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Collection
6.1

Waste Collection: Equipment and Vehicles

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The collection and transport of waste from the source to the treatment or disposal facility involve many technical and organizational issues: Receptacles for the waste, collection vehicles, collection frequency, collection routes and pay schemes. The collection and transport of waste is a very important part of the waste management system for many reasons:

- Waste collection constitutes the organizational interface between those generating the waste and the waste management system and as such determines the success of the system in accommodating the waste generated and avoiding uncontrolled dumping of the waste.
- Waste collection constitutes the technical interface between the waste generated and the treatment and disposal system and hence waste collection may determine which technologies may be feasible and successful in the further processing of the waste.
- Waste collection often accounts for two-thirds of all the costs involved in waste management and thus has to be cost-effective.

This chapter describes the material, equipment and vehicles used in waste collection with primary focus on the collection of residential waste in industrialized countries, but also treats the collection of commercial and industrial waste as well as special aspects related to waste collection in developing countries. The chapter presents the basic principles and technology used in the collection of waste and recyclables with respect to:

- Receptacles for waste: Sacks, bins and containers.
- Compaction of waste.
- Collection vehicles.
- Special collection technology (pipes/sewers).

Systems and organization of waste collection is described in Chapter 6.2 and specific aspects of source segregation schemes are described in Chapter 6.3. The special aspects of long-distance transport of waste via transfer stations are dealt with in Chapter 6.4.
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6.1.1 Receptacles for Waste

In some third-world countries household waste and waste from small commercial enterprises is still just dumped in heaps in front of the houses and collection is performed by simply shoveling the waste onto the collection vehicle. Apart from this gradually disappearing practice, the waste producer always has some kind of receptacle for storing the waste until it is collected.

Inhouse storage of waste at the point of generation is usually done in bins or bags or (for recyclables, e.g. newspapers) by piling and usually the choice of material is left to the individual waste producer. Only in a few cases are specific inhouse collection bags prescribed; for example if the waste is later subjected to optical sorting, certain material fractions must be placed in special identifiable bags that can be closed.

Receptacles for the organized collection of waste can be categorized according to their main features, as described in the following sections:

- Manually handled receptacles for waste.
- Large containers (mechanically handled) for waste.
- Receptacles for recyclables.
- Receptacles for biodegradable organics.
- Underground receptacles.

6.1.1.1 Manually Handled Receptacles

Sacks and bins are flexible receptacles for waste storage on the premises. These receptacles can be manually handled and taken to the collection vehicle.

Sacks

The simplest piece of equipment for storing waste is a sack made of either plastic or paper. The sack is one-way packaging, which makes it a very hygienic and odorless receptacle. For efficient use, the sack must be fixed in a stand with a hinged lid. Sacks are vulnerable to attacks from cats, rats, birds etc. and stands used outdoors should have a protective net or the like (Figure 6.1.1).

Plastic bags are typically 60–150 l, thickness 0.06–0.08 mm. The plastic material is usually polyethylene (PE). Unlike some other plastic materials, such as PVC with its content of chlorine, PE is well suited for incineration. In landfilling and especially in composting, however, it is a problem that PE does not decompose, even over many years. To overcome this problem and to make the plastic decompose more readily, some manufacturers are marketing sacks and small bags for kitchen use made of PE with a content of starch or other organic material. However, so far this type of sack has gained limited use.

In some countries paper sacks are widely used, especially for household waste. The material is a high-quality paper, which maintains its strength even in wet conditions. The high strength allows the use of sacks with a volume up to approximately 250 l. An advantage of the paper sack is that it decomposes in landfills and biological treatment facilities.

The practice of putting plastic sacks out in front of highrise buildings for collection is gradually disappearing in industrialized countries, as more efficient large-volume bins are introduced. However, in single-family houses, the weekly collection of one sack of 110–150 l is still an attractive, hygienic alternative to a plastic bin. Especially in a full service collection scheme (see Chapter 6.2), the advantage of not having to return the empty bin saves cost.

Sacks are still widely used for interior handling of waste, household as well as commercial and institutional. For instance in highrise buildings, sacks, sometimes in an automatic shifting mechanism, can be used under waste chutes and transferred by janitors to a centrally located container or compaction container. Another example is cleaning of offices and institutions where cleaners use sacks that are subsequently loaded into a large container.

