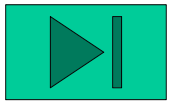
Waste Disposal

Old history of Solid Waste Management in Tokyo



1. Some basics in waste management

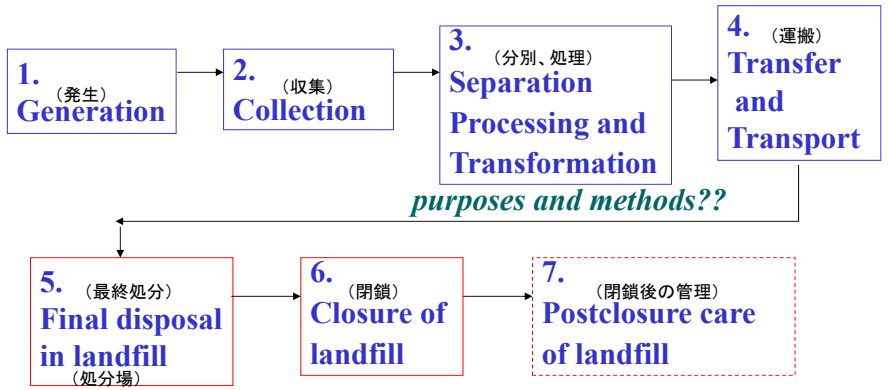
Human activities have generated both **municipal and industrial waste materials** (一般廃棄物) (産業廃棄物) from the ancient period. But disposal of the wastes was not much of a problem in that time, because the quantity and quality (mainly organic matter) of the wastes were not serious so that power of nature could treat them. In other words, the waste could be included in the ecological cycle giving less impacts on the nature.

However, the civilization and urbanization have made the waste disposal problem extremely complex, both for quality and quantity wise.

Hence the **proper waste management** is necessary, which can be done by the integration of various disciplines, not only science and engineering (***ecology, chemistry, biology, geology, hydrology, geotechnical engineering, sanitary engineering, construction management, planning***) but also social sciences (***economics, laws, politics***).

An engineer who will be involved with projects on waste management should have some basic knowledge on these disciplines

Flow of solid waste management



In the planning stage, some predictions and assessments are required for all processes. Various disciplines are necessary to make them reliable. Safety operation of waste management systems also needs integrated technology.

1.1 Ecology

1.1.1 Food chain in Ecosystems （生態系における食物連鎖）

Material and Energy flows in ecosystems:

Energy cannot be created or destroyed and flows only one way in the system.

Materials flow in a cyclical manner as nutrients. (Fig.1.1)

Living organisms need **nutrients** in addition to **energy**.

All organisms need **water**, most needs gaseous **oxygen**.

In addition, plants and animals require **carbon, hydrogen, phosphorus, potassium, nitrogen, sulfur, calcium, iron, and magnesium,** which also flow through ecosystem changing forms. (Fig.1.2) Certain other elements are required in smaller amounts as well.

(リン) (カリウム) (硫黄)

Fig.1.1 Simplified version of food chain: K.L. Shah (2000)
(食物連鎖)

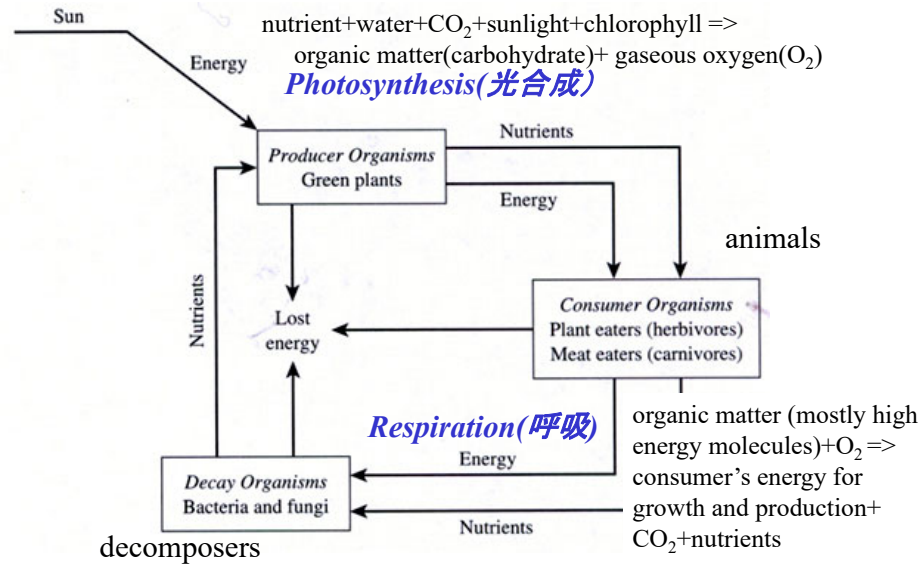
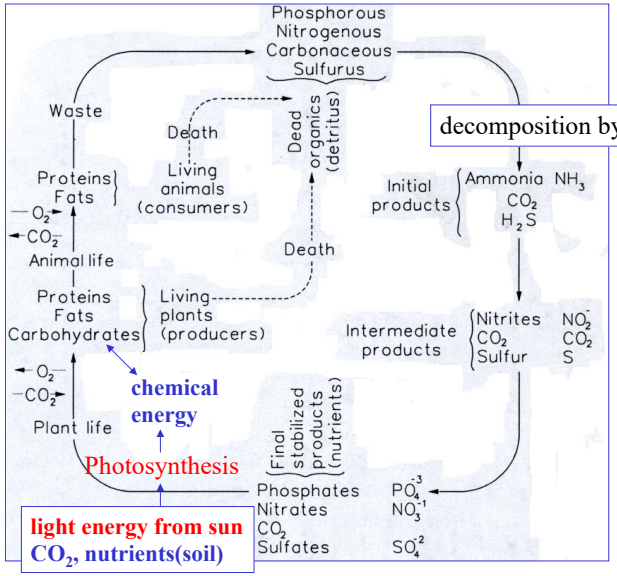


Fig.1.2 Aerobic cycle for phosphorus, nitrogen, carbon and sulfur K.L. Shah (2000)



