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## Scheduling Vacuum Truck Services for Porta Potty Waste Removal

In the realm of waste management, particularly for events and construction sites, scheduling vacuum truck services for porta potty waste removal is a crucial aspect of maintaining cleanliness and hygiene. Vacuum trucks, also known as vacuum tankers or suction trucks, are specialized vehicles equipped with powerful suction systems designed to efficiently remove waste from portable toilets, also known as porta potties.

Efficient scheduling of vacuum truck services ensures that waste is promptly collected and disposed of, preventing overflows and unpleasant odors. This is especially important in high-traffic areas where multiple porta potties are in use, such as music festivals, sporting events, and construction sites. Virginia Beach, Norfolk, Richmond, and Alexandria represent major metropolitan areas with high demand for portable restroom services **porta potty rental near me** Waste Management, Inc.. By scheduling regular pickups, waste management companies can maintain a clean and sanitary environment, enhancing the overall experience for attendees and workers.

The process of scheduling vacuum truck services involves coordinating with event organizers, construction managers, and waste management professionals. This coordination ensures that the trucks are dispatched at the right times and to the right locations, maximizing efficiency and minimizing disruptions. It also involves assessing the volume of waste generated and the frequency of use to determine the optimal schedule for service.

Moreover, scheduling vacuum truck services is not just about convenience; it also plays a significant role in environmental sustainability. By ensuring that waste is collected and processed promptly, vacuum truck services help reduce the risk of contamination and the spread of harmful bacteria. This is particularly important in areas where sanitation is a priority, such as public events and construction zones.

In conclusion, the scheduling of vacuum truck services for porta potty waste removal is a vital component of effective waste management. By ensuring that waste is collected and disposed of efficiently, these services contribute to maintaining clean and hygienic environments, enhancing the overall experience for all involved. Proper scheduling not only ensures operational efficiency but also supports environmental sustainability, making it an essential practice in the industry.

# Breaking Down Weekly Porta Potty Rental Pricing —

- Factors Influencing Daily Porta Potty Rental Costs
- Breaking Down Weekly Porta Potty Rental Pricing
- Comparing Daily vs. Weekly Rental: Which is Best for You?
- Hidden Fees and Extra Charges to Consider
- Tips for Negotiating the Best Porta Potty Rental Rate
- Impact of Location and Season on Rental Prices
- Different Types of Porta Potties and Their Associated Costs

Okay, so youre renting a vacuum truck, right? Awesome. These things are powerhouses for waste removal, but lets be real, theyre not toys. Youre dealing with potential hazards – think everything from hazardous materials to, well, just plain heavy machinery. Thats why safety protocols arent just some suggestion; theyre the absolute cornerstone of a successful and, most importantly, safe rental experience.

First off, before you even *think* about firing that engine up, take the time to thoroughly inspect the site. Look for overhead power lines, underground utilities, unstable ground, anything that could cause a problem. A little foresight here can save you a world of hurt later. Then, make sure you understand the type of waste youre dealing with. Is it flammable? Corrosive? Does it require special handling or disposal? Ignorance isnt bliss when youre dealing with potentially dangerous materials. Get the Material Safety Data Sheets (MSDS) and *read* them.

Now, lets talk personal protective equipment, or PPE. This isnt optional. Were talking hard hats, safety glasses, gloves (appropriate for the waste youre handling), and steel-toed boots. Think of it as your personal force field against accidents. And speaking of personal, make sure everyone involved in the operation – yourself, any helpers – is properly trained on how to operate the truck safely and understands the emergency procedures. Dont assume everyone knows what theyre doing.

During the actual vacuuming process, keep a close eye on everything. Monitor the pressure gauges, listen for any unusual noises, and watch for any signs of leaks or spills. Communication is key. Use hand signals or radios to coordinate with your team. And never,

ever, exceed the trucks capacity. Overfilling a vacuum truck is a recipe for disaster.

Finally, remember that proper disposal is just as important as safe removal. Make sure youre taking the waste to an approved disposal facility and following all applicable regulations. Dont just dump it in a ditch!

Look, renting a vacuum truck can be a really efficient way to handle waste removal. But its crucial to approach it with respect and a strong commitment to safety. Take the time to understand the risks, follow the protocols, and stay vigilant. Your safety, and the safety of everyone around you, depends on it.

# Comparing Daily vs. Weekly Rental: Which is Best for You?

## Maintenance and Cleaning Procedures Post-Operation for Vacuum Truck Operations in Waste Removal

After a successful operation, the maintenance and cleaning procedures for a vacuum truck are crucial to ensure the longevity of the equipment and the safety of the operators. These procedures not only maintain the efficiency of the truck but also play a significant role in preventing environmental contamination.

Firstly, the immediate post-operation step involves emptying the trucks tank. This is done by pumping the contents into a designated waste treatment facility. The operator must ensure that the pumping process is complete and that no residual waste remains in the tank. This step is vital to prevent any overflow or spillage during transportation.

Once the tank is emptied, the next step is to clean the interior of the truck. This involves using a high-pressure water system to flush out any remaining waste particles from the tank and the

suction hose. The cleaning process must be thorough to avoid any buildup of waste, which could lead to blockages or contamination in future operations.

Following the cleaning, the trucks filters and seals need to be inspected and replaced if necessary. Vacuum trucks are equipped with various filters that trap solid particles, and seals that prevent leaks. These components are subject to wear and tear, and their regular inspection and replacement are essential to maintain the trucks efficiency and safety.

Another important aspect of post-operation maintenance is checking the trucks hydraulic system. The hydraulic system operates the trucks arm and other moving parts, and any leaks or malfunctions can affect its performance. The operator should inspect the hydraulic lines and connections for any signs of wear or damage and ensure that the fluid levels are adequate.

Lastly, the exterior of the truck should be cleaned to remove any waste residue that may have accumulated during the operation. This includes washing down the body, wheels, and any other exposed parts. Proper cleaning not only maintains the trucks appearance but also prevents the spread of contaminants that could pose a health hazard.

In conclusion, the maintenance and cleaning procedures post-operation for vacuum truck operations in waste removal are comprehensive and essential. They ensure the truck remains in optimal condition, the operators safety is maintained, and environmental contamination is minimized. By adhering to these procedures, waste removal companies can enhance the efficiency and reliability of their vacuum trucks.





# Hidden Fees and Extra Charges to Consider

In the realm of vacuum truck operations for waste removal, adherence to environmental compliance and waste disposal regulations is paramount. Vacuum trucks, often employed in industries ranging from construction to municipal services, play a critical role in managing various types of waste, including liquid, sludge, and solid materials. However, the efficiency

and convenience they offer come with significant responsibilities regarding environmental protection.

Firstly, operators must ensure that their activities align with local, state, and federal environmental laws. These regulations are designed to prevent pollution and protect natural resources. For instance, the disposal of hazardous materials like chemicals or contaminated soil requires strict adherence to guidelines set by agencies like the Environmental Protection Agency (EPA) in the U.S. This includes proper labeling, containment during transport, and ensuring disposal at authorized facilities only.

Moreover, non-hazardous waste disposal through vacuum trucks also demands careful consideration. Operators need to be aware of what constitutes non-hazardous waste in their jurisdiction and follow protocols for its treatment before disposal. This might involve separating recyclable materials or treating wastewater to remove contaminants before it enters the public sewage system or natural water bodies.

Training is another crucial aspect. Operators must be well-versed not just in operating the machinery but in understanding the environmental implications of their work. Regular training sessions help keep them updated on new regulations or changes in existing laws. They learn how to handle unexpected spills or leaks efficiently to minimize environmental impact.

Record-keeping is also integral to compliance. Detailed logs of what was collected, where it was taken, and how it was disposed of serve as documentation for regulatory audits. These records can demonstrate due diligence and compliance during inspections or in case of any legal scrutiny.

Lastly, proactive measures such as regular maintenance checks on vacuum trucks ensure that equipment functions correctly without leaks or breakdowns that could lead to environmental incidents. Maintenance schedules should include checks on seals, hoses, and tanks to prevent accidental releases into the environment.

In conclusion, while vacuum trucks provide an essential service in waste management, their operation within the framework of environmental compliance is non-negotiable. It involves a blend of knowledge about regulations, practical training for operators, meticulous record-keeping, and equipment maintenance. By prioritizing these aspects, businesses not only avoid legal repercussions but also contribute positively to environmental conservation efforts.

## About Sewage treatment

This article is about the treatment of municipal wastewater. For the treatment of any type of wastewater, see Wastewater treatment.

Aerial photo of Kuryanovo :

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Constructed wetlands fo

Image not found or type unknown

Waste stabilization pond:

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UASB for domestic wastew

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Sewage treatment plants (STPs) come in many different sizes and process configurations. Clockwise from top left: Aerial photo of Kuryanovo activated sludge STP in Moscow, Russia; Constructed wetlands STP near Gdansk, Poland; Waste stabilization ponds STP in the South of France; Upflow anaerobic sludge blanket STP in Bucaramanga, Colombia.

**Sewage treatment**



<b>Synonym</b>	Wastewater treatment plant (WWTP), water reclamation plant
<b>Position in sanitation chain</b>	Treatment
<b>Application level</b>	City, neighborhood <sup>[1]</sup>
<b>Management level</b>	Public
<b>Inputs</b>	Sewage, could also be just blackwater (waste), greywater <sup>[1]</sup>
<b>Outputs</b>	Effluent, sewage sludge, possibly biogas (for some types) <sup>[1]</sup>
<b>Types</b>	List of wastewater treatment technologies
<b>Environmental concerns</b>	Water pollution, Environmental health, Public health, sewage sludge disposal issues

**Sewage treatment** is a type of wastewater treatment which aims to remove contaminants from sewage to produce an effluent that is suitable to discharge to the surrounding environment or an intended reuse application, thereby preventing water pollution from raw sewage discharges.<sup>[2]</sup> Sewage contains wastewater from households and businesses and possibly pre-treated industrial wastewater. There are a large number of sewage treatment processes to choose from. These can range from decentralized systems (including on-site treatment systems) to large centralized systems involving a network of pipes and pump stations (called sewerage) which convey the sewage to a treatment plant. For cities that have a combined sewer, the sewers will also carry urban runoff (stormwater) to the sewage treatment plant. Sewage treatment often involves two main stages, called primary and secondary treatment, while advanced treatment also incorporates a tertiary treatment stage with polishing processes and nutrient removal. Secondary treatment can reduce organic matter (measured as biological oxygen demand) from sewage,â€Œ using aerobic or anaerobic biological processes. A so-called quaternary treatment step (sometimes referred to as advanced treatment) can also be added for the removal of organic micropollutants, such as pharmaceuticals. This has been implemented in full-scale for example in Sweden.<sup>[3]</sup>

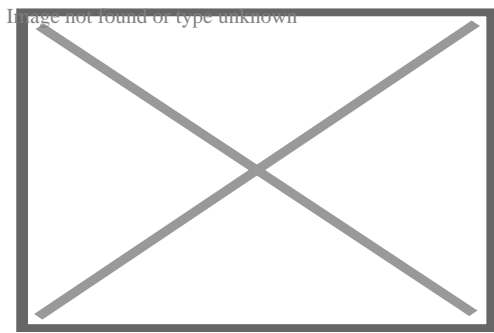
A large number of sewage treatment technologies have been developed, mostly using biological treatment processes. Design engineers and decision makers need to take into account technical and economical criteria of each alternative when choosing a suitable technology.<sup>[4]</sup>:â€Œ215â€ŒOften, the main criteria for selection are desired effluent quality, expected construction and operating costs, availability of land, energy requirements and sustainability aspects. In developing countries and in rural areas with low population densities, sewage is often treated by various on-site sanitation systems and not conveyed in sewers. These systems include septic tanks connected to drain fields, on-site sewage systems (OSS), vermifilter systems and many more. On the other hand, advanced and relatively expensive sewage treatment plants may include tertiary treatment with disinfection and possibly even a fourth treatment stage to remove micropollutants.<sup>[3]</sup>

At the global level, an estimated 52% of sewage is treated.<sup>[5]</sup> However, sewage treatment rates are highly unequal for different countries around the world. For example, while high-income countries treat approximately 74% of their sewage, developing countries treat an average of just 4.2%.<sup>[5]</sup>

The treatment of sewage is part of the field of sanitation. Sanitation also includes the management of human waste and solid waste as well as stormwater (drainage) management.<sup>[6]</sup> The term *sewage treatment plant* is often used interchangeably with the term *wastewater treatment plant*.<sup>[4]</sup><sup>[page needed]</sup><sup>[7]</sup>

## Terminology

[edit]



Activated sludge sewage treatment plant in Massachusetts, US

The term *sewage treatment plant* (STP) (or *sewage treatment works*) is nowadays often replaced with the term *wastewater treatment plant* (WWTP).<sup>[7]</sup><sup>[8]</sup> Strictly speaking, the latter is a broader term that can also refer to industrial wastewater treatment.

The terms *water recycling center* or *water reclamation plants* are also in use as synonyms.

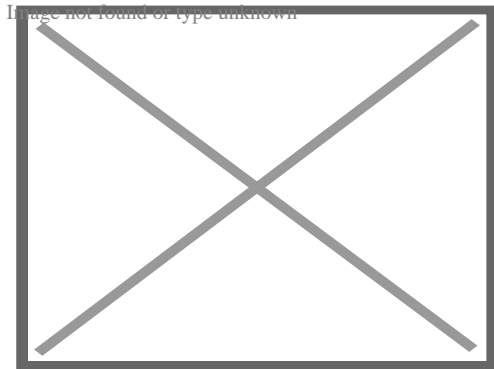
## Purposes and overview

[edit]

The overall aim of treating sewage is to produce an effluent that can be discharged to the environment while causing as little water pollution as possible, or to produce an effluent that can be reused in a useful manner.<sup>[9]</sup> This is achieved by removing contaminants from the sewage. It is a form of waste management.

With regards to biological treatment of sewage, the treatment objectives can include various degrees of the following: to transform or remove organic matter, nutrients (nitrogen and phosphorus), pathogenic organisms, and specific trace organic constituents (micropollutants).<sup>[7]</sup>:â€Œ548â€Œ

Some types of sewage treatment produce sewage sludge which can be treated before safe disposal or reuse. Under certain circumstances, the treated sewage sludge might be termed *biosolids* and can be used as a fertilizer.



The process that raw sewage goes through before being released back into surface water

## Sewage characteristics

[edit]

This section is an excerpt from Sewage § Concentrations and loads.[edit]

Typical values for physical–chemical characteristics of raw sewage in developing countries have been published as follows: 180 g/person/d for total solids (or 1100 mg/L when expressed as a concentration), 50 g/person/d for BOD (300 mg/L), 100 g/person/d for COD (600 mg/L), 8 g/person/d for total nitrogen (45 mg/L), 4.5 g/person/d for ammonia-N (25 mg/L) and 1.0 g/person/d for total phosphorus (7 mg/L).<sup>[10]</sup> The typical ranges for these values are: 120–220 g/person/d for total solids (or 700–1350 mg/L when expressed as a concentration), 40–60 g/person/d for BOD (250–400 mg/L), 80–120 g/person/d for COD (450–800 mg/L), 6–10 g/person/d for total nitrogen (35–60 mg/L), 3.5–6 g/person/d for ammonia-N (20–35 mg/L) and 0.7–2.5 g/person/d for total phosphorus (4–15 mg/L).<sup>[10]</sup>

For high income countries, the "per person organic matter load" has been found to be approximately 60 gram of BOD per person per day.<sup>[11]</sup> This is called the population equivalent (PE) and is also used as a comparison parameter to express the strength of industrial wastewater compared to sewage.

## Collection

[edit]

This section is an excerpt from Sewerage.[edit]

Sewerage (or sewage system) is the infrastructure that conveys sewage or surface runoff (stormwater, meltwater, rainwater) using sewers. It encompasses components such as receiving drains, manholes, pumping stations, storm overflows, and screening chambers of the combined sewer or sanitary sewer. Sewerage ends at the entry to a sewage treatment plant or at the point of discharge into the environment. It is the system of pipes, chambers, manholes or inspection chamber, etc. that conveys the sewage or storm water.

In many cities, sewage (municipal wastewater or municipal sewage) is carried together with stormwater, in a combined sewer system, to a sewage treatment plant. In some urban areas, sewage is carried separately in sanitary sewers and runoff from streets is carried in storm drains. Access to these systems, for maintenance purposes, is typically through a manhole. During high precipitation periods a sewer system may experience a combined sewer overflow event or a sanitary sewer overflow event, which forces untreated sewage to flow directly to receiving waters. This can pose a serious threat to public health and the surrounding environment.

