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The nature of hazardous wastes and their recycling potential

Identifying the problem

There is no consensus of opinion which enables us to define hazardous waste and therefore we must begin by defining industrial wastes. Industrial wastes are the byproducts, spent residues and discarded components of industrial manufacturing processes which have no realisable value. They are produced in gaseous, liquid, solid and semi-solid forms. Excluded from consideration in this textbook are explosive residuals from military sources, spoil heaps from mining and quarrying and radioactive wastes.

A tentative definition being considered by the World Health Organisation defines hazardous wastes as those wastes which present either:

(a) short-term hazards, such as acute toxicity by ingestion, inhalation or skin absorption, corrosivity or other skin or eye contact hazards or the risk of fire and explosion or

(b) long-term environmental hazards including chronic toxicity upon repeated exposure, carcinogenicity (which may in some cases result from acute exposure but with a long latent period), resistance to detoxification processes such as biodegradation, the potential to pollute underground or surface waters or aesthetically objectionable properties such as offensive smells.

Difficulties of definition continue to exist, especially when it is recognised that a waste can be hazardous in one circumstance though not in another. Hazards arise not only from dangerous substances themselves but also from catalytic, synergistic or antagonistic reactions of two or more substances which are in themselves harmless. Catalytic and synergistic effects are not always predictable and, as we shall see, can produce

circumstances in which pollutants can be mobilised to threaten valuable water supplies.

Table 1 [1] shows a list of categories of hazardous waste but it must be emphasised that this list is by no means comprehensive. Indeed, with industrial producers adding new chemical products at a rate which exceeds one per day, it would be impossible to produce an inclusive definitive list of hazardous wastes.

Table 1. *Categories of hazardous waste*

Type of waste	Groups and *Sub-groups*	Group code	Sub-group code
Inorganic acids	Hydrochloric acid	A10	
	Sulphuric acid	A20	
	Nitric acid	A30	
	Chromic acid	A40	
	Phosphoric acid	A50	
	Hydrofluoric acid	A60	
	Others	A90	
Organic acids and related compounds	All	B10	
	Aliphatic acids eg formic, acetic and oxalic acids		*B11*
	Aromatic acids eg benzoic, phthalic acids		*B12*
	Acid anhydrides eg acetic, phthalic anhydrides		*B13*
	Acid chlorides eg acetyl, benzoyl chlorides		*B14*
	Sulphonic acids		*B15*
	Others		*B19*
Alkalis	Alkali metal oxides and hydroxides, calcium oxide, proprietary alkaline cleaners	C10	
	Sodium and/or potassium hydroxides or oxides		*C11*
	Calcium oxide		*C12*
	Proprietary alkaline cleaners		*C13*
	Ammonia	C20	
	Others	C90	
	Calcium hydroxide		*C91*
	Sodium and/or potassium carbonates		*C92*

Table 1. (*cont.*)

Type of waste	Groups and *Sub-groups*	Group code	Sub-group code
Toxic metal compounds	Cadmium	D10	
	Mercury	D20	
	Lead	D30	
	Arsenic	D40	
	Others	D90	
	Copper		*D91*
	Zinc		*D92*
	Barium (water soluble forms)		*D93*
	Thallium		*D94*
	Nickel		*D95*
	Vanadium		*D96*
	Silver		*D97*
	Others		*D99*
Non-toxic metal compounds	Iron	E10	
	Others	E90	
	Ammonium salts		*E91*
	Titanium		*E92*
	Others		E99
Metals (Elemental)	Alkali, alkaline earth and other hazardous metals	F10	
	Sodium and potassium		*F11*
	Cadmium		*F12*
	Mercury		*F13*
	Aluminium		*F14*
	Magnesium		*F15*
	Other metals	F90	
Metal oxides	Hazardous oxides	G10	
	Cadmium oxide		*G11*
	Beryllium oxide		*G12*
	Others		*G19*
	Other oxides	G90	

Table 1. (*cont.*)