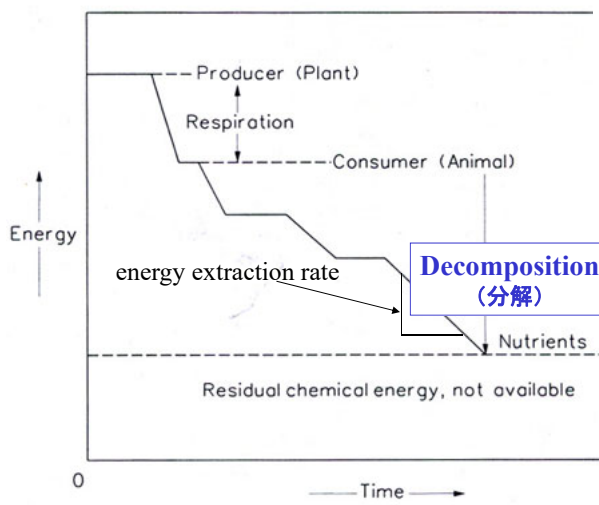
in landfill

decomposition by microorganism

nutrient cycles
(Biogeochemical cycles)
bio: living
geo: water, rock and soil
chemical: changing of matter

-Carbon cycle
-Nitrogen cycle
-Phosphorus cycle

Fig.1.3 Loss of energy through food chain: K.L. Shah (2000)



Energy from the sun received by plants is used by consumers and decomposers to make cellular material for maintenance of the organism.

three types of decomposer:
-aerobic
（好気性）
-anaerobic
（嫌気性）
-facultative organisms
(寄生)

1.1.2 Aerobic and Anaerobic Decomposition

Aerobic decomposition (好気性分解)occurs in the presence of molecular **oxygen,** which results in **oxidation** of carbon, hydrogen, sulfur, nitrogen, and phosphorus in complex organism molecules, forming simple substances: carbon dioxide, water sulfate, nitrate. It is **clean biochemical process that does not produce offensive odor.**

Aerobes: microorganisms that thrive in oxygen.

The equation of aerobic decomposition process is:

organics + O_2 => **CO_2**+H_2O + energy (1)

Most wastewater treatment plants (including leachate treatment) use aerobic process and it is also used for composting. *For example ??*

Anaerobic decomposition (嫌気性分解) occurs without free available oxygen, in which process **anaerobes** decompose organic materials, producing methane(CH_4), ammonia, hydrogen sulfide(H_2S) and volatile organic acids. Many of these compounds have **unpleasant odors**.

The equations of anaerobic decomposition are:

organics => organic acids + CO_2 +H_2O + energy (2) *by acid former*

organic acids => **CH_4** + CO_2 + energy (3) *by methane former*

Anaerobic decay is used in some wastewater treatment processes. **Methane** is one of the few odorless products with high energy value, thus the methane collected at sewage treatment plant and sanitary landfill is used as a fuel.

In addition to nutrients, water and oxygen, some condition affecting decomposition process, growth of bacteria => ***temperature, pH***.

Factors affecting decomposing process

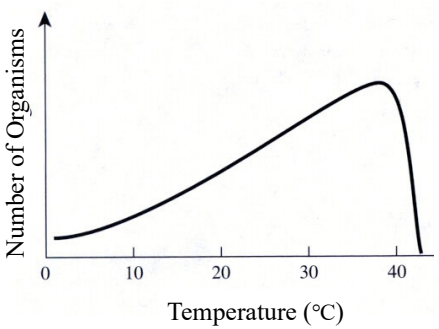


Fig.1.4(a) Optimum temperature range for bacteria growth for the most engineered system: K.L. Shah (2000)

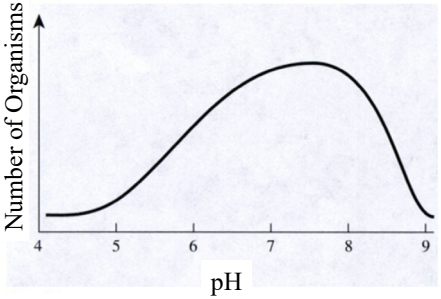


Fig.1.4(b) Optimum pH range for bacteria growth : K.L. Shah (2000)

1.2 Public Health

The public health and aesthetic problems associated with improper disposal of solid and hazardous wastes are the most important concerns in the waste managements.

Trends in developed countries: As the waste landfill is a typical nuisance facility, it is considered better to be away from human environment, even with reasonable standards, i.e.,well-designed treatment and disposal facility to avoid the situation which affects human health.

Garbage is heaven of **disease-causing organisms** (i.e.,pathogens). (病原菌)
Putrescible organic materials contained in garbage attract rodents and flies
Retain water also breed mosquitoes. (ねずみ)
Rodent-borne disease: *typhus, bubonic plague* (ペスト)
Diseases caused by flies and mosquitoes: *gastroenteritis, hepatitis, dysentery*(赤痢), *encephalitis*(脳炎), *malaria, typhoid*(腸チフス) *and paratyphoid fever*(パラチフス), *cholera and yellow fever.* (発疹チフス, 胃腸炎, 肝炎)

Improper disposal of the ***hazardous waste*** generated by industrial and commercial companies and consumption of the products, motor oil, batteries, paint and so on can harm public health and the environment. Examples of diseases caused by pollution of the environment:

cancer, asthma(気管支喘息), *bronchitis* (気管支炎), *emphysema*(肺気腫), *and nervous system related problems*.

It is impossible to shut down domestic industry or sacrifice the lifestyle of citizens.

Waste with high potential to affect public health should be managed properly ***by law and technology***.

1.3 Geology and Soils

Soils and geology are of the most importance in the landfill construction for various aspects, for examples:

•Expansion of **ground water contamination** highly related to geology and soil condition at the site.

•Soil plays important roles in the **prevention of the contamination**,

- ***liner system***;
- ***Leachate collection and drainage system***
- ***Cover materials*** both for temporary and final

Geological and soil conditions are **crucial factors in selecting ladfill site.**

Geotechnical engineers can be involved in the project as a main contributor

1.4 Environmental laws and regulations

•**Soil Waste Disposal Act and Resource Recovery Act(UAS)** 1965,1970

•**Waste Management and Public Cleansing Law** in Japan (廃棄物の処理および清掃に関する法律：廃掃法)(1970-2000)

•**Hazardous and Solid Waste Amendment (USA)** 1984

1.5 Feasibility of projects

1.5.1Financing

Financing is the crucial factor for the success of the project and also for avoiding the abundant waste disposal site.

Cost components:

• ***Capital costs***:

-predevelopment costs:*data collection, site selection, investigation* for land survey, geotechnical investigation, environmental impact statement and feasibility report, and also *permitting*.