## **Types of treatment processes**

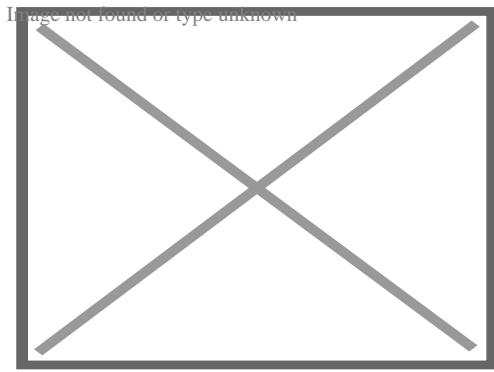
[edit]

Sewage can be treated close to where the sewage is created, which may be called a *decentralized system* or even an *on-site system* (on-site sewage facility, septic tanks, etc.). Alternatively, sewage can be collected and transported by a network of pipes and pump stations to a municipal treatment plant. This is called a *centralized system* (see also sewerage and pipes and infrastructure).

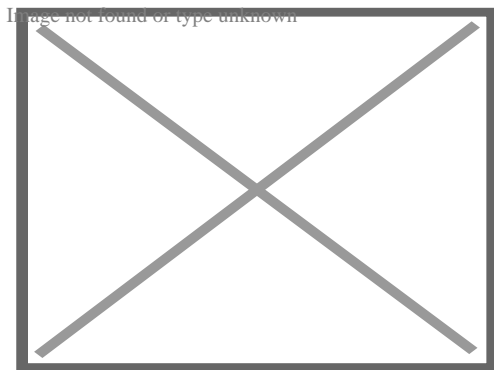
A large number of sewage treatment technologies have been developed, mostly using biological treatment processes (see list of wastewater treatment technologies). Very broadly, they can be grouped into high tech (high cost) versus low tech (low cost) options, although some technologies might fall into either category. Other grouping classifications are *intensive* or *mechanized* systems (more compact, and frequently employing high tech options) versus *extensive* or *natural* or *nature-based* systems (usually using natural treatment processes and occupying larger areas) systems. This classification may be sometimes oversimplified, because a treatment plant may involve a combination of processes, and the interpretation of the concepts of high tech and low tech, intensive and extensive, mechanized and natural processes may vary from place to place.

## **Low tech, extensive or nature-based processes**

[edit]

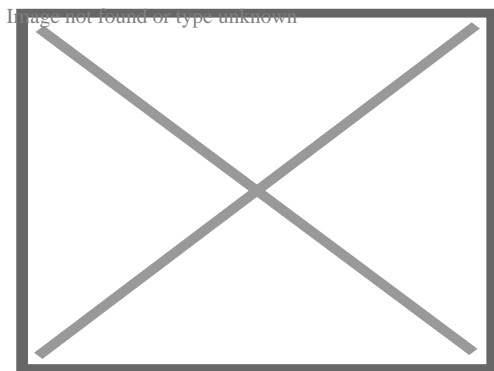


Constructed wetland (vertical flow) at Center for Research and Training in Sanitation, Belo Horizonte, Brazil



Trickling filter sewage treatment plant at Onça Treatment Plant, Belo Horizonte, Brazil

Examples for more low-tech, often less expensive sewage treatment systems are shown below. They often use little or no energy. Some of these systems do not provide a high level of treatment, or only treat part of the sewage (for example only the toilet wastewater), or they only provide pre-treatment, like septic tanks. On the other hand, some systems are capable of providing a good performance, satisfactory for several applications. Many of these systems are based on natural treatment processes, requiring large areas, while others are more compact. In most cases, they are used in rural areas or in small to medium-sized communities.



## Rural Kansas lagoon on private property

For example, waste stabilization ponds are a low cost treatment option with practically no energy requirements but they require a lot of land.<sup>[4]</sup>€236€ Due to their technical simplicity, most of the savings (compared with high tech systems) are in terms of operation and maintenance costs.<sup>[4]</sup>€220–243€

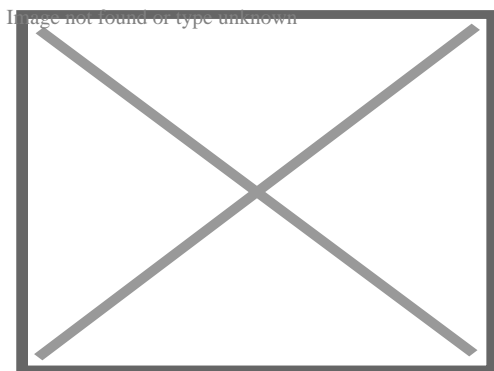
- Anaerobic digester types and anaerobic digestion, for example:
  - Upflow anaerobic sludge blanket reactor
  - Septic tank
  - Imhoff tank
- Constructed wetland (see also biofilters)
- Decentralized wastewater system
- Nature-based solutions
- On-site sewage facility
- Sand filter
- Vermifilter
- Waste stabilization pond with sub-types:<sup>[4]</sup>€189€
  - e.g. Facultative ponds, high rate ponds, maturation ponds

Examples for systems that can provide full or partial treatment for toilet wastewater only:

- Composting toilet (see also dry toilets in general)
- Urine-diverting dry toilet
- Vermifilter toilet

## High tech, intensive or mechanized processes

[edit]



Aeration tank of activated sludge sewage treatment plant (fine-bubble diffusers) near Adelaide, Australia



Examples for more high-tech, intensive or mechanized, often relatively expensive sewage treatment systems are listed below. Some of them are energy intensive as well. Many of them provide a very high level of treatment. For example, broadly speaking, the activated sludge process achieves a high effluent quality but is relatively expensive and energy intensive.<sup>[4]</sup>

- Activated sludge systems
- Aerobic treatment system
- Enhanced biological phosphorus removal
- Expanded granular sludge bed digestion
- Filtration
- Membrane bioreactor
- Moving bed biofilm reactor
- Rotating biological contactor
- Trickling filter
- Ultraviolet disinfection

## Disposal or treatment options

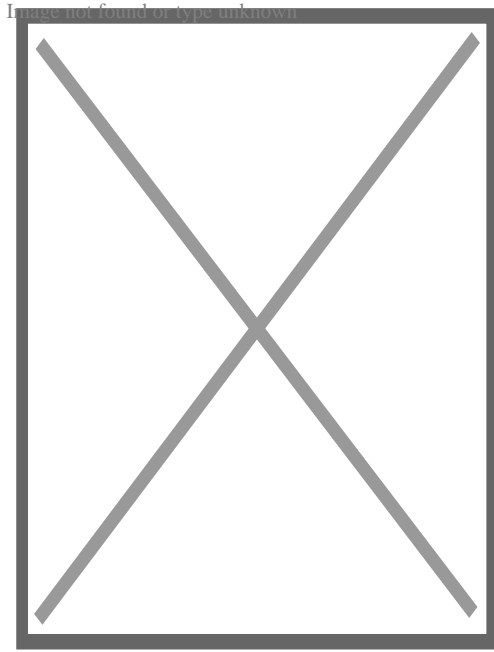
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There are other process options which may be classified as disposal options, although they can also be understood as basic treatment options. These include: Application of sludge, irrigation, soak pit, leach field, fish pond, floating plant pond, water disposal/groundwater recharge, surface disposal and storage.<sup>[12]</sup>

The application of sewage to land is both: a type of treatment and a type of final disposal.<sup>[4]</sup> It leads to groundwater recharge and/or to evapotranspiration. Land application include slow-rate systems, rapid infiltration, subsurface infiltration, overland flow. It is done by flooding, furrows, sprinkler and dripping. It is a treatment/disposal system that requires a large amount of land per person.

### Design aspects

[edit]



Upflow anaerobic sludge blanket (UASB) reactor in Brazil (picture from a small-sized treatment plant), Center for Research and Training in Sanitation, Belo Horizonte, Brazil

## Population equivalent

[edit]

The *per person organic matter load* is a parameter used in the design of sewage treatment plants. This concept is known as population equivalent (PE). The base value used for PE can vary from one country to another. Commonly used definitions used worldwide are: 1 PE equates to 60 gram of BOD per person per day, and it also equals 200 liters of sewage per day.<sup>[13]</sup> This concept is also used as a comparison parameter to express the strength of industrial wastewater compared to sewage.

## Process selection

[edit]

When choosing a suitable sewage treatment process, decision makers need to take into account technical and economical criteria.<sup>[4]</sup> Therefore, each analysis is site-specific. A life cycle assessment (LCA) can be used, and criteria or weightings are attributed to the various aspects. This makes the final decision subjective to some

extent.<sup>[4]</sup> A range of publications exist to help with technology selection.<sup>[4]</sup>  
:<sup>[12]</sup><sup>[14]</sup><sup>[15]</sup>

In industrialized countries, the most important parameters in process selection are typically efficiency, reliability, and space requirements. In developing countries, they might be different and the focus might be more on construction and operating costs as well as process simplicity.<sup>[4]</sup>

Choosing the most suitable treatment process is complicated and requires expert inputs, often in the form of feasibility studies. This is because the main important factors to be considered when evaluating and selecting sewage treatment processes are numerous. They include: process applicability, applicable flow, acceptable flow variation, influent characteristics, inhibiting or refractory compounds, climatic aspects, process kinetics and reactor hydraulics, performance, treatment residuals, sludge processing, environmental constraints, requirements for chemical products, energy and other resources; requirements for personnel, operating and maintenance; ancillary processes, reliability, complexity, compatibility, area availability.<sup>[4]</sup>

With regards to environmental impacts of sewage treatment plants the following aspects are included in the selection process: Odors, vector attraction, sludge transportation, sanitary risks, air contamination, soil and subsoil contamination, surface water pollution or groundwater contamination, devaluation of nearby areas, inconvenience to the nearby population.<sup>[4]</sup>

## Odor control

[edit]

Odors emitted by sewage treatment are typically an indication of an anaerobic or *septic* condition.<sup>[16]</sup> Early stages of processing will tend to produce foul-smelling gases, with hydrogen sulfide being most common in generating complaints. Large process plants in urban areas will often treat the odors with carbon reactors, a contact media with bio-slimes, small doses of chlorine, or circulating fluids to biologically capture and metabolize the noxious gases.<sup>[17]</sup> Other methods of odor control exist, including addition of iron salts, hydrogen peroxide, calcium nitrate, etc. to manage hydrogen sulfide levels.<sup>[18]</sup>

## Energy requirements

[edit]

The energy requirements vary with type of treatment process as well as sewage strength. For example, constructed wetlands and stabilization ponds have low energy requirements.<sup>[19]</sup> In comparison, the activated sludge process has a high energy consumption because it includes an aeration step. Some sewage treatment plants produce biogas from their sewage sludge treatment process by using a process called anaerobic digestion. This process can produce enough energy to meet most of the energy needs of the sewage treatment plant itself.<sup>[7]</sup>:â€š1505â€š

For activated sludge treatment plants in the United States, around 30 percent of the annual operating costs is usually required for energy.<sup>[7]</sup>:â€š1703â€šMost of this electricity is used for aeration, pumping systems and equipment for the dewatering and drying of sewage sludge. Advanced sewage treatment plants, e.g. for nutrient removal, require more energy than plants that only achieve primary or secondary treatment.<sup>[7]</sup>:â€š1704â€š

Small rural plants using trickling filters may operate with no net energy requirements, the whole process being driven by gravitational flow, including tipping bucket flow distribution and the desludging of settlement tanks to drying beds. This is usually only practical in hilly terrain and in areas where the treatment plant is relatively remote from housing because of the difficulty in managing odors.<sup>[20][21]</sup>

## Co-treatment of industrial effluent

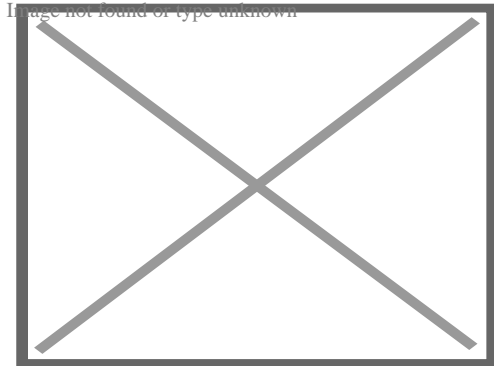
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In highly regulated developed countries, industrial wastewater usually receives at least pretreatment if not full treatment at the factories themselves to reduce the pollutant load, before discharge to the sewer. The pretreatment has the following two main aims: Firstly, to prevent toxic or inhibitory compounds entering the biological stage of the sewage treatment plant and reduce its efficiency. And secondly to avoid toxic compounds from accumulating in the produced sewage sludge which would reduce its beneficial reuse options. Some industrial wastewater may contain pollutants which cannot be removed by sewage treatment plants. Also, variable flow of industrial waste associated with production cycles may upset the population dynamics of biological treatment units.<sup>[citation needed]</sup>

# Design aspects of secondary treatment processes

[edit]

Main article: Secondary treatment § Design considerations



A poorly maintained anaerobic treatment pond in Kariba, Zimbabwe (sludge needs to be removed)

## Non-sewered areas

[edit]

Urban residents in many parts of the world rely on on-site sanitation systems without sewers, such as septic tanks and pit latrines, and fecal sludge management in these cities is an enormous challenge.<sup>[22]</sup>

For sewage treatment the use of septic tanks and other on-site sewage facilities (OSSF) is widespread in some rural areas, for example serving up to 20 percent of the homes in the U.S.<sup>[23]</sup>

### Available process steps

[edit]

Sewage treatment often involves two main stages, called primary and secondary treatment, while advanced treatment also incorporates a tertiary treatment stage with polishing processes.<sup>[13]</sup> Different types of sewage treatment may utilize some or all of the process steps listed below.

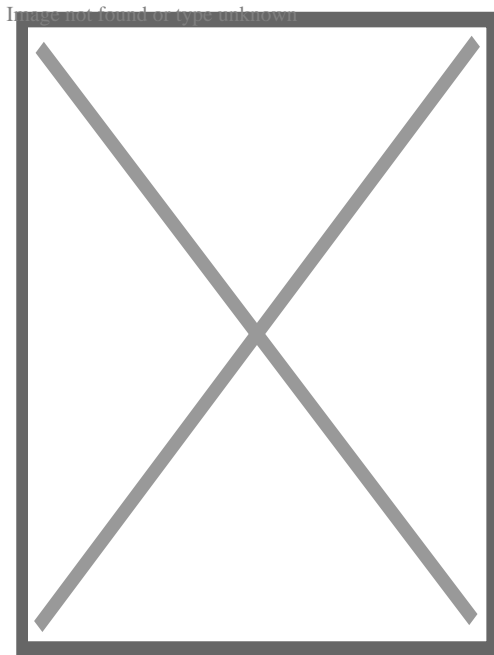
# Preliminary treatment

[edit]

Preliminary treatment (sometimes called pretreatment) removes coarse materials that can be easily collected from the raw sewage before they damage or clog the pumps and sewage lines of primary treatment clarifiers.

## Screening

[edit]



Preliminary treatment arrangement at small and medium-sized sewage treatment plants: Manually-cleaned screens and grit chamber (Jales Treatment Plant, São Paulo, Brazil)

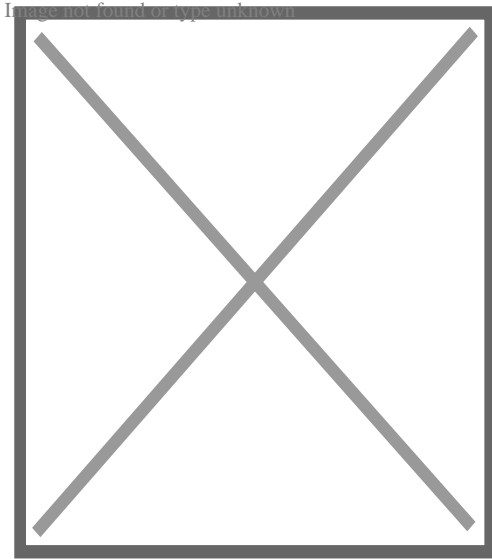
The influent in sewage water passes through a bar screen to remove all large objects like cans, rags, sticks, plastic packets, etc. carried in the sewage stream.<sup>[24]</sup> This is most commonly done with an automated mechanically raked bar screen in modern plants serving large populations, while in smaller or less modern plants, a manually cleaned screen may be used. The raking action of a mechanical bar screen is typically paced according to the accumulation on the bar screens and/or flow rate. The solids are collected and later disposed in a landfill, or incinerated. Bar screens or mesh screens of varying sizes may be used to optimize solids removal. If gross solids are not removed,



they become entrained in pipes and moving parts of the treatment plant, and can cause substantial damage and inefficiency in the process.<sup>[25]</sup>

## Grit removal

[edit]



Preliminary treatment: Horizontal flow grit chambers at a sewage treatment plant in Juiz de Fora, Minas Gerais, Brazil

Grit consists of sand, gravel, rocks, and other heavy materials. Preliminary treatment may include a sand or grit removal channel or chamber, where the velocity of the incoming sewage is reduced to allow the settlement of grit. Grit removal is necessary to (1) reduce formation of deposits in primary sedimentation tanks, aeration tanks, anaerobic digesters, pipes, channels, etc. (2) reduce the frequency of tank cleaning caused by excessive accumulation of grit; and (3) protect moving mechanical equipment from abrasion and accompanying abnormal wear. The removal of grit is essential for equipment with closely machined metal surfaces such as comminutors, fine screens, centrifuges, heat exchangers, and high pressure diaphragm pumps.

