Part 3 -

Technical resources on Solid Waste Management

Contents

(A) Solid waste management – Facts and Figures

Solid waste definition

Waste is a generic term that refers to something which is no longer used and is discarded. Solid waste is waste generated in homes, restaurants, shopping centers, school, etc. when we consume a product and want to get rid of it.

Solid waste management as a global challenge

It is estimated that the world population now generates around 2 billion tons of solid waste each year of which 30% remains uncollected and is mostly openly burned or dumped somewhere. For the collected fraction, 70% is disposed in landfills and dumpsites [6]. If we look at numbers worldwide, 2 billion people are still lacking access to waste collection service, and 3 billion people do not have access to controlled waste disposal site. Current SWM practices are responsible for 8 to 10% of greenhouse gas (GHG) emissions worldwide [5].

Figure 18: SWM key figures

Yearly, 8 tons of plastic end up in the ocean which is equivalent to one garbage truck full of plastic dumping waste into the ocean every minutes, as shown in Figure 19.

Figure 19: Plastic key figures

Impact of waste mismanagement

Burning and dumping mixed waste are common practices that have a huge impact on human health and the environment.

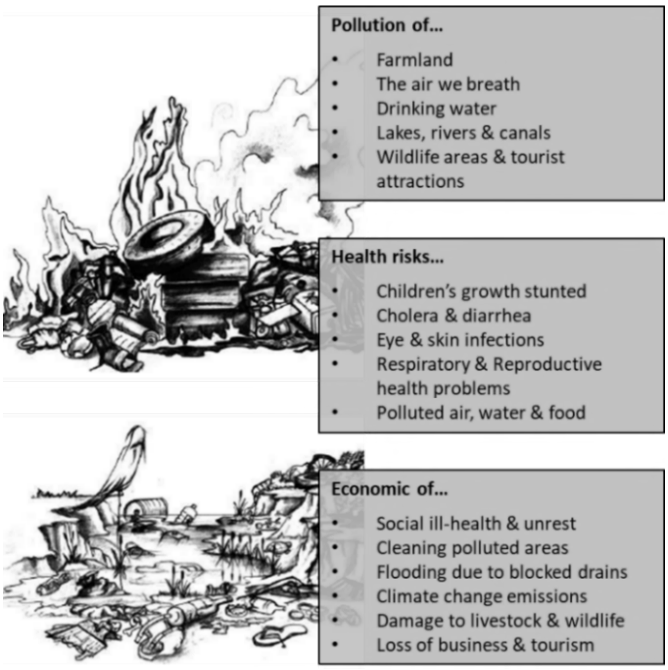


Figure 20: Impact of waste mismanagement [6] adapted from [8]

Burning threat: Even if sometimes not visible, the smoke from burning waste can enter lungs through nose and mouth and the tiny particles can poison the blood, cause respiratory diseases and cancer. Burning waste exacerbate soil pollution, water pollution and food contamination. It also pollutes the air by releasing toxic emissions (dioxin, furans, etc.) and contributes to climate change by emitting greenhouse gases (GHG) as well as short-lived climate pollutants such as black carbon (BC), or soot, which is 460 to 1'500 more harmful than CO2 (see Box 23 for more information on BC)[28]. Note that open burning of waste is prohibited by law in most countries worldwide.

Dumping threat: Dumping waste leads to visible plastic accumulation in nature, environmental pollution of soil and water. It is responsible for flooding due to drainage system blocking, spreading of diseases as it encourages breeding of mosquitoes among others disease vectors and GHG emissions (see Table 5 for organic waste specific issues). When waste is washed by the rain, it contaminated water supplies, harming crops, livestock and people. Plastic waste eventually reaches streams, rivers and the sea causing ecological and public health problems [8].

Box 23: Black Carbon [28]

Black carbon (BC), also called soot, is a fine particulate air pollutant (PM2.5), which is formed by the incomplete combustion of fossil fuels, wood and other fuels [28]. BC is a short-lived climate pollutant with a lifetime of 4 to 12 days only, yet with a great climate warming potential 460 to 1'500 times stronger than CO2 per unit of mass [28].

According to CCAC [28] and as shown in Figure 21, BC impacts on :

- **Health,** by increasing the risk of heart diseases, stroke, as well as lung diseases and cancer;
- **Climate,** by absorbing sunlight and converting it into heat;
- **Weather,** by preventing clouds formation and altering regional weather patterns and rainfall;
- **Snow and ice,** by accelerating the melting of ice and snow;
- **Agriculture & ecosystems,** by reducing sunlight and affecting plant health and its productivity

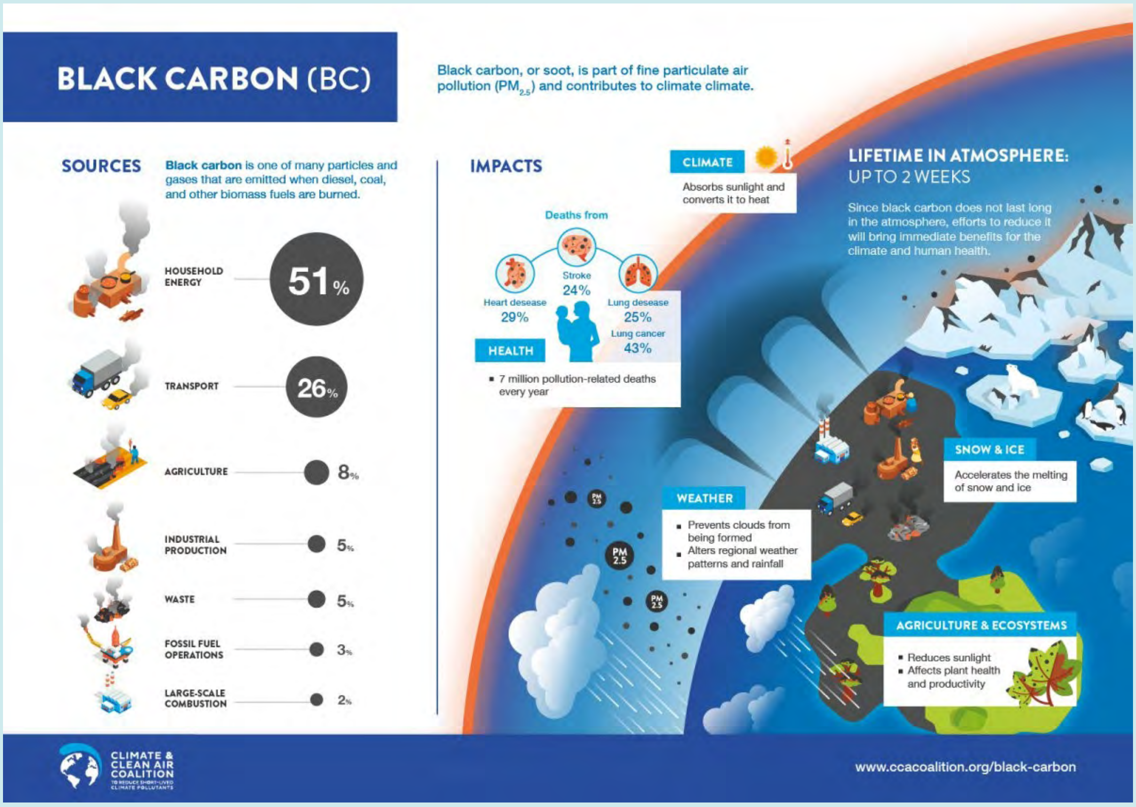


Figure 21: Black carbon key features [28]

As BC does not stay long in the atmosphere, efforts to reduce it will immediately bring benefits for climate and human health.

Additional resources:

Bond, T.C. et al., 2013. Bounding the role of black carbon in the climate system: A scientific assessment [29]

Reyna-Bensusan, N., 2020. The Impact of Black Carbon Emissions from Open Burning of Solid Waste [30]

CCAC - Black carbon [28]

Waste generation and composition worldwide

Waste generation and composition are key elements to be able to plan appropriate waste management systems at any scale. Waste generation refers to the amount of waste produced over a certain period of time, usually expressed in terms of kg per person per day, while waste composition refers to the type of material present in the waste, usually expressed in terms of percentage of a specific waste fraction amount over the total waste amount of waste generated (see Table 3).

