





Sustainable solid waste management (SWM) framework

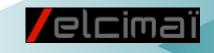






GIRUS (2005-2007)

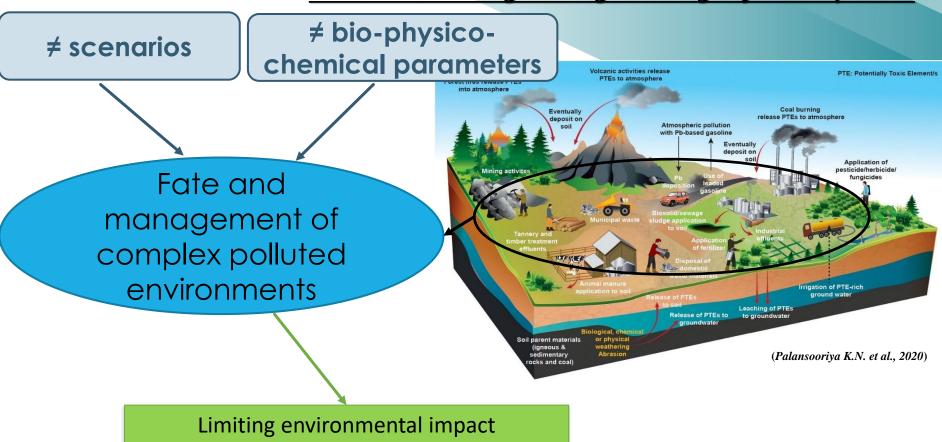






Laboratoire DEEP (Déchets, Eau, Environnement et Pollutions - Wastes Water Environment Pollutions)

Environmental engineering in the age of Anthropocene



Human influence on planet (nonlinear scale)

« Anthropocene [...] marks the collision of the planet's history with that of the humanity that occupies it. »

[Atlas de l'Anthropocène, p. 11, F. Gemenne, A. Rankovic, atelier de cartographie de Sciences Po, presses de Sciences Po, 2019]

O Possible proposed start date of Anthropocene **PLANETARY** BOUNDARIES History of humanity > history of access to energy in more available and more concentrated forms European conquest of Amerinalhi Y. et. Al. 2017) Spread of farming Homo sapiens expansion out of Africa Fire and Emergence meat eating of Homo Revolution Large-scale mining Megafaunal extinctions 10 million 1 million 100,000 10.000 1,000 100

This increased use of energy is leading to:

- Disrupting the Earth's major biogeochemical cycles;
- Depleting the various "stocks" of living organisms;
 - Generate a considerable amount of waste (3.8 Gt of waste/year for OECD countries alone, according to UNEP in 2015).





Le Monde ACTUALITÉS Y ÉCONOMIE Y VIDÉOS Y DÉBATS Y CULTURE Y LE GOÛT DU MONDE Y

Comment les déchets ont envahi tous les milieux : la folle histoire du « poubellocène »

les déchets ont colonisé le vivant. Au-delà des défis techniques qu'ils soulèvent, ils sont devenus un terrain d'enquête pour les sciences humaines, qui s'attachent à éclairer les systèmes et les mythes à la source de leur production.

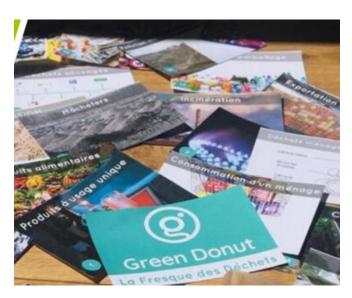
How waste has spread to every environment:

the crazy story of
"wastocene"

And you, what do you know about waste and Critical Raw Materials (CRM)?



Activity: The Waste Fresk



Objective: To uncover the hidden environmental impact of your daily consumption by tracing the journey of the resources and waste we generate.

How it works: In this collaborative workshop, you will work in groups to connect a set of cards representing different stages of a product's life cycle. By establishing cause-effect relationships and mapping material flows, you will collectively build a visual "fresco" that reveals the complete story behind our waste.

Inspired by the "Climate Fresk" methodology.

Waste fresk

Lot 1

The Systemic Dilemma: Products vs. Consumption

An analysis of the interdependent relationship between product design and consumer demand in shaping waste streams.

- End-of-Life Pathways for Common Products

A review of dominant waste treatment methods (landfill, incineration, recycling), their environmental consequences, and a special focus on composting as a sustainable alternative for organic waste.