-construction costs: *site development, general excavation, liner construction, leachate collection and treatment, landfill gas management, groundwater monitoring, surface water drainage controls, equipment (e.g., vehicles, scales), other facilities(e.g., maintenance building, access roads, utilities, fencing)*

•***Operation and maintenance cost***: *labor, equipment, utilities, administration costs, legal and fiscal services*

1.5.2 Benefit/Cost analysis

Tipping fee is the benefit of the landfill operation.

Not only tipping fee but also tax can be used for waste management e.p. municipal waste (MSW).

In Japan, MSW landfills are operated by public sectors and industrial waste landfills by private companies. Some bankrupted companies abandon the industrial (hazardous) waste landfill. Feasibility study is crucial and regal permission should be severely controlled.

1.5.3 Risk Analysis

Cost/benefit analysis becomes very complex when **life and health issues** is considered in the calculation. Risk analysis is conducted for this purpose. The risk analysis is divided into two phases: **risk assessment and risk management**, from which the risk in terms of money can be obtained. They are very useful tools for decision making but also for verifying the technical investment.

In order to make the risk analysis more reliable, the reliabilities on uncertainties should be increased, which is the mission of engineers.

The assessment of human exposure – one of the elementary concepts of risk assessment, consisting of two risks:

-toxicity of the substance or its hazardous nature

-amount of the length of the exposure to the substance, which can be described by exposure pathways:

Fig.1.6 Exposure pathways: K.L. Shah (2000)

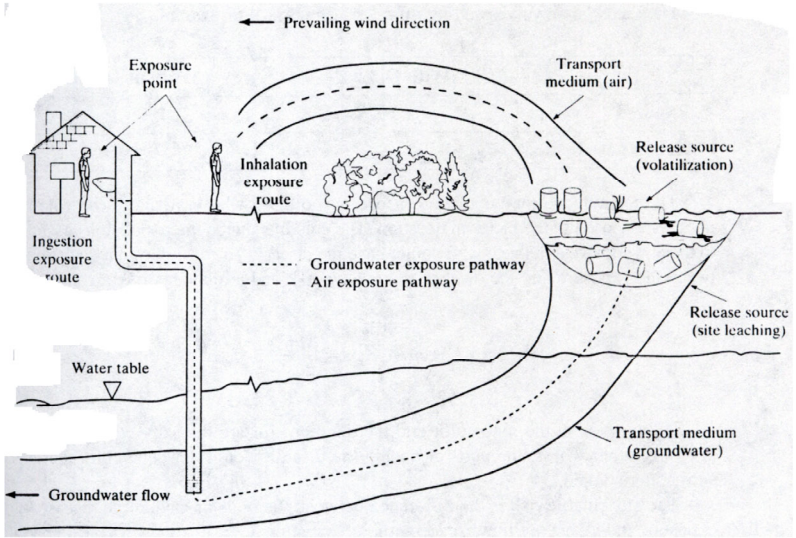


Table 1.1 Toxicity data for selected potential carcinogens K.L. Shah (2000)

Chemical	*Category*	*Potency Factor Oral Route* $(mg/kg/day)^{-1}$	*Potency Factor Inhalation Route* $(mg/kg/day)^{-1}$
Arsenic ヒ素	A	1.75	50
Benzene	A	2.9×10^{-2}	2.9×10^{-2}
Benzol (a) pyrene	B2	11.5	6.11
Cadmium カドミウム	B1	—	6.1
Carbon tetrachloride	B2	0.013	—
Chloroform	B2	6.1×10^{-3}	8.1×10^{-2}
Chromium VI 六価クロム	A	—	41
DDT	B2	0.34	—
1,1-Dichloroethylene	C	0.58	1.16
Dieldrin ディルドリン	B2	30	—
Heptachlor	B2	3.4	—
Hexachloroethane	C	1.4×10^{-2}	—
Methylene chloride	B2	7.5×10^{-3}	1.4×10^{-2}
Nickel and compounds	A	—	1.19
Polychlorinated biphenyls (PCBs)	B2	7.7	—
2,3,7,8-TCDD (dioxin)	B2	1.56×10^{5}	—
Tetrachloroethylene	B2	5.1×10^{-2}	$1.0–3.3 \times 10^{-3}$
1,1,1-Trichloroethane (1,1,1-TCA)	D	—	—
Trichlorethylene (TCE)	B2	1.1×10^{-2}	1.3×10^{-2}
Vinyl chloride	A	2.3	0.295

Source: U.S. Environmental Protection Agency, "Guidelines for Carcinogen Risk Assessment," *Federal Register*, Vol. 51, No. 185, 1986.

PF: Potency Factor

$$PF = \frac{\text{incremental life time risk}}{\text{chronic daily intake (mg/kg/day)}}$$

life time risk= average daily dose x *PF*

2.1 Types and generation of waste

Waste management and public cleansing law

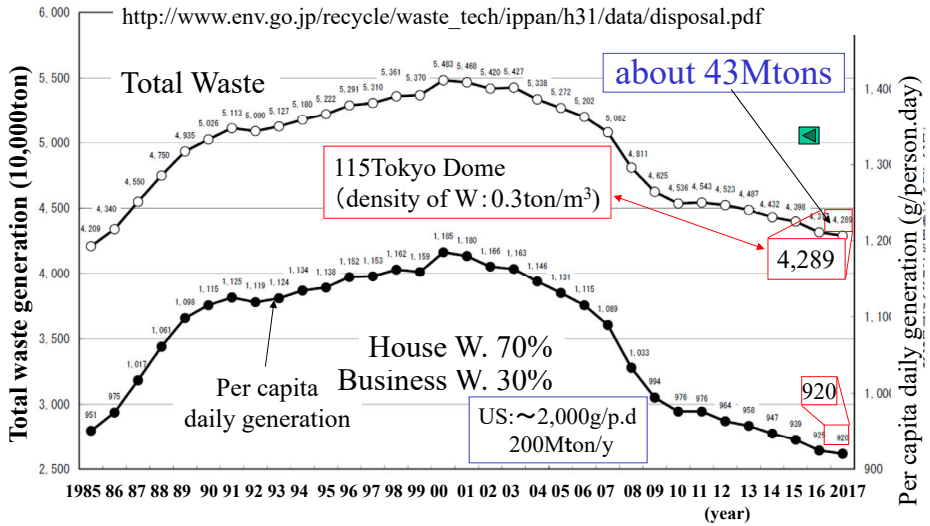
廃掃法（廃棄物の処理 および清掃に関する法律）　http://www.env.go.jp/en/laws/

Wastes: refuse, bulky refuse, ashes, sludge, excreta, waste oil, waste acid and alkali, carcasses and other filthy and unnecessary matter, which are in solid or liquid state (excluding ***radioactive waste*** **and waste polluted by radioactivity, soils generated in construction**).