Table 3: Waste generation and composition definition

	Definition	Typical units
Waste generation	Amount of waste generated/ produced over a time period	Kg/pers/day Kg/pers/year
Waste composition	Categorization of types of waste materials (e.g. organics, paper, glass, plastics, etc.)	% wet weight over total weight

Such data will for example influence:

- Waste prevention and reduction strategies,
- Help determine the capacity and number of collection vehicles or infrastructure needed to store the waste,
- Assess the feasibility and scale of treatment option,
- Identify recycling opportunities,
- Estimate lifespan of landfill and disposal sites, and
- Estimate trends to plans for the future.

On a global scale, waste generation rates varies from countries to countries and is highly influenced by the income levels, as shown in Figure 22. Low-income countries usually generated around 0.4-0.5 kg of waste per capita per day, whereas high-income countries generate up to 2 kg of waste per capita per day.

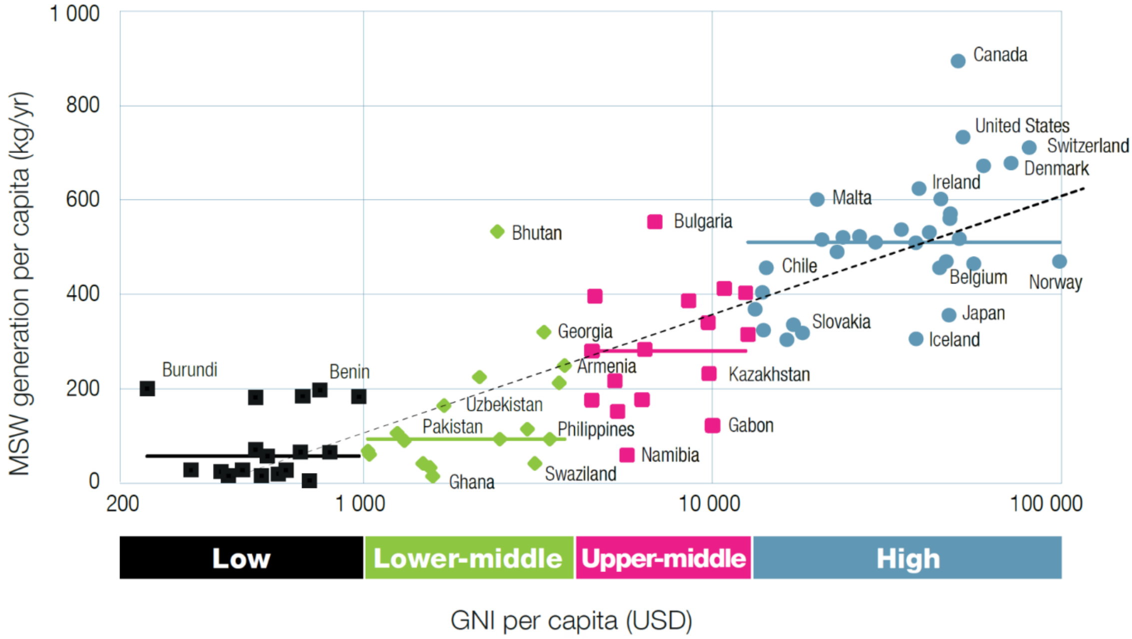


Figure 22: Waste generations rates and income levels [5]

The income level also influences the composition of the waste, as shown in Figure 23. Generally speaking, most of the waste produced in low-income settings is organic waste (typically 50-70% of total waste generated). Other waste fractions such as paper, plastic and glass have a higher percentage in high income settings than in low income settings.

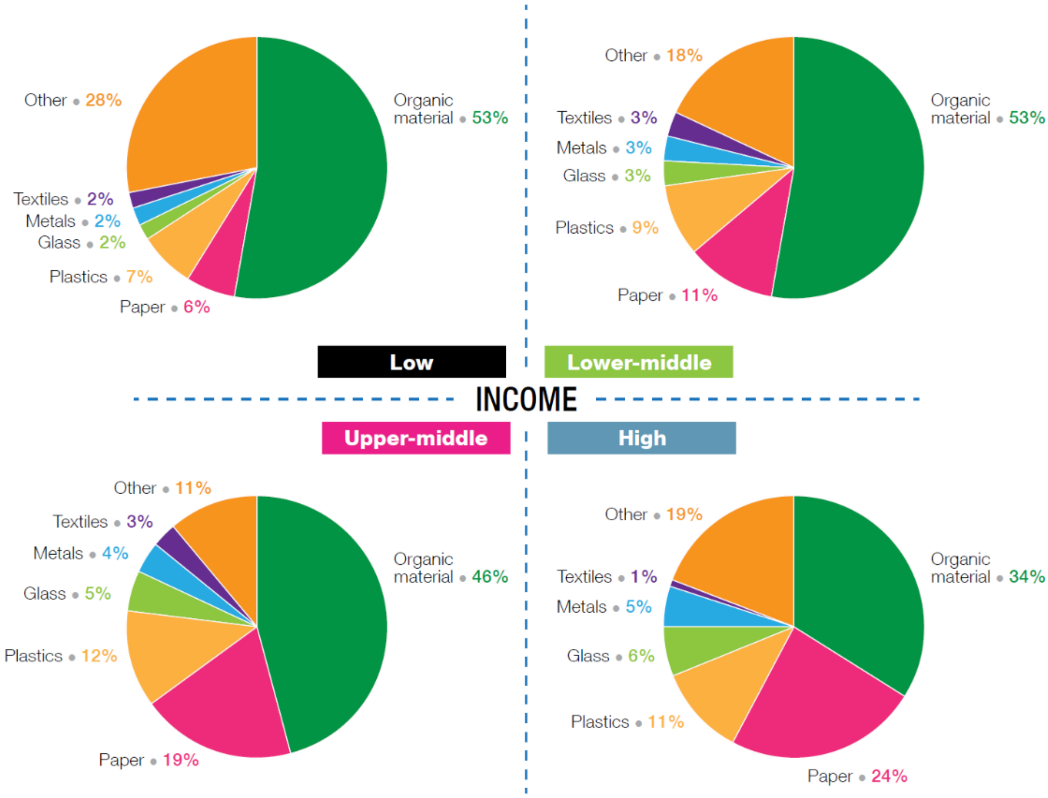


Figure 23: Waste composition patterns per income level (wet weight) [5]

Data on specific waste generation rate and waste composition per country can be found in the online database of the World Bank as well as in the "What A Waste 2.0" publication [10].

Besides general tendency, waste generation and composition may vary significantly from one location to another and is generally influenced by:

- Lifestyle
- Degree of urbanization
- Income levels
- Seasons (crops, tourism, festivities, etc.)

It is therefore recommended to rely on a local waste characterization study rather than national or regional data, and check for seasonal patterns. Information on how to perform a waste characterizations study can be found in T 2.A1.

Additional resources:

Wilson, 2015. Global Waste Management Outlook [5]

Kaza et al., 2018. What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050 [10]

(B) Solid waste fractions

Solid waste is not homogenous and is composed of a broad variety of materials. According to UN-Habitat, solid waste can be divided into the following categories [9]:

Organic

- Kitchen/ canteen waste – Cooked or uncooked food, organic waste from food preparation
- Garden/ park waste – Non-food biodegradable materials resulting from landscaping
- Paper & cardboard – Paper and cardboard packaging and products

Non Organic

- Plastics - film – Thins plastic used in packaging and for other purposes
- Plastic - dense – Hard plastic used in packaging and for other purposes
- Metal – Ferrous and non-ferrous metals packaging and products
- Glass – Glass packaging and products
- Textiles & shoes – Clothes and other textiles as well as shoes
- Wood (processed) – Untreated and treated processed wood
- Special waste – Waste electric and electronic equipment (anything with a cable), batteries / accumulators, other hazardous waste
- Composite products – Products that are made of more than one of the above
- Other – Anything that cannot be classified in one of the above categories

In Table 4, each category defined by UN-Habitat is further described with examples. Key properties are highlighted on the left side.