- Quantifying the Impact: A Case Study of Incineration









Lot 1

The **incineration of 1 ton of waste** doesn't make it disappear; it transforms it into other forms of waste:

- ▶ Bottom Ash: ~180 kg (often used for road base or landfilled)
- > Fly Ash: ~30 kg (a hazardous material requiring special disposal)
- Recovered Metals: ~11 kg (a positive output that can be recycled)



Lot 2

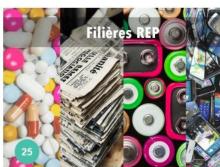
- Our consumption decisions determine what becomes waste.
- Distinguishing between composting (aerobic) and anaerobic digestion.
- Packaging represents up to 40% of the average household's waste stream.

Waste fresk













Waste fresk

Lot 3

- Our Waste Breakdown
 51% Residual Waste
 29% Recycled Materials (sorted waste)
 20% Dedicated Disposal (e.g., hazardous materials)
- Treatment Pathways
 68% of residual waste is
 incinerated (often with energy recovery).
- The Impact of Recycling
 Recycling saves 23 million tons of CO₂
 annually compared to virgin material production.

Source: CITEO, 2022 (France)







Waste fresk

Lot 4

- The European Plastic Challenge

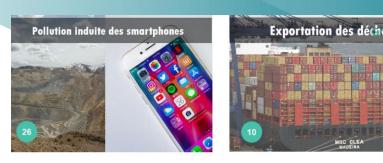
- The EU generates 30 million tons of plastic waste annually.
- Yet, only 17% is recycled—the rest is incinerated, landfilled, or leaks into the environment.

- The Hidden Material Footprint of Technology

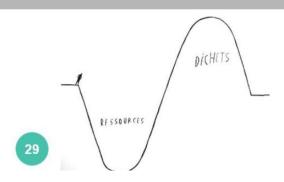
- Producing a 150g smartphone requires over 70 kg of raw materials.
- That's a material footprint 600 times its final weight.

- Approaching Planetary Boundaries

- Growing demand is accelerating resource depletion.
- We are moving closer to a critical threshold for key non-renewable materials.



Raréfaction des ressources



Waste fresk

Lot 5







- Waste's Contribution to Climate Change
- While not the largest source, waste management is a significant. emitter, responsible for 2.5% of France's total GHG emissions.
- The upstream impact of products we throw away—their ———— "ecological backpack"—is often far greater.

- The Hidden Weight of Consumption: The Ecological Backpack

The "Ecological Backpack" is the total weight of natural resources (water, soil, minerals) extracted and moved to create a product. Example: A 5g gold ring has a backpack of over 3 tons of mined ore. This "hidden" upstream impact is a major, but often overlooked, driver of climate change.

Waste fresk



LECTURES OVERVIEW



- Introduction Waste system
- Classification and current legislation
 - Sustainable waste management

Watch this video to learn SWM is a universal issue that requires immediate attention

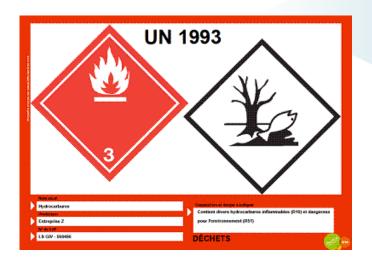
(OLC) Open Learning Campus



Waste is growing and it makes sense to manage it properly. In an era of rapid urbanization and population growth, waste management is a critical component of sustainable, healthy and inclusive cities and communities.



- > No satisfactory waste definition.
- Depending on the actors involved and the context to which we refer, the notion of waste may cover objects of different natures and functions.
- ➤ Each definition aims to establish, for a given stakeholder group, the set of targets that must be met with particular behavior or attention, but it is ultimately the legal definition that must serve as a reference.



Regulatory approach

Code de l'environnement : Art L 541-1 (15 juillet 1975)

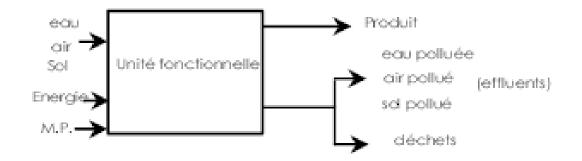
« For the purposes of the present law, "waste" means any residue of a production, transformation or use process, any substance, material, product or, more generally, any movable resource discarded or intended for discarding by its holder ».