Type of waste	Groups and *Sub-groups*	Group code	Sub-group code
Inorganic compounds	Cyanides	H10	
	Sodium and potassium cyanides		*H11*
	Soluble complex cyanides		*H12*
	Ferro and ferri cyanides		*H13*
	Other cyanides		*H19*
	Others which liberate toxic gases on acidification	H20	
	Sulphides, selenides, tellurides and arsenides		*H21*
	Oxidizing compounds	H30	
	Hypochlorites and chlorites		*H31*
	Chlorates, perchlorates, bromates, iodates, periodates, persulphates and permanganates		*H32*
	Peroxides		*H33*
	Toxic compounds	H40	
	Chromates		*H41*
	Fluorides, silicofluorides, borofluorides		*H42*
	Arsenates and arsenites		*H43*
	Others	H90	
	Carbides and acetylides		*H91*
	Borates		*H92*
	Nitrites		*H93*
	Nitrates		*H94*
Other inorganic materials	Asbestos	J10	
	Slag including boiler and flue cleanings	J20	
	Mineral processing wastes	J30	
	Silt and dredgings	J40	
	Water (contaminated)	J50	
	Metal scrap	J60	
	Ferrous metal scrap		*J61*
	Non-ferrous metal scrap		*J62*
	Others	J90	

Table 1. (*cont.*)

Type of waste	Groups and *Sub-groups*	Group code	Sub-group code
Organic compounds	Hydrocarbons (not included in M)	K10	
	Aliphatic hydrocarbons		*K11*
	Aromatic hydrocarbons		*K12*
	Phenols, analogues and derivatives	K20	
	Chlorinated phenols and analogues		*K21*
	Peroxides	K30	
	Halogenated cleaning compounds	K40	
	Trichloroethylene		*K41*
	Perchloroethylene		*K42*
	Trichlorethane		*K43*
	Trichlorotrifluoroethane		*K44*
	Others		*K49*
	Halogenated compounds excluding cleaning compounds	K50	
	PCBs and analogues		*K51*
	Other halogenated hydrocarbons		*K52*
	Other halogenated organics eg chlorinated dioxins		*K53*
	Organo metallics	K60	
	Tetra ethyl lead		*K61*
	Tetra methyl lead		*K62*
	Others		*K69*
	Nitrogen, sulphur or phosphorus-containing compounds	K70	
	Amines and amides		*K71*
	Nitro compounds		*K72*
	Nitriles		*K73*
	Isocyanates		*K74*
	Other organo nitrogen compounds		*K75*
	Organophosphorus compounds		*K76*
	Organosulphur compounds		*K77*
	Oxygen containing compounds	K80	
	Esters		*K81*

Table 1. (*cont.*)

Type of waste	Groups and *Sub-groups*	Group code	Sub-group code
Organic compounds (*contd.*)	*Ethers*		*K82*
	Aldehydes and Ketones		*K83*
	Alcohols		*K84*
	Others	K90	
	Chelating compounds		*K91*
	Phthalates		*K92*
Polymeric materials and precursors	Precursors, monomers and products of incomplete polymerization	L10	
	Epoxy resins (not finished products)		*L11*
	Polyester resins (not finished products)		*L12*
	Phenol-formaldehyde resins (not finished products)		*L13*
	Finished products and manufacturing scrap	L20	
	Polyurethane		*L22*
	Other resins and polymeric materials		*L29*
	Scrap rubber (including tyres)	L30	
	Latex, latex and rubber solutions and suspensions	L40	
	Synthetic adhesive wastes	L50	
	Ion-exchange resin wastes	L60	
Fuel, oils and greases	Mineral oils	M10	
	Kerosene and derv	M20	
	Fuel oil	M30	
	Vegetable and other oils	M40	
	Oil/water mixtures	M50	
	Fats, waxes and greases	M60	
Fine chemicals and biocides	Pharmaceutical and cosmetic products	N10	
	Pharmaceutical products in retail containers		*N11*
	Pharmaceutical products in bulk and production containers		*N13*
	Biocides	N20	
	Pesticides		*N21*
	Herbicides		*N22*