Table 4: Solid waste category - Adapted from UN-Habitat [9], pictures from [9]

Kitchen/ canteen waste	Examples	Key properties
	Bread, coffee grinds, cooked or uncooked food items, food leftovers, fruit and vegetables, meat and fish, pet foods, tea bags, peels, skins, shells, pips and stones, etc.	Degrade naturally over time; Rich in nitrogen; See subchapter Focus on organic waste (B) for more information on organic waste and recovery option in Organic waste (F)
Garden/ park waste	**Examples**	**Key properties**
	Flowers; Fruit and vegetable garden waste; Grass Cuttings; Hedge trimmings; Leaves; Pruning; Tree branches; Weeds, etc.	Degrade naturally over time; Rich in carbon; See subchapter Focus on organic waste (B) for more information on organic waste and recovery option in Organic waste (F)

[6] https://datacatalog.worldbank.org/dataset/what-waste-global-database

[7] Note that there is to date no unified waste categories across the globe and official waste sorting categories can be defined at national level. It is therefore important to check on national regulations to see if the proposed waste category list provided in T 2.A1 should be adapted to your local context when performing a waste audit.

Paper & cardboard	**Examples**	**Key properties**
	Brochures, magazines, newspapers; cereal packets, noodle boxes; Food Paper bags/ wrapping ; Cards, books, wallpapers; Paper bags, tissue boxes, wrapping paper, tissue paper, Writing paper, printouts, envelopes, etc.	Degrade naturally over time but issues with ink; Easy to recycle; Low to middle recycling market value
Plastic – film	**Examples**	**Key properties**
	Biscuit wrappers; Cling film; Frozen food bags; Packaging plastic film; Cellotape; Garden sheets; Non-packaging film; Plastic bags; waste liner bags; etc.	Do not degrade over time; Low to no recycling market value; Heterogeneous plastic type (mix of polymers, PP, LDPE, etc.)
Plastic - dense	**Examples**	**Key properties**
	All plastic bottles/ jars; Appliance packaging; Egg boxes; Food packaging trays; Plastic lids; Ready meal trays; Bank/credit cards; Buttons; CDs; music cassettes; Cosmetic/ glue/paint applicators; lighters; pens; etc.	Do not degrade over time; Middle recycling market value; Less heterogeneous plastic type than plastic film (PET, HDPE, etc.)
Metals	**Examples**	**Key properties**
	Packaging for carbonated drinks; Shoe polish cans; Tinned food; Aerosols (deodorant, perfume, hairspray); Aluminium foil sheets; Bike parts; Cutlery; Keys; Metal shelves; Nails; Paper clips; Ring pulls; Safety pins; Screws; Tools; Locks; etc.	Do not degrade over time; Easy to recycle; High recycling market value
Glass	**Examples**	**Key properties**
	Alcoholic and non-alcoholic drinks bottles/jars; Food jars; Medicine bottles; Cookware; Flat glass (e.g. table top, window, mirrors, reinforced, windscreens); Mixed broken glass; etc.	Do not degrade over time; Easy to recycle; Usually high recycling market value (unless long transport distances)

Textiles & shoes	Examples	Key properties
	Clothes; Balls of wool; Blankets; Carpets; Cloths; Cords; Curtains; Household soft furnishings and upholstery; Mats; Pillow cases; Rags; Ropes; Rugs; Sheets; Threads; Towels; Shoes (incl. flip-flops); etc.	Cotton textiles and other natural fibers degrade over time however synthetic fibers, plastic components do not degrade. Easy to reuse
Wood (processed)	**Examples**	**Key properties**
	Bottle corks, Cork packaging,: Pallets; Solid timber and timber fragments; Particle board (e.g. chipboard, plywood, mdf); Wood fencing; Wooden furniture; Wood work tops; etc.	Untreated wood naturally degrade over time; Can be used to produce heat. Easy to reuse
E-waste	**Examples**	**Key properties**
	All Electric and Electronic Equipment, such as clocks, electric tools, phones, laptops, PCs, printers, screens, etc; Batteries/ Accumulators; Other Hazardous Waste such as fire extinguishers; chemicals; glues and solvents; medicines; paint products, etc.	Do not degrade over time; Composite mix; Hazardous substances; need special care when managing and disposing!
Composite products	**Examples**	**Key properties**
	Composite Packaging, such as "tetrapack" ; Products made out of different materials, e.g. Scissors, knifes, razors, umbrellas, etc.	Do not degrade over time; Difficult to recycle due to composite materials
E-waste	**Examples**	**Key properties**
	e.g. inert (Boulders; Bricks; Gravel; Pebbles; Sand; Soil; Stones; Ceramics, Clay plant pots; Crockery; Stone/ceramic floor and wall tiles; Vases); Nappies/diapers; Rubber; Light bulbs (all kinds)	Inert materials can easily be used for other purposes (crushed to gravel for inert filler). Nappies, diapers, sanitary pads light bulbs will require special treatment as they are potentially harmful

Waste degradation rates

As highlighted in Table 4, not all the waste can naturally and easily fully degrade over time. Figure 24 shows typical waste and their respective degradation rates.