European Directive of March 18, 1991



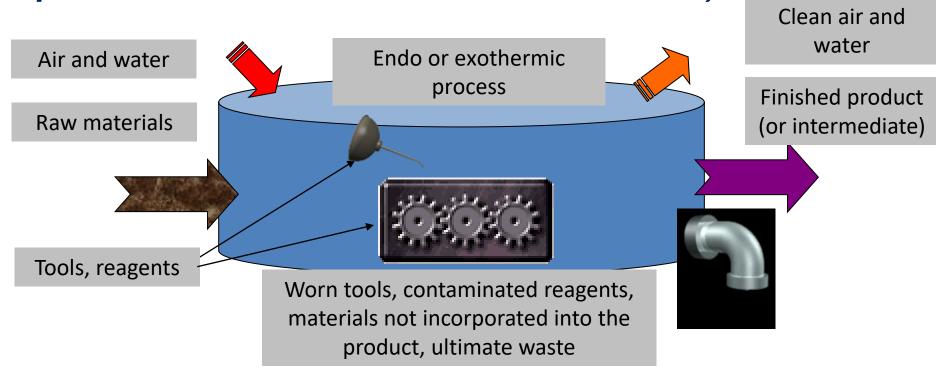
Functional approach

« Waste is then considered as a flow of material from a functional unit, representing an activity or set of activities »



WASTE SYSTEM

Nature of waste: Concept of reactor (unitary operation of implementation and transformation of material)



■ Waste vs Effluents

- Effluents: continuous production via a liquid or gaseous outfall (sewer, chimney, etc.)
- Waste : batch production (solids or liquids, rarely gaseous)
- Common characteristic: composition and characteristics not voluntarily controlled by the process (difference with co-product)





WASTE SYSTEM

Nature of waste: Concept of reactor (unitary operation of implementation and transformation of material)

Most industrial systems evolve towards this scheme ideal which favors the choice of materials, savings of energy and material, develops recycling, minimizes use dangerous substances ... any strategy that we found in what is now commonly called ecology industrial.







A large variety of definitions and classification approaches are used.

Defining waste can at times also be a case-by-case decision.

The national waste regulation is the main reference point in this regard.

Waste can be characterized (and classified) by its nature, but also by its producer, its method of collection, the organization that supports it, or a mix of these concepts.

Classification according to the waste producer

- "household waste", the initial producer of which is a household;
- "waste from economic activities" (DAE), the initial producer of which is not a household.





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Classification of waste by origin







Classification according to waste nature

Here are two main categories of waste according to the risk they pose to humans or the environment.

- hazardous waste;
- non-hazardous waste (paper, plastics, metals, organic waste...).
 In this last category, we also distinguish inert waste, which is neither chemically nor biologically reactive and will not decompose or only very slowly.

Hazardous waste - Generalities

Hazardous waste induces risks to both people and the environment. They must therefore be the subject of special precautions. As with other waste, the priority is to reduce their quantity and their harmfulness.



Regulation and classification of hazardous waste

Content in variable quantities, toxic or hazardous elements presenting **risks to human health and the environment** (article R. 541-8 of the environment code: *).

Whatever their origin or the quantity produced, classified as dangerous if it has 1 or more of the 15 hazardous properties listed in Appendix I (Art. R. 541-8 EC). They can be organic (solvents, hydrocarbons...), mineral (acids, metal hydroxide sludges...) or gas.

With around **11 million tons**, hazardous waste represents **3% of the waste produced** in France. The mixing of hazardous waste is prohibited, except by exemption (Art. R. 41-7-2 EC).

Hazardous waste - Particularities

Most hazardous waste originates from industrial production.

- **E-waste**: from electric and electronic equipment such as end-of-life computers, phones and home appliances. (PCB, metals...).
- **Medical waste**: from the human and animal healthcare systems (medicines, chemicals, pharmaceuticals...). It could be infectious, toxic or radioactive or contain bacteria and harmful microorganisms.
- Radioactive waste, with a special management and regulation.



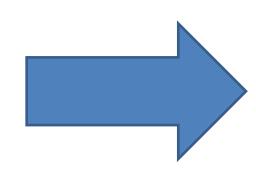
GENERAL STRATEGY OF WASTE MANAGEMENT

Paradigm shift from Waste Management to Resource Management

20th CENTURY

WASTE MANAGEMENT

"How do we get rid of our waste efficiently with minimum damage to public health and the environment?"



21st CENTURY

RESOURCE MANAGEMENT

"How do we handle our discarded resources in ways which do not deprive future generations of some, if not all, of their value?"