A problem with bags, irrespective of the material, is the vulnerability to pointed and sharp items. Spilled waste is of course a nuisance, but still worse, sharps may cause injury to collectors carrying the bags. It is therefore important to instruct the citizens to carefully wrap broken glass etc. before depositing it in the bag.
Figure 6.1.1  Sack for separate collection of biowaste and residual waste from a single family house. The left compartment holds a 125 l paper sack for residual waste and the sack for biowaste is 60 l. The empty space below the 60 l sack may be used for paper, glass etc. for recycling.

Bins for Lifting and Carrying

Not so many decades ago almost all household waste, even in highly developed countries, was collected in metal bins that had to be lifted, carried and emptied manually onto the collection vehicle. Even the empty bin weighed 10–25 kg and the full bin could weigh 50 kg, sometimes more. Even though the galvanized steel bins were gradually replaced by aluminum or plastic bins, this was heavy work and detrimental to the waste collector’s health. Compared with more modern collection methods, the productivity in terms of kilograms collected per hour was also low, and the use of lift and carry bins is seldom seen in industrialized countries today. Productivity may be a less important issue in developing countries where the labor is much less costly. Even then, the use of bins to be manually lifted and carried should be limited to the absolute minimum due to the occupational health risks implied.

Bins with Wheels

The demand for higher productivity and reduced physical workload on the waste collector has led to the introduction of two-wheels plastic bins with a capacity ranging from < 1001 up to approximately 4001 and four-wheeled bins of plastic or metal ranging from 400 to 11001, in some cases even more. Figure 6.1.2 shows three of the most widely used wheeled
Figure 6.1.2  Bins made of polyethylene (PE) for waste collection (front and side view). Top: 2401 bin (also available as 120l, 180l, 360l), middle: 6601 bin, bottom: 11001 bin. All dimensions are mm.
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bins. A precondition for using the larger bins is that the specific weight of the contents is low, as is typical for modern cities with a large amount of empty packaging in the household waste. If the waste contains a large proportion of wet organic components or ashes from coal burning stoves it is not advisable to use the largest bins. The same applies if the bin has to be transported over a soft, uneven surface or a steep slope. It is good practice to avoid pushing/pulling forces exceeding 200 N and a threshold force of 400 N for starting when one person operates the bin.

A two-wheeled bin stands on its bottom and must be tilted for transportation. A four-wheeled bin is standing on its wheels, normally castors, and may need a braking system, especially if it is parked on the street or sidewalk.

All wheeled bins are emptied into the collection vehicle by means of a mechanical system capable of lifting the bin and turning it upside down. Different systems apply. For two- and four-wheeled containers the prevailing lift system has an upward edge (‘comb’) on the lifting frame which fits under the front edge of the bin (Figure 6.1.3). Containers larger than 800 l normally have trunnions (Figure 6.1.2) on both lateral sides for lifting and tilting by means of hydraulically operated arms on the collection vehicle.

Wheeled bins are used extensively worldwide, not only for residential waste but also for commercial, institutional and light industrial waste, as well as source-segregated materials for recycling. In many cases shifting from lift and carry bins to wheeled bins has more than doubled the productivity of the residential waste collection system in a large city in terms of kg/man/h and the occupational health conditions have improved considerably.

Figure 6.1.3  Lift-frame for the ‘Comb’ system. The upward teeth fit into the U-shaped front lifting edge of any size of two- and four-wheeled container in the CEN standard. During the lifting movement, the arrester bar (a) moves down and locks the bin to the comb when turned upside down.
In Europe standards exist for both two- and four-wheeled bins. The dimensions shown in Figure 6.1.2 all comply with Comité Européenne de Normalisation (European Committee for Standardization, CEN) standards.

6.1.1.2 Large Containers

Larger containers include containers with a volume of 2–12 m$^3$ that are emptied into a collection vehicle as well as containers > 10 m$^3$, which are transported individually to the treatment or disposal facility.

Stationary Containers

Containers larger than approximately 2 m$^3$ are usually stationary and not intended for manual handling. They may be fitted with wheels but can only be moved by a tractor or other mechanical means.

Stationary containers made of steel or aluminum with capacities ranging 2–12 m$^3$ can be emptied on location in specialized vehicles fitted with appropriate lifting gear.