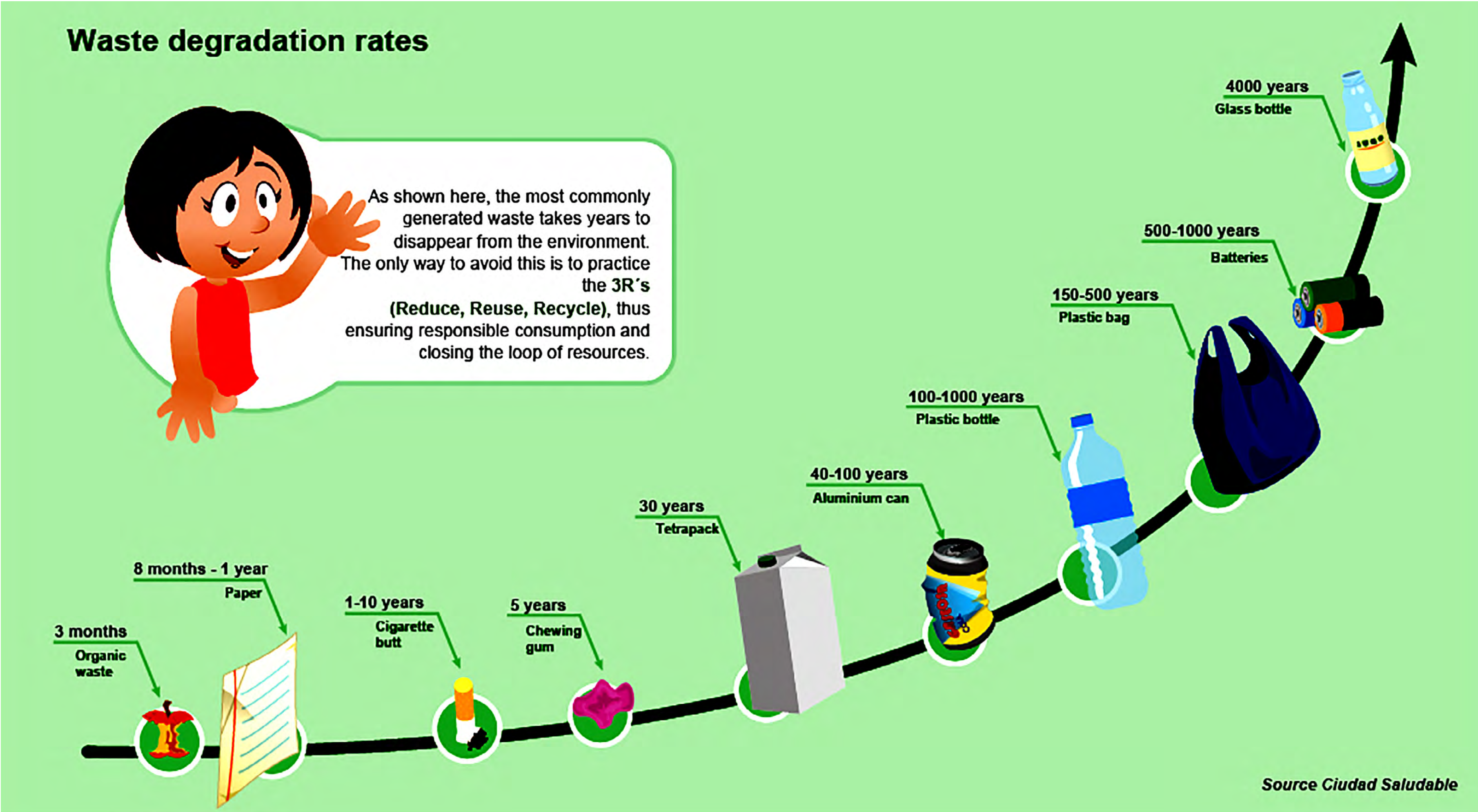


Figure 24: Waste degradation rates ©Ciudad Saludable

Focus on organic waste

Organic waste, also known as biodegradable waste, or biowaste refers to any waste that is capable of undergoing anaerobic (without oxygen) or aerobic (with oxygen) decomposition such as food, garden waste, agricultural waste, animal waste, etc. [31].

Most of the solid waste generated in low- and middle-income countries consists of organic waste, which typically represents 50 to 70% of the total amount of waste generated [5].

In school settings, organic waste is typically produced in kitchen, kiosk or canteen area when food is provided onsite, as well as from garden and green areas.

Even if organic waste does degrade naturally over time, it is necessary to manage it adequately to prevent harmful environmental and health impacts as highlighted in Box 24. More information on organic waste recovery options are presented in chapter (F) Waste recovery.

Box 24: Impacts of uncontrolled organic waste degradation

Uncontrolled organic waste degradation in large amounts may generate harmful environmental and health impacts as summarized in Table 5.

Table 5: Potential impacts of unmanaged organic waste, adapted from [31]

	Negative impact	Consequence
Soil	Contamination of soil through leachate Devaluation of the fields	Deterioration of public and environmental health Economic costs
Water	Contamination of groundwater through leachate Need for water treatment downstream	Deterioration of public and environmental health Economic costs
Air	Release of greenhouse gases such as methane (28 CO2eq at 100y [32]) and N2O (265 CO2eq at 100y [32]) Bad smell	Global warming Deterioration of comfort and public health
Other	Promoting/attracting carrying diseases vectors (flies, rodents) Esthetical contamination	Deterioration of public health Deterioration of landscape impacting on tourism

Additional resources:

Zurbrügg, 2017. Biowaste management: the key to sustainable municipal solid waste management [33]

MOOC module – Overview of biowaste treatment technologies (Eawag/Sandec)

Focus on plastic waste

The mass production of plastic only started in the 1950's. Until today, around 6'300 million tons of plastics have been produced globally, of which only 9% has been recycled, 12% incinerated and the remaining 79% discarded and therefore accumulated in stocks, landfill and in the environment [34].

Plastic is a synthetic material made from organic polymers. Plastics are usually classified in 7 categories as explained in Box 25.

In school settings, plastic waste is typically under the form of food packaging (LDPE, PP), single-use plastic cutlery (PP, PS), plastic bags (LDPE), drinking bottles (PET) and plastic furniture (HDPE).

Box 25: Plastic type and specificities

Plastics can be divided in 7 main categories based on their polymer, as shown in Figure 25. This composition influences their melting and decomposition temperature as well as the general quality of the final product.

— **PET** (or PETE) is often used in plastic drinking bottles. They are often collected and recycled in large scale facilities. However, at small scale, their recycling is difficult as PET is highly hygroscopic (it absorbs moisture from the atmosphere) and lead to brittle result when moisture is present in the melting phase [35].

— **HDPE** (or PE-HD) are typically found in households as milk, shampoo or detergent bottles. This polymer is also often collected and is easy to recycle.

— **PVC** is used for a broad range of items, from plumbing to food packaging. Yet **PVC should never be attempted to be recycled in an uncontrolled environment** as this polymer is leading to a risk of production of toxic hydrochloric acid, dioxins, other polychlorinated biphenyls and furans [36].

— **LDPE** (or PE-LD) are light plastic wrappers, sandwich bags, squeezable bottles, and plastic grocery bags. Usually, LDPE is usually not recycled in large scale industry, but small scale recycling could be possible as it is quite easy to melt and mould.

— **PP** is one of the most commonly used plastic and is widely used for food packaging. It is strong and can withstand high temperatures. PP is often not recycled in large industry and often contains layers of various materials (e.g. silver coat, etc.).

— **PS** also known as Styrofoam is used for disposable coffee cups, plastic food boxes, plastic cutlery. PS is rarely recycled in large scale industry.

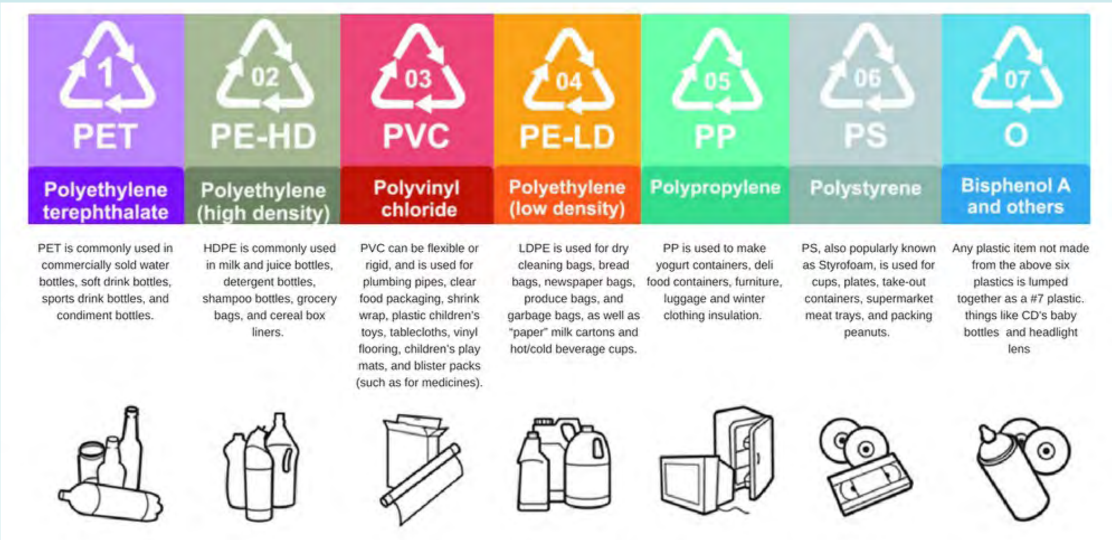
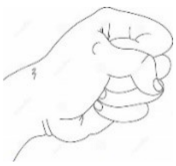
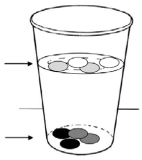


Figure 25: Plastic types ©Green Peace in https://plasticoceans.org/7-types-of-plastic/

Plastic recovery options are presented in chapter (F) Waste recovery. Note that melting different plastics together should be avoided as this reduces the end-product quality [37] or may not even be impossible because of immiscibility [36], and make it impossible to recycle the polymers again [38]. A compilation of methods for plastic identification are presented in Box 26.