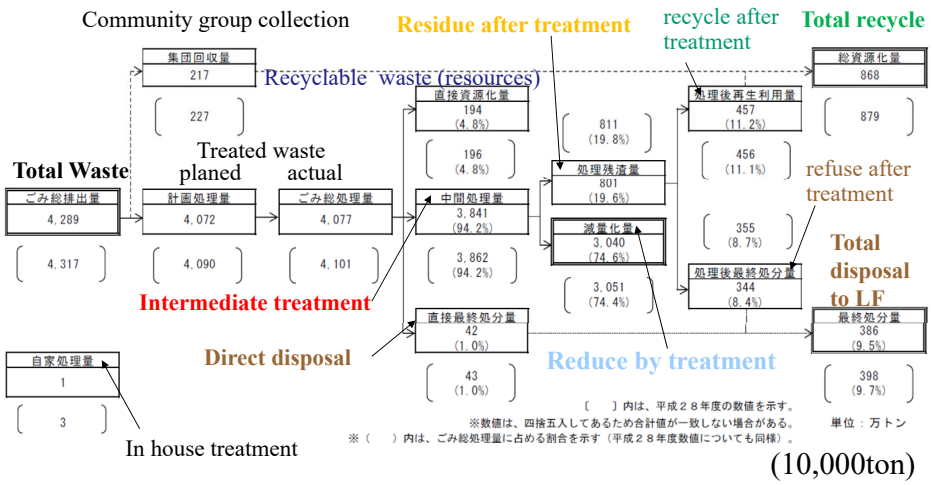
Wastes
- （一般廃棄物）**Municipal waste (household, office paper)**:
  - refuses（combustible, incombustible)（可燃、不燃）
  - bulky refuse （粗大ゴミ）
- （産業廃棄物）**Industrial waste:results as business activities**
  - Ashes, sludge, waste oil, waste acid, waste alkali, waste plastics and others specified by cabinet order
  - incombustible（5 stable wastes）

Disaster waste ?

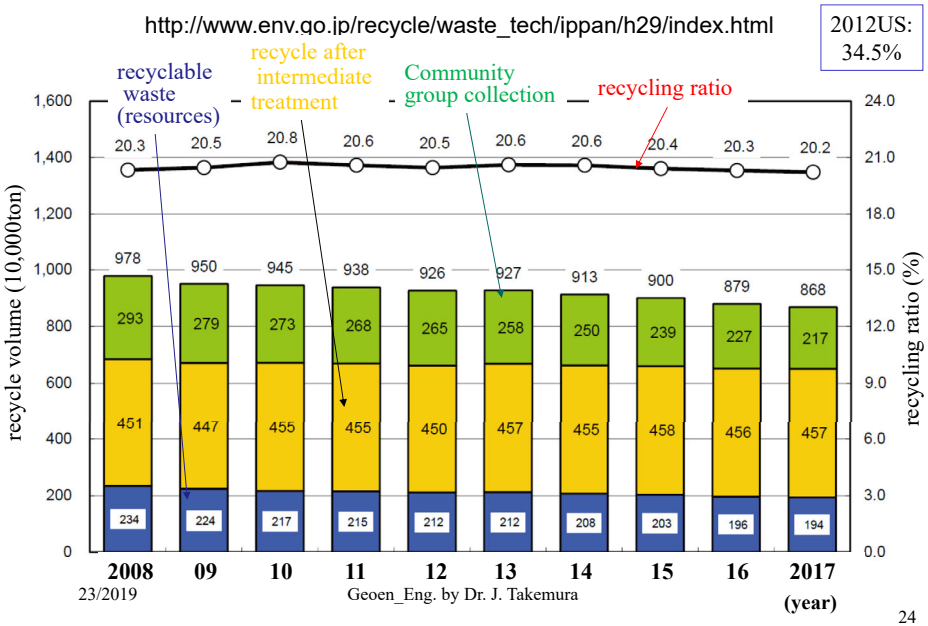
Chronological change in amount of municipal waste (nation wide in Japan)



