{6}m^3/d of industrial effluent, but the figure has been dropping significantly in the past 10 years. In addition, a considerable flow of industrial effluent is discharged directly to water courses or to the sea, either with or without prior treatment. This is summarised in Table 5,[14] which shows discharges for England and Wales.

An investigation in Venice[15] showed the major significance of discharges from the chemical and allied industries. Approximately 50 per cent of the discharge flows (135,000m^3/d) and 75 per cent of the organic load from the industrial complex of 239 factories at Porto Marghera was associated with chemical and allied manufacturing.

The weights of toxic materials discharged in such flows may be approximately derived from the consent conditions applied for their reception into sewers. In the UK where consent limits apply, the average concentrations of a toxicant discharged in a pre-treated effluent is about two thirds of the limit. It is well known that a sewage treatment works designed to produce an effluent with BOD and SS not exceeding 20 and 30mg/litre respectively is likely to give an effluent having values about two thirds of these figures on average.[2] The same is broadly true of trade effluent pre-treatment plants, which in my experience are designed on this basis. The validity of

Table 3 **Organic chemicals production: process raw waste loads**

Product	Product description	Flow (litre/t)	Process raw waste loads BOD (mg/litre)	COD (mg/litre)
Benzoic acid and benzaldehyde	Catalytic oxidation of toluene	2840	9010	17,900
Chlorobenzene	Chlorination of benzene	50	300	7700
Chlorotoluene	Chlorination of toluene	121,000	2	15
Maleic anhydride	Oxidation of benzene	2300	47,000	126,000
Acrylonitrile	Ammoxidation of propylene	4470	8620	32,800
Cresol, synthetic	Methylation of phenol	334	143,000	303,000
Propylene glycol	Hydrolysis of propylene oxide	5500	3	10
Sec-butyl alcohol	Sulfonation and hydrolysis of mixed butylenes	626	22,800	62 000
Dyes and dye intermediates	Batch manufacture	947,000	620	1290
Miscellaneous batch chemicals		78,700	306	1250
Plasticisers	Condensation of phthalic anhydride	650	82,000	127,000

this approximation is illustrated by the results at a major UK sewage treatment works which receives 635kg/d of total toxic metals in aflow of 385Mlitres/d. From the consent limit of 30mg/litre total toxic metals, the expected daily load would be 578kg although there is some contribution from domestic and storm water.

Limits for other toxic chemicals are prescribed individually where necessary, if not already limited by a general restriction on the COD. Determination of these limits requires consideration of the acute and chronic toxicity of the substance at the most critical point in the circumstances prevailing. This may be in the sewers, storm overflows, biological treatment, sewage sludge, or the effluent ultimately discharged and requires a detailed knowledge of the characteristics of the substance including, for example, its biodegradability as shown in Table 6.

Limit figures for toxic non-metallic substances in industrial effluent discharges tend to be misleading, since they depend significantly upon the local conditions. In the UK there are general prohibitions on the discharge to sewers of petroleum spirit, calcium carbide, and effluents at a higher temperature than 43.3°C. Limits for these are effectively zero, and limits for substances in the 'black list' of the EEC are tending to zero.

In deriving loads from consent limits, care is necessary to use the actual volumes discharged to sewers rather than the permitted maximum volumes which are generally higher. It should be remembered too that industrial water consumption is no longer rising at the 3 per cent per annum compound rate that was forecast 10 years ago. It has been estimated in the UK that a 10 per cent increase in production is likely to be accompanied by only a 5 per cent increase in water consumption. Weights of materials discharged to sewers are also tending to fall significantly with the application of advanced technology.