Box 26: Methods for plastic identification

Method	Explanations
Polymer identification number 	The easiest way to identify polymer is to look for SPI code (see Figure 25).
Source investigation	Investigate what the plastic was used for (food wrapper, bottle seal, grocery bag,…) and formulate an hypothesis using the information provided in Box 25.
"Feeling" (breaking and listening) 	When touching the plastic you can also feel some difference: – PP wrappers feel "greasy", they can be extended a little – PET wrappers "sound loud", like a thin aluminum foil. – Multiple polymer film: By trying to stretch a film, one might see two different layers. More information on that can be found in Precious Plastic Manual [38]
Floating test 	Cut out a flat piece of plastic and put it in fresh water. Look if it floats or sinks. – Float: LDPE, HDPE, PP and PS – Sinks: PET, PVC Floating test in other liquids can be performed to identify other polymers, as described in the "Floating properties" in Precious Plastic Manual [38]
Flame test (unsafe)  ! DO NOT BURN PVC!	Take a small piece of plastic, go outside and light it using a long stick or match. Observe the color of the flame: – Blue flame with yellow tip: LDPE, HDPE and PP – Yellow flame and dark smoke: PET and PS – Yellow flame with green tip: PVC More information on that can be found in Wasteaid toolkitl [39]
Melting trial	By trying to melt a plastic at different temperature, one can find what polymer this item is made of. More information on that can be found in Precious Plastic Manual [38]
Other methods	Other methods are applied at the industrial level: – Fourrier Transform Infrared identification (FTIR) – Sorting by using fluorescent lamps – Optical automated sorting

As plastic pollution has become one of the most pressing environmental issues due to rapidly increasing production of disposable and single-use plastic products and low recycling rates, new alternatives to conventional plastics have now entered the market under the name of "bio-based plastic", "biodegradable plastic" and "oxo(bio)degradable plastics".

Yet, there is a widespread confusion among people about the sustainability and environmental impacts of these different alternatives and their name can be quite misleading, as explained in Box 27.

Box 27: Biodegradable plastic, biobased plastic, oxo-degradable plastics

The terms "bio-based", "biodegradable" and "oxo(bio)degradable are nowadays largely used for alternatives to conventional plastic. Yet these terms can be misleading regarding the environmental impacts of such alternatives. Here below some definitions taken from the European Commission [40] and from European Bioplastics [41, 42]:

- Biodegradable: Biodegrade in certain conditions and may be made from fossil-fuel based materials. Biodegradation is a chemical process during which microorganisms convert materials into water, carbon dioxide and compost without artificial additives. The process of biodegradation depends on the surrounding environmental conditions (e.g. temperature, location), on the material and on the application [41].
- Bio-based plastics: Plastics that are fully or partially made from biological resources rather than fossil raw materials. They are not necessarily compostable or biodegradable [40].
- Oxo(bio)degradable: Oxo(bio)degradable plastics are made from conventional plastics and supplemented with specific additives in order to mimic biodegrdation [42]. As such, it fragments the plastic into very small particles that remains in the environment (i.e. so-called micro-plastics). Oxo(bio)degradable plastics are not biodegradable. There is to date no internationally established and acknowledged standard or certification on oxo-degradable plastic and is therefore "just an appealing marketing term" [42] that is currently widely used and often misleads consumers. Also note that in some countries, oxo(bio)degradable plastic are often simply called "biodegradable plastic", even if they are not biodegradable.

As shown in Figure 26 conventional plastic, as well as bio-based PE, PET, PA, PTT are not biodegradable. The only one being biodegradable are: PBAT, PCL, PLA, PHA, PBS and starch blends.

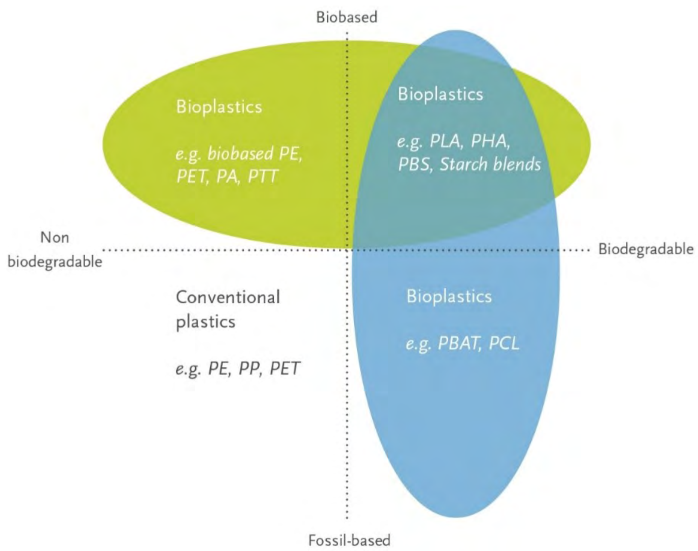


Figure 26: Plastic origin and biodegradability [41]

Additional resources:

Wasteaid, 2017. Making Waste Work: A toolkit – How to prepare plastics to sell to market [39]

Precious Plastic, 2017. Manual 1.0 [38]

EuropeanBioplastics, 2021 – Bioplastic materials [41]

MOOC module – Plastic waste management - Theory (Eawag/Sandec)

(C) Waste reduction & reuse

The best way to manage waste is to not produce it at the very first place. Therefore, efforts should always be put on reducing the amount of waste by:

1. Avoiding consumption of goods generating high amounts of waste;
2. Adapting the procurement of goods to the actual needs for it;
3. Systematically reusing material and item before it becomes a waste.

Here below a list of key elements to consider to reduce typical waste generated at school:

Kitchen/ canteen waste

— Change the serving system to avoid food leftover served

— Implement a system to know how many people eat every day

— Adjust the ratio of food cooked per person

— Invest in cold storage system

Plastic waste

— Buy things in bulk to avoid small plastic packages

— Stop using single-use plastics and replace with reusable items (e.g. cutlery, beverages container, etc.)

Paper & cardboard

— Optimize paper use

— Re-use school books and cardboard

Sanitary waste

— Promote reusable hygienic alternatives (reusable sanitary pads, menstrual cup, etc.)! If reusable alternatives are promoted, make sure to provide necessary infrastructure and trainings to ensure a safe and hygienic reuse of sanitary products!

See Tool 4.A1.2 for waste-specific reduction strategies.

(D) Waste segregation

Separating the waste into different fractions allows to consider it as potential resources and not as trash anymore. Waste can be separated at different moments along the SWM chain. Usually, when done at the generation point, it is called "waste segregation", and when it is first mixed together and then separated, it is called "waste sorting".

Waste segregation at source is preferable over waste sorting as it allows a higher quality of the material. Table 6 gives a definition of waste segregation and waste sorting and summarizes the main pros and cons.

Table 6: Waste segregation and waste sorting

	Definition	Pros and Cons
Waste segregation	Waste separated at source, when the waste is put thrown away, i.e. put into a bin	+ Quality of the material (waste = resource) − Require a change of practice and therefore a behavior change
Waste sorting	Waste first mixed together in a bin and then separated into different fractions	+ Don't require a change of practice − Materials are soiled and more difficult to recycle

Different waste segregation systems can be put in place:

- **2-bins system:** organic + other (i.e wet and dry)
- **3-bins system:** organic + recyclables + other
- **4-bins system:** organic + paper + other recyclables + other
- ...

It is advised to put in place at least a 2-bins system to make sure that organic waste does not soil the rest of the recyclables.

Note that the bins do not have to be plastic bins. It can also be made out of cardboard boxes or other materials (see Figure 27), PET bottles, etc.

Figure 27: Examples of cardboard bins ©Ciudad Saludable

Box 28: Waste segregation & behavior change

Remember that asking people to segregate their waste, is actually asking for a behavior change from people. As such, it goes beyond bringing solely the adequate infrastructure to people; it requires the use of appropriate trainings and behavior change techniques.

See the Behavior change chapter in Part 1 for more information.

Figure 28: Waste segregation ©Ciudad Saludable

Whenever a waste segregation system is put in place, it is important to:

— Ensure a separate collection system for the separated waste fraction;

— Make sure to consider behavior change interventions (software aspect) to complement the infrastructure implementation (hardware aspect).

Additional resources:

Mosler Contzen, 2016. Systematic behavior change in water, sanitation and hygiene. A practical guide using the RANAS approach [15

Cavin, 2017. Behavior Change Manual [17]

Ranasmosler.com

MOOC module – Triggering Community Participation with the RANAS approach (Eawag/Sandec)

(E) Waste collection

Collecting waste means to gather it from where it is produced and transport it, either to an intermediate collection site (e.g. a container located at the entrance of the school, from where an external person is going to come and pick up the waste), or to a final place of recycling or disposal.