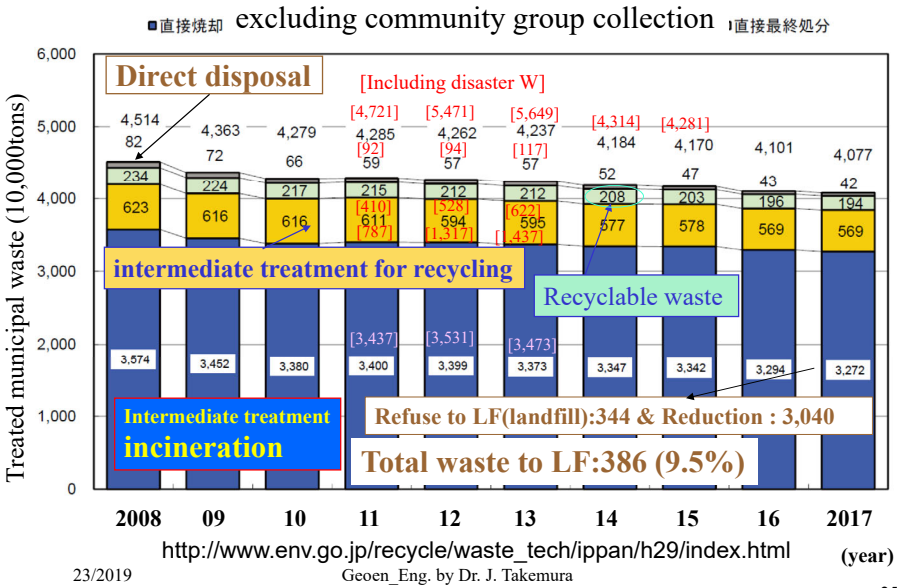
MSW management flow in Japan 2017



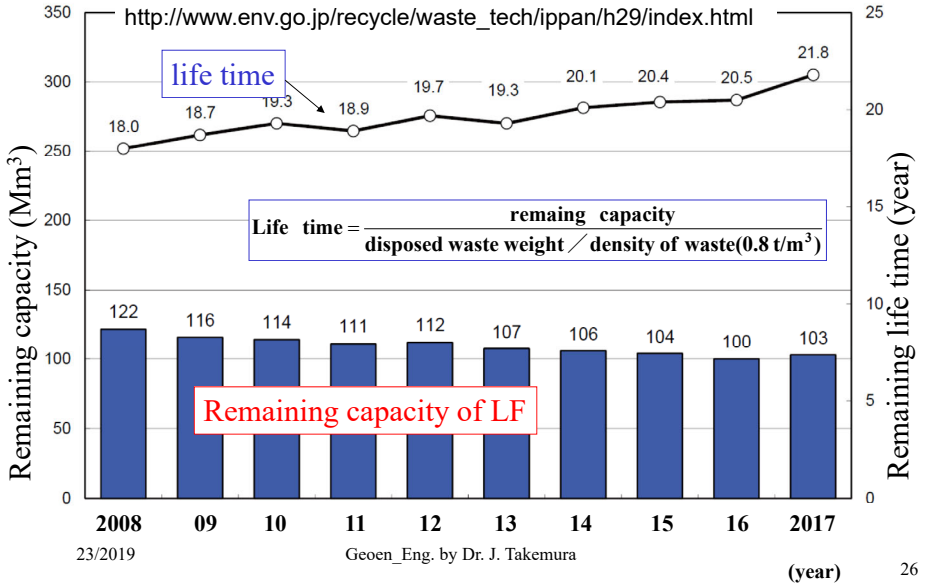
Recycle of municipal waste in Japan (Ministry of Env.)



Chronological variation of treated municipal waste



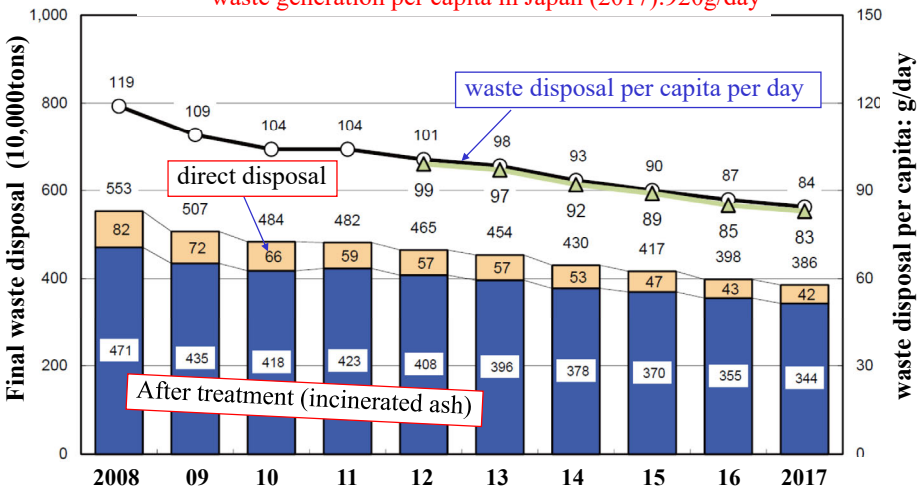
Remaining capacity of municipal landfill and life time



Chronological change of final landfill disposal volume

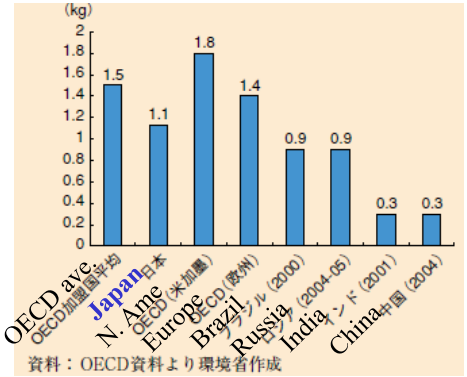
http://www.env.go.jp/recycle/waste_tech/ippan/h29/index.html

waste generation per capita in Japan (2017):920g/day

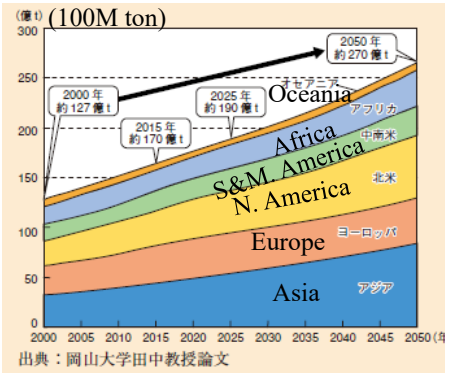


Generation of Municipal Soil Waste in the world

Generation Per capita. day (2005)