Effects of discharges to sewers

There are some advantages in discharging chemical and other industrial wastes to sewers for treatment at sewage disposal works. They often show increased amenability to bio-oxidation when treated in combination with sewage, and the domestic sewage stream can supply the necessary nutrients often lacking in industrial wastewaters. In addition, the

Table 4 **Waste loads from pesticide manufacture**

Halogenated organic pesticide plant	
Production (small plant), t/d	16.2
Production (large plant), t/d	85.7
Flow litre/t	35,000
Total pesticide kg/t	0.327
Total pesticide mg/litre	9.26
After treatment by BPT, mg/litre	0.09
Organophosphorus pesticide plant	
Production (small plant), t/d	6.57
Production (large plant), t/d	72.0
Flow litre/t	43,900
Total pesticide kg/t	0.454
Total pesticide mg/litre	10.34
After treatment by BPT, mg/litre	0.04
Organonitrogen pesticide plant	
Production (small plant), t/d	9.43
Production (large plant), t/d	116
Flow litre/t	35,400
Total pesticide kg/t	2.82
Total pesticide mg/litre	79.66
After treatment by BPT, mg/litre	0.20

BPT Best practicable technology

Table 5 **Discharges of industrial effluents in England and Wales**

Industrial effluents to sea **($10^6m^3/d$)**		21.6
Electricity generating stations (mainly cooling water)		20
Chemical and allied industries	1.3	
Iron and steel industry	0.04	
Food processing and manufacture	0.04	
Gas and coke production	0.03	
Paper and board manufacture	0.02	
All others	0.17	1.6
(More than 50 per cent of the $1.6 \times 10^6 m^3/d$ of significant discharges is through private outfalls independent of public sewers)		
Industrial effluents to inland rivers under water authortiy control ($10^6m^3/d$)		10.8

dilution of chemical wastes afforded by the domestic sewage can reduce the concentration of potential inhibitory or toxic chemicals to a level harmless to the treatment organisms, thus enabling the waste to be effectively degraded.

However, many chemical and allied works produce large volumes of effluent of high strength, compared with sewage, and local sewage treatment works are often insufficiently large to deal with either the organic or the volume load.[16] In addition, if chemical wastes are accepted into the local sewers, stringent safeguards are essential to prevent effects upon the fabric of sewers, men working in the sewers, and efficient operation of sewage works. A classification of toxic materials used and toxic wastes produced in different industries is given by Toogood and Hobson.[17]

Volatile toxic substances

In order to comply with the UK Health and Safety at Work Act 1974, sewerage authorities must control discharges to sewers of any material which may be toxic or injurious to their employees. The UK Water Research Centre produced an excellent report in June 1980 on the determination of safe limits for the discharge of volatile materials to sewers.[17] This gives a scientific basis for the derivation of limits for ammonia, sulphur dioxide, hydrogen cyanide, hydrogen sulphide, and 50 volatile organic substances which may reach sewers at low concentrations in industrial effluents. Consideration is required of the threshold limit value (TLV) in an atmosphere in equilibrium with sewage, vapour pressure, limiting activity coefficients, temperature, and in the case of inorganic substances, pH value. Indicated limits for sewage flowing in a sewer include: 4.1mg/litre and 0.09mg/litre for hydrogen cyanide and hydrogen sulphide respectively at pH 7.0 and 15°C; 1.7mg/litre and 1.2mg/litre for xylene and trichloroethylene respectively at 25°C.

Other factors affecting the toxicity of atmospheres in sewers which may need to be considered include the relative atmospheric toxicity of a mixture of volatile toxic substances, and the effects of ventilation in sewers. Many other volatile organic substances are under investigation. Where data are not available for any suspect substance they should be determined experimentally: methods have been indicated by the Water Research Centre and by Thames Water Authority.

The indicated limit for hydrogen sulphide is well below the concentration of about 1mg/litre usually found in domestic sewage, although ventilation in most sewers is likely to render that figure safe. There is little if any room however, for the acceptance of sulphides in industrial effluent discharges. This is of significance to a number of industries notably tanneries and gas works. Sulphides, or conditions for their formation from sulphates, are also restricted in sewers to minimise corrosion effects. In an investigation by my colleagues in Baghdad, contributory factors to severe sewer corrosion by sulphides were found to include discharges of sulphates from battery manufacture and distillery wastes in addition to septic sewage. Sewer flows of 0.8-1.0m/s tend to prevent the formation of sulphide in sewers, and this criterion is sometimes used in design in connection with corrosion prevention. However, in the light of current knowledge, the potential toxic effects of sulphides are usually the dominating constraints.