Probably the most widespread system of this kind is the front-loader (see Figure 6.1.4). Without leaving the cab the driver can lift and empty containers from 2 m$^3$ to approximately 8 m$^3$. Different types of interface between lifting arms and container exist. The most commonly seen is a fork matching steel ‘sleeves’ on either of the container’s lateral sides. If the container has a lid, it must be hinged so as to open automatically when the container is tilted approximately 135°.

Another system is the 4–12 m$^3$ skip intended for emptying in a heavy-duty compaction vehicle of the rear-loading type. The front of the container slopes at approximately 45°. Pivots on either side of the container landing in sockets on the vehicle tailgate enable the container to be raised to a vertical position by means of a cable winch on top of the vehicle body (see Figures 6.1.5, 6.1.6).

Stationary containers may be fitted with adequate lids or hatches and even a compactor. The two types of stationary container described, and also some other systems, are used extensively for commercial and industrial waste and sometimes also for household waste from highrise blocks. Another use is for paper, cardboard and other materials for recycling.

Figure 6.1.4  A front-loader container (7 m$^3$) with hinged top lid and sliding side doors for loading.
is a precondition for the use of stationary containers that the usually very large and heavy collection vehicle can drive or back right up to the container stand.

**Containers for Individual Transport**

Containers larger than 10–12 m³ must be transported individually to the treatment or disposal facility and returned after emptying. The dominant principle for large containers is the so-called roll-off system. The container is pulled and lifted onto a truck chassis with a tipping frame by either a cable winch or a system of moving arms with a lifting hook (see later description in Section 6.1.3).

Containers are built on a standard subframe compatible with the tipping frame and cable or hook system of the truck. The container can be designed to suit any individual application provided that its dimensions do not exceed the legal maximum for a road vehicle. In most countries, this implies a maximum width and height of approximately 2.5 m and a maximum length about 6.5 m, corresponding to a net volume of about 32–35 m³. Figure 6.1.7 shows typical roll-off containers.

Unloading the container is performed by opening the hinged tailgate and tipping the container 50–60° from the horizontal. If the waste is compacted, gravity may not always be enough to overcome friction against the sides, bottom and roof of the container. To solve this problem compaction containers may be tapered or have a hydraulically activated push-out panel like in a waste collection truck.

Roll-off containers exist in a lot of different types and designs to suit different purposes, such as:

- Open-top containers for bulky household waste, park and yard waste.
- Heavy-duty open-tops for construction and demolition waste.
- Closed containers for household waste in bags, light commercial waste, paper, cardboard etc.
- Heavy-duty containers for stationary compactors or with a built-in compaction unit.
- Containers adapted to chute or ramp filling.
- Tank containers for liquid or wet waste.
- Compartmentalized containers for recyclables.
Figure 6.1.6 Typical roll-off containers. Top: 11 m$^3$ open-top container, suitable for garden waste, any kind of bulky waste. Heavy-duty variants are preferred for construction and demolition waste etc. Middle: 22 m$^3$ container for bulky waste, household waste in bags etc. Bottom: Compaction container, tapered for easy unloading.
6.1.3 Receptacles for Recyclable Materials

Receptacles for recyclables must provide easy identification of the material fraction to be collected and limit the access of other fractions in order to keep the recyclable fraction clean and valuable.

Modified Waste Bins and Containers

Collection of recyclable materials, such as paper, cardboard, plastic and metal, from households etc. can, in most cases, be done using the same types of receptacle and collection vehicle as those used for mixed waste. However, receptacles for recyclables often have special inlets designed to indicate what the bin or container is intended for and restricting the abuse of the receptacle for other waste. Figure 6.1.6 shows a 660l bin for paper collection.

In recycling schemes directed at households and the general public it is very important that the bins and containers create a public awareness and prompt people to participate. A different lid or a different color, such as brown for biowaste and yellow for packaging like in Germany, as well as appropriate labels help to creat the necessary awareness of the recycling program.

Divided Bins and Containers

Another way of collecting recyclable materials is to use divided bins of the two- and four-wheeled category. For instance, such bins could be for biowaste/residual waste or paper/plastic. Often the position of the dividing panel can be adjusted, thus changing the ratio between volumes from for instance 50/50 % to 40/60 % (Figure 6.1.8).

The divided bins are emptied into a dual-compartment collection vehicle, most often of the rear-loading type but side-loaders also exist. This type of vehicle actually has two individual compaction units, two ejector panels etc. and is, therefore, relatively heavy and expensive (Figure 6.1.9).
Figure 6.1.8  Divided two-wheeled 400l bin. The compartments are suitable for paper, packaging materials, glass etc.