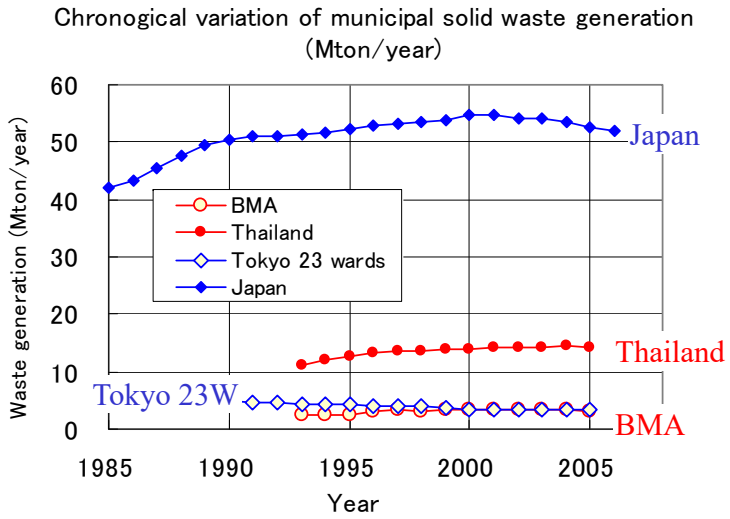


Prediction of generation (2000-2050)
世界の廃棄物排出量の将来予測



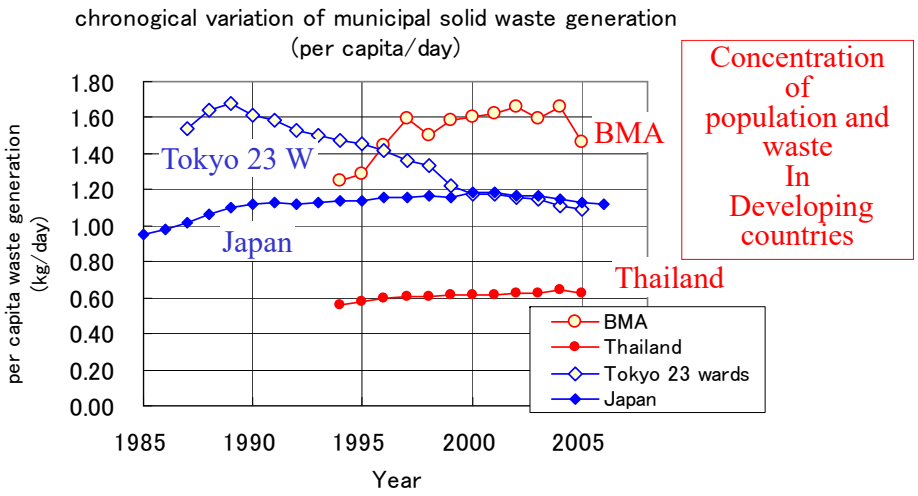
2008 White paper on Environment and Recycling Society, MOE
平成20年版環境・循環型社会白書（環境省）

Annual generation of municipal waste in Japan, Tokyo, Thailand and Bangkok



MOE, MGT, Bureau of Environment, TMG, 2006

Per capita daily generation of municipal waste in Japan, Tokyo, Thailand and Bangkok

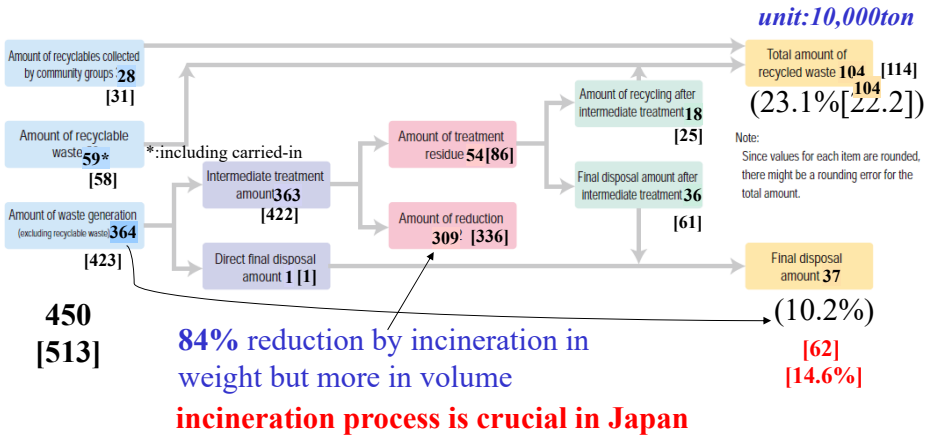


Concentration of population and waste In Developing countries

MOE, MGT, Bureau of Environment, TMG, 2006

Flow of municipal waste in Tokyo (as of FY2015) [2007]

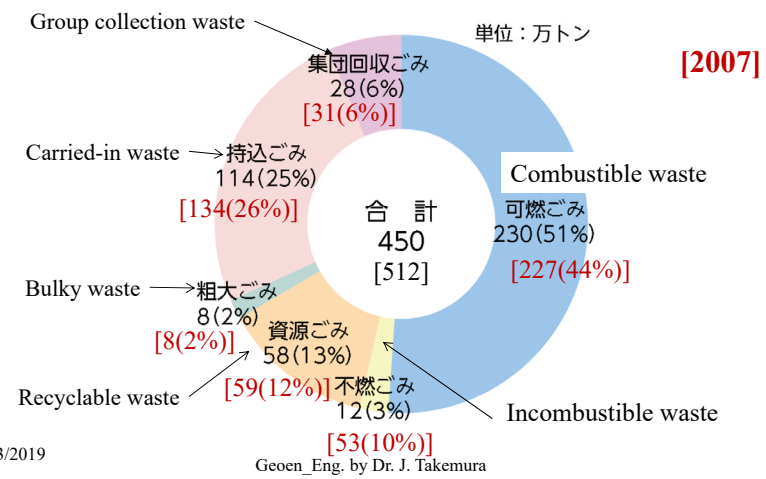
(Tokyo Metropolitan Government Environmental White Paper 2017)



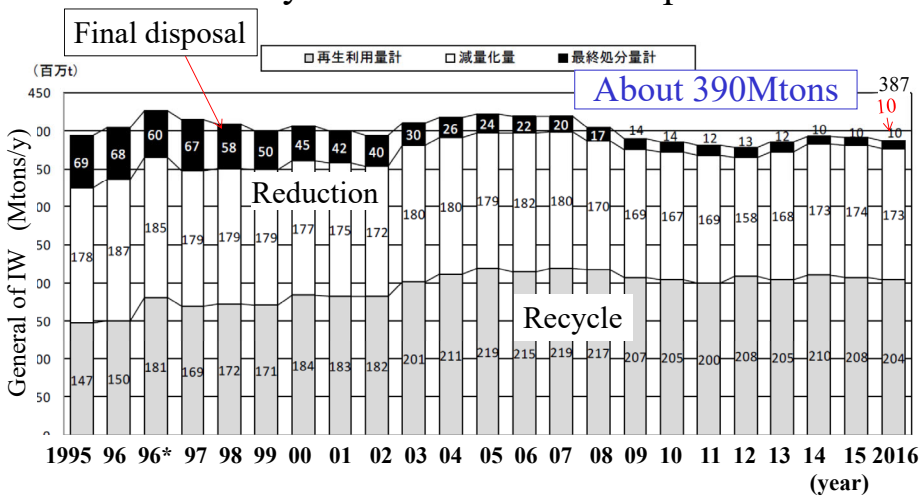
Amount of General Waste Generation by Waste Type in Tokyo 2015

(Tokyo Metropolitan Government Environmental White Paper 2017)