Toxic products formed in sewers

The discharge of substances that may interact with others present in sewers to form toxic products is normally restricted under UK legislation. While many such reactions can be predicted, others are less obvious and it is necessary to remain alert for these. In investigating a death in a sewer atmosphere I found that highly volatile and toxic dichloroacetylene had been formed from the interaction of trichlorethylene and sodium hydroxide – an effect previously associated mainly with the reaction of soda lime and trilene in closed circuit anaesthesia in child birth.

Aqueous poisons

Concentrations of poisons which are acceptable in sewage flows or storm overflows because they are not toxic to sewage treatment processes do not pose significant hazards to people working in sewers. Substances which may attack the sewers, or cause fires or explosions are restricted for these reasons.

Effects on sewage treatment

Many, if not most, chemical works produce large volumes of effluent of high strength compared with sewage. BOD loads in excess of 50,000mg/litre are not uncommon in certain waste streams. While these are toxic in the concentrations produced, dilution at a large sewage treatment works such as Davyhulme, Manchester allows effective treatment of the substantial chemical waste flows there. In other cases pre-treatment of the waste prior to discharge to sewers may be mandatory. Thus, a synthetic fibre factory producing 27m^3/d of effluent at 15,000mg/litre BOD and discharging to a relatively small sewage treatment works, had to apply extensive pre-treatment including bio-oxidation in combination with domestic sewage from the site.

Toxicity

Aerobic sewage treatment processes are affected by many toxic metals in the range <1—10mg/litre. Table 7 shows acceptable concentrations for typical processes. Most organic substances exert such effects only at higher concentrations, and cyanides have been successfully treated at concentrations well in excess of 10mg/litre.

Metal concentrations in industrial effluents may therefore have to be controlled so that the sewage does not contain more than the limiting amount that will affect the most sensitive part of the sewage treatment process. This applies to metals in solution. Metals in suspension, apart from some tendency to dissolution in sewage, are removed on sedimentation treatment, and these accumulate in the sludge together with those from secondary sedimentation after removal on biological treatment. Removal of metal during

Table 6 Degree of removal of various chemical wastes by biological oxidation

Compounds reduced 0-10 per cent	**Compounds reduced 70-90 per cent**
Ammonia	Acetaldehyde
Acetophenone	Acetic acid
Ethylene cyanohydrin	Acrylonitrile
	Butanol
Compounds reduced 10-30 per cent	Ethanol
Acetone	Hexanol
Methyl ethyl pyridine	iso-Propanol
	iso-Propyl ether
Compounds reduced 30-50 per cent	Naphthalene
Ethylbutanol	Styrene
2-Ethylhexanol	Toluene
Methanol	
Paraldehyde	**Compounds reduced 90-100 per cent**
	Benzene
Compounds reduced 50-70 per cent	Benzoic acid
Acrylic and butyric acids	Crotonaldehyde
Dioctylphthalate	Ethyl acetate
Phenyl methyl carbinol	Ethyl acrylate
	Ethyl benzene
	2-Ethylhexyl acrylate
	Heptane

activated sludge treatment varies with the influent concentrations. Although figures approaching 100 per cent removal have been reported from Ontario, these are unusual and associated with low influent concentrations. More typical are those found at Dallas, USA[18] shown in Table 8.

The distinction between the effects of metals in solution and in suspension leads to the possibility of differential limits for their amounts in trade effluent discharges to sewers and some authorities apply these. It is, however, the total amount accumulating in sludge which nowadays is often the dominating constraint on the reception of metals into sewage treatment.

Biodegradability

A significant number of organic compounds are not susceptible to biological degradation, or are affected only to a limited extent. Some indication of these has been given in Table 6. In such cases, their effects on passage through a sewage treatment works must be assessed from a knowledge of their toxicity in relation to the receiving environment, and this is an arithmetic exercise.