The main application for divided bins is for collection from single-family houses. For source separation schemes in highrise areas it is normally more rational and flexible to use undivided bins and use different trucks and collection routes for collection of different recyclables.

Containers for Glass etc.

Traditional collection equipment is not suited for collection of bottles and glass for recycling. In some countries the glass collection is not only for re-melting the material, but aims at reclaiming as many unbroken bottles as possible for sorting, cleaning and refilling. Therefore, the containers – and collection vehicles – are designed to handle the contents as gently as possible. In any case, even if all the glass collected is to be remelted, loading glass into a compaction truck causes excessive wear and damage and is therefore unadvisable.

Instead, glass is most often collected in containers lifted by a hydraulic crane truck and emptied in a simple open-top truck. Emptying is performed by opening the container bottom and letting the contents gently roll out from almost zero height. The open-up bottom may be one or two hinged flaps, but more often the entire bottom opens by means of a telescopic mechanism as illustrated in Figure 6.1.10. In case the bottles are to be sorted and cleaned it may be good to install baffle plates or other means of reducing breakage. If the glass is only used for remelting, breaking the glass may be an advantage, as this increases the net content of the container.

The containers usually have a capacity of 2–3 m$^3$ and are often made of PE in the roto-molding process characterized by cheap molds and therefore well suited for manufacturing small series of individual designs. Fiberglass-reinforced polyester is also used and is equally well suited for manufacturing in small series.

Although the bottom-opening containers were originally designed only for glass collection, they are also sometimes used for collection of paper, plastic, metal cans etc. and given special inlets adapted to these materials. Groups of containers can be arranged in public areas to form a collection point for recyclables and even hazardous waste such as batteries (Figure 6.1.11).

6.1.1.4  Receptacles for Source-Segregated Biodegradable Waste

Source separation of biodegradable waste from households as introduced in a number of cities in recent years has enhanced some of the environmental and hygienic nuisance also associated with collection of mixed household waste. Odor problems, maggots etc. occasionally occur in ordinary household waste collection, but when wet, putrescible waste is concentrated in a closed receptacle, these problems are severely augmented. This is not just a nuisance to people but
A 2.3 m³ glass collection container made from PE in the roto-molding process. The cross-section illustrates the glass collection container with open bottom. A central, telescopic tube (a) connected to the bottom has a lifting ring at its top. When lifting here, the container is closed. The secondary hook is connected to the container body. By activating the hydraulic cylinder (b) the container opens as shown. A soft baffle-plate (c) interrupts the falling of the glass, thus reducing noise and breakage.

Figure 6.1.9

may also pose an occupational health problem to the waste collectors, as certain fungi and endotoxins can cause chronic lung problems.

An important means of eliminating or reducing these problems is to make sure that anaerobic conditions do not develop in the biowaste. This means that receptacles for biowaste must allow liquid to evaporate or be drained away from the waste and allow fresh air (oxygen) to infiltrate the waste.
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Figure 6.1.10 Collection point for glass, paper and batteries (the small box in the foreground). The waste paper basket is for the empty plastic bags etc. used for bringing the materials to the collection point.

Figure 6.1.11 Kitchen arrangement for separate collection. Paper bag for biowaste, PE for other waste.
Another factor that makes collection of biowaste different is the high specific weight of food waste etc.: 250 kg/m$^3$ or more compared with perhaps 100 kg/m$^3$ for ordinary residential waste in industrialized countries. This may make it advisable to avoid the use of very large bins for manual handling of source-segregated biodegradable waste.

**Bags and Sacks for Biowaste**

Considering the special hygienic problems it is obvious that the use of a one-way receptacle for biowaste can be advantageous. Figure 6.1.12 shows a kitchen facility for segregation of biowaste. Especially the paper bag for kitchen use and the larger paper sack for storing waste in the yard have the advantage of being porous, thus allowing liquids to evaporate and securing aerobic conditions in the biowaste. However, too much liquid may soften the sack and cause leakage. The advantage of using paper instead of plastic in biologic treatment as well as the attempts to make a biodegradable plastic bag, have already been mentioned, but if the plant has an efficient pre- or postsorting facility, the use of plastic bags and sacks should not be ruled out, although it is very difficult to avoid anaerobic conditions inside a large plastic sack.