Table 1. (*cont.*)

Type of waste	Groups and *Sub-groups*	Group code	Sub-group code
Fine chemicals and biocides (*contd.*)	*Fungicides*		*N23*
	Other biocides		*N29*
Miscellaneous chemical waste	Mixed organic compounds	P10	
	Mixed inorganic compounds	P20	
	Unidentified chemical waste	P30	
	Organics identified by trade names only*		*P31*
	Inorganics identified by trade names only*		*P32*
Filter materials, treatment sludge and contaminated rubbish	Used filter materials eg kieselguhr, carbon, filter cloths	Q10	
	Contaminated rubbish (including bags and sacks)	Q20	
	Empty used containers	Q30	
	Industrial effluent treatment sludge	Q40	
Interceptor wastes, tars, paint, dyes and pigments	Tank cleaning sludge (note K60 for lead content)	R10	
	Interceptor pit wastes (note M10–M30 for oil content)	R20	
	Printing industry wastes (ink manufacture and use)	R30	
	Dyestuffs waste	R40	
	Distillation residues	R50	
	Acid tars	R60	
	Tar, pitch, bitumen and asphalts	R70	
	Paint waste (manufacture and use)	R80	
Miscellaneous wastes	Tannery and fellmongers waste	S10	
	Tannery waste		*S11*
	Fellmongers waste		*S12*
	Cellulose wastes (natural and synthetic)	S20	
	Waste treated timber	S30	
	Soap and detergents	S50	
	Soap		*S51*
	Detergents		*S52*
	Other industrial wastes	S90	
Animal and food wastes	Animal processing wastes	T10	
	Carcasses and flesh		*T11*

*Where trade names are used the source of the material should be specified.

Table 1. (*cont.*)

Type of waste	Groups and *Sub-groups*	Group code	Sub-group code
Animal and food wastes (*contd.*)	*Blood, fat grease etc*		*T12*
	Excrement		*T13*
	Food processing wastes (including starch)	T20	
	Glue wastes	T30	

Source: Reference [1].

The term 'toxic waste' is often used in waste management circles and again the definition of the term causes some difficulty. However, it seems appropriate to comment that the term 'toxic waste' does not imply 'causing death'. Toxic effects should include growth retardation, decreased fullness of health and intellectual capability, detrimental changes in reproductive cycle with mortality of offspring, increased morbidity, pathological change, appearance of tumours, chronic disease symptoms and decreased longevity and can be applied to animal (and plant) life as well as humans.

We shall encounter, during the course of this book, other important definitions such as *notifiable waste* and *special waste* which have profound legal meanings. The term 'special waste' in Britain originates from the Control of Pollution Act (Special Waste) Regulations 1980. This definition is discussed in detail in Dr Willetts' contribution in Chapter 4 but it is important to note here that a special waste is described [2] by reference to:

(a) it containing any substance listed in Part 1, Schedule 1 to S1 1980 No. 1709 *and* by reason of the presence of such substance;

(i) is dangerous to life by way of carcinogenicity, corrosivity to tissues or toxicity,

(ii) has a flash point less than 21°C,

(b) is a prescribed medicinal product.

These regulations are quite new in Britain and the Department of the Environment is reviewing them at the present time. The definition is very restrictive since it ignores water pollution, damage to animals and vegetation and site sterilisation. Critics of these regulations include The National Water Council, The Scottish River Purification Boards Association, Friends of The Earth, the Association of County Councils in evidence to the House of Lords Inquiry [3]. This author has drawn

attention to the differences between these regulations and American ones [4].