Unit: 10,000tons

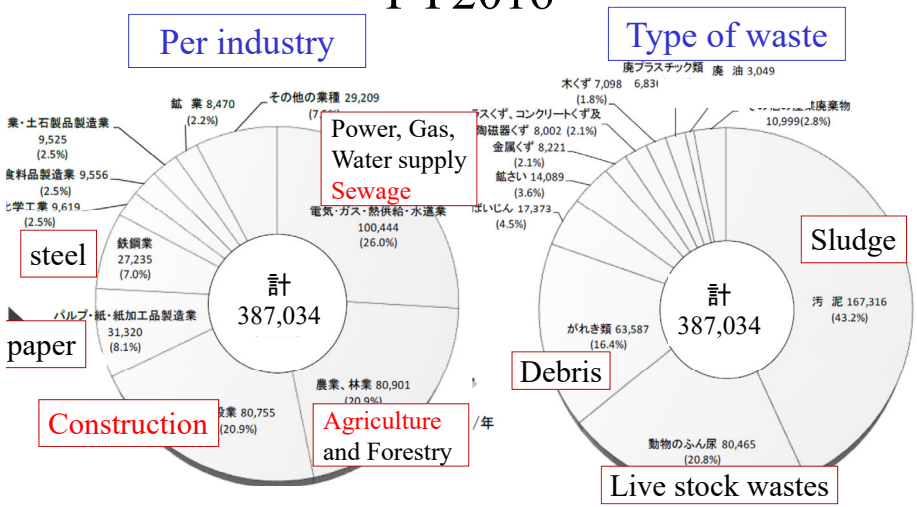


Generation of Industrial Wastes in Japan
Recycle、Reduce、final disposal



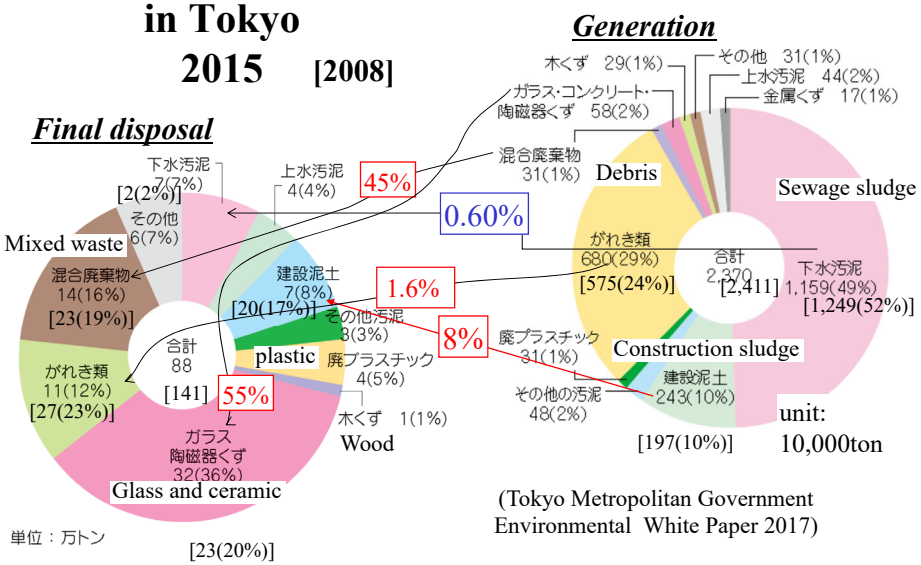
https://www.env.go.jp/press/files/jp/110521.pdf

Fraction of Industrial Wastes
FY2016



https://www.env.go.jp/press/files/jp/110521.pdf

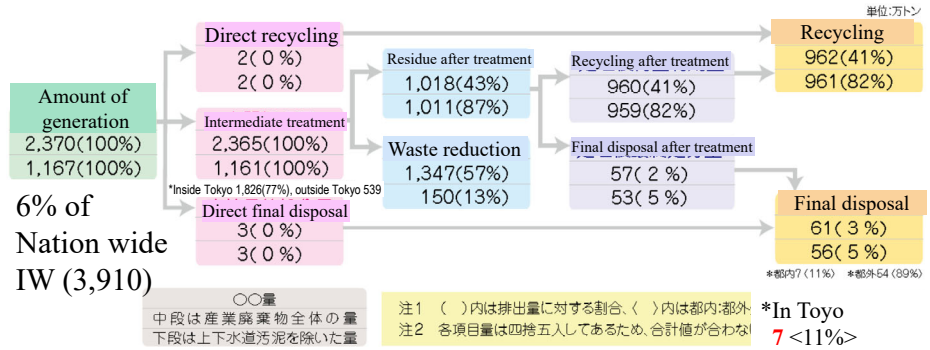
Industrial waste in Tokyo 2015 [2008]



(Tokyo Metropolitan Government Environmental White Paper 2017)

Flow of **industrial waste** generated in Tokyo- FY2015

upper:Total volume of industrial waste
lower:Volume excluding sewage and water works sludge



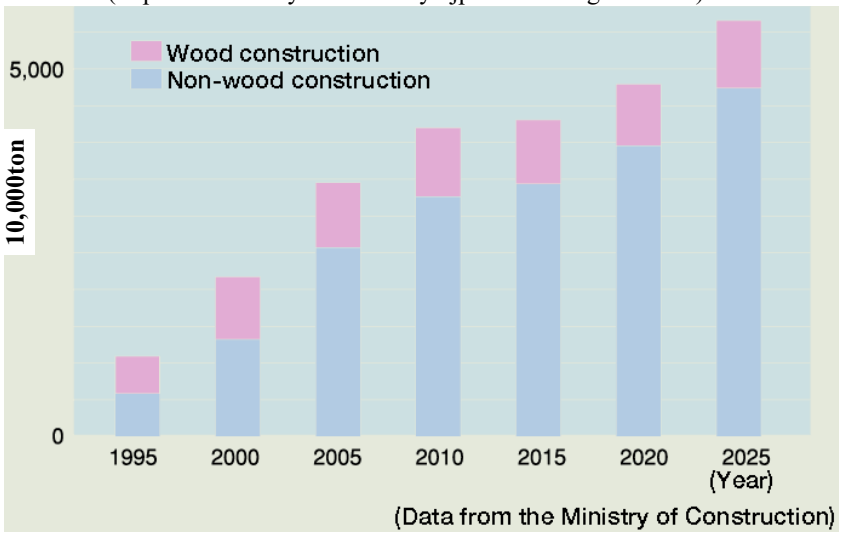
6% of Nation wide IW (3,910)

*In Toyo 7 <11%>
Outside of Tokyo 64<89%>

(Tokyo Metropolitan Government Environmental White Paper 2012)