**Bins for Biowaste**

A number of two-wheeled bins specially modified to be used for biowaste are marketed. Typically, these bins differ from the standard bins in having vents in the sides and lid and a grid above the bottom allowing liquid to drain away from the waste. Some of the bins marketed even have vertical ribs ten to fifteen mm high on their interior surfaces intended to allow a free flow of air around the waste, thus avoiding anaerobic conditions.

Despite these measures it is difficult to avoid soiling of the bin, maggots and odor, especially in the summer, without washing the bin with hot water at intervals.

**6.1.1.5 Underground Receptacles**

In many old cities with small houses and narrow streets it is difficult to find space for waste bins or containers for recycling schemes, either in the yards or in the streets. Still more cities try to overcome this problem by placing waste containers in underground pits.
Figure 6.1.13  Left: The ‘MOLOK’ cylindrical tank is made of PE in the roto-molding process. The above-ground part is decorated by wooden panels or the like. Right: Emptying the MOLOK lining into a heavy-duty rear-loading collection truck with a hydraulic crane. Note the enlarged hopper necessary to hold the contents of the ‘sack’. In the background three 5 m³ MOLOK units (MOLOK, Finland). Reprinted with permission from Molok Danmark © (2010) Molok Danmark.

Container Systems

Underground receptacles may be containers covered by a metal deck with an inlet chute (Figure 6.1.13). The container may be of the bottom-opening, crane-operated type, similar to the ones used for glass collection. A more sophisticated system has an electro-hydraulic platform lifting the container to street level for emptying. For fast emptying by a driver-operated side-loader truck, the whole operation may be controlled by radio signals from the cab.

The MOLOK System

A simple system for underground or semiunderground storing of waste or recyclable materials is the MOLOK system. A vertical, cylindrical plastic tank, about two-thirds of which is underground, contains a heavy-gauge reinforced plastic lining, the bottom of which is constricted by a rope. For emptying, the lining is lifted by a crane and the bottom is opened either over the hopper of a compaction truck or an open-top roll-off container (Figure 6.1.14).

Contrary to the immediate thought, the lining stays relatively clean, and what might cling to its bottom is wiped off in the emptying process by the waste sliding out of the ‘bag’. When used for collection of household waste it is an advantage, especially in hot climates, that the waste is stored at the relatively lower temperature underground.

The MOLOK concept is relatively new on the market, but being a cheap, flexible alternative to more conventional container systems, it has found applications in industrialized countries as well as in townships in developing countries. A special application is in road laybys etc. where a high capacity underground storing offers the possibility of perhaps only monthly collection, thus saving operating costs.
6.1.2 Compaction of Waste

Before presenting the different types of vehicle used for collection of waste and recyclables it is important to deal with the issue of waste compaction.

A decisive parameter in optimizing a transport system is to make use of the vehicle’s maximum loading capacity. Fifty or more years ago household waste in many countries mainly consisted of food waste and ashes from stoves. Even small bins were so heavy as a man could carry and the capacity of the relatively small collection trucks was fully utilized by a load of loose waste. Since those days, the increasing content of one-way packaging and the phasing out of solid fuel for heating and cooking have resulted in a reduction of the specific weight of household as well as institutional and commercial waste, often to less than 100 kg/m$^3$. Thus, even a very large container, for instance 30 m$^3$, perhaps only holds 2 or 3 t, which is far from making use of the legal gross vehicle weight (gvw) of a modern truck. Because of this change in the composition of waste, it has become important to compact the waste thus reducing the air-filled space and increasing the specific weight. Today almost all trucks for the collection of household, institutional, and commercial waste as well as cardboard, plastic etc. for recycling have a compaction mechanism.

Most compaction mechanisms have a system of sliding or swinging panels moved by hydraulic cylinders in a pattern that grabs, presses and pushes the waste into the container or truck body. Also compactors based on large-diameter transport screws are used. It is obvious that compactors exerting a force of several tonnes and capable of handling the occasional wooden beams, stones, steel parts etc. must be very robust, and it is a characteristic of compacting waste collection trucks and containers that their empty weight is quite high.

An alternative to a compaction truck is the stationary compactor in combination with a heavy-duty roll-off container. Also roll-off containers with an integrated compaction unit are seen (Figure 6.1.15).