Passage of toxicants

The fate of chemicals on sewage treatment is not always known, and may have to be determined experimentally. It is important to establish if they are completely removed on sewage treatment and what amounts accumulate in the sludge; whether there is any release to atmosphere during sewage treatment processes (including heat treatment of sludge where this is applied); and what amounts of the original substances or toxic degradation products may appear in the final effluent discharge.

In an investigation of the treatment of herbicide effluents, the removal on experimental pilot trickling filters was 72 per cent. Increasing the herbicide content of the sewage from 0.4 per cent to 0.8 per cent caused a 16.4 per cent deterioration in treatment efficiency. There was some accumulation of herbicide in the sludge, which has implications for its ultimate disposal.

Effects on sewage treatment works design

The presence of toxic or high-load chemicals in industrial discharges to sewers influences the nature as well as the size of the sewage treatment works required. Recent investigations in Syria have shown that the nature of the sewage treatment process at two works being designed has been effectively determined by the 30 per cent or so of industrial wastes to be discharged to sewers.

Effects on sludge treatment and disposal

Anaerobic processes of sludge digestion are particularly susceptible to toxicants and it may be necessary to limit the amounts of individual toxic metals in the sewage flow to <2mg/litre, chlorinated hydrocarbons to <1mg/litre and anionic detergents to <30mg/litre. The presence of toxic chemicals in a sludge may determine whether or not it is acceptable for disposal to agricultural land or to the sea. Pesticides and herbicides are significant in this connection. Of even greater effect however, are metals which in many countries are limited for disposal to land by legal constraints or guidelines. Dumping to sea is strictly controlled by the Ministry of Agriculture, Fisheries and Food in the UK and by many European countries following the conventions adopted in Oslo, London and Paris.

Effects upon receiving waters

River quality objectives are being established for many rivers and these vary with the downstream use of the water. The World Health Organization limits for drinking supplies form the basis for many of the standards applied to potential drinking sources. Limits applicable to fish of various kinds, together with synergistic effects of poisons and the mineral water quality are also reasonably well established for many substances. Where information is lacking on acute toxicity, fish toxicity tests form a useful guide, and a water which is non-toxic to fish is often regarded as safe. There are however, a number of cases where little or nothing is known about the chronic toxicity of organic chemicals and in the absence of adequate information these are often prohibited.

Health effects

While much is known about the effects of many chemicals in common use – the Russians have standards for more than 500 chemicals in drinking water supplies – there remain many for which the effects, particularly chronic effects, are not yet known. Increased analytical capability in recent years has shown the presence of large numbers of micropollutants in river waters.

Following a case of ground water pollution in Vicenza Province in Italy, the WHO Regional Office for Europe convened a working group on criteria and guidelines for halogenated aromatic compounds in Venice in September 1979.

The group's report covers the major uses and environmental occurrence of the substances, and their physical, chemical and toxicological properties, and assesses the health hazards. It recommended, *inter alia*, systematic environmental impact assessments before decisions are made regarding the siting and design of chemical plants, and the establishment of safeguards in the prevention of occupational risks and the control of liquid and gaseous emissions and solid wastes. Data from the International Register of Potentially Toxic Chemicals was also considered to be of use.

Table 7 **Typical acceptable metal concentrations**

Heavy metal ion	Acceptable concentration for aerobic processes of sewage treatment (mg/litre)	
	Oxidation of organic compounds	Nitrification of ammonia
Cd	1	5
Cu	25	1
Cr(VI)	1-5	1-10
Pb	10	—
Ni	2.5-10	1-2
Ag	0.03	
Zn	2-25	1

Table 8 **Removal of metals: Dallas tertiary plant**

Metal	Plant influent (mg/litre)	Removal by activated sludge (per cent)
Cd	0.013	39
Cr	0.215	57
Cu	0.092	33
Hg	0.00051	69
Ni	0.073	21
Pb	0.095	56
Zn	0.320	65

Effects on manufacturing costs

This developing knowledge imposes significant costs upon industry, which is generally responsible and responsive. Minimising, or eliminating discharges of specific substances to sewers has a bearing on the siting and development of new factories and imposes costs on process modifications, pre-treatment requirements and extensions to sewage treatment works.