It is important to collect waste safely and frequently enough to avoid attracting animals and insects, bad smell and spread of diseases. Recommendations below are taken from Wasteaid [43] and adapted to a school context.

Waste bins and containers

Waste bins and containers are useful to temporarily hold the waste before it is collected for disposal or recycling. The type of container and size may vary from one location to another depending on locally available material (plastic, metal, wood, etc.) and preferences. Sizes can vary from 5L, small bin, to 200L. The number of containers needed depends on the amount of waste produced and the frequency of collection. Do not forget that the weight of the full bin or container needs to match the carrier!

Cleaning equipment

Once the waste is collected, it is important to make sure that the area is clean of any residue. As mentioned by Wasteaid [43], the type of equipment used for cleaning the ground depends on the nature of the waste as well as the floor condition.

Brooms and dustpans can be used to clean out classrooms, whereas litter pickers are useful for picking up small pieces of waste littered. Straw or wooden broom are useful to sweep pavements and streets.

Transporting waste

There are many ways to collect and transport waste depending on the amount and type of material and the distances. As mentioned by Wasteaid [43], waste can be collected by hand in sacks or wooden baskets (a), transported with wheelbarrow or handcart (b) or bicycle trailer (c), for larger amounts, animal drawn-cart (d) or motorized vehicle (e) can be used, as shown in Figure 29.

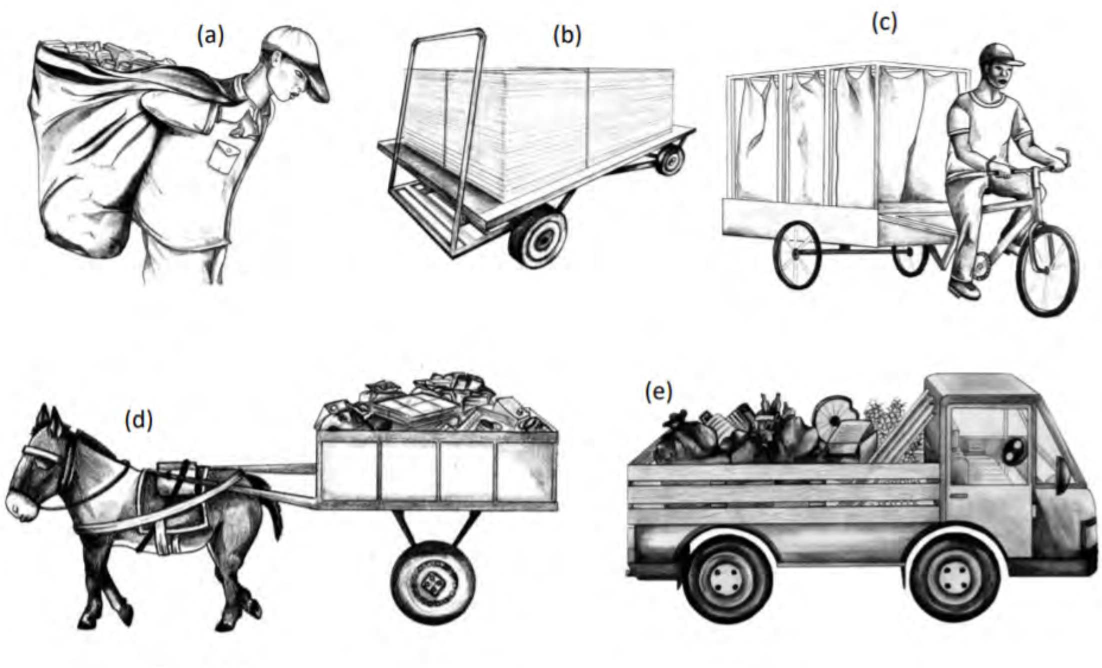


Figure 29: Ways to collect waste – from [43]

Frequency of collection

Solid waste should be collected often enough so that the amounts produced are easily handled and do not produce too many nuisances. This could mean a daily collection, or two-three times a week [43].

The collection frequency is highly influenced by the type of waste collected and the ambient conditions; in warm and wetter climates, organic waste will start rotting quickly, creating bad smell and attracting insects and other pests. Under such conditions, it is advised to collect organic waste every 1-2 days. Dry materials such as paper, plastics, glass and metal can be stored and collected less frequently.

Placement of waste containers and collection routes

Containers and bins should be located in strategic waste-generation spots to avoid littering and easily accessible to the waste collection team. Establishing a collection route is important to save time and effort. An established collection route will encourage a routine of cleanliness in the school. Plan the route so that it is as short as possible. If the school is located in a hilly/sloping area, try to end the route on the lower side of the slope/hill to avoid carrying waste uphill.

Additional resources:

Wasteaid, 2017. Making Waste Work: A toolkit – How to collect waste safely and efficiently [43]

Coffey et al., 2010. Collection of Municipal Solid Waste in Developing Countries [44]

MOOC module – Waste collection and transport (Eawag/Sandec)

(F) Waste recovery

Depending on the type of waste considered, different recovery options exist. We usually cluster the recovery options in two categories:

- **Recovery options for non-organic waste** (metal, glass, plastics, etc.), commonly called recycling options;
- **Recovery options for organic waste** (kitchen/canteen waste, garden and park waste, etc.), commonly called organic waste treatment options.

The recovery options for each waste category are described in the following subchapters.

Key elements to consider for selecting appropriate recovery options are highlighted in Box 29.

Box 29: Key elements for selecting appropriate recovery option

It is important to keep in mind that not every option suits every context, and it is therefore very important to select recovery options which fits the technical, economic and social context of the specific location considered. Typical questions to be answered to select an appropriate recovery option in a given context are summarized in Table 7.

Table 7: Technical, economic, social and legal elements to consider for appropriate recovery option selection

Technical aspect	Economic aspect
– Is the waste characteristic and amounts suitable for the considered recovery option? – Is there access to external expert who can design and build adequate treatment facility if needed? – Is there a sufficient level of knowledge in-house to operate and maintain the facility? If not, is it possible to train school staff on that?	– Is there a market-demand for the end-product (inside or outside the school)? – Is the school budget enough to cover the capital cost (CAPEX) and operational cost (OPEX)?
Social & Educational aspect	**Legal aspect**
– Is it socially appropriate in the given context to use the end-product? (e.g. cook with biogas from waste source, etc.) – Does the school have any past bad/good experience with such a recovery option which could discourage/favor the use of such an option? – Is it possible to link the use of such a recovery option for any educational purpose? (e.g. link composting practices with science courses on plant growth, etc.)	– Is there any legislation/policy preventing the use of such a recovery option? – Is there any legislation/policy preventing the use of the end-product? – Is there any legislation/policy setting standards for process or end-product quality?

Non-organic waste

Recovery options for non-organic waste are often referred to as "recycling". Yet, it is important to distinguish three possible cycles, depending on the quality of the end-product compared to the initial material as presented in Box 30

Box 30: Recycling, upcycling & downcycling definitions

 Recycling, converts a material into something of roughly the same value as it originally was (e.g. using PET bottle to make new PET bottles, using metal scraps to make new metallic items, etc.)	 Upcycling, converts a material into something with a greater value than it originally was (e.g. using plastic pouches to make bags, etc.)	 Downcycling, converts a material into something of less value than it originally was (e.g. making ecobricks with PET bottle and light plastics, etc.)

Usually, the market demand for recycled products is higher than for upcycled or downcycled products. Recycling is thus usually performed by for-profit businesses and often at larger scale than upcycling and downcycling, which is mostly performed by social businesses or non-for-profit organizations at smaller scale.

It is important to mention that when a material is downcycled or when different plastic materials are mixed together, it is no longer possible to recycle them. As a rule of thumb, we recommend to link the recyclable waste produced at the school with the existing (in)formal recycling system as described hereafter.