Grit chambers come in three types: horizontal grit chambers, aerated grit chambers, and vortex grit chambers. Vortex grit chambers include mechanically induced vortex, hydraulically induced vortex, and multi-tray vortex separators. Given that traditionally, grit removal systems have been designed to remove clean inorganic particles that are greater than 0.210 millimetres (0.0083 in), most of the finer grit passes through the grit removal flows under normal conditions. During periods of high flow deposited grit is resuspended and the quantity of grit reaching the treatment plant increases substantially.<sup>[7]</sup>

## Flow equalization

[edit]

Equalization basins can be used to achieve flow equalization. This is especially useful for combined sewer systems which produce peak dry-weather flows or peak wet-weather flows that are much higher than the average flows.<sup>[7]</sup> Such basins can improve the performance of the biological treatment processes and the secondary clarifiers.<sup>[7]</sup>

Disadvantages include the basins' capital cost and space requirements. Basins can also provide a place to temporarily hold, dilute and distribute batch discharges of toxic or high-strength wastewater which might otherwise inhibit biological secondary treatment (such as wastewater from portable toilets or fecal sludge that is brought to the sewage treatment plant in vacuum trucks). Flow equalization basins require variable discharge control, typically include provisions for bypass and cleaning, and may also include aerators and odor control.<sup>[26]</sup>

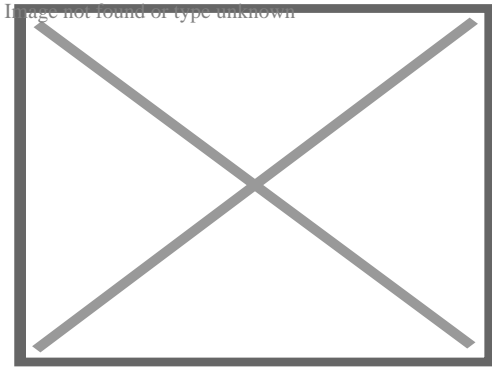
## Fat and grease removal

[edit]

In some larger plants, fat and grease are removed by passing the sewage through a small tank where skimmers collect the fat floating on the surface. Air blowers in the base of the tank may also be used to help recover the fat as a froth. Many plants, however, use primary clarifiers with mechanical surface skimmers for fat and grease removal.

# Primary treatment

[edit]



Rectangular primary settling tanks at a sewage treatment plant in Oregon, US

Primary treatment is the "removal of a portion of the suspended solids and organic matter from the sewage".<sup>[7]</sup> It consists of allowing sewage to pass slowly through a basin where heavy solids can settle to the bottom while oil, grease and lighter solids float to the surface and are skimmed off. These basins are called *primary sedimentation tanks* or *primary clarifiers* and typically have a hydraulic retention time (HRT) of 1.5 to 2.5 hours.<sup>[7]</sup> The settled and floating materials are removed and the remaining liquid may be discharged or subjected to secondary treatment. Primary settling tanks are usually equipped with mechanically driven scrapers that continually drive the collected sludge towards a hopper in the base of the tank where it is pumped to sludge treatment facilities.<sup>[25]</sup>

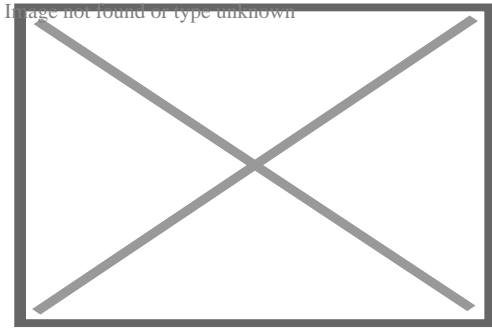
Sewage treatment plants that are connected to a combined sewer system sometimes have a bypass arrangement after the primary treatment unit. This means that during very heavy rainfall events, the secondary and tertiary treatment systems can be bypassed to protect them from hydraulic overloading, and the mixture of sewage and storm-water receives primary treatment only.<sup>[27]</sup>

Primary sedimentation tanks remove about 50–70% of the suspended solids, and 25–40% of the biological oxygen demand (BOD).<sup>[7]</sup>

## Secondary treatment

[edit]

Main article: Secondary treatment



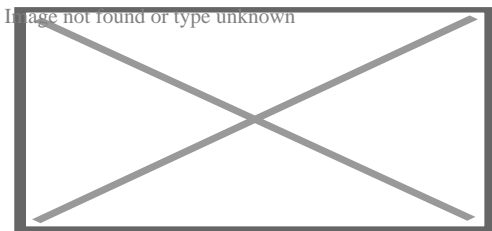
Simplified process flow diagram for a typical large-scale treatment plant using the activated sludge process

The main processes involved in secondary sewage treatment are designed to remove as much of the solid material as possible.<sup>[13]</sup> They use biological processes to digest and remove the remaining soluble material, especially the organic fraction. This can be done with either suspended-growth or biofilm processes. The microorganisms that feed on the organic matter present in the sewage grow and multiply, constituting the biological solids, or biomass. These grow and group together in the form of flocs or biofilms and, in some specific processes, as granules. The biological floc or biofilm and remaining fine solids form a sludge which can be settled and separated. After separation, a liquid remains that is almost free of solids, and with a greatly reduced concentration of pollutants.<sup>[13]</sup>

Secondary treatment can reduce organic matter (measured as biological oxygen demand) from sewage, using aerobic or anaerobic processes. The organisms involved in these processes are sensitive to the presence of toxic materials, although these are not expected to be present at high concentrations in typical municipal sewage.

## Tertiary treatment

[edit]



Overall setup for a micro filtration system

Advanced sewage treatment generally involves three main stages, called primary, secondary and tertiary treatment but may also include intermediate stages and final polishing processes. The purpose of tertiary treatment (also called *advanced treatment*)

is to provide a final treatment stage to further improve the effluent quality before it is discharged to the receiving water body or reused. More than one tertiary treatment process may be used at any treatment plant. If disinfection is practiced, it is always the final process. It is also called *effluent polishing*. Tertiary treatment may include biological nutrient removal (alternatively, this can be classified as secondary treatment), disinfection and partly removal of micropollutants, such as environmental persistent pharmaceutical pollutants.

Tertiary treatment is sometimes defined as anything more than primary and secondary treatment in order to allow discharge into a highly sensitive or fragile ecosystem such as estuaries, low-flow rivers or coral reefs.<sup>[28]</sup> Treated water is sometimes disinfected chemically or physically (for example, by lagoons and microfiltration) prior to discharge into a stream, river, bay, lagoon or wetland, or it can be used for the irrigation of a golf course, greenway or park. If it is sufficiently clean, it can also be used for groundwater recharge or agricultural purposes.

Sand filtration removes much of the residual suspended matter.<sup>[25]:â€š22–23â€š</sup> Filtration over activated carbon, also called *carbon adsorption*, removes residual toxins.<sup>[25]:â€š19â€š</sup> Micro filtration or synthetic membranes are used in membrane bioreactors and can also remove pathogens.<sup>[7]:â€š854â€š</sup>

Settlement and further biological improvement of treated sewage may be achieved through storage in large human-made ponds or lagoons. These lagoons are highly aerobic, and colonization by native macrophytes, especially reeds, is often encouraged.

## Disinfection

[edit]

Disinfection of treated sewage aims to kill pathogens (disease-causing microorganisms) prior to disposal. It is increasingly effective after more elements of the foregoing treatment sequence have been completed.<sup>[29]:â€š359â€š</sup> The purpose of disinfection in the treatment of sewage is to substantially reduce the number of pathogens in the water to be discharged back into the environment or to be reused. The target level of reduction of biological contaminants like pathogens is often regulated by the presiding governmental authority. The effectiveness of disinfection depends on the quality of the water being treated (e.g. turbidity, pH, etc.), the type of disinfection being used, the disinfectant dosage (concentration and time), and other environmental variables. Water with high turbidity will be treated less successfully, since solid matter can shield organisms, especially from ultraviolet light or if contact times are low. Generally, short contact times, low doses and high flows all militate against effective disinfection.

Common methods of disinfection include ozone, chlorine, ultraviolet light, or sodium hypochlorite.<sup>[25]</sup> Monochloramine, which is used for drinking water, is not used in the treatment of sewage because of its persistence.

Chlorination remains the most common form of treated sewage disinfection in many countries due to its low cost and long-term history of effectiveness. One disadvantage is that chlorination of residual organic material can generate chlorinated-organic compounds that may be carcinogenic or harmful to the environment. Residual chlorine or chloramines may also be capable of chlorinating organic material in the natural aquatic environment. Further, because residual chlorine is toxic to aquatic species, the treated effluent must also be chemically dechlorinated, adding to the complexity and cost of treatment.

Ultraviolet (UV) light can be used instead of chlorine, iodine, or other chemicals. Because no chemicals are used, the treated water has no adverse effect on organisms that later consume it, as may be the case with other methods. UV radiation causes damage to the genetic structure of bacteria, viruses, and other pathogens, making them incapable of reproduction. The key disadvantages of UV disinfection are the need for frequent lamp maintenance and replacement and the need for a highly treated effluent to ensure that the target microorganisms are not shielded from the UV radiation (i.e., any solids present in the treated effluent may protect microorganisms from the UV light). In many countries, UV light is becoming the most common means of disinfection because of the concerns about the impacts of chlorine in chlorinating residual organics in the treated sewage and in chlorinating organics in the receiving water.

As with UV treatment, heat sterilization also does not add chemicals to the water being treated. However, unlike UV, heat can penetrate liquids that are not transparent. Heat disinfection can also penetrate solid materials within wastewater, sterilizing their contents. Thermal effluent decontamination systems provide low resource, low maintenance effluent decontamination once installed.

Ozone ( $O_3$ ) is generated by passing oxygen ( $O_2$ ) through a high voltage potential resulting in a third oxygen atom becoming attached and forming

$O_3$ . Ozone is very unstable and reactive and oxidizes most organic material it comes in contact with, thereby destroying many pathogenic microorganisms. Ozone is considered to be safer than chlorine because, unlike chlorine which has to be stored on site (highly poisonous in the event of an accidental release), ozone is generated on-site as needed from the oxygen in the ambient air. Ozonation also produces fewer disinfection by-products than chlorination. A disadvantage of ozone disinfection is the high cost of the ozone generation equipment and the requirements for special operators. Ozone sewage

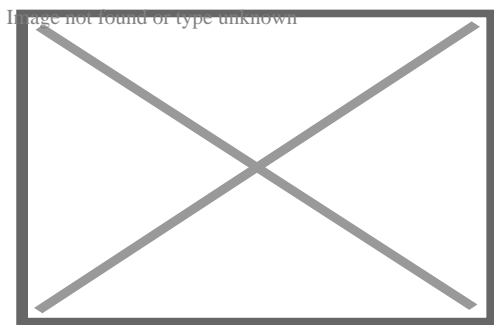


treatment requires the use of an ozone generator, which decontaminates the water as ozone bubbles percolate through the tank.

Membranes can also be effective disinfectants, because they act as barriers, avoiding the passage of the microorganisms. As a result, the final effluent may be devoid of pathogenic organisms, depending on the type of membrane used. This principle is applied in membrane bioreactors.

## Biological nutrient removal

[edit]



Nitrification process tank at an activated sludge plant in the United States

Sewage may contain high levels of the nutrients nitrogen and phosphorus. Typical values for nutrient loads per person and nutrient concentrations in raw sewage in developing countries have been published as follows: 8 g/person/d for total nitrogen (45 mg/L), 4.5 g/person/d for ammonia-N (25 mg/L) and 1.0 g/person/d for total phosphorus (7 mg/L).<sup>[4]</sup> The typical ranges for these values are: 6–10 g/person/d for total nitrogen (35–60 mg/L), 3.5–6 g/person/d for ammonia-N (20–35 mg/L) and 0.7–2.5 g/person/d for total phosphorus (4–15 mg/L).<sup>[4]</sup>

Excessive release to the environment can lead to nutrient pollution, which can manifest itself in eutrophication. This process can lead to algal blooms, a rapid growth, and later decay, in the population of algae. In addition to causing deoxygenation, some algal species produce toxins that contaminate drinking water supplies.

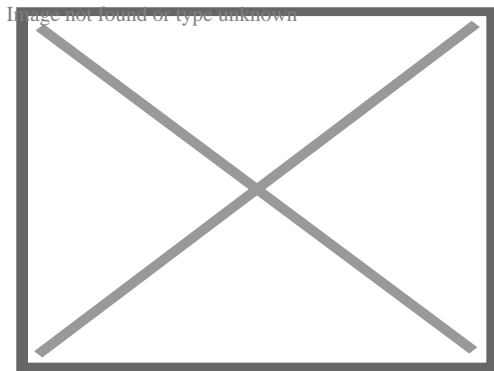
Ammonia nitrogen, in the form of free ammonia ( $\text{NH}_3$ ) is toxic to fish. Ammonia nitrogen, when converted to nitrite and further to nitrate in a water body, in the process of nitrification, is associated with the consumption of dissolved oxygen. Nitrite and nitrate may also have public health significance if concentrations are high in drinking water, because of a disease called methemoglobinemia.<sup>[4]</sup>

Phosphorus removal is important as phosphorus is a limiting nutrient for algae growth in many fresh water systems. Therefore, an excess of phosphorus can lead to eutrophication. It is also particularly important for water reuse systems where high phosphorus concentrations may lead to fouling of downstream equipment such as reverse osmosis.

A range of treatment processes are available to remove nitrogen and phosphorus. Biological nutrient removal (BNR) is regarded by some as a type of secondary treatment process,<sup>[7]</sup> and by others as a *tertiary* (or *advanced*) treatment process.

## Nitrogen removal

[edit]



Constructed wetlands (vertical flow) for sewage treatment near Shanghai, China

Nitrogen is removed through the biological oxidation of nitrogen from ammonia to nitrate (nitrification), followed by denitrification, the reduction of nitrate to nitrogen gas. Nitrogen gas is released to the atmosphere and thus removed from the water.

Nitrification itself is a two-step aerobic process, each step facilitated by a different type of bacteria. The oxidation of ammonia ( $\text{NH}_4^+$ ) to nitrite ( $\text{NO}_2^-$ ) is most often facilitated by bacteria such as *Nitrosomonas* spp. (*nitroso* refers to the formation of a nitroso functional group). Nitrite oxidation to nitrate ( $\text{NO}_3^-$ ), though traditionally believed to be facilitated by *Nitrobacter* spp. (nitro referring the formation of a nitro functional group), is now known to be facilitated in the environment predominantly by *Nitrospira* spp.

Denitrification requires anoxic conditions to encourage the appropriate biological communities to form. *Anoxic conditions* refers to a situation where oxygen is absent but nitrate is present. Denitrification is facilitated by a wide diversity of bacteria. The activated sludge process, sand filters, waste stabilization ponds, constructed wetlands and other processes can all be used to reduce nitrogen.<sup>[25]</sup> Since denitrification is the reduction of nitrate to dinitrogen (molecular nitrogen) gas, an

electron donor is needed. This can be, depending on the wastewater, organic matter (from the sewage itself), sulfide, or an added donor like methanol. The sludge in the anoxic tanks (denitrification tanks) must be mixed well (mixture of recirculated mixed liquor, return activated sludge, and raw influent) e.g. by using submersible mixers in order to achieve the desired denitrification.