LECTURES OVERVIEW



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- Classification and current legislation
 - Sustainable waste management

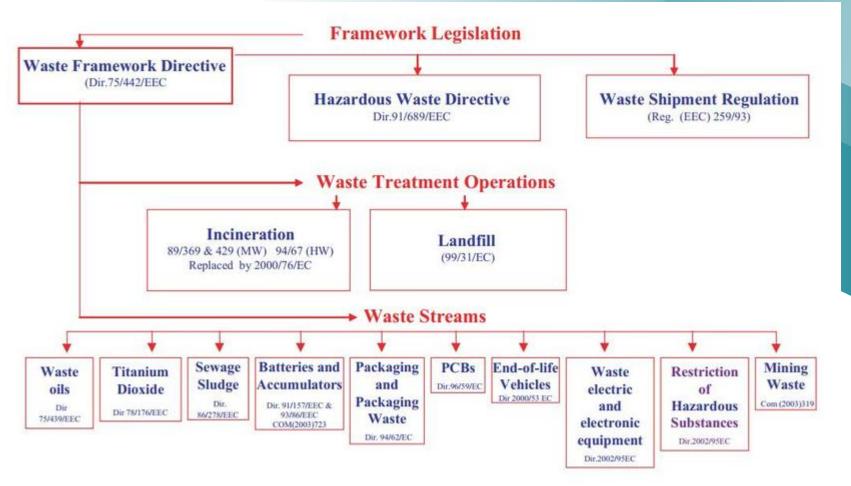


How to deal with Europe's waste?

https://youtu.be/ufL3yDs1ZQ8

Europe needs to reduce landfills and food waste, handle and recycle packaging waste better: these are the main goals of the "Waste Package" to be adopted by the European Parliament in Strasbourg.

EC WASTE LEGISLATION



- horizontal legislation;
- legislation on waste treatment operations;
- legislation on specific waste streams.

HORIZONTAL LEGISLATION

Horizontal legislation establishes the overall framework for the management of waste.

Council directive 75/442/EEC of 15 July 1975 on waste (the "waste framework directive" or WFD) includes the main definitions and principles concerning waste management. It was comprehensively revised in 1991, 1996 and again in 2008 and finally in 2018 (Directive (EU) 2018/851).

https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L .2018.150.01.0109.01.ENG

In essence, the WFD requires
Member States to give priority to



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- Waste prevention and to
- encourage re-use and recovery of waste.
- Member States must also ensure that waste is recovered and disposed of without endangering human health and
- without using processes or methods which could harm the environment.
- The directive also requires Member States to draw-up waste management plans and to establish a system for the authorization of waste management installations.

The WFD defines waste as "any substance or object in the categories set out in Annex I which the holder discards or intends or is required to discard." Annex I of the WFD lists 16 categories of waste.

This annex is now replaced by the **EWC** (**European Waste Catalog**)
Finally, the Waste Framework Directive (EU) 2008/98/EC (updated in **2018** - Directive (EU) 2018/851) sets criteria for By-products and End of Waste process

✓ By-product is a substance or object, resulting from a production process, the primary aim of which is not the production of that item. By-products can come from a wide range of business sectors, and can have very different environmental impacts. An incorrect classification could be the cause of environmental damage or unnecessary costs for business.

Examples: lacto-serum in a cheese factory, beet pulp from the production of sugar, HCl in aqueous solution from the manufacture of lubricant additive, etc.

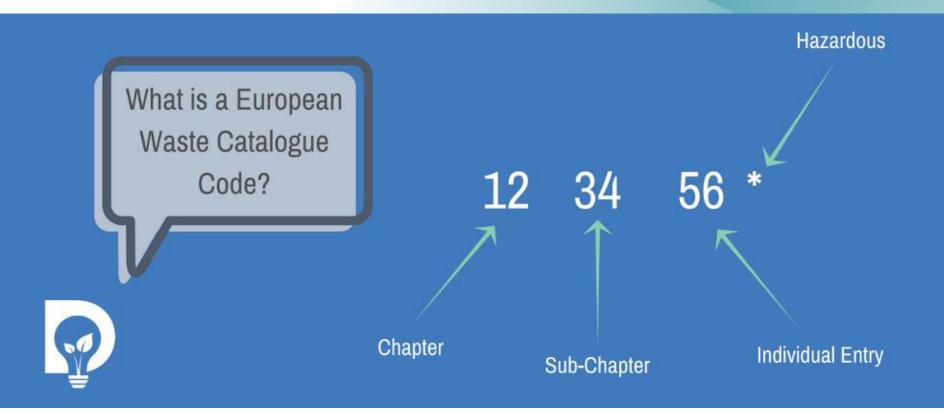
What are the end-of-waste criteria, and why are they needed?