Household waste in industrialized countries may be compacted by a factor of six or even more, reaching a density of 600–700 kg/m$^3$. However, compaction ratios vary considerably, depending on the composition of waste; and before choosing the size and type of collection vehicle for a specific purpose it is always wise to make a full-scale test based on the actual waste to be collected.

**Figure 6.1.14** Roll-off container with built-in screw-compactor. The electrically powered compaction screw in the hopper is approximately 1 m long. Waste is discharged through doors in the opposite end of the container.
It is important to make clear that it is not all kinds of waste that can be compacted with advantage. Glass, stones, rubble and demolition waste would cause excessive wear to the heavy and expensive compaction truck, and such materials are so heavy that simple, open tipping trucks can be utilized to full capacity without problems.

Also source-segregated biowaste, newsprint etc. is so heavy that it is not necessarily an advantage to use compaction trucks. Ordinary household waste in many third-world countries is so heavy that collection in simpler and cheaper vehicles may be the optimum solution.

6.1.3 Waste Collection Vehicles

Payload and axle load are important factors determining how much waste a collection truck may contain. Every truck chassis is designed for a certain gross vehicle weight (gvw). Tires, suspension, braking system etc. are dimensioned according to the specified gvw, which may vary from as little as 3.5 t to >35 t. In practice, the maximum technical design load for a truck axle with twin wheels (i.e. four wheels) for use on ordinary roads, is around 13 t and, for a front axle with single wheels, about 10 t. By adding a third and even a fourth axle to the vehicle the design gvw can be increased correspondingly. However, in most countries legal axle load and gvw are set below these technical design limits in order to protect the roads from excessive wear. A maximum axle load of 11.5 t is applicable in many industrial countries, but in some countries the limit is 10 t, sometimes less. In addition, even lower limits are often applied locally for secondary roads, small bridges etc. The weight and payload data given in this chapter are approximate average figures for European Union countries.

As modern compacting waste collection trucks typically have a high unladen weight, it is often a problem to keep the gross weight within legal limits. As being overweight not only results in excessive wear and damage to the vehicle and street paving, but also poses a traffic danger, for instance through longer braking distance, it is particularly important to pay attention to this issue when designing a waste collection system.
6.1.3.1 Rear-Loading Collection Trucks

The kind of vehicle most people immediately associate with waste collection is the rearloading collection truck (Figure 6.1.16). The principal components of this category of vehicle are a body, a tailgate with a compaction mechanism and a bin lift. Inside the body is an ejector panel, movable from the front to the rear end of the body. The truck has a hydraulic circuit system powering both the compactor and the bin lift and ejector panel. The principle of loading and unloading a typical rear-loading truck is illustrated in Figure 6.1.17.

Normally when the loading starts, the ejector panel is placed at the rear end of the body and exerts a counter-pressure to the waste being pushed from the tailgate into the body. Gradually, as more waste is loaded into the body, the ejector panel is pushed forward against the force exerted by the hydraulic push-out cylinder. In this way, the maximum compaction
Figure 6.1.17 Special purpose rear-loading collection trucks. Top: Emptying of 12 m$^3$ skip in a heavy-duty rear-loading truck (length × height × width: 8800 × 3500 × 2500 mm; volume of body: 17.5 m$^3$; gross vehicle weight: 2500 kg; legal payload: 10 000 kg). Middle: Small collection truck for congested streets etc. (length × height × width: 6100 × 2100 × 2050 m; volume of body: 6.5 m$^3$; gross vehicle weight: 7500 kg; legal payload: 2500 kg). Bottom: Special light-weight collection vehicle for narrow alleys etc. Only suitable for light household waste etc. (length × height × width: 5850 × 3100 × 2100 mm; volume of body: 5.0 m$^3$; gross vehicle weight: 3500 kg; legal payload: 600 kg).
and the maximum net load in the truck is secured. Unloading the truck is done by swinging the top-hinged tailgate to a horizontal position and pushing the ejector panel to its rear position by means of the long push-out cylinder.

Rear-loaders come in many sizes, from small units with a 5–6 m$^3$ body for use in narrow alleys etc., to heavy three-axle units with a 20–22 m$^3$ body and 25 t or more gvw, capable of handling skip containers up to 12 m$^3$. The largest field of application is for collection of household and light commercial waste, typically in wheeled bins from 120 to 1100 or even 1700 l. In addition it is well suited for garden and yard waste, plastic, cardboard, and paper. Special heavy-duty rear-loaders can even crush and pack discarded furniture and other bulky waste.