Over time, different treatment configurations for activated sludge processes have evolved to achieve high levels of nitrogen removal. An initial scheme was called the Ludzack–Ettinger Process. It could not achieve a high level of denitrification.<sup>[7]</sup>  
:â€Š616â€ŠThe Modified Ludzak–Ettinger Process (MLE) came later and was an improvement on the original concept. It recycles mixed liquor from the discharge end of the aeration tank to the head of the anoxic tank. This provides nitrate for the facultative bacteria.<sup>[7]</sup>:â€Š616â€Š

There are other process configurations, such as variations of the Bardenpho process.<sup>[30]</sup>  
]:â€Š160â€ŠThey might differ in the placement of anoxic tanks, e.g. before and after the aeration tanks.

## Phosphorus removal

[edit]

Studies of United States sewage in the late 1960s estimated mean per capita contributions of 500 grams (18 oz) in urine and feces, 1,000 grams (35 oz) in synthetic detergents, and lesser variable amounts used as corrosion and scale control chemicals in water supplies.<sup>[31]</sup> Source control via alternative detergent formulations has subsequently reduced the largest contribution, but naturally the phosphorus content of urine and feces remained unchanged.

Phosphorus can be removed biologically in a process called enhanced biological phosphorus removal. In this process, specific bacteria, called polyphosphate-accumulating organisms (PAOs), are selectively enriched and accumulate large quantities of phosphorus within their cells (up to 20 percent of their mass).<sup>[30]</sup>  
:â€Š148–155â€Š

Phosphorus removal can also be achieved by chemical precipitation, usually with salts of iron (e.g. ferric chloride) or aluminum (e.g. alum), or lime.<sup>[25]</sup>:â€Š18â€ŠThis may lead to a higher sludge production as hydroxides precipitate and the added chemicals can be expensive. Chemical phosphorus removal requires significantly smaller equipment footprint than biological removal, is easier to operate and is often more reliable than biological phosphorus removal. Another method for phosphorus removal is to use granular laterite or zeolite.<sup>[32]</sup><sup>[33]</sup>

Some systems use both biological phosphorus removal and chemical phosphorus removal. The chemical phosphorus removal in those systems may be used as a backup system, for use when the biological phosphorus removal is not removing enough phosphorus, or may be used continuously. In either case, using both biological and chemical phosphorus removal has the advantage of not increasing sludge production as much as chemical phosphorus removal on its own, with the disadvantage of the increased initial cost associated with installing two different systems.

Once removed, phosphorus, in the form of a phosphate-rich sewage sludge, may be sent to landfill or used as fertilizer in admixture with other digested sewage sludges. In the latter case, the treated sewage sludge is also sometimes referred to as biosolids. 22% of the world's phosphorus needs could be satisfied by recycling residential wastewater.<sup>[34][35]</sup>

## Fourth treatment stage

[edit]

Further information: Environmental impact of pharmaceuticals and personal care products

Micropollutants such as pharmaceuticals, ingredients of household chemicals, chemicals used in small businesses or industries, environmental persistent pharmaceutical pollutants (EPPP) or pesticides may not be eliminated in the commonly used sewage treatment processes (primary, secondary and tertiary treatment) and therefore lead to water pollution.<sup>[36]</sup> Although concentrations of those substances and their decomposition products are quite low, there is still a chance of harming aquatic organisms. For pharmaceuticals, the following substances have been identified as toxicologically relevant: substances with endocrine disrupting effects, genotoxic substances and substances that enhance the development of bacterial resistances.<sup>[37]</sup> They mainly belong to the group of EPPP.

Techniques for elimination of micropollutants via a fourth treatment stage during sewage treatment are implemented in Germany, Switzerland, Sweden<sup>[3]</sup> and the Netherlands and tests are ongoing in several other countries.<sup>[38]</sup> In Switzerland it has been enshrined in law since 2016.<sup>[39]</sup> Since 1 January 2025, there has been a recast of the Urban Waste Water Treatment Directive in the European Union. Due to the large number of amendments that have now been made, the directive was rewritten on November 27, 2024 as Directive (EU) 2024/3019, published in the EU Official Journal on December 12, and entered into force on January 1, 2025. The member states now have 31 months, i.e. until July 31, 2027, to adapt their national legislation to the new directive ("implementation of the directive").

The amendment stipulates that, in addition to stricter discharge values for nitrogen and phosphorus, persistent trace substances must at least be partially separated. The target, similar to Switzerland, is that 80% of 6 key substances out of 12 must be removed between discharge into the sewage treatment plant and discharge into the water body. At least 80% of the investments and operating costs for the fourth treatment stage will be passed on to the pharmaceutical and cosmetics industry according to the polluter pays principle in order to relieve the population financially and provide an incentive for the development of more environmentally friendly products. In addition, the municipal wastewater treatment sector is to be energy neutral by 2045 and the emission of microplastics and PFAS is to be monitored.

The implementation of the framework guidelines is staggered until 2045, depending on the size of the sewage treatment plant and its population equivalents (PE). Sewage treatment plants with over 150,000 PE have priority and should be adapted immediately, as a significant proportion of the pollution comes from them. The adjustments are staggered at national level in:

- 20% of the plants by 31 December 2033,
- 60% of the plants by 31 December 2039,
- 100% of the plants by 31 December 2045.

Wastewater treatment plants with 10,000 to 150,000 PE that discharge into coastal waters or sensitive waters are staggered at national level in:

- 10% of the plants by 31 December 2033,
- 30% of the plants by 31 December 2036,
- 60% of the plants by 31 December 2039,
- 100% of the plants by 31 December 2045.

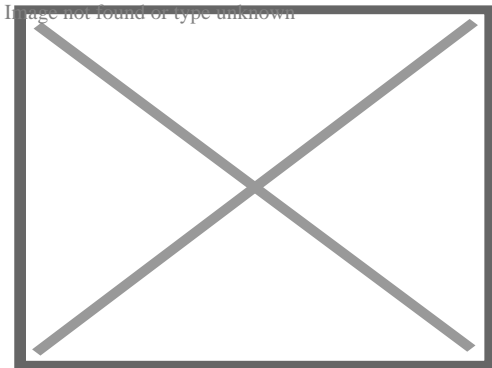
The latter concerns waters with a low dilution ratio, waters from which drinking water is obtained and those that are coastal waters, or those used as bathing waters or used for mussel farming. Member States will be given the option not to apply fourth treatment in these areas if a risk assessment shows that there is no potential risk from micropollutants to human health and/or the environment.<sup>[40][41]</sup>

Such process steps mainly consist of activated carbon filters that adsorb the micropollutants. The combination of advanced oxidation with ozone followed by granular activated carbon (GAC) has been suggested as a cost-effective treatment combination for pharmaceutical residues. For a full reduction of microplastics the combination of ultrafiltration followed by GAC has been suggested. Also the use of enzymes such as laccase secreted by fungi is under investigation.<sup>[42][43]</sup> Microbial biofuel cells are investigated for their property to treat organic matter in sewage.<sup>[44]</sup>

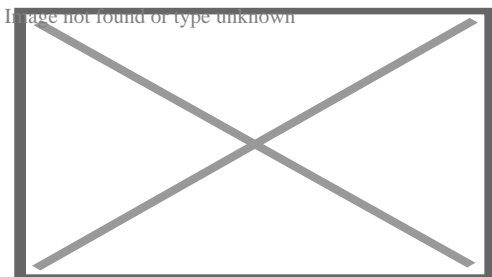
To reduce pharmaceuticals in water bodies, source control measures are also under investigation, such as innovations in drug development or more responsible handling of drugs.<sup>[37]</sup><sup>[45]</sup> In the US, the National Take Back Initiative is a voluntary program with the general public, encouraging people to return excess or expired drugs, and avoid flushing them to the sewage system.<sup>[46]</sup>

## Sludge treatment and disposal

[edit]



View of a belt filter press at the Blue Plains Advanced Wastewater Treatment Plant, Washington, D.C.



Mechanical dewatering of sewage sludge with a centrifuge at a large sewage treatment plant (Arrudas Treatment Plant, Belo Horizonte, Brazil)

This section is an excerpt from Sewage sludge treatment.[edit]

Sewage sludge treatment describes the processes used to manage and dispose of sewage sludge produced during sewage treatment. Sludge treatment is focused on reducing sludge weight and volume to reduce transportation and disposal costs, and on reducing potential health risks of disposal options. Water removal is the primary means of weight and volume reduction, while pathogen destruction is frequently accomplished through heating during thermophilic digestion, composting, or incineration. The choice of a sludge treatment method depends on the volume of sludge generated, and



comparison of treatment costs required for available disposal options. Air-drying and composting may be attractive to rural communities, while limited land availability may make aerobic digestion and mechanical dewatering preferable for cities, and economies of scale may encourage energy recovery alternatives in metropolitan areas.

Sludge is mostly water with some amounts of solid material removed from liquid sewage. Primary sludge includes settleable solids removed during primary treatment in primary clarifiers. Secondary sludge is sludge separated in secondary clarifiers that are used in secondary treatment bioreactors or processes using inorganic oxidizing agents. In intensive sewage treatment processes, the sludge produced needs to be removed from the liquid line on a continuous basis because the volumes of the tanks in the liquid line have insufficient volume to store sludge.<sup>[47]</sup> This is done in order to keep the treatment processes compact and in balance (production of sludge approximately equal to the removal of sludge). The sludge removed from the liquid line goes to the sludge treatment line. Aerobic processes (such as the activated sludge process) tend to produce more sludge compared with anaerobic processes. On the other hand, in extensive (natural) treatment processes, such as ponds and constructed wetlands, the produced sludge remains accumulated in the treatment units (liquid line) and is only removed after several years of operation.<sup>[48]</sup>

Sludge treatment options depend on the amount of solids generated and other site-specific conditions. Composting is most often applied to small-scale plants with aerobic digestion for mid-sized operations, and anaerobic digestion for the larger-scale operations. The sludge is sometimes passed through a so-called pre-thickener which de-waters the sludge. Types of pre-thickeners include centrifugal sludge thickeners,<sup>[49]</sup> rotary drum sludge thickeners and belt filter presses.<sup>[50]</sup> Dewatered sludge may be incinerated or transported offsite for disposal in a landfill or use as an agricultural soil amendment.<sup>[51]</sup>

## **Environmental impacts**

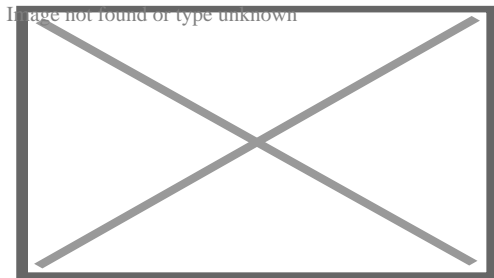
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Sewage treatment plants can have significant effects on the biotic status of receiving waters and can cause some water pollution, especially if the treatment process used is only basic. For example, for sewage treatment plants without nutrient removal, eutrophication of receiving water bodies can be a problem.

This section is an excerpt from Water pollution.[edit]

Water pollution (or aquatic pollution) is the contamination of water bodies, with a negative impact on their uses.<sup>[52]</sup>:â€Š6â€Š It is usually a result of human activities.

Water bodies include lakes, rivers, oceans, aquifers, reservoirs and groundwater. Water pollution results when contaminants mix with these water bodies. Contaminants can come from one of four main sources. These are sewage discharges, industrial activities, agricultural activities, and urban runoff including stormwater.<sup>[53]</sup> Water pollution may affect either surface water or groundwater. This form of pollution can lead to many problems. One is the degradation of aquatic ecosystems. Another is spreading water-borne diseases when people use polluted water for drinking or irrigation.<sup>[54]</sup> Water pollution also reduces the ecosystem services such as drinking water provided by the water resource.



Treated effluent from sewage treatment plant in DÄ›Ä•ín, Czech Republic, is discharged to surface waters.

In 2024, The Royal Academy of Engineering released a study into the effects wastewater on public health in the United Kingdom.<sup>[55]</sup> The study gained media attention, with comments from the UK's leading health professionals, including Sir Chris Whitty. Outlining 15 recommendations for various UK bodies to dramatically reduce public health risks by increasing the water quality in its waterways, such as rivers and lakes.

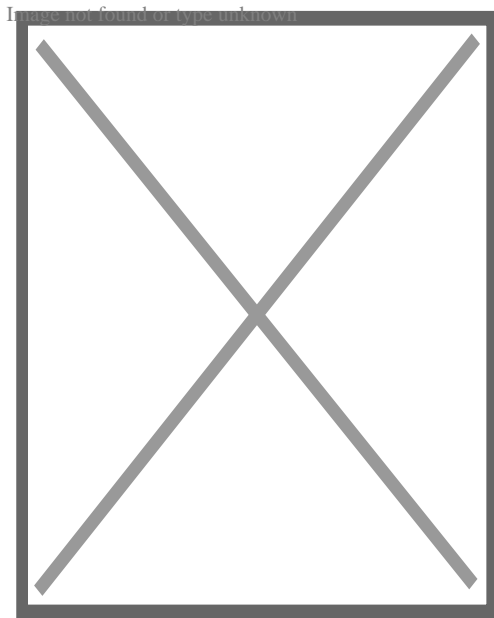
After the release of the report, The Guardian newspaper interviewed Whitty, who stated that improving water quality and sewage treatment should be a high level of importance and a "public health priority". He compared it to eradicating cholera in the 19th century in the country following improvements to the sewage treatment network.<sup>[56]</sup> The study also identified that low water flows in rivers saw high concentration levels of sewage, as well as times of flooding or heavy rainfall. While heavy rainfall had always been associated with sewage overflows into streams and rivers, the British media went as far to warn parents of the dangers of paddling in shallow rivers during warm weather.<sup>[57]</sup>

Whitty's comments came after the study revealed that the UK was experiencing a growth in the number of people that were using coastal and inland waters recreationally. This could be connected to a growing interest in activities such as open water swimming or other water sports.<sup>[58]</sup> Despite this growth in recreation, poor water quality meant some were becoming unwell during events.<sup>[59]</sup> Most notably, the 2024 Paris Olympics had to delay numerous swimming-focused events like the triathlon due to high levels of sewage in the River Seine.<sup>[60]</sup>

## Reuse

[edit]

Further information: Reuse of excreta



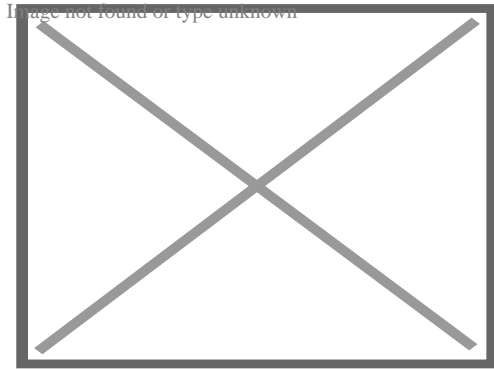
Sludge drying beds for sewage sludge treatment at a small treatment plant at the Center for Research and Training in Sanitation, Belo Horizonte, Brazil

## Irrigation

[edit]

See also: Sewage farm

Increasingly, people use treated or even untreated sewage for irrigation to produce crops. Cities provide lucrative markets for fresh produce, so are attractive to farmers. Because agriculture has to compete for increasingly scarce water resources with industry and municipal users, there is often no alternative for farmers but to use water polluted with sewage directly to water their crops. There can be significant health hazards related to using water loaded with pathogens in this way. The World Health Organization developed guidelines for safe use of wastewater in 2006.<sup>[61]</sup> They advocate a 'multiple-barrier' approach to wastewater use, where farmers are encouraged to adopt various risk-reducing behaviors. These include ceasing irrigation a few days before harvesting to allow pathogens to die off in the sunlight, applying water carefully so it does not contaminate leaves likely to be eaten raw, cleaning vegetables with disinfectant or allowing fecal sludge used in farming to dry before being used as a human manure.<sup>[62]</sup>



Circular secondary sedimentation tank at activated sludge sewage treatment plant at Arrudas Treatment Plant, Belo Horizonte, Brazil

## Reclaimed water

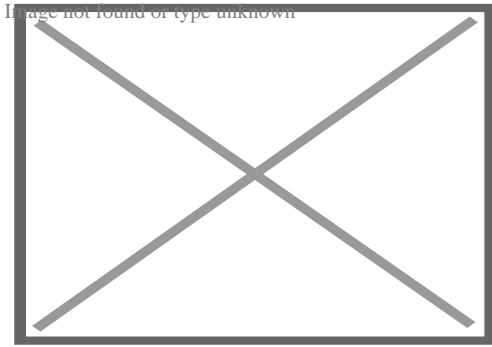
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This section is an excerpt from Reclaimed water.[edit]