End-of-waste criteria specify when certain waste ceases to be waste and obtains a status of a product (or a secondary raw material).

According to Article 6 of the WFD 2008/98/EC, certain specified waste shall cease to be waste when it has undergone a recovery (including recycling) operation and complies with specific criteria to be developed in line with certain legal conditions, in particular:

- > the substance or object is commonly used for specific purposes;
- > there is an existing market or demand for the substance or object;
- > the use is lawful (substance or object fulfils the technical requirements for the specific purposes and meets the existing legislation and standards applicable to products);
- > the use will not lead to overall adverse environmental or human health impacts.

Examples: a plywood panel made with a certain percentage of packaging wood chips, a fleece jacket made from waste plastic bottles ...



An EWC Code is a 6-digit code used to identify waste as listed in the EWC. It is formatted as 3 pairs of numbers, for example 12 34 56. It identifies and classifies waste into categories according to how these wastes have been produced. It adequately describes the waste being transported, handled or treated.

What is the structure of the EWC Code?

Chapters

The EWC is divided into 20 chapters, numbered 01 to 20.

Some chapters are based on the type of industrial process or business activity that produced the waste. For example:

✓ Chapter 04: Wastes from the Leather, Fur and Textile Industries

Other chapters are based on the type of waste. For example:

✓ Chapter 13: Oil Wastes and Wastes of Liquid Fuels (except edible oils, and those in chapters 05, 12 and 19)

The titles of these chapters are important. The waste must fall within the scope of the title to be considered within it. Some titles, like that for chapter 13, also exclude certain wastes from that entire chapter.

What is the structure of the EWC Code?

Sub-chapters

Most chapters contain several sub-chapters. These divide the chapter into sub-groups based on either industrial process and business activity, or type of waste..

Each sub-chapter is given another two-digit number (creating a four-digit number with the chapter number). For example:

- ✓ Sub-chapter 04 02: wastes from the textile industry
- ✓ Sub-chapter 13 01: waste hydraulic oils

The sub-chapter title, like the chapter title, is also important.

What is the structure of the EWC Code?

Individual entries

Within each sub-chapter are the classification codes for individual wastes.

These are given an additional two-digit number, to create a six-digit number with the chapter and sub-chapter numbers. For example

- √ 04 02 16* dyestuffs and pigments containing hazardous substances
- √ 13 01 10* mineral based non-chlorinated hydraulic oils

The description accompanying the code explains the scope of the code. It may do this in a variety of ways including references to the type of waste, the activity or process that produced it, its composition, or properties.

What is the structure of the EWC Code?

The asterisk (*)

The asterisk (*) indicates that the waste is hazardous, however there are 2 types of hazardous waste entries in the catalogue:

✓ "Absolute entries":

Those entries with an asterisk (*) and without a specific or general reference to "dangerous substances". Wastes covered under these entries are hazardous waste regardless of the concentration of any "dangerous substance" within the waste. "Absolute entries" are highlighted in red and marked with an "A".

- ✓ "Mirror entries": Those entries with an asterisk (*) and with a specific or general reference to "dangerous substances", which are generally identified by the word "containing" in the description and have a corresponding entry without an asterisk (*). "Mirror entries" are highlighted in blue and marked with an "M".
- √ 01 03 04* acid-generating tailings from processing of sulphide ore
- √ 01 03 05* other tailings containing dangerous substances

 M

Hazardous Waste Directive & Waste Shipment regulation

Council directive 91/689/EEC of 12 December 1991 on hazardous waste, as amended, complements the WFD for hazardous waste.

Annex III of the directive lists 15 properties of waste which render them hazardous within the meaning of the directive.

The directive also contains substantive requirements concerning, for example :

- ✓ the permitting of installations handling hazardous waste.
- ✓ it contains additional requirements concerning, for example,
 - limitations of mixing of hazardous waste,
 - record keeping and the shipment of waste at national level, which must be accompanied by a tracking form.

The Community has also adopted legislation concerning the cross-border shipment of waste. The main legal instrument in this field is Council regulation (EEC) No 259/93 of 1 February 1993 on the supervision and control of shipments of waste within, into and out of the European Community, as amended.