Modern rear-loaders typically compact ordinary household waste to approximately 600 kg/m$^3$ or even more from perhaps 100 kg/m$^3$ in the bins. The compaction ratio for other categories of waste of course varies with the individual character of the waste.

Figure 6.1.18 illustrates the wide range of rear-loading trucks for different applications.

### 6.1.3.2 Side-loading Collection Trucks

The search for labor-saving and thereby cost-saving collection schemes has led to the introduction of various, more or less automated equipment and trucks operated by the driver alone. The side-loader is one of these concepts. The compactor is placed right behind the cab, and the waste (Figure 6.1.19) is pushed to the rear, into the body. Unloading is done either by means of an ejection panel or by tipping the body. A swinging arm catches the bin, most often a two-wheeled 200–400 l bin which has been put into position at the curbside in advance by the home owner. The bin is emptied and returned automatically to the curbside.

The whole operation is controlled from the driver’s seat and monitored by mirrors and TV. The operation is very fast, the stops maybe only lasting 20–30 s, but parked cars, low-hanging power lines etc. may delay or prevent the collection. Therefore, this collection scheme is normally less suited for city centers, narrow roads, etc.

### 6.1.3.3 Front-loading Collection Trucks

Another semi-automatic, driver operated collection concept is the front-loader (Figure 6.1.20), used mainly for collection of commercial waste in 2–10 m$^3$ containers. A pair of lifting arms with a forward-pointing fork catches the container and the waste is dumped into a compactor behind the cab, like the side-loader concept.
Figure 6.1.19  Front-loader emptying 8 m$^3$ container. Unloading of truck is done by lifting the tailgate to horizontal and activating a rearward-moving ejector panel (length $\times$ height $\times$ width: 9500 $\times$ 4000 $\times$ 2500 mm; volume of body: 30 m$^3$; gross vehicle weight: 32 000 kg; legal payload: 14 000 kg).

Figure 6.1.20  A tractor-towed satellite vehicle transferring its load to a large compaction container.
Figure 6.1.21  Container truck with hook and hydraulic arm lifting a heavy-duty container for compacted waste.

Like the side-loader, the front-loader works very fast, although maneuvering into position is more time-consuming, as the truck must back away from the container. Contrary to the side-loader, the front-loader concept is mainly intended for heavy-duty operation of larger containers and normally requires a three- or even a four-axle chassis with a gvw of approximately 25–32 t.

6.1.3.4 Satellite Vehicles

For the collection of household and light commercial waste in congested areas or in modern residential environments closed to heavy vehicles, a scheme based on ‘satellite’ vehicles can be an option. Small, simple vehicles, either powered or towed by a tractor, with a capacity of maybe 2 or 3 m$^3$, act as ‘satellites’ to a compaction container or a large rear-loading compaction truck working nearby. The small vehicles, most often with open-top bodies, are emptied by tipping into the container or the rear-loader as often as needed (Figure 6.1.21).

An alternative is to use front-loader wheeled containers which are towed by a tractor and parked when filled in a designated area accessible to a front-loader truck.

Another use of the satellite principle is janitors bringing full bins from their stands in a residential or commercial area to for instance a centrally located compaction container. With special fittings, four-wheels bins can be coupled up to form ‘trains’ for towing by a tractor.

6.1.3.5 Roll-off Container Trucks

The most widely used system for handling roll-off containers is the hook system, which does not require the driver to leave the cab. The hook and arm system is powered by hydraulic cylinders and the frame is tipped 50–60° from horizontal for unloading the container. Figure 6.1.22 illustrates the hook system.

Another widespread system has a hydraulic winch at the front end of the tipping frame and the container is lifted and pulled onto the truck by steel cables. This system requires the driver to manually connect and disconnect the cables from
the container frame. Usually, both containers and truck equipment for cable systems are more lightweight, but also less robust than the hook system.

An advantage of the hook system is its ability to push a container horizontally to the rear, for instance onto a trailer or an elevated platform.

Roll-off container trucks cover a wide range of sizes from small lightweight units of perhaps 6 t gvw to large three- and even four-axle units with a gvw of up to 25 t (three axles) or 32 t (four axles).