The effects can be substantial, e.g. the adoption of best practicable technology for treatment of wastes from pesticide production involves the costly addition of activated carbon treatment to existing systems. Weiss[20] in 1978 studied the cost to the USA zinc industry of complying with environmental regulations and judged the impact on future development. He determined that compliance with regulations could increase the cost of zinc by about 10 per cent and that some high-cost producers might have to shut down. During the past 10 years, nine smelters in the United States have closed, with the costs for environmental control being a major factor in several cases.

Generally however, industry accepts these costs, so long as they are shown to be necessary, and collaborates with research and development organisations concerned with the water cycle. It is in countries where water is scarce, such as South Africa, where this shows most clearly. There, industry is collaborating with the Water Research Commission in a comprehensive investigation on the effect of potentially harmful chemicals in effluents, with a view to determining policies that should be followed in connection with water re-use.

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See following article

Treatment before discharge

John M Sidwick and Richard Barnard

Many manufacturing processes use toxic chemicals, often in solution. If not dealt with by the manufacturer these chemicals, or their derivatives, find their way into the trade effluent streams discharging from the industrial premises. The trade effluents pass directly or indirectly to surface water or, less often, to ground water. In order to protect the environment, or treatment facilities such as municipal sewage treatment works, the concentrations and/or loads of any toxic constituents have to be reduced to acceptable levels. The question of acceptable levels for specific chemicals is complex, and other factors must be considered. These include the possible presence of toxic materials from other sources, the nature of the receiving environment and the uses to which it is put, the interaction between one toxic constituent and others that may be present, and the current state of knowledge about toxicity.

Trade effluent survey

If it is required that the toxicity of the effluent be lessened, and if the requirement is reasonable, the toxic constituents must be reduced in concentration, removed altogether, or converted to a less toxic or non-toxic form. Whichever approach is most appropriate and economical will cost money and final decisions should not be taken lightly; they must be based on a thorough understanding of the characteristics of the waste in question, and how it arises. The first step therefore, should be a comprehensive examination of all the waste-related manufacturing processes including flow measurement, sampling and analysis at selected points within the factory as well as at the points of discharge of effluent. As a result of a careful and expert interpretation of the data resulting from a properly designed study, decisions can be made. The main stages of activity available to the designer are shown in Fig 1.

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Table 1 Some common pollutants, their origins and treatment methods

Pollutant	Type of waste and some sources	Possible treatment methods
Acids	Any mineral or organic acid causing pH depression to < 6 usually requires treatment. Typically: Battery manufacture; Steel industry; Chemical works	Neutralisation using alkali – typically lime or sodium hydroxide.
Alkalis	Presence of any alkali causing pH to rise to >9 usually requires treatment. Typically: Laundries; Textile industry; Chemical works	Neutralisation using acid – usually a mineral acid such as sulphuric or hydrochloric.
Ammonia	Usually free ammonia (ammoniacal nitrogen) but combined nitrogen can create problems. Typically: Coke oven effluents; Domestic sewage; Fertiliser factories	Desorption by air stripping. Nitrification possibly followed by denitrification. Incineration. Chemical oxidation.
Biodegradable waste	Organic wastes with no toxic compounds present. Nutrients may have to be added. Typically: Domestic sewage; Food waste	Settlement if necessary. Biological treatment followed by settlement and tertiary treatment if necessary.
Chromium	Chromium often present in hexavalent form which is most toxic. This is soluble as chromate and dichromate. Typically: Plating wastes; Chrome tanning; *Aluminium anodising*; Boiler water blowdown	Cr^{6+} reduced to Cr^{3+} by electrolysis or chemical reduction prior to removal by coagulation and settlement. Can be removed directly by ion-exchange. Direct precipitation with [illegible]

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