Existing recycling system

In most cases, when some waste material have a value on the local recycling market, a recycling chain, also called recovery chain, is already in place, being formal or informal [9]:

- Formal recycling system implies registered organizations and businesses buying recyclables and selling them to recycling facility; whereas
- Informal recycling system implies non-registered small businesses and people extracting recyclable materials from the waste stream to support their livelihood and selling the materials into the recovery system.

The recovery chain is explained in the following subchapter.

Typical recyclable materials value, as well as technical complexity, occurrence and scale of recycling processes are presented in Box 31. Examples of recycling processes can be found in the MOOC video provided in the additional resources.

Box 31: Recycling processes overview

Figure 30 gives a comparative indication among the different recycling processes in terms of recyclable value on the market, the complexity of the recycling process, whether the recycling process usually occurs or not and the scale at which the recycling process usually takes place (small scale being individuals or small businesses, and large scale being more at large businesses or industry level).

	Recyclable value [Market value of the material]	**Complexity** [Technical complexity of the recycling process]	**Occurrence** [If recycling process usually exists or not]	**Scale** [Usual size of recycling facility (from small to large scale)]
Paper	•	•	•••	• - •••
Glass[9]	•(••)	••	••	•• - •••
Metal	••(•)	•	•••	• - •••
Dense Plastic[10]	••	•••	•(•)	•••

Where: • low/ small // ••• high/ large (example: paper has a low value on market compared to other, it occurs very often at different scale (from small recycling business to large scale industries)

Figure 30: Recyclables value, technical complexity, occurrence and scale of recycling processes

[9] In remote places, the value of glass is very less due to high transportation cost, whereas in cities, the price of glass goes up quickly.

[10] Typical recycled dense plastic are: PET and HDPE.

Additional resources:

MOOC module – [Recycling municipal waste](#) (Eawag/Sandec)

Recycling chain

A recycling chain usually involved several steps from the point where a recyclable material is extracted from the waste stream until it gets recycled.

In many low and low-to-middle income countries, this involves waste pickers, intermediate traders, apex traders and end-of-chain recyclers, as defined by UN-Habitat [9]:

Waste pickers extract recyclable materials from the waste stream to support their livelihood, selling materials into the recovery system.

Intermediate traders receive materials from both formal and informal recyclable collection systems (including waste pickers), store and prepare these materials for onward trading to apex traders.

Apex traders receive materials from intermediate traders or directly from both formal and informal recyclable collection systems (including waste pickers), store and prepare these materials for onward trading to end-of-chain recyclers.

End of chain recycler receives materials from apex traders or direct from both formal and informal MSW collection systems and processes them into materials and products that have value in the economy either through recycling, incineration with energy recovery, or other recovery process

Figure 31: Recycling chain [9]

Considering a school setting, different scenarios are possible to link the school with the existing (in)formal recycling system: A) the recyclables can be collected by waste pickers, or B) the recyclables can be sold to intermediate traders. Both scenarios pros and cons are described in Table 8.

Scenarios	Pros	Cons
A) Recyclables collected by waste pickers	– No additional work for the school (just access to school compound provided) – Improving livelihood of waste pickers	– No revenue for the school from selling recyclables – Limited educational activities linked with this practice
B) Recyclables sold to intermediate traders	– Generating revenue for the school from selling recyclables – High potential for educational activities (e.g. waste sorting, accounting, etc.)	– More work and logistic for the school – Need a designated area to sort and store recyclables – Need a responsible person to manage recyclables selling

Table 8: Scenarios for linking schools with existing (in)formal recycling system pros and cons

More information on how to increase the market value of recyclables for scenario B are provided in the next subchapter.

Additional resources:

UN-Habitat, 2021. Waste Wise Cities Tool (Step 4) [4]

Increasing recyclable's value

The value of recyclables on the recycling market will depend on the quantity and the quality of the material.

Good quality recyclables are defined by Wasteaid [39] as:

- **Clean and dry**, not covered by food waste, dirt or left out the in the rain
- **Very well sorted**, with only the type of recyclable that the buyer wants
- **Compacted and baled** whenever possible, to reduce transport cost.

Table 9 shows some key steps for increasing recyclables values. This table was adapted from Wasteaid focusing mainly on how to prepare plastics to sell to market [39].

Cleaning	Drying	Sorting	Compacting & storing
– Empty any contents of containers – Remove other materials – Manual washing in large drums or containers (you might use soap to remove the oil)	– Sun drying – Use a fan for drying	– Remove all unwanted material (labels, stickers, lid,etc.) – Separate the materials by type and color depending on the buyer request	– Make sure to store the material in the most compacted way (jute bag, metallic boxes, cardboard boxes, etc.)

Table 9: Pre-treatment steps to increase recyclables value, adapted from Wasteaid [39]

Here below a list of recommendations per recyclable material:

- **Glass:** Make sure to avoid breaking glass; Clean & dry glass; Sort by glass color if needed
- **Paper:** Avoid wrinkling the paper; Keep it dry; Sort paper by paper type (newspaper, paper, etc.); Compact paper to reduce volume
- **Cardboard:** Keep it dry; Sort cardboard by cardboard type (cardboard boxes, egg crates, etc.); Compact cardboard to reduce volume
- **Metal:** Clean & dry metal; Sort ferrous and non-ferrous metal
- **Plastic:** Clean & dry plastic; Sort plastic by plastic type according to recycling market needs (see Box 26 for more information on identification methods); Compact plastics to reduce volume

In addition to that, the quantity will affect the price a buyer would give for a certain material. If the quantities are big enough, the buyer might send a vehicle to pick it up, thus reducing the logistics needed for handling the recyclables. We therefore recommend to have a recyclable storage system, commonly referred to as Material Recovery Facility (MRF), so that the different recyclables can be stored for a while before reaching the desired amounts to be picked up by the buyer(s).

More information on MRF can be found in the Factsheet R.1 MRF.

Additional resources:

Wasteaid, 2017. Making Waste Work: A toolkit – How to prepare plastics to sell to market [39]

Plastic recovery options

For plastics which do not have a market value, such as plastic films (LDPE, PP, etc.), options exist to recycle and downcycle them with low-tech solutions easily implementable in a school context.

Among them, we recommend:

- **P.1 Ecobricks –** Building material made of PET bottle filled with plastic film
- **P.2 Paving tiles –** Melting LDPE plastic with sand to produce paving tiles
- **P.3 Shredding –** Breaking down plastic into smaller pieces for further processing or selling
- **P.4 Extrusion –** Extruding plastic waste into filament to create new[12]
- **HC.1 Plastic film crochet –** Handicraft option to crochet plastic film into bags and mats

Table 10 summarizes the main concept as well as advantages and limitations of each of these options.

Detailed information for each option can be found in the Factsheets P.1 Ecobricks, P.2 Paving tiles, P.3 Shredding, P.4 Extrusion, HC.1 Plastic film crochet.

Please consider the questions highlighted in Table 7 to choose an appropriate recovery option in your given context.

Additional resources:

MOOC module – Plastic waste management - Examples (Eawag/Sandec)

[11] In urban area, unbroken glass might be taken back from the supplier.