The United States Federal Register [5] begins by defining solid waste as

> any garbage, refuse, sludge from a waste water treatment plant, water supply treatment plant or air pollution control facility and other discarded material including solid, liquid, semi-solid or contained gaseous material resulting from industrial, commercial or mining and agricultural operations, and from community activities but does not include solid or dissolved materials in domestic sewage or solid or dissolved materials in irrigation return flows, or industrial discharges which are point sources subject to permits under Section 402 of the Federal Water Pollution Control Act: or certain special nuclear or byproduct material as defined by the Atomic Energy Act of 1954.

The United States Environmental Protection Agency (USEPA) employs extensive and rigorous criteria to determine whether a waste is hazardous [5]. A waste is hazardous if:

(1) it is not excluded in listings which identify domestic sewage, point source discharges to surface waters, overburden waste from mines and sewage sludge from publicly owned treatment works;

(2) it exhibits any of the characteristics of hazardous waste in terms of ignitability, corrosivity, reactivity or extractive procedure toxicity.

Ignitability of liquids is determined by a Pensky–Martens Closed Cup Tester or a Setaflash Closed Cup Tester in accordance with prescribed methods. A flash point of less than 60°C (140°F) qualifies liquid wastes in this category. Solid wastes which cause fire under friction at standard temperature and pressure or by absorption of moisture or spontaneous chemical change or solids which, when ignited, burn so vigorously and persistently that they cause a hazard are also included in this category. Ignitable compressed gases and specific oxidizers are also included in this category.

Corrosive wastes are liquid wastes with a pH less than or equal to 2 or greater than or equal to 12.5 or which corrode steel under specified test conditions at a rate greater than 6.35 mm per year.

Reactive wastes are those which are normally unstable and readily undergo violent change without detonating, or react violently with water, or form potentially explosive mixtures with water, or when mixed with water generate toxic gases, vapours or fumes in a quantity sufficient to present a danger to human health or the environment, or is a cyanide or sulphide which, when exposed to pH conditions between 2 and 12.5, can

generate toxic gases, or are capable of detonation or explosive decomposition or reaction at normal temperatures and pressures.

The extractive procedure toxicity (EP toxicity) is a test in which 100 grams of a representative sample are obtained by a prescribed sampling procedure and separated into solid and liquid components by a prescribed method. Solid residues are segregated according to particle size. Residues which pass through a 9.5 mm standard sieve are weighed and placed in an extractor with 16 times its weight of de-ionised water. Residues which have larger particle size are first ground and then subjected to the same procedure. The extractor mixes the contents so that all sample surfaces are wetted. The pH is measured and if greater than 5.0 it is reduced to 5.0 ± 0.2 by adding 0.5 N acetic acid. The pH is monitored at prescribed intervals and if it rises above 5.2 more acetic acid is added to maintain this condition. The limit of acid addition is set at 4 ml of acid per gram of solid. The mixture is agitated for 24 hours at 20–40°C. At the end of this time the components are separated. Any liquid retained from the sample preparation procedure is added to the solution obtained from the extractive procedure. The aqueous solution is analysed for arsenic, barium, cadmium, chromium, lead, mercury, selenium, silver and six other organic halogen compounds by prescribed methods. The maximum concentration of these components is specified. In order to allow for attenuation and dilution, USEPA consider that if the concentration of any pollutant in this extract exceeds the Federal Drinking Water Standard by 100-fold then the waste is classified as hazardous. USEPA chose these conditions of test to simulate the acidic leaching medium which occurs in actively decomposing landfills. USEPA recognises that codisposal of industrial waste in a municipal landfill generates more aggressive leachate media than other landfills and describes codisposal as a 'mismanagement scenario'.

(3) it contains any of the toxic constituents listed in Table 2 unless after consideration of any of the following factors the 'Administrator' considers that the waste is not capable of posing a substantial present or potential hazard to human health or the environment when improperly treated, stored, transported or disposed of or otherwise managed;

(i) the nature of the toxicity presented by the constituent,

(ii) the concentration of the constituent in the waste,

(iii) the potential of the constituent or any toxic degradation product of the constituent to migrate from the waste into the environment under improper management,

(iv) the persistence of the constituent or any toxic degradation product of the constituent,