Hazardous waste - List of hazardous properties

H1	"Explosive": substances and preparations which may explode under the effect of flame or which are more sensitive to shocks or friction than dinitrobenzene.
H2	"Oxidising": substances and preparations which exhibit highly exothermic reactions when in contact with other substances, particularly flammable substances.
НЗА	"Highly Flammable"
	 liquid substances and preparations having a flashpoint of below 21°C (including extremely flammable liquids), or
	 substances and preparations which may become hot and finally catch fire in contact with air at ambient temperature without any application of energy, or
	 solid substances and preparations which may readily catch fire after brief contact with a source of ignition and which continue to burn or to be consumed after removal of the source of ignition, or
	- gaseous substances and preparations which are flammable in air at normal pressure, or
	 substances and preparations which, in contact with water or damp air, evolve highly flammable gases in dangerous quantities.
НЗВ	"Flammable": liquid substances and preparations having a flashpoint equal to or greater than 21°C and less than or equal to 55°C.
H4	"Irritant": non-corrosive substances and preparations which, through immediate, prolonged or repeated contact with the skin or mucous membrane, can cause inflammation.

H7	"Carcinogenic": substances and preparations which, if they are inhaled or ingested or if they penetrate the skin, may induce cancer or increase its incidence.
H8	"Corrosive": substances and preparations which may destroy living tissue on contact.
H9	"Infectious": substances containing viable micro-organisms or their toxins which are known or reliably believed to cause disease in man or other living organisms.
H10²	"Toxic for reproduction": substances and preparations which, if they are inhaled or ingested or it they penetrate the skin, may produce or increase the incidence of non-heritable adverse effects in the progeny and/or of male or female reproductive functions or capacity.
H11	"Mutagenic": substances and preparations which, if they are inhaled or ingested or if they penetrate the skin, may induce hereditary genetic defects or increase their incidence.
H12	Substances and preparations which release toxic or very toxic gases in contact with water, air or an acid.
H13	Substances and preparations capable by any means, after disposal, of yielding another substance, e.g. a leachate, which possesses any of the characteristics listed above.
H14	"Ecotoxic": substances and preparations which present or may present immediate or delayed risks for one or more sectors of the environment.
HP 15	'Yielding another substance': waste capable of exhibiting a hazardous property listed above not directly displayed by the original waste.

"Harmful": substances and preparations which, if they are inhaled or ingested or if they

"Toxic": substances and preparations (including very toxic substances and preparations) which, if they are inhaled or ingested or if they penetrate the skin, may involve serious, acute or chronic

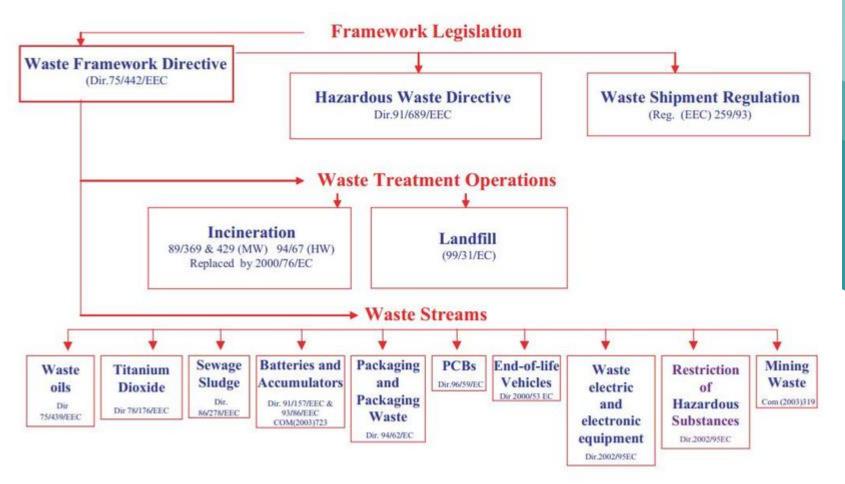
penetrate the skin, may involve limited health risks.

health risks and even death.

Н5

Н6

EC WASTE LEGISLATION



- horizontal legislation;
- legislation on waste treatment operations;
- legislation on specific waste streams.





Vincent Chatain
INSA Lyon – Laboratory DEEP
Bâtiment Sadi Carnot
Vincent.Chatain@insa-lyon.fr

THANK YOU FOR YOUR ATTENTION