Water reclamation is the process of converting municipal wastewater or sewage and industrial wastewater into water that can be reused for a variety of purposes. It is also called wastewater reuse, water reuse or water recycling. There are many types of reuse. It is possible to reuse water in this way in cities or for irrigation in agriculture. Other types of reuse are environmental reuse, industrial reuse, and reuse for drinking water, whether planned or not. Reuse may include irrigation of gardens and agricultural fields or replenishing surface water and groundwater. This latter is also known as groundwater recharge. Reused water also serve various needs in residences such as toilet flushing, businesses, and industry. It is possible to treat wastewater to reach drinking water standards. Injecting reclaimed water into the water supply distribution system is known as direct potable reuse. Drinking reclaimed water is not typical.<sup>[63]</sup> Reusing treated municipal wastewater for irrigation is a long-established practice. This is especially so in arid countries. Reusing wastewater as part of sustainable water management allows water to remain an alternative water source for human activities. This can reduce scarcity. It also eases pressures on groundwater and other natural water bodies.<sup>[64]</sup>

### Global situation

[edit]



Share of domestic wastewater that is safely treated (in 2018)<sup>[65]</sup>

Before the 20th century in Europe, sewers usually discharged into a body of water such as a river, lake, or ocean. There was no treatment, so the breakdown of the human waste was left to the ecosystem. This could lead to satisfactory results if the assimilative capacity of the ecosystem is sufficient which is nowadays not often the case due to increasing population density.<sup>[4]</sup>

Today, the situation in urban areas of industrialized countries is usually that sewers route their contents to a sewage treatment plant rather than directly to a body of water. In many developing countries, however, the bulk of municipal and industrial wastewater is discharged to rivers and the ocean without any treatment or after preliminary treatment or primary treatment only. Doing so can lead to water pollution. Few reliable figures exist on the share of the wastewater collected in sewers that is being treated worldwide. A global estimate by UNDP and UN-Habitat in 2010 was that 90% of all wastewater generated is released into the environment untreated.<sup>[66]</sup> A more recent study in 2021 estimated that globally, about 52% of sewage is treated.<sup>[5]</sup> However, sewage treatment rates are highly unequal for different countries around the world. For example, while high-income countries treat approximately 74% of their sewage, developing countries treat an average of just 4.2%.<sup>[5]</sup> As of 2022, without sufficient treatment, more than 80% of all wastewater generated globally is released into the environment. High-income nations treat, on average, 70% of the wastewater they produce, according to UN Water.<sup>[34][67][68]</sup> Only 8% of wastewater produced in low-income nations receives any sort of treatment.<sup>[34][69][70]</sup>

The Joint Monitoring Programme (JMP) for Water Supply and Sanitation by WHO and UNICEF report in 2021 that 82% of people with sewer connections are connected to sewage treatment plants providing at least secondary treatment.<sup>[71]</sup> However, this value varies widely between regions. For example, in Europe, North America, Northern Africa and Western Asia, a total of 31 countries had universal (>99%) wastewater treatment. However, in Albania, Bermuda, North Macedonia and Serbia "less than 50% of sewered wastewater received secondary or better treatment" and in Algeria, Lebanon and Libya the value was less than 20% of sewered wastewater that was being treated. The report also found that "globally, 594 million people have sewer connections that don't receive sufficient treatment. Many more are connected to

wastewater treatment plants that do not provide effective treatment or comply with effluent requirements.".[<sup>71</sup>]:â€Š55â€Š

## Global targets

[edit]

Sustainable Development Goal 6 has a Target 6.3 which is formulated as follows: "By 2030, improve water quality by reducing pollution, eliminating,dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally."[<sup>65</sup>] The corresponding Indicator 6.3.1 is the "proportion of wastewater safely treated". It is anticipated that wastewater production would rise by 24% by 2030 and by 51% by 2050.[<sup>34</sup>][<sup>72</sup>][<sup>73</sup>]

Data in 2020 showed that there is still too much uncollected household wastewater: Only 66% of all household wastewater flows were collected at treatment facilities in 2020 (this is determined from data from 128 countries).[<sup>8</sup>]:â€Š17â€ŠBased on data from 42 countries in 2015, the report stated that "32 per cent of all wastewater flows generated from point sources received at least some treatment".[<sup>8</sup>]:â€Š17â€ŠFor sewage that has indeed been collected at centralized sewage treatment plants, about 79% went on to be safely treated in 2020.[<sup>8</sup>]:â€Š18â€Š

## History

[edit]

Further information: History of water supply and sanitation § Sewage treatment

The history of sewage treatment had the following developments: It began with land application (sewage farms) in the 1840s in England, followed by chemical treatment and sedimentation of sewage in tanks, then biological treatment in the late 19th century, which led to the development of the activated sludge process starting in 1912.[<sup>74</sup>][<sup>75</sup>]

This section is an excerpt from History of water supply and sanitation § Biological treatment.[edit]

It was not until the late 19th century that it became possible to treat the sewage by biologically decomposing the organic components through the use of microorganisms and removing the pollutants. Land treatment was also steadily becoming less feasible, as cities grew and the volume of sewage produced could no longer be absorbed by the

farmland on the outskirts.

Edward Frankland conducted experiments at the sewage farm in Croydon, England during the 1870s and was able to demonstrate that filtration of sewage through porous gravel produced a nitrified effluent (the ammonia was converted into nitrate) and that the filter remained unclogged over long periods of time.<sup>[76]</sup> This established the then revolutionary possibility of biological treatment of sewage using a contact bed to oxidize the waste. This concept was taken up by the chief chemist for the London Metropolitan Board of Works, William Dibdin, in 1887:

...in all probability the true way of purifying sewage...will be first to separate the sludge, and then turn into neutral effluent... retain it for a sufficient period, during which time it should be fully aerated, and finally discharge it into the stream in a purified condition. This is indeed what is aimed at and imperfectly accomplished on a sewage farm.<sup>[77]</sup>

From 1885 to 1891, filters working on Dibdin's principle were constructed throughout the UK and the idea was also taken up in the US at the Lawrence Experiment Station in Massachusetts, where Frankland's work was confirmed.<sup>[78]</sup> In 1890, the LES developed a 'trickling filter' that gave a much more reliable performance.<sup>[79]</sup>

## Regulations

[edit]

In most countries, sewage collection and treatment are subject to local and national regulations and standards.

## By country

[edit]

# Overview

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- v
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Wastewater treatment by country

- Benin
- China
- Costa Rica
- Egypt
- Ireland
- Jordan
- Morocco
- Pakistan
- Palestine
- Peru
- Portugal
- South Africa
- Uganda
- Yemen

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Water supply and sanitation by country



- Afghanistan
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- Angola
- Argentina
- Australia
- Azerbaijan
- Bangladesh
- Belgium
- Belize
- Benin
- Bhutan
- Bolivia
- Bosnia and Herzegovina
- Brazil
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- Cambodia
- Canada
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- Colombia
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- Cuba
- Democratic Republic of the Congo
- Denmark
- Dominican Republic
- Ecuador
- Egypt
- El Salvador
- Ethiopia
- France
- Georgia
- Germany
- Ghana
- Greece
- Grenada
- Guatemala
- Guyana
- Haiti
- Honduras
- India
- Indonesia
- Iran
- Iraq
- Ireland
- Israel
- Italy
- Jamaica
- Japan
- Jordan

# Europe

[edit]

In the European Union, 0.8% of total energy consumption goes to wastewater treatment facilities.<sup>[34][80]</sup> The European Union needs to make extra investments of €90 billion in the water and waste sector to meet its 2030 climate and energy goals.<sup>[34][81][82]</sup>

In October 2021, British Members of Parliament voted to continue allowing untreated sewage from combined sewer overflows to be released into waterways.<sup>[83][84]</sup>

This section is an excerpt from Urban Waste Water Treatment Directive § Description.[edit]

The Urban Waste Water Treatment Directive (full title "Council Directive 91/271/EEC of 21 May 1991 concerning urban waste-water treatment") is a European Union directive regarding urban wastewater collection, wastewater treatment and its discharge, as well as the treatment and discharge of "waste water from certain industrial sectors". It was adopted on 21 May 1991.<sup>[85]</sup> It aims "to protect the environment from the adverse effects of urban waste water discharges and discharges from certain industrial sectors" by mandating waste water collection and treatment in urban agglomerations with a population equivalent of over 2000, and more advanced treatment in places with a population equivalent above 10,000 in sensitive areas.<sup>[86]</sup>

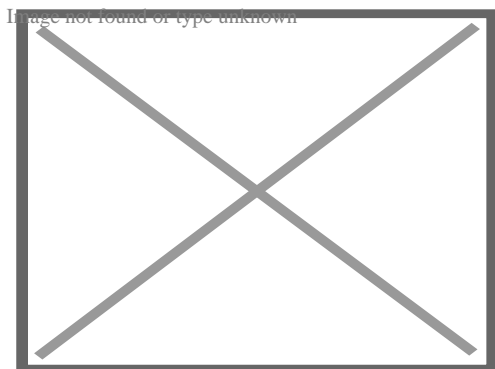
# Asia

[edit]

## India

[edit]

This section is an excerpt from Water supply and sanitation in India § Wastewater treatment.[edit]



Picture of a wastewater stream

In India, wastewater treatment regulations come under three central institutions, the ministries of forest, climate change housing, urban affairs and water.<sup>[87]</sup> The various water and sanitation policies such as the "National Environment Policy 2006" and "National Sanitation Policy 2008" also lay down wastewater treatment regulations. State governments and local municipalities hold responsibility for the disposal of sewage and construction and maintenance of "sewerage infrastructure". Their efforts are supported by schemes offered by the Government of India, such as the National River Conservation Plan, Jawaharlal Nehru National Urban Renewal Mission, National Lake Conservation Plan. Through the Ministry of Environment and Forest, India's government also has set up incentives that encourage industries to establish "common facilities" to undertake the treatment of wastewater.<sup>[88]</sup>

The 'Delhi Jal Board' (DJB) is currently operating on the construction of the largest sewage treatment plant in India. It will be operational by the end of 2022 with an estimated capacity of 564 MLD. It is supposed to solve the existing situation wherein untreated sewage water is being discharged directly into the river 'Yamuna'.

## Japan

[edit]

This section is an excerpt from Water supply and sanitation in Japan § Wastewater treatment and sanitation.<sup>[edit]</sup>

Currently, Japan's methods of wastewater treatment include rural community sewers, wastewater facilities, and on-site treatment systems such as the Johkasou system to treat domestic wastewater.<sup>[89]</sup> Larger wastewater facilities and sewer systems are generally used to treat wastewater in more urban areas with a larger population. Rural sewage systems are used to treat wastewater at smaller domestic wastewater treatment plants for a smaller population. Johkasou systems are on-site wastewater treatment systems tanks. They are used to treat the wastewater of a single household or to treat the wastewater of a small number of buildings in a more decentralized manner than a

sewer system.<sup>[90]</sup>

## Africa

[edit]

### Libya

[edit]

This section is an excerpt from Environmental issues in Libya § Wastewater treatment. [edit]

In Libya, municipal wastewater treatment is managed by the general company for water and wastewater in Libya, which falls within the competence of the Housing and Utilities Government Ministry. There are approximately 200 sewage treatment plants across the nation, but few plants are functioning. In fact, the 36 larger plants are in the major cities; however, only nine of them are operational, and the rest of them are under repair.<sup>[91]</sup>

The largest operating wastewater treatment plants are situated in Sirte, Tripoli, and Misurata, with a design capacity of 21,000, 110,000, and 24,000 m<sup>3</sup>/day, respectively. Moreover, a majority of the remaining wastewater facilities are small and medium-sized plants with a design capacity of approximately 370 to 6700 m<sup>3</sup>/day. Therefore, 145,800 m<sup>3</sup>/day or 11 percent of the wastewater is actually treated, and the remaining others are released into the ocean and artificial lagoons although they are untreated. In fact, nonoperational wastewater treatment plants in Tripoli lead to a spill of over 1,275, 000 cubic meters of unprocessed water into the ocean every day.<sup>[91]</sup>

## Americas

[edit]

### United States

[edit]


This section is an excerpt from Water supply and sanitation in the United States § Wastewater treatment. [edit]

The United States Environmental Protection Agency (EPA) and state environmental agencies set wastewater standards under the Clean Water Act.<sup>[92]</sup> Point sources must obtain surface water discharge permits through the National Pollutant Discharge

Elimination System (NPDES). Point sources include industrial facilities, municipal governments (sewage treatment plants and storm sewer systems), other government facilities such as military bases, and some agricultural facilities, such as animal feedlots. [93] EPA sets basic national wastewater standards: The "Secondary Treatment Regulation" applies to municipal sewage treatment plants, [94] and the "Effluent guidelines" which are regulations for categories of industrial facilities. [95]

## See also

[edit]

-  [Environment portal](#)
- Decentralized wastewater system
- List of largest wastewater treatment plants
- List of water supply and sanitation by country
- Organisms involved in water purification
- Sanitary engineering
- Waste disposal

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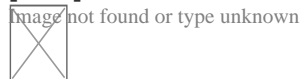
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## External links

[edit]



Wikimedia Commons has media related to **Sewage treatment**.

- Water Environment Federation – Professional association focusing on municipal wastewater treatment
- v
- t
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## Wastewater

### Sources and types

- Acid mine drainage
- Ballast water
- Bathroom
- Blackwater (coal)
- Blackwater (waste)
- Boiler blowdown
- Brine
- Combined sewer
- Cooling tower
- Cooling water
- Fecal sludge
- Greywater
- Infiltration/Inflow
- Industrial wastewater
- Ion exchange
- Leachate
- Manure
- Papermaking
- Produced water
- Return flow
- Reverse osmosis
- Sanitary sewer
- Septage
- Sewage
- Sewage sludge
- Toilet
- Urban runoff
- Adsorbable organic halides
- Biochemical oxygen demand
- Chemical oxygen demand
- Coliform index
- Oxygen saturation
- Heavy metals

### Quality indicators

- pH
- Salinity
- Temperature
- Total dissolved solids
- Total suspended solids
- Turbidity
- Wastewater surveillance

## **Treatment options**

- Activated sludge
- Aerated lagoon
- Agricultural wastewater treatment
- API oil–water separator
- Carbon filtering
- Chlorination
- Clarifier
- Constructed wetland
- Decentralized wastewater system
- Extended aeration
- Facultative lagoon
- Fecal sludge management
- Filtration
- Imhoff tank
- Industrial wastewater treatment
- Ion exchange
- Membrane bioreactor
- Reverse osmosis
- Rotating biological contactor
- Secondary treatment
- Sedimentation
- Septic tank
- Settling basin
- Sewage sludge treatment
- Sewage treatment
- Sewer mining
- Stabilization pond
- Trickling filter
- Ultraviolet germicidal irradiation
- UASB
- Vermifilter
- Wastewater treatment plant

## Disposal options

- Combined sewer
- Evaporation pond
- Groundwater recharge
- Infiltration basin
- Injection well
- Irrigation
- Marine dumping
- Marine outfall
- Reclaimed water
- Sanitary sewer
- Septic drain field
- Sewage farm
- Storm drain
- Surface runoff
- Vacuum sewer

-  Category: Sewerage

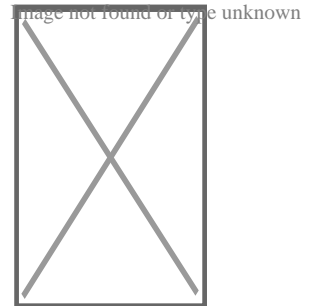
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Environmental technology

## General

- Appropriate technology
- Clean technology
- Climate smart agriculture
- Environmental design
- Environmental impact assessment
- Eco-innovation
- Ecotechnology
- Electric vehicle
- Energy recycling
- Environmental design
- Environmental impact assessment
- Environmental impact design
- Green building
- Green vehicle
- Environmentally healthy community design
- Public interest design
- Sustainability
- Sustainability science
- Sustainable (agriculture
- architecture
- design
- development
- food systems
- industries
- procurement
- refurbishment
- technology
- transport)
- Air pollution (control
- dispersion modeling)
- Industrial ecology
- Solid waste treatment
- Waste management
- Water (agricultural wastewater treatment
- industrial wastewater treatment
- sewage treatment
- waste-water treatment technologies
- water purification)