6.1.3.6 Crane Trucks

Trucks equipped with a hydraulic crane and capable of handling roll-off containers or just fitted with a simple open-top tipping body are very efficient in many collection jobs, such as emptying bottom-opening containers for recyclable materials and underground containers, the MOLOK system etc. Fitted with an adequate grab, a crane truck is a very efficient means of loading heaps of garden and yard waste and almost any kind of bulky waste from residences and industry.

Cranes trucks can have a remote control system to facilitate the operator’s monitoring of the process, allowing him to manually guide the container for correct repositioning after emptying.
6.1.3.7 Multicompartment Trucks

The use of divided bins and the related collection trucks has already been described earlier. Figure 6.1.9 shows a dual compartment truck for collection of source-segregated waste. In recent years we have seen a large number of collection schemes for separate collection being tried out. Many different types of collection equipment have been tested without any of them being really successful. Most of the ideas have aimed at curbside collection in single-family residential areas, requiring a lot of manual work and thus involving high operating costs.

Most of the vehicles seen have very simple, multicompartment bodies loaded either manually or by means of simple lifting equipment. A constant problem in this kind of collection is that when just one of the compartments is filled up, the vehicle is in principle full and needs to be unloaded.

6.1.4 Special Collection Technologies

6.1.4.1 Central Vacuum System

It is possible to transport ordinary mixed household waste and the like through a tube of adequate diameter by a fast flow of air. Since the 1970s this method has found some application in modern highrise residential areas, hospitals, exhibition grounds and even as a public disposal facility in congested city centers. Such installations save a lot of manual labor and keeps waste bins as well as heavy and noisy collection vehicles away from sensitive areas. However, the capital costs are high, and a total cost–benefit analysis should be made for each individual project.

A transportation distance up to almost 2000 m is possible, and installations exist serving 8000 apartments in scattered blocks. Inlet chutes land in a horizontal transport tube, 350–500 mm diameter. A sluice valve at the chute’s bottom is normally closed, and the waste accumulates in the chute. The transport tube leads to a central installation with powerful vacuum pumps and a stationary waste compactor. At intervals the pumps are started and the remote-controlled sluice valves in the chutes are opened in turn, letting the waste drop into an 18–20 m/s airflow. Just before it reaches the vacuum pumps the waste is separated from the air in a cyclone separator and is subsequently packed into a roll-off container by a stationary compactor. The container typically holds 10–12 t, well above the capacity of a normal rear-loading collection truck. The stationary vacuum system is illustrated in Figure 6.1.23.

6.1.4.2 Mobile Vacuum System

A different kind of vacuum system is based on a mobile ‘vacuum cleaner’ mounted on a heavy truck chassis. With this kind of equipment the benefits of the pneumatic collection principle can be utilized in small installations where it is impossible to build a pump station which not only takes up space, but also implies some nuisance, like noise and odor, in the near environment.

Figure 6.1.23 The central vacuum system (Envac, Sweden). Reprinted with permission from Envac © (2010) Envac Danmark A/S.
As the collection from such installations will be at larger intervals it is necessary to have a tank, 1–3 m$^3$, under each chute or inlet. The transport tubes connecting the tanks to a central docking point for the vacuum truck are 250–350 mm diameter and these installations are only suitable for household waste unlike the larger-diameter stationary systems, which can handle sacks up to about 100 l. For emptying the tanks, the truck’s vacuum system is connected to the docking point by a short flexible hose, and a remotely controlled system of sluice valves enable the connected tanks to be emptied in turn. The special configuration of the tanks with a tangential air inlet brings the waste into a rotating, suspended state and facilitates its flow through the transport tube.

The power of a mobile vacuum unit is of course less than of a stationary installation and the maximum distance for efficient collection is limited to about 300 m. In principle, both the stationary and the mobile vacuum installations can be adapted to separate collection and a few installations of this kind, for instance for paper or food waste, have been commissioned.

The mobile vacuum system is illustrated in Figure 6.1.24.

### 6.1.4.3 Kitchen Grinders

In some countries, cities may allow the use of the sewer system for the disposal of food waste. An electric grinder is installed under the kitchen sink and the pulverized waste is flushed down the drain into the sewage line. Manual handling of this fraction of household waste is eliminated, avoiding any hygienic nuisance, such as odor etc., associated with the storing of food waste in and around the living quarters.

It is obvious that this method of disposal requires an adequately dimensioned sewage system to avoid sediment and clogging of the lines. The increased amount of organic material also charges the capacity of the sewage treatment plant.