[12] Shredding and extrusion done with Precious Plastic technologies: https://preciousplastic.com/

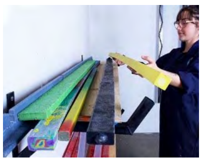
Options	Concept / Product	Advantage and limitations	Key additional references
P.1 Ecobricks 	Create building material from PET filled up with light plastic	+ Very easy-to-do; Easily replicable at home; Suitable for all type of plastic film (packaging, wrappers,…); Easy way of storing plastic and avoiding waste littering – Downcycling option; No economic value; Relevance would depend on the amount of PET bottle produced at the school and need for such building material at the school	Wasteaid 2017 [45] Ecobricks.org 2014 [46]
P.2 Paving Tiles 	Re-melting of LDPE (plastic bags,…) to produce paving tiles	+ Relatively easy-to-use technology (only barrel, fired and mould); Useful end-product – Downcycling option; Sand must be available; Melting temperature should be carefully looked at to avoid plastic burning (risk of environmental and health impact)	Wasteaid 2017 [47]
P.3 Shredding 	Breaking down plastic into smaller pieces for further processing or selling	+ Important first step for most plastic recycling processes; effective way to granulate plastic and reduce storage volume – Need machinery; Need careful plastic sorting	Precious Plastic, 2017 [38]; Precious Plastic shredder webpage
P.4 Extrusion 	Extruding specific plastic (typically either HDPE or PP) to produce plastic filament	+ Upcycling option; Various types of products could be designed depending on the need of the school – Need machinery and know-how; Need careful plastic sorting (extrusion can be done with one type of plastic only)	Precious Plastic, 2017 [38]; Precious Plastic extrusion webpage
HC.1 Plastic film crochet 	Crochet plastic film into bags and mats	+ Very easy-to-do; Easily replicable at home; Suitable for all type of plastic film (packaging, wrappers,…) – Low economic value; Limited amounts of film plastic can be upcycled with that process	Wasteaid 2017 [48]

Table 10: Overview of low-tech plastic recovery options for schools

Organic waste

Various organic waste treatment options exist (see additional resources for more information). Among them and considering a school setting, we recommend the following options:

- **O.1 Direct animal feed –** Using organic waste to feed animal such as pigs
- **O.2 Composting –** Aerobic degradation of organic waste to produce compost
- **O.3 Vermicomposting –** Aerobic degradation of organic waste with worms
- **O.4 Biogas production –** Anaerobic degradation of organic waste to produce biogas

Note that for each of these options, it is necessary to have pure organic waste and therefore, waste segregation at source should be implemented and carefully monitored.

Table 11 summarizes the main concept as well as advantages and limitations of each of these options.

Detailed information for each option can be found in the Factsheets O.1 Direct animal feed, O.2 Composting, O.3 Vermicomposting, O.4 Biogas production.

To define which option should be used in your school context, please consider the questions highlighted in Table 7.

Options	Concept / Product	Advantage and limitations	Key additional references
O.1 Direct Animal feed 	Using organic waste to feed animals such as pigs	+ Largely practices; Very easy-to-do; No infrastructure required and no associated cost for operation and maintenance − Limited economic value; Limited link with educational purpose; Using organic waste to feed animals might be restricted by law to avoid diseases transmission	Lohri et al. 2017 [49]
O.2 Composting 	Aerobic degradation of organic waste to produce compost	+ Simple and robust technology; Low capital and operating costs; Limited know-how required; Compost can be used in school garden and green area; Easy to link with educational purposes − Downcycling option; Sand must be available; Melting temperature should be carefully looked at to avoid plastic burning (risk of environmental and health impact)	Wasteaid 2017 [50]; CCAC,2016 [51]; Rothenberger et al. 2006 [52] Blue Schools Kit (8.1-2) [53] Composting MOOC module
O.3 Vermicomposting 	Aerobic degradation of organic waste with worms to produce vermicompost	+ Limited infrastructure required; Limited know-how required; Higher quality end-product than composting; Easy to link with educational purposes − Pre-composting phase recommend; Significant land area required; Worms sensitive to environmental condition and climate variations	Wasteaid 2017 [54]; CCAC,2016 [51];¨ Blue Schools Kit (8.3) [53] Vermicomposting MOOC module
O.4 Biogas production 	Anaerobic degradation of organic waste to produce biogas	+ Produce biogas that can be used for onsite cooking; Shorter treatment time than composting (10-40 days) − Required expert design and skills for construction; Medium level investment costs; Required know-how for operation and maintenance; Need to treat the digestate slurry	Wasteaid 2017 [55]; Vögeli et al. 2014 [56]; Blue Schools Kit (8.4) [53] Anaerobic digestion MOOC module

Table 11: Organic waste treatment option for schools

Additional resources:

Zurbrügg, 2017. Biowaste management: the key to sustainable municipal solid waste management [33]

Lohri et al., 2017. Treatment technologies for urban solid biowaste to create value products: a review with focus on low- and middle-income settings [49]

Zabaleta et al., 2020. Selecting Organic Waste Treatment Technologies (SOWATT) [31]

MOOC module – Overview of biowaste treatment technologies (Eawag/Sandec)

(G) Waste disposal

Waste disposal should be done in a way that controls and limits the impacts on the environment and public health (see examples of impacts in chapter "Impact of waste mismanagement"). Among waste common disposal practices, we can mention landfilling and incineration. Here it is important to make the distinction of landfilling versus open dumping as well as incineration versus open burning, as shown in Figure 32.

In low- to middle-income settings, incineration is usually not recommended due to the very wet type of waste generated, and the high cost associated with proper incineration technologies and therefore, landfilling should be preferred (see the additional resources for more information on landfilling and the level of control defined by UN-Habitat [9]).

LANDFILLING VS OPEN DUMPING

Sanitary landfill

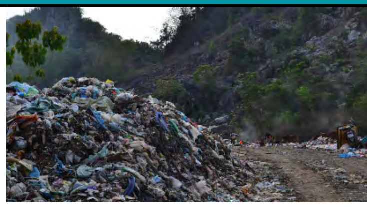
Characteristics:

- Controlled access (fences)
- Waste disposal strategy
- Leachate and pollution prevention measures (geomembrane)
- Waste compaction
- Cover layer for waste
- No waste burning

Controlled disposal

Characteristics:

- Controlled access (fences)
- Waste disposal strategy
- No leachate /pollution prevention measures
- Waste compaction
- Cover layer for waste
- No waste burning



(Uncontrolled) dumpsite

Characteristics:

- Waste dumped, no strategy
- No leachate /pollution prevention measures
- No waste compaction
- Waste burning

INCINERATION VS OPEN BURNING

Incinerator

Characteristics:

- Complete combustion (sufficient oxygen + temperature)
- Control and cleaning of gas and fumes
- **VERY EXPENSIVE AND HIGH TECH**

"Burner"

Characteristics:

- Waste burned in a commonly-called «incinerator» which actually acts as a waste burner (controlled burning)
- No complete combustion
- No control and cleaning of gas and fumes

Open burning

Characteristics:

- aste burned in the open (uncontrolled burning)
- No complete combustion
- No control and cleaning of gas and fumes

Figure 32: Definition and characteristics of key waste disposal practices

Considering a school setting, the generated waste which cannot be recycled or recovered is usually either given for waste disposal outside the school compound to a SWM service - usually provided by the municipality or a private entity - , or disposed of onsite.

For onsite waste disposal, we recommend to dispose waste in waste pits having the following key characteristics[13] :

— Designated location & access control
    - Waste is disposed of in a single designated area (referred to as waste pit)
    - Access to people and animals is limited using fences or barriers

— Environmental protection measures:
  - o Air pollution & waste wind blowing
    - No waste is burnt
    - Green buffer with trees or bushes are used to reduce the visual impact, reduce waste wind blowing and act as vegetation filter for potential smell emissions reduction
    - Waste is covered regularly with a layer of soil to avoid wind transport as well as birds and vermin
  - o Groundwater protection:
    - Bottom of the waste pit is located well above the highest groundwater level (>2m)
    - Small berm and ditch are dug around the waste pit to avoid rainwater accumulation inside the waste pit
    - If possible a layer of clay should cover the bottom and the walls to avoid water leaching into the environment

These elements are summarized in Factsheet D.1 Waste pit.

Additional resources:

Jaramillo, 2003. Guidelines for the design, construction and operation of manual sanitary landfills [57]

Wasteaid, 2017. Making Waste Work: A toolkit – How to design and operate a basic waste disposal site [58]

Blue Schools Kit, 2018. Blue Schools - Linking WASH in schools with environmental education and practice, Catalogue of Technologies (8.5) [53]

UN-Habitat, 2021. Waste Wise Cities Tool - Step by step guide to assess a city's municipal solid waste management performance through SDG indicator 11.6.1 Monitoring (Step 5) [9]

MOOC module – Upgrading a Dump Site (Eawag/Sandec)