## Pollution



## **Sustainable energy**

- Efficient energy use
- Electrification
- Energy development
- Energy recovery
- Fuel (alternative fuel
- biofuel
- carbon-neutral fuel
- hydrogen technologies)
- List of energy storage projects
- Renewable energy
  - commercialization
  - transition
- Sustainable lighting
- Transportation (electric vehicle
- hybrid vehicle)
- Building (green
- insulation
- natural
- sustainable architecture
- New Urbanism
- New Classical)
- Conservation biology
- Ecoforestry
- Efficient energy use
- Energy conservation
- Energy recovery
- Energy recycling
- Environmental movement
- Environmental remediation
- Glass in green buildings
- Green computing
- Heat recovery ventilation
- High-performance buildings
- Land rehabilitation
- Nature conservation
- Permaculture
- Recycling
- Water heat recycling

## **Conservation**

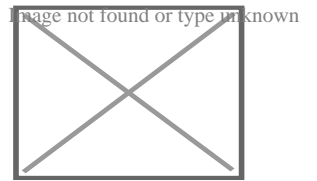
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Biosolids, waste, and waste management



## Major types

- Agricultural wastewater
- Biodegradable waste
- Biomedical waste
- Brown waste
- Chemical waste
- Construction waste
- Demolition waste
- Electronic waste
  - by country
- Food waste
- Green waste
- Hazardous waste
- Heat waste
- Industrial waste
- Industrial wastewater
- Litter
- Marine debris
- Mining waste
- Municipal solid waste
- Open defecation
- Packaging waste
- Post-consumer waste
- Radioactive waste
- Scrap metal
- Sewage
- Sharps waste
- Surface runoff
- Toxic waste



## **Processes**

- Anaerobic digestion
- Balefill
- Biodegradation
- Composting
- Durable good
- Ecological design
- Garden waste dumping
- Illegal dumping
- Incineration
- Landfill
- Landfill mining
- Mechanical biological treatment
- Mechanical sorting
- Photodegradation
- Reclaimed lumber
- Recycling
  - appliance recycling
  - battery recycling
  - bottle recycling
  - fluorescent lamp recycling
  - land recycling
  - plastic recycling
  - textile recycling
  - timber recycling
  - tire recycling
  - water heat recycling
  - water recycling shower
- Repurposing
- Resource recovery
- Reusable packaging
- Right to repair
- Sewage treatment
- Urban mining
- Waste collection
- Waste sorting
- Waste trade
- Waste treatment
- Waste-to-energy

## **Countries**

- Afghanistan
- Albania
- Armenia
- Australia
- Belgium
- Bangladesh
- Brazil
- Bosnia and Herzegovina
- Egypt
- Georgia
- Hong Kong
- India
- Israel
- Japan
- Kazakhstan
- New Zealand
- Russia
- South Korea
- Sri Lanka
- Switzerland
- Syria
- Tanzania
- Taiwan
- Thailand
- Turkey
- United Kingdom
- United States
- Bamako Convention
- Basel Convention
- EU directives

## **Agreements**



- batteries
    - Recycling
  - framework
  - incineration
  - landfills
  - RoHS
  - vehicles
  - waste water
  - WEEE
- London Convention
- Oslo Convention
- OSPAR Convention

## Occupations

- Sanitation worker
- Street sweeper
- Waste collector
- Waste picker
- Blue Ribbon Commission on America's Nuclear Future
- China's waste import ban
- Cleaner production
- Downcycling
- Eco-industrial park
- Extended producer responsibility
- High-level radioactive waste management

## Other topics

- History of waste management
- Landfill fire
- Sewage regulation and administration
- Supervised injection site
- Toxic colonialism
- Upcycling
- Waste hierarchy
- Waste legislation
- Waste minimisation
- Zero waste

-  [Environment portal](#)
-  [Category: Waste](#)
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- Journals
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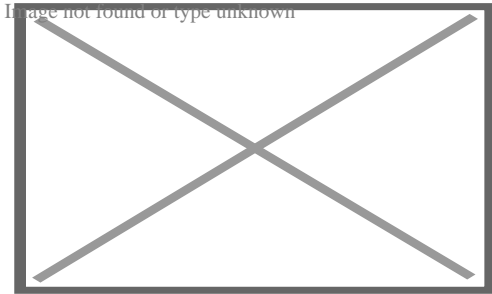
## Authority control databases [Edit this at Wikidata](#)

### National

- Germany
- United States
- Japan
- Latvia
- Israel
- Yale LUX

### Other

## About Ventilation (architecture)



An Ab anbar (water reservoir) with double domes and windcatchers (openings near the top of the towers) in the central desert city of Naeen, Iran. Windcatchers are a form of natural ventilation.<sup>[1]</sup>



This article's lead section **may need to be rewritten**. Please review the lead guide and help improve the lead of this article if you can. *(July 2025) (Learn how and when to remove this message)*

**Ventilation** is the intentional introduction of outdoor air into a space. Ventilation is mainly used to control indoor air quality by diluting and displacing indoor effluents and pollutants. It can also be used to control indoor temperature, humidity, and air motion to benefit thermal comfort, satisfaction with other aspects of the indoor environment, or other objectives.

The intentional introduction of outdoor air is usually categorized as either mechanical ventilation, natural ventilation, or mixed-mode ventilation.<sup>[2]</sup>

- Mechanical ventilation is the intentional fan-driven flow of outdoor air into and/or out from a building. Mechanical ventilation systems may include supply fans (which push outdoor air into a building), exhaust<sup>[3]</sup> fans (which draw air out of a building and thereby cause equal ventilation flow into a building), or a combination of both (called balanced ventilation if it neither pressurizes nor depressurizes the inside air, <sup>[3]</sup> or only slightly depressurizes it). Mechanical ventilation is often provided by equipment that is also used to heat and cool a space.
- Natural ventilation is the intentional passive flow of outdoor air into a building through planned openings (such as louvers, doors, and windows). Natural ventilation does not require mechanical systems to move outdoor air. Instead, it relies entirely on passive physical phenomena, such as wind pressure, or the stack effect. Natural ventilation openings may be fixed, or adjustable. Adjustable openings may be controlled automatically (automated), owned by occupants (operable), or a combination of both. Cross ventilation is a phenomenon of natural ventilation.
- Mixed-mode ventilation systems use both mechanical and natural processes. The mechanical and natural components may be used at the same time, at different

times of day, or in different seasons of the year.<sup>[4]</sup> Since natural ventilation flow depends on environmental conditions, it may not always provide an appropriate amount of ventilation. In this case, mechanical systems may be used to supplement or regulate the naturally driven flow.

Ventilation is typically described as separate from infiltration.

- Infiltration is the circumstantial flow of air from outdoors to indoors through leaks (unplanned openings) in a building envelope. When a building design relies on infiltration to maintain indoor air quality, this flow has been referred to as adventitious ventilation.<sup>[5]</sup>

The design of buildings that promote occupant health and well-being requires a clear understanding of the ways that ventilation airflow interacts with, dilutes, displaces, or introduces pollutants within the occupied space. Although ventilation is an integral component of maintaining good indoor air quality, it may not be satisfactory alone.<sup>[6]</sup> A clear understanding of both indoor and outdoor air quality parameters is needed to improve the performance of ventilation in terms of occupant health and energy.<sup>[7]</sup> In scenarios where outdoor pollution would deteriorate indoor air quality, other treatment devices such as filtration may also be necessary.<sup>[8]</sup> In kitchen ventilation systems, or for laboratory fume hoods, the design of effective effluent capture can be more important than the bulk amount of ventilation in a space. More generally, the way that an air distribution system causes ventilation to flow into and out of a space impacts the ability of a particular ventilation rate to remove internally generated pollutants. The ability of a system to reduce pollution in space is described as its "ventilation effectiveness". However, the overall impacts of ventilation on indoor air quality can depend on more complex factors such as the sources of pollution, and the ways that activities and airflow interact to affect occupant exposure.

An array of factors related to the design and operation of ventilation systems are regulated by various codes and standards. Standards dealing with the design and operation of ventilation systems to achieve acceptable indoor air quality include the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Standards 62.1 and 62.2, the International Residential Code, the International Mechanical Code, and the United Kingdom Building Regulations Part F. Other standards that focus on energy conservation also impact the design and operation of ventilation systems, including ASHRAE Standard 90.1, and the International Energy Conservation Code.

When indoor and outdoor conditions are favorable, increasing ventilation beyond the minimum required for indoor air quality can significantly improve both indoor air quality and thermal comfort through ventilative cooling, which also helps reduce the energy demand of buildings.<sup>[9][10]</sup> During these times, higher ventilation rates, achieved through passive or mechanical means (air-side economizer, ventilative pre-cooling), can

be particularly beneficial for enhancing people's physical health.<sup>[11]</sup> Conversely, when conditions are less favorable, maintaining or improving indoor air quality through ventilation may require increased use of mechanical heating or cooling, leading to higher energy consumption.

Ventilation should be considered for its relationship to "venting" for appliances and combustion equipment such as water heaters, furnaces, boilers, and wood stoves. Most importantly, building ventilation design must be careful to avoid the backdraft of combustion products from "naturally vented" appliances into the occupied space. This issue is of greater importance for buildings with more air-tight envelopes. To avoid the hazard, many modern combustion appliances utilize "direct venting" which draws combustion air directly from outdoors, instead of from the indoor environment.

**Design of air flow in rooms**

[edit]

The air in a room can be supplied and removed in several ways, for example via ceiling ventilation, cross ventilation, floor ventilation or displacement ventilation.<sup>[citation needed]</sup>

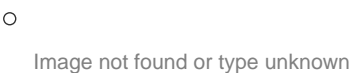
Ceiling ventilation



Ceiling ventilation  
Cross ventilation



Cross ventilation  
Floor ventilation



## Floor ventilation Displacement ventilation

○

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## Displacement ventilation

Furthermore, the air can be circulated in the room using vortexes which can be initiated in various ways:

Tangential flow vortices, initiated horizontally

○

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Tangential flow  
vortices, initiated  
horizontally

Tangential flow vortices, initiated vertically

○

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Tangential flow  
vortices, initiated  
vertically

Diffused flow vortices from air nozzles

○

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Diffused flow  
vortices from air  
nozzles



## Diffused flow vortices due to roof vortices

○

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Diffused flow  
vortices due to roof  
vortices

## Ventilation rates for indoor air quality

[edit]

The examples and perspective in this article **deal primarily with the United States and do not represent a worldwide view of the subject**. You may improve this article, discuss the issue on the talk page, or create a new article, as appropriate. *(April 2024)* *(Learn how and when to remove this message)*

The ventilation rate, for commercial, industrial, and institutional (CII) buildings, is normally expressed by the volumetric flow rate of outdoor air, introduced to the building. The typical units used are cubic feet per minute (CFM) in the imperial system, or liters per second (L/s) in the metric system (even though cubic meter per second is the preferred unit for volumetric flow rate in the SI system of units). The ventilation rate can also be expressed on a per person or per unit floor area basis, such as CFM/p or CFM/ft<sup>2</sup>, or as air changes per hour (ACH).

## Standards for residential buildings

[edit]

For residential buildings, which mostly rely on infiltration for meeting their ventilation needs, a common ventilation rate measure is the air change rate (or air changes per hour): the hourly ventilation rate divided by the volume of the space (*I* or *ACH*; units of 1/h). During the winter, ACH may range from 0.50 to 0.41 in a tightly air-sealed house to 1.11 to 1.47 in a loosely air-sealed house.<sup>[12]</sup>

ASHRAE now recommends ventilation rates dependent upon floor area, as a revision to the 62-2001 standard, in which the minimum ACH was 0.35, but no less than 15 CFM/person (7.1 L/s/person). As of 2003, the standard has been changed to 3 CFM/100 sq. ft. (15 L/s/100 sq. m.) plus 7.5 CFM/person (3.5 L/s/person).<sup>[13]</sup>

# Standards for commercial buildings

[edit]

## Ventilation rate procedure

[edit]

Ventilation Rate Procedure is rate based on standard and prescribes the rate at which ventilation air must be delivered to space and various means to the condition that air.<sup>[14]</sup> Air quality is assessed (through CO<sub>2</sub> measurement) and ventilation rates are mathematically derived using constants. Indoor Air Quality Procedure uses one or more guidelines for the specification of acceptable concentrations of certain contaminants in indoor air but does not prescribe ventilation rates or air treatment methods.<sup>[14]</sup> This addresses both quantitative and subjective evaluations and is based on the Ventilation Rate Procedure. It also accounts for potential contaminants that may have no measured limits, or for which no limits are not set (such as formaldehyde off-gassing from carpet and furniture).

### Natural ventilation

[edit]

Main article: Natural ventilation

Natural ventilation harnesses naturally available forces to supply and remove air in an enclosed space. Poor ventilation in rooms is identified to significantly increase the localized moldy smell in specific places of the room including room corners.<sup>[11]</sup> There are three types of natural ventilation occurring in buildings: wind-driven ventilation, pressure-driven flows, and stack ventilation.<sup>[15]</sup> The pressures generated by 'the stack effect' rely upon the buoyancy of heated or rising air. Wind-driven ventilation relies upon the force of the prevailing wind to pull and push air through the enclosed space as well as through breaches in the building's envelope.

Almost all historic buildings were ventilated naturally.<sup>[16]</sup> The technique was generally abandoned in larger US buildings during the late 20th century as the use of air conditioning became more widespread. However, with the advent of advanced Building Performance Simulation (BPS) software, improved Building Automation Systems (BAS), Leadership in Energy and Environmental Design (LEED) design requirements, and improved window manufacturing techniques; natural ventilation has made a resurgence

in commercial buildings both globally and throughout the US.[<sup>17</sup>]

The benefits of natural ventilation include:

- Improved indoor air quality (IAQ)
- Energy savings
- Reduction of greenhouse gas emissions
- Occupant control
- Reduction in occupant illness associated with sick building syndrome
- Increased worker productivity

Techniques and architectural features used to ventilate buildings and structures naturally include, but are not limited to:

- Operable windows
- Clerestory windows and vented skylights
- Lev/convection doors
- Night purge ventilation
- Building orientation
- Wind capture façades

## **Airborne diseases**

[edit]

Natural ventilation is a key factor in reducing the spread of airborne illnesses such as tuberculosis, the common cold, influenza, meningitis or COVID-19.[<sup>18</sup>] Opening doors and windows are good ways to maximize natural ventilation, which would make the risk of airborne contagion much lower than with costly and maintenance-requiring mechanical systems. Old-fashioned clinical areas with high ceilings and large windows provide the greatest protection. Natural ventilation costs little and is maintenance-free, and is particularly suited to limited-resource settings and tropical climates, where the burden of TB and institutional TB transmission is highest. In settings where respiratory isolation is difficult and climate permits, windows and doors should be opened to reduce the risk of airborne contagion. Natural ventilation requires little maintenance and is inexpensive.[<sup>19</sup>]

Natural ventilation is not practical in much of the infrastructure because of climate. This means that the facilities need to have effective mechanical ventilation systems and or use Ceiling Level UV or FAR UV ventilation systems.

Ventilation is measured in terms of air changes per hour (ACH). As of 2023, the CDC recommends that all spaces have a minimum of 5 ACH.[<sup>20</sup>] For hospital rooms with airborne contagions the CDC recommends a minimum of 12 ACH.[<sup>21</sup>] Challenges in facility ventilation are public unawareness,[<sup>22</sup>][<sup>23</sup>] ineffective government oversight,

poor building codes that are based on comfort levels, poor system operations, poor maintenance, and lack of transparency.<sup>[24]</sup>

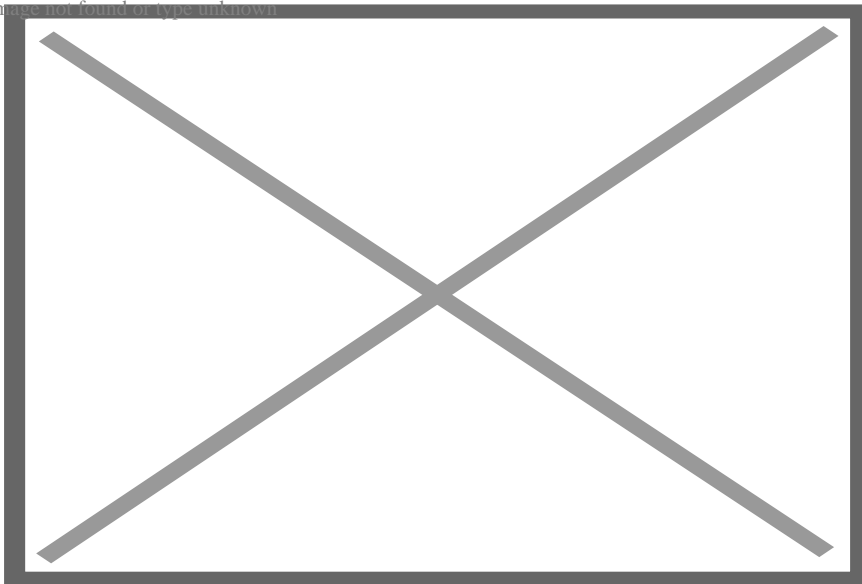
Pressure, both political and economic, to improve energy conservation has led to decreased ventilation rates. Heating, ventilation, and air conditioning rates have dropped since the energy crisis in the 1970s and the banning of cigarette smoke in the 1980s and 1990s.<sup>[25]</sup><sup>[26]</sup><sup>[better source needed]</sup>

## Mechanical ventilation

[edit]

Main article: HVAC

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An axial belt-drive exhaust fan serving an underground car park. This exhaust fan's operation is interlocked with the concentration of contaminants emitted by internal combustion engines.