Future prospects of **construction waste** generation in Japan

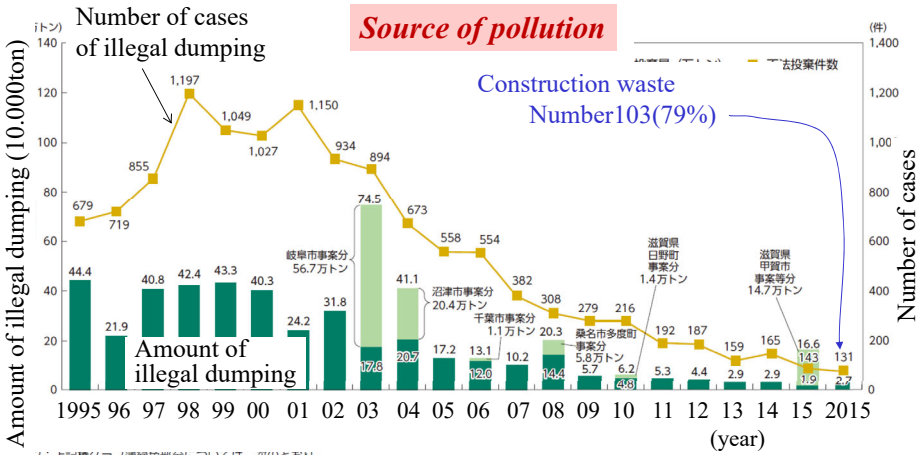
(http://www.kankyo.metro.tokyo.jp/kouhou/english2002/)



Transition of number of cases and amount of illegal dumping in Japan

産業廃棄物の不法投棄件数と量

(Environmental White Paper 2018, MOE)



Dada shows incidents in which the volume of waste dumped weighed 10tons or more.
Source; Ministry of the Environment

Demand of Waste Disposal

Never-ending generation of waste (e.g. municipal and industrial waste, sewage sludge, dredged soils)

⇩

3R: Recycle, Reduce and Reuse

⇩

Final disposal site

Strong opposition, Shortage of disposal site

⇩ ⇩

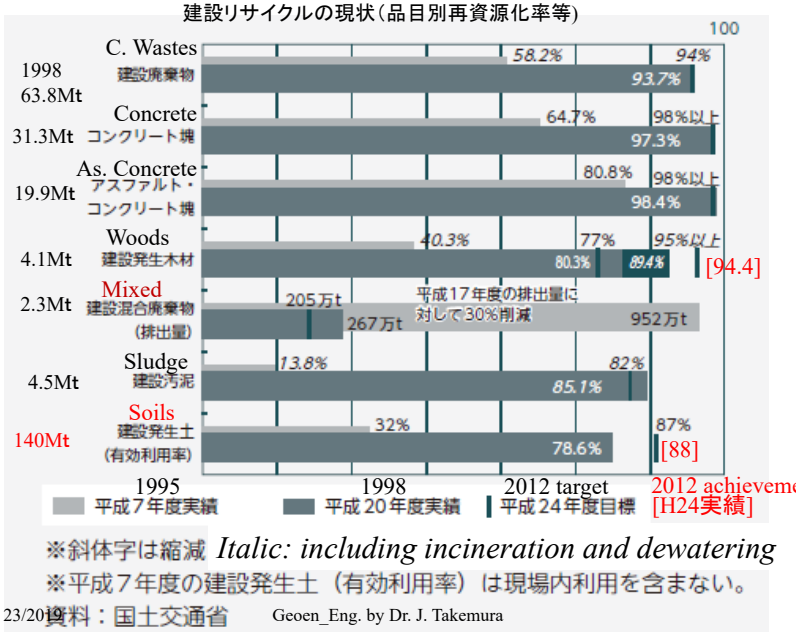
Well controlled Sanitary landfill

Sea surface reclamation as waste disposal landfill:

Must be Secured facility

Recycle of construction wastes

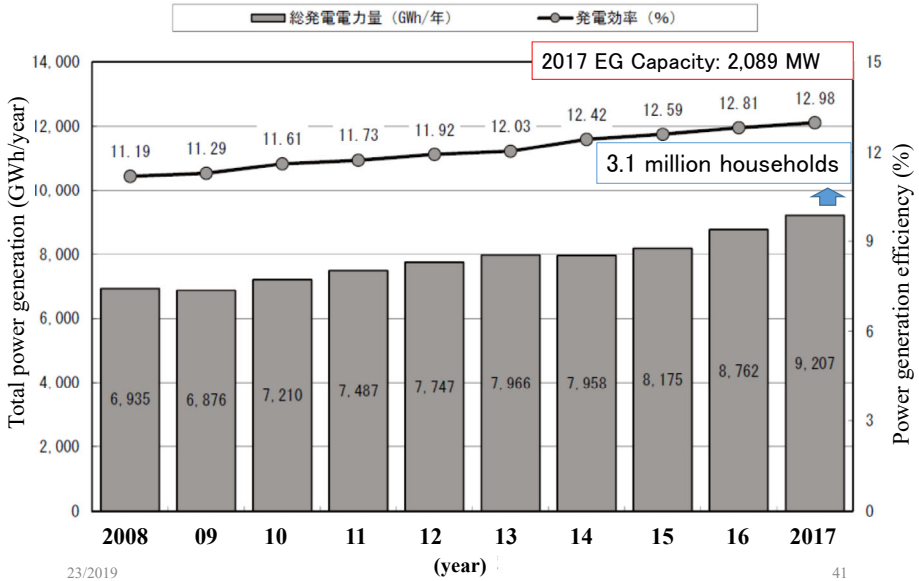
建設リサイクルの現状（品目別再資源化率等）



2009,2014 Environmental white papers

Electric power produced in Japan from waste power

http://www.env.go.jp/recycle/waste_tech/ippan/h29/index.html



Various Recycles

- Material Recycle
- Chemical Recycle
- Thermal Recycle

+Energy recovery

What need for enhancing the recycles?

- ***Segregation***
- ***Public awareness, education***
- ***Laws =>various recycle laws***
- ***Technology***

Waste Management Sustainability

Concerns for sustainable waste managements

Wastes

Source of Contaminants => Landfilling with risk reduction against environment, economic and social issues

What can we do as researchers or engineers?

What are proper disposal, treatment and monitoring?

What kinds of events and issues should be considered?

Short term ⇔ Long term

Technologically ⇔ Socially

Social benefit ⇔ Individual right

Expected events ⇔ Unexpected events

+ **NIMBY syndrome**

Disposal facilities
landfill, incineration, segregation

Resources => recycles, reuse