Mechanical ventilation of buildings and structures can be achieved by the use of the following techniques:

- Whole-house ventilation
- Mixing ventilation
- Displacement ventilation
- Dedicated subaerial air supply

## Demand-controlled ventilation (DCV)

[edit]

Demand-controlled ventilation (**DCV**, also known as Demand Control Ventilation) makes it possible to maintain air quality while conserving energy.<sup>[27]</sup><sup>[28]</sup> ASHRAE has determined that "It is consistent with the ventilation rate procedure that demand control be permitted for use to reduce the total outdoor air supply during periods of less occupancy."<sup>[29]</sup> In a DCV system, CO<sub>2</sub> sensors control the amount of ventilation.<sup>[30]</sup><sup>[31]</sup> During peak occupancy, CO<sub>2</sub> levels rise, and the system adjusts to deliver the same amount of outdoor air as would be used by the ventilation-rate procedure.<sup>[32]</sup> However, when spaces are less occupied, CO<sub>2</sub> levels reduce, and the system reduces ventilation to conserve energy. DCV is a well-established practice,<sup>[33]</sup> and is required in high occupancy spaces by building energy standards such as ASHRAE 90.1.<sup>[34]</sup>

## Personalized ventilation

[edit]



This section needs to be **updated**. Please help update this article to reflect recent events or newly available information. (*September 2024*)

Personalized ventilation is an air distribution strategy that allows individuals to control the amount of ventilation received. The approach delivers fresh air more directly to the breathing zone and aims to improve the air quality of inhaled air. Personalized ventilation provides much higher ventilation effectiveness than conventional mixing ventilation systems by displacing pollution from the breathing zone with far less air volume. Beyond improved air quality benefits, the strategy can also improve occupants' thermal comfort, perceived air quality, and overall satisfaction with the indoor environment. Individuals' preferences for temperature and air movement are not equal, and so traditional approaches to homogeneous environmental control have failed to achieve high occupant satisfaction. Techniques such as personalized ventilation facilitate control of a more diverse thermal environment that can improve thermal satisfaction for most occupants.

## Local exhaust ventilation

[edit]

See also: Power tool

Local exhaust ventilation addresses the issue of avoiding the contamination of indoor air by specific high-emission sources by capturing airborne contaminants before they are spread into the environment. This can include water vapor control, lavatory effluent

control, solvent vapors from industrial processes, and dust from wood- and metal-working machinery. Air can be exhausted through pressurized hoods or the use of fans and pressurizing a specific area.<sup>[35]</sup>

A local exhaust system is composed of five basic parts:

1. A hood that captures the contaminant at its source
2. Ducts for transporting the air
3. An air-cleaning device that removes/minimizes the contaminant
4. A fan that moves the air through the system
5. An exhaust stack through which the contaminated air is discharged<sup>[35]</sup>

In the UK, the use of LEV systems has regulations set out by the Health and Safety Executive (HSE) which are referred to as the Control of Substances Hazardous to Health (CoSHH). Under CoSHH, legislation is set to protect users of LEV systems by ensuring that all equipment is tested at least every fourteen months to ensure the LEV systems are performing adequately. All parts of the system must be visually inspected and thoroughly tested and where any parts are found to be defective, the inspector must issue a red label to identify the defective part and the issue.

The owner of the LEV system must then have the defective parts repaired or replaced before the system can be used.

## **Smart ventilation**

[edit]

Smart ventilation is a process of continually adjusting the ventilation system in time, and optionally by location, to provide the desired IAQ benefits while minimizing energy consumption, utility bills, and other non-IAQ costs (such as thermal discomfort or noise). A smart ventilation system adjusts ventilation rates in time or by location in a building to be responsive to one or more of the following: occupancy, outdoor thermal and air quality conditions, electricity grid needs, direct sensing of contaminants, operation of other air moving and air cleaning systems. In addition, smart ventilation systems can provide information to building owners, occupants, and managers on operational energy consumption and indoor air quality as well as a signal when systems need maintenance or repair. Being responsive to occupancy means that a smart ventilation system can adjust ventilation depending on demand such as reducing ventilation if the building is unoccupied. Smart ventilation can time-shift ventilation to periods when a) indoor-outdoor temperature differences are smaller (and away from peak outdoor temperatures and humidity), b) when indoor-outdoor temperatures are appropriate for ventilative cooling, or c) when outdoor air quality is acceptable. Being responsive to electricity grid needs means providing flexibility to electricity demand (including direct signals from utilities) and integration with electric grid control strategies. Smart ventilation systems can have sensors to detect airflow, systems pressures, or fan energy use in such a way

that systems failures can be detected and repaired, as well as when system components need maintenance, such as filter replacement.<sup>[36]</sup>

## Ventilation and combustion

[edit]

Combustion (in a fireplace, gas heater, candle, oil lamp, etc.) consumes oxygen while producing carbon dioxide and other unhealthy gases and smoke, requiring ventilation air. An open chimney promotes infiltration (i.e. natural ventilation) because of the negative pressure change induced by the buoyant, warmer air leaving through the chimney. The warm air is typically replaced by heavier, cold air.

Ventilation in a structure is also needed for removing water vapor produced by respiration, burning, and cooking, and for removing odors. If water vapor is permitted to accumulate, it may damage the structure, insulation, or finishes. <sup>[citation needed]</sup> When operating, an air conditioner usually removes excess moisture from the air. A dehumidifier may also be appropriate for removing airborne moisture.

## Calculation for acceptable ventilation rate

[edit]

Ventilation guidelines are based on the minimum ventilation rate required to maintain acceptable levels of effluents. Carbon dioxide is used as a reference point, as it is the gas of highest emission at a relatively constant value of 0.005 L/s. The mass balance equation is:

$$Q = G / (C_i - C_a)$$

- Q = ventilation rate (L/s)
- G = CO<sub>2</sub> generation rate
- C<sub>i</sub> = acceptable indoor CO<sub>2</sub> concentration
- C<sub>a</sub> = ambient CO<sub>2</sub> concentration<sup>[37]</sup>

## Smoking and ventilation

[edit]

ASHRAE standard 62 states that air removed from an area with environmental tobacco smoke shall not be recirculated into ETS-free air. A space with ETS requires more ventilation to achieve similar perceived air quality to that of a non-smoking environment.

The amount of ventilation in an ETS area is equal to the amount of an ETS-free area plus the amount V, where:

$$V = \text{DSD} \times \text{VA} \times A/60E$$

- V = recommended extra flow rate in CFM (L/s)
- DSD = design smoking density (estimated number of cigarettes smoked per hour per unit area)
- VA = volume of ventilation air per cigarette for the room being designed (ft<sup>3</sup>/cig)
- E = contaminant removal effectiveness<sup>[38]</sup>

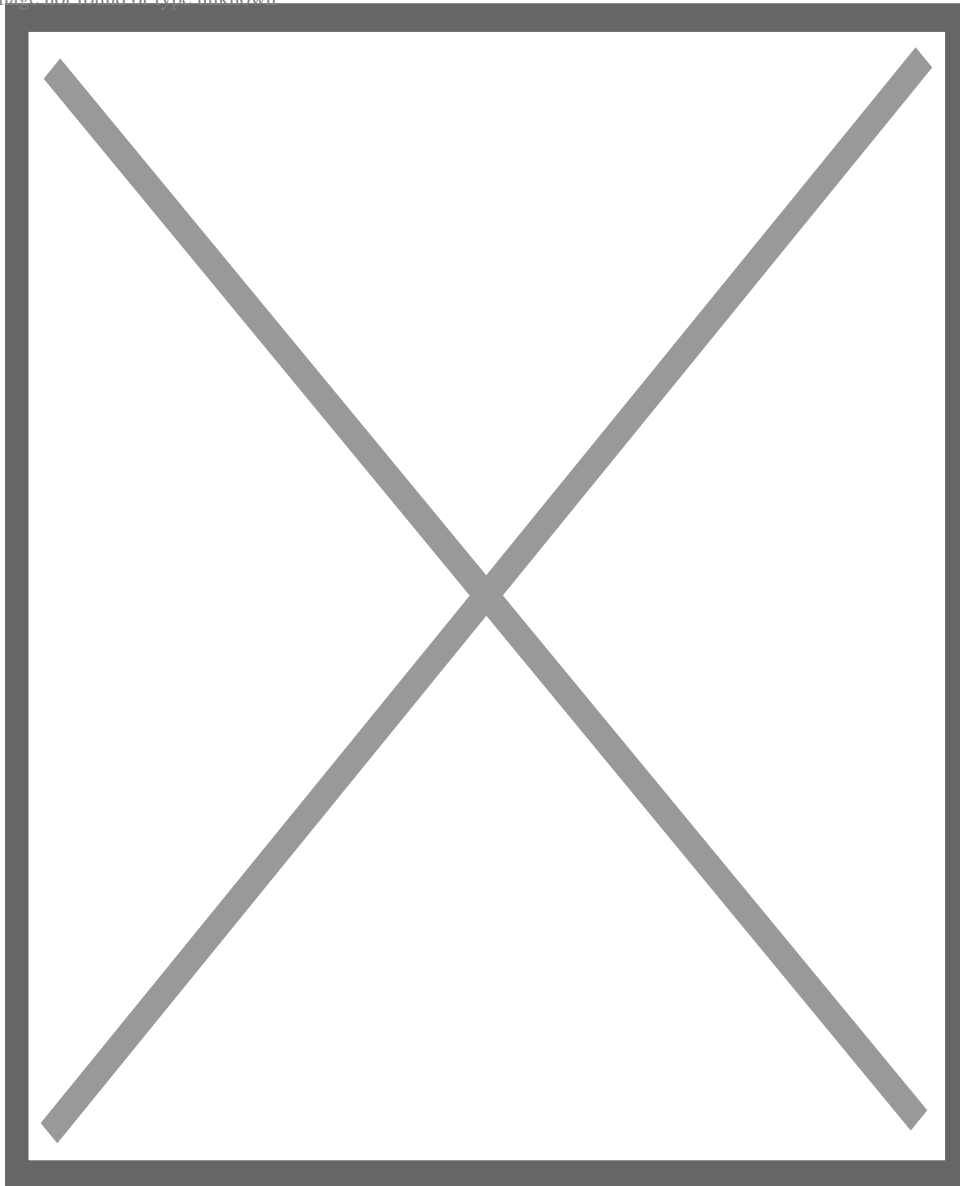
## History

[edit]

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This ancient Roman house uses a variety of passive cooling and passive ventilation techniques. Heavy masonry walls, small exterior windows, and a



narrow walled garden oriented N-S shade the house, preventing heat gain. The house opens onto a central atrium with an impluvium (open to the sky); the evaporative cooling of the water causes a cross-draft from atrium to garden.

Primitive ventilation systems were found at the Pločnik archeological site (belonging to the Vinča culture) in Serbia and were built into early copper smelting furnaces. The furnace, built on the outside of the workshop, featured earthen pipe-like air vents with hundreds of tiny holes in them and a prototype chimney to ensure air goes into the furnace to feed the fire and smoke comes out safely.<sup>[39]</sup>

Passive ventilation and passive cooling systems were widely written about around the Mediterranean by Classical times. Both sources of heat and sources of cooling (such as fountains and subterranean heat reservoirs) were used to drive air circulation, and buildings were designed to encourage or exclude drafts, according to climate and function. Public bathhouses were often particularly sophisticated in their heating and cooling. Icehouses are some millennia old, and were part of a well-developed ice industry by classical times.

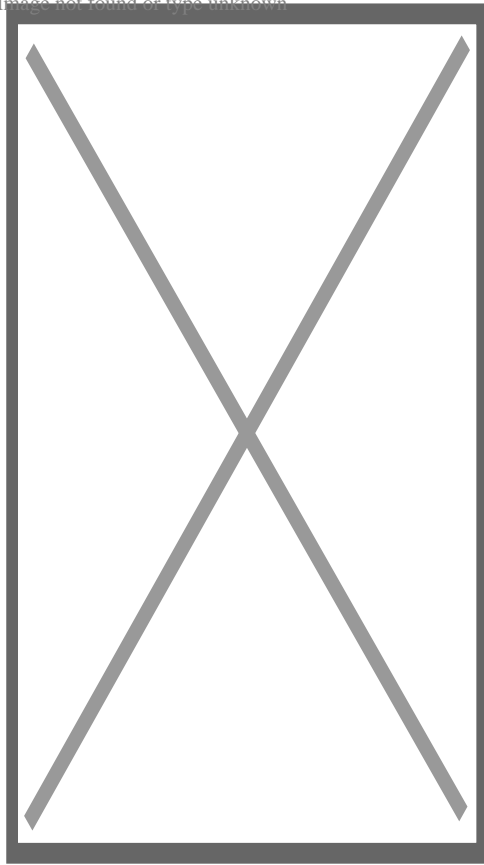
The development of forced ventilation was spurred by the common belief in the late 18th and early 19th century in the miasma theory of disease, where stagnant 'airs' were thought to spread illness. An early method of ventilation was the use of a ventilating fire near an air vent which would forcibly cause the air in the building to circulate. English engineer John Theophilus Desaguliers provided an early example of this when he installed ventilating fires in the air tubes on the roof of the House of Commons. Starting with the Covent Garden Theatre, gas burning chandeliers on the ceiling were often specially designed to perform a ventilating role.

## Mechanical systems

[edit]

Further information: Heating, ventilation, and air conditioning § Mechanical or forced ventilation

Image not found or type unknown



The Central Tower of the Palace of Westminster. This octagonal spire was for ventilation purposes, in the more complex system imposed by Reid on Barry, in which it was to draw air out of the Palace. The design was for the aesthetic disguise of its function.<sup>[40][41]</sup>

A more sophisticated system involving the use of mechanical equipment to circulate the air was developed in the mid-19th century. A basic system of bellows was put in place to ventilate Newgate Prison and outlying buildings, by the engineer Stephen Hales in the mid-1700s. The problem with these early devices was that they required constant human labor to operate. David Boswell Reid was called to testify before a Parliamentary committee on proposed architectural designs for the new House of Commons, after the old one burned down in a fire in 1834.<sup>[40]</sup> In January 1840 Reid was appointed by the committee for the House of Lords dealing with the construction of the replacement for the Houses of Parliament. The post was in the capacity of ventilation engineer, in effect; and with its creation there began a long series of quarrels between Reid and Charles Barry, the architect.<sup>[42]</sup>

Reid advocated the installation of a very advanced ventilation system in the new House. His design had air being drawn into an underground chamber, where it would undergo either heating or cooling. It would then ascend into the chamber through thousands of small holes drilled into the floor, and would be extracted through the ceiling by a special ventilation fire within a great stack.<sup>[43]</sup>

Reid's reputation was made by his work in Westminster. He was commissioned for an air quality survey in 1837 by the Leeds and Selby Railway in their tunnel.<sup>[44]</sup> The steam vessels built for the Niger expedition of 1841 were fitted with ventilation systems based on Reid's Westminster model.<sup>[45]</sup> Air was dried, filtered and passed over charcoal.<sup>[46]</sup><sup>[47]</sup> Reid's ventilation method was also applied more fully to St. George's Hall, Liverpool, where the architect, Harvey Lonsdale Elmes, requested that Reid should be involved in ventilation design.<sup>[48]</sup> Reid considered this the only building in which his system was completely carried out.<sup>[49]</sup>

## Fans

[edit]

With the advent of practical steam power, ceiling fans could finally be used for ventilation. Reid installed four steam-powered fans in the ceiling of St George's Hospital in Liverpool, so that the pressure produced by the fans would force the incoming air upward and through vents in the ceiling. Reid's pioneering work provides the basis for ventilation systems to this day.<sup>[43]</sup> He was remembered as "Dr. Reid the ventilator" in the twenty-first century in discussions of energy efficiency, by Lord Wade of Chorlton.<sup>[50]</sup>

## History and development of ventilation rate standards

[edit]

Ventilating a space with fresh air aims to avoid "bad air". The study of what constitutes bad air dates back to the 1600s when the scientist Mayow studied asphyxia of animals in confined bottles.<sup>[51]</sup> The poisonous component of air was later identified as carbon dioxide (CO<sub>2</sub>), by Lavoisier in the very late 1700s, starting a debate as to the nature of "bad air" which humans perceive to be stuffy or unpleasant. Early hypotheses included excess concentrations of CO<sub>2</sub> and oxygen depletion. However, by the late 1800s, scientists thought biological contamination, not oxygen or CO<sub>2</sub>, was the primary component of unacceptable indoor air. However, it was noted as early as 1872 that CO<sub>2</sub> concentration closely correlates to perceived air quality.

The first estimate of minimum ventilation rates was developed by Tredgold in 1836.<sup>[52]</sup> This was followed by subsequent studies on the topic by Billings <sup>[53]</sup> in 1886 and Flugge

in 1905. The recommendations of Billings and Flugge were incorporated into numerous building codes from 1900–the 1920s and published as an industry standard by ASHVE (the predecessor to ASHRAE) in 1914.<sup>[51]</sup>

The study continued into the varied effects of thermal comfort, oxygen, carbon dioxide, and biological contaminants. The research was conducted with human subjects in controlled test chambers. Two studies, published between 1909 and 1911, showed that carbon dioxide was not the offending component. Subjects remained satisfied in chambers with high levels of CO<sub>2</sub>, so long as the chamber remained cool.<sup>[51]</sup> (Subsequently, it has been determined that CO<sub>2</sub> is, in fact, harmful at concentrations over 50,000ppm<sup>[54]</sup>)

ASHVE began a robust research effort in 1919. By 1935, ASHVE-funded research conducted by Lemberg, Brandt, and Morse – again using human subjects in test chambers – suggested the primary component of "bad air" was an odor, perceived by the human olfactory nerves.<sup>[55]</sup> Human response to odor was found to be logarithmic to contaminant concentrations, and related to temperature. At lower, more comfortable temperatures, lower ventilation rates were satisfactory. A 1936 human test chamber study by Yaglou, Riley, and Coggins culminated much of this effort, considering odor, room volume, occupant age, cooling equipment effects, and recirculated air implications, which guided ventilation rates.<sup>[56]</sup> The Yagle research has been validated, and adopted into industry standards, beginning with the ASA code in 1946. From this research base, ASHRAE (having replaced ASHVE) developed space-by-space recommendations, and published them as ASHRAE Standard 62-1975: Ventilation for acceptable indoor air quality.

As more architecture incorporated mechanical ventilation, the cost of outdoor air ventilation came under some scrutiny. In 1973, in response to the 1973 oil crisis and conservation concerns, ASHRAE Standards 62-73 and 62-81) reduced required ventilation from 10 CFM (4.76 L/s) per person to 5 CFM (2.37 L/s) per person. In cold, warm, humid, or dusty climates, it is preferable to minimize ventilation with outdoor air to conserve energy, cost, or filtration. This critique (e.g. Tiller<sup>[57]</sup>) led ASHRAE to reduce outdoor ventilation rates in 1981, particularly in non-smoking areas. However subsequent research by Fanger,<sup>[58]</sup> W. Cain, and Janssen validated the Yagle model. The reduced ventilation rates were found to be a contributing factor to sick building syndrome.<sup>[59]</sup>

The 1989 ASHRAE standard (Standard 62-89) states that appropriate ventilation guidelines are 20 CFM (9.2 L/s) per person in an office building, and 15 CFM (7.1 L/s) per person for schools, while 2004 Standard 62.1-2004 has lower recommendations again (see tables below). ANSI/ASHRAE (Standard 62-89) speculated that "comfort (odor) criteria are likely to be satisfied if the ventilation rate is set so that 1,000 ppm CO<sub>2</sub> is not exceeded"<sup>[60]</sup> while OSHA has set a limit of 5000 ppm over 8 hours.<sup>[61]</sup>

## Historical ventilation rates

Author or source	Year	Ventilation rate (IP)	Ventilation rate (SI)	Basis or rationale
Tredgold	1836	4 CFM per person	2 L/s per person	Basic metabolic needs, breathing rate, and candle burning
Billings	1895	30 CFM per person	15 L/s per person	Indoor air hygiene, preventing spread of disease
Flugge	1905	30 CFM per person	15 L/s per person	Excessive temperature or unpleasant odor
ASHVE	1914	30 CFM per person	15 L/s per person	Based on Billings, Flugge and contemporaries
Early US Codes	1925	30 CFM per person	15 L/s per person	Same as above
Yaglou	1936	15 CFM per person	7.5 L/s per person	Odor control, outdoor air as a fraction of total air
ASA	1946	15 CFM per person	7.5 L/s per person	Based on Yaglou and contemporaries
ASHRAE	1975	15 CFM per person	7.5 L/s per person	Same as above
ASHRAE	1981	10 CFM per person	5 L/s per person	For non-smoking areas, reduced.
ASHRAE	1989	15 CFM per person	7.5 L/s per person	Based on Fanger, W. Cain, and Janssen

ASHRAE continues to publish space-by-space ventilation rate recommendations, which are decided by a consensus committee of industry experts. The modern descendants of ASHRAE standard 62-1975 are ASHRAE Standard 62.1, for non-residential spaces, and ASHRAE 62.2 for residences.

In 2004, the calculation method was revised to include both an occupant-based contamination component and an area-based contamination component.<sup>[62]</sup> These two components are additive, to arrive at an overall ventilation rate. The change was made to recognize that densely populated areas were sometimes overventilated (leading to higher energy and cost) using a per-person methodology.

### Occupant Based Ventilation Rates,<sup>[62]</sup> ANSI/ASHRAE Standard 62.1-2004

IP Units	SI Units	Category	Examples
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0 cfm/person	0 L/s/person	Spaces where ventilation requirements are primarily associated with building elements, not occupants.	Storage Rooms, Warehouses
5 cfm/person	2.5 L/s/person	Spaces occupied by adults, engaged in low levels of activity	Office space
7.5 cfm/person	3.5 L/s/person	Spaces where occupants are engaged in higher levels of activity, but not strenuous, or activities generating more contaminants	Retail spaces, lobbies
10 cfm/person	5 L/s/person	Spaces where occupants are engaged in more strenuous activity, but not exercise, or activities generating more contaminants	Classrooms, school settings
20 cfm/person	10 L/s/person	Spaces where occupants are engaged in exercise, or activities generating many contaminants	dance floors, exercise rooms

### Area-based ventilation rates,<sup>[62]</sup> ANSI/ASHRAE Standard 62.1-2004

IP Units	SI Units	Category	Examples
0.06 cfm/ft <sup>2</sup>	0.30 L/s/m <sup>2</sup>	Spaces where space contamination is normal, or similar to an office environment	Conference rooms, lobbies
0.12 cfm/ft <sup>2</sup>	0.60 L/s/m <sup>2</sup>	Spaces where space contamination is significantly higher than an office environment	Classrooms, museums
0.18 cfm/ft <sup>2</sup>	0.90 L/s/m <sup>2</sup>	Spaces where space contamination is even higher than the previous category	Laboratories, art classrooms
0.30 cfm/ft <sup>2</sup>	1.5 L/s/m <sup>2</sup>	Specific spaces in sports or entertainment where contaminants are released	Sports, entertainment
0.48 cfm/ft <sup>2</sup>	2.4 L/s/m <sup>2</sup>	Reserved for indoor swimming areas, where chemical concentrations are high	Indoor swimming areas

The addition of occupant- and area-based ventilation rates found in the tables above often results in significantly reduced rates compared to the former standard. This is compensated in other sections of the standard which require that this minimum amount of air is delivered to the breathing zone of the individual occupant at all times. The total outdoor air intake of the ventilation system (in multiple-zone variable air volume (VAV) systems) might therefore be similar to the airflow required by the 1989 standard. From 1999 to 2010, there was considerable development of the application protocol for ventilation rates. These advancements address occupant- and process-based ventilation rates, room ventilation effectiveness, and system ventilation effectiveness<sup>[63]</sup>

### Problems

[edit]

- In hot, humid climates, unconditioned ventilation air can daily deliver approximately 260 milliliters of water for each cubic meters per hour ( $\text{m}^3/\text{h}$ ) of outdoor air (or one pound of water each day for each cubic feet per minute of outdoor air per day), annual average.<sup>[citation needed]</sup> This is a great deal of moisture and can create serious indoor moisture and mold problems. For example, given a  $150 \text{ m}^2$  building with an airflow of  $180 \text{ m}^3/\text{h}$  this could result in about 47 liters of water accumulated per day.
- Ventilation efficiency is determined by design and layout, and is dependent upon the placement and proximity of diffusers and return air outlets. If they are located closely together, supply air may mix with stale air, decreasing the efficiency of the HVAC system, and creating air quality problems.
- System imbalances occur when components of the HVAC system are improperly adjusted or installed and can create pressure differences (too much-circulating air creating a draft or too little circulating air creating stagnancy).
- Cross-contamination occurs when pressure differences arise, forcing potentially contaminated air from one zone to an uncontaminated zone. This often involves undesired odors or VOCs.
- Re-entry of exhaust air occurs when exhaust outlets and fresh air intakes are either too close, prevailing winds change exhaust patterns or infiltration between intake and exhaust air flows.
- Entrainment of contaminated outdoor air through intake flows will result in indoor air contamination. There are a variety of contaminated air sources, ranging from industrial effluent to VOCs put off by nearby construction work.<sup>[64]</sup> A recent study revealed that in urban European buildings equipped with ventilation systems lacking outdoor air filtration, the exposure to outdoor-originating pollutants indoors resulted in more Disability-Adjusted Life Years (DALYs) than exposure to indoor-emitted pollutants.<sup>[65]</sup>

## See also

[edit]

- Architectural engineering
- Biological safety
- Cleanroom
- Environmental tobacco smoke
- Fume hood
- Head-end power
- Heating, ventilation, and air conditioning
- Heat recovery ventilation
- Mechanical engineering
- Room air distribution
- Sick building syndrome
- Siheyuan
- Solar chimney
- Tulou

- Windcatcher

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-  Media from Commons
-  News from Wikinews
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## Air Infiltration & Ventilation Centre (AIVC)

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- Publications from the Air Infiltration & Ventilation Centre (AIVC)

## International Energy Agency (IEA) Energy in Buildings and Communities Programme (EBC)

[edit]

- Publications from the International Energy Agency (IEA) Energy in Buildings and Communities Programme (EBC) ventilation-related research projects-annexes:
  - EBC Annex 9 Minimum Ventilation Rates
  - EBC Annex 18 Demand Controlled Ventilation Systems
  - EBC Annex 26 Energy Efficient Ventilation of Large Enclosures
  - EBC Annex 27 Evaluation and Demonstration of Domestic Ventilation Systems
  - EBC Annex 35 Control Strategies for Hybrid Ventilation in New and Retrofitted Office Buildings (HYBVENT)
  - EBC Annex 62 Ventilative Cooling

# **International Society of Indoor Air Quality and Climate**

[edit]

- Indoor Air Journal
- Indoor Air Conference Proceedings

# **American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)**

[edit]

- ASHRAE Standard 62.1 – Ventilation for Acceptable Indoor Air Quality
- ASHRAE Standard 62.2 – Ventilation for Acceptable Indoor Air Quality in Residential Buildings
- v
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Heating, ventilation, and air conditioning

**Fundamental  
concepts**

- Air changes per hour (ACH)
- Bake-out
- Building envelope
- Convection
- Dilution
- Domestic energy consumption
- Enthalpy
- Fluid dynamics
- Gas compressor
- Heat pump and refrigeration cycle
- Heat transfer
- Humidity
- Infiltration
- Latent heat
- Noise control
- Outgassing
- Particulates
- Psychrometrics
- Sensible heat
- Stack effect
- Thermal comfort
- Thermal destratification
- Thermal mass
- Thermodynamics
- Vapour pressure of water

## Technology

- Absorption-compression heat pump
- Absorption refrigerator
- Air barrier
- Air conditioning
- Antifreeze
- Automobile air conditioning
- Autonomous building
- Building insulation materials
- Central heating
- Central solar heating
- Chilled beam
- Chilled water
- Constant air volume (CAV)
- Coolant
- Cross ventilation
- Dedicated outdoor air system (DOAS)
- Deep water source cooling
- Demand controlled ventilation (DCV)
- Displacement ventilation
- District cooling
- District heating
- Electric heating
- Energy recovery ventilation (ERV)
- Firestop
- Forced-air
- Forced-air gas
- Free cooling
- Heat recovery ventilation (HRV)
- Hybrid heat
- Hydronics
- Ice storage air conditioning
- Kitchen ventilation
- Mixed-mode ventilation
- Microgeneration
- Passive cooling
- Passive daytime radiative cooling
- Passive house
- Passive ventilation
- Radiant heating and cooling
- Radiant cooling
- Radiant heating
- Radon mitigation
- Refrigeration
- Renewable heat
- Room air distribution
- Solar air heat
- Solar combisystem
- Solar cooling
- Solar heating

- Air conditioner inverter
- Air door
- Air filter
- Air handler
- Air ionizer
- Air-mixing plenum
- Air purifier
- Air source heat pump
- Attic fan
- Automatic balancing valve
- Back boiler
- Barrier pipe
- Blast damper
- Boiler
- Centrifugal fan
- Ceramic heater
- Chiller
- Condensate pump
- Condenser
- Condensing boiler
- Convection heater
- Compressor
- Cooling tower
- Damper
- Dehumidifier
- Duct
- Economizer
- Electrostatic precipitator
- Evaporative cooler
- Evaporator
- Exhaust hood
- Expansion tank
- Fan
- Fan coil unit
- Fan filter unit
- Fan heater
- Fire damper
- Fireplace
- Fireplace insert
- Freeze stat
- Flue
- Freon
- Fume hood
- Furnace
- Gas compressor
- Gas heater
- Gasoline heater
- Grease duct
- Grille



**Measurement  
and control**

- Air flow meter
- Aquastat
- BACnet
- Blower door
- Building automation
- Carbon dioxide sensor
- Clean air delivery rate (CADR)
- Control valve
- Gas detector
- Home energy monitor
- Humidistat
- HVAC control system
- Infrared thermometer
- Intelligent buildings
- LonWorks
- Minimum efficiency reporting value (MERV)
- Normal temperature and pressure (NTP)
- OpenTherm
- Programmable communicating thermostat
- Programmable thermostat
- Psychrometrics
- Room temperature
- Smart thermostat
- Standard temperature and pressure (STP)
- Thermographic camera
- Thermostat
- Thermostatic radiator valve
- Architectural acoustics
- Architectural engineering
- Architectural technologist
- Building services engineering
- Building information modeling (BIM)
- Deep energy retrofit

**Professions,  
trades,  
and services**

- Duct cleaning
- Duct leakage testing
- Environmental engineering
- Hydronic balancing
- Kitchen exhaust cleaning
- Mechanical engineering
- Mechanical, electrical, and plumbing
- Mold growth, assessment, and remediation
- Refrigerant reclamation
- Testing, adjusting, balancing

**Industry  
organizations**

- AHRI
- AMCA
- ASHRAE
- ASTM International
- BRE
- BSRIA
- CIBSE
- Institute of Refrigeration
- IIR
- LEED
- SMACNA
- UMC

**Health and safety**

- Indoor air quality (IAQ)
- Passive smoking
- Sick building syndrome (SBS)
- Volatile organic compound (VOC)
- ASHRAE Handbook
- Building science
- Fireproofing

**See also**

- Glossary of HVAC terms
- Warm Spaces
- World Refrigeration Day
- Template:Fire protection
- Template:Home automation
- Template:Solar energy

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**National**

- Czech Republic

**Other**

- NARA

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