

Portable Toilet



- **User Experience Upgrades**

User Experience Upgrades Adding Hand Wash Stations to Restroom Rentals Benefits of Foot Pump Sinks in Portable Toilets Improving Visibility with Solar Interior Lighting Touch Free Hardware Options for Restroom Doors Including Baby Changing Stations at Outdoor Events Providing Coat Hooks and Mirrors for Guests Selecting Wheelchair Ramps for Accessible Cabins Enhancing Ventilation with Solar Fans Choosing Interior Shelves for Personal Items Offering Urinal Troughs for High Volume Venues Using Motion Activated Lights for Nighttime Safety Evaluating Foldable Quick Set Toilet Frames

- **Odor Control and Waste Treatment**

Odor Control and Waste Treatment How Blue Chemical Solutions Work in Portables Advantages of Bio Enzymatic Waste Treatment Using Enzyme Packets for Odor Reduction Choosing Fragrance Discs for Guest Comfort Vent Stack Design for Improved Airflow Chemical Refill Volumes for Different Tank Sizes Comparing Deodorizer Colors and Uses Managing Waste Treatment in Extreme Temperatures Antimicrobial Surfaces and Odor Prevention Balancing pH Levels in Portable Toilet Tanks Eco Friendly Alternatives to Formaldehyde

## Solutions Monitoring Fill Levels to Prevent Odor Spikes

- About Us



## Balancing pH Levels in Portable Toilet Tanks

### Understanding pH and Its Importance in Portable Toilets

Okay, lets talk about pH balance in portable toilets. Some contracts require a refundable damage waiver royal portable restrooms



wheelchair ramp. It might not be the most glamorous topic, but trust me, understanding it makes a huge difference in how these little sanitation stations function and smell (or rather, don't smell!).

Think of pH as a scale that tells you how acidic or alkaline (basic) something is. It runs from 0 to 14, with 7 being neutral. Anything below 7 is acidic, like lemon juice, and anything above 7 is alkaline, like baking soda.

Now, why is this important in a portable toilet? Well, the whole goal is to break down waste and control odors. The bacteria that do this best prefer a slightly alkaline environment. If the tank becomes too acidic, those helpful bacteria struggle, and the waste doesn't break down as effectively. That's when the unpleasant smells start to build up.

On the other hand, if the tank becomes too alkaline, it can also cause problems. It can lead to the precipitation of minerals, creating hard-to-clean deposits, and potentially damaging the tank's components over time.

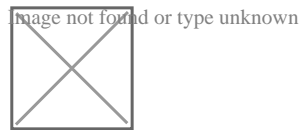
So, balancing the pH is key. This is usually achieved through the use of chemical additives specifically designed for portable toilets. These additives often contain enzymes to aid in waste breakdown and deodorizers to mask odors, but importantly, they also help maintain that sweet spot in the pH range where the bacteria are happy and the toilet stays relatively fresh. Essentially, its about creating an environment where the good bacteria can thrive and keep the unpleasant odors at bay. Its a delicate balance, but getting it right makes a world of difference to the portable toilet experience!

### **Common Causes of pH Imbalance in Porta Potties**

#### Common Causes of pH Imbalance in Porta Potties

Maintaining proper pH levels in portable toilets can be challenging due to several common factors that contribute to imbalances. One of the primary causes is heavy usage, particularly during large events or construction sites, where frequent use leads to rapid waste accumulation. This increased waste load can quickly overwhelm the chemical treatment solution, causing pH levels to shift towards acidic conditions.

Weather conditions also play a significant role in pH fluctuations. Hot temperatures accelerate bacterial growth and decomposition, while rainfall can dilute the chemical solution, reducing its effectiveness. Additionally, when users dispose of unauthorized materials like food waste, cigarettes, or cleaning products, these items can interfere with the carefully balanced chemical formulation designed to maintain optimal pH levels.



Another often overlooked factor is the mixing ratio of chemicals to water. When service providers don't follow proper dilution guidelines or when tanks aren't emptied frequently enough, the chemical balance becomes compromised. The introduction of external substances like hand sanitizers, soap, or beverage spillage can also disrupt the pH balance, as these products often contain acids or bases that interact with the existing chemical treatment.

Understanding these common causes helps portable toilet operators implement better maintenance schedules and educate users about proper usage, ultimately leading to more effective pH management and improved sanitary conditions.

## **The Impact of Imbalanced pH on Sanitation and Odor Control**

### The Impact of Imbalanced pH on Sanitation and Odor Control

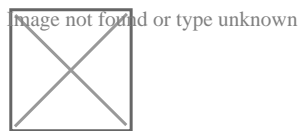
Maintaining proper pH balance in portable toilet tanks is crucial for effective waste management and odor control. When pH levels become imbalanced, a cascade of problems can quickly develop, affecting both sanitation and user experience.

In an environment that's too acidic (low pH), harmful bacteria can thrive, leading to increased odor production and slower waste breakdown. These conditions not only create unpleasant smells but also compromise the effectiveness of cleaning chemicals and deodorizers. Additionally, acidic conditions can accelerate the corrosion of tank components, potentially causing damage to the unit's infrastructure.

Conversely, when pH levels become too alkaline (high pH), different challenges arise. While high pH can help control certain odor-causing bacteria, it may also interfere with the natural decomposition process of organic waste. This disruption can lead to solid waste accumulation

and create an environment where different types of problematic bacteria flourish.

The key to effective portable toilet maintenance lies in achieving and maintaining a balanced pH level, typically between 6.5 and 7.5. This optimal range supports beneficial bacterial activity while inhibiting harmful microorganisms. It also ensures that cleaning chemicals work as intended, maximizing their effectiveness in controlling odors and maintaining sanitary conditions.



Regular monitoring and adjustment of pH levels, combined with proper chemical treatment, helps prevent these issues and ensures a more pleasant experience for users while extending the service life of the portable toilet unit.

### **Simple Methods for Testing pH Levels in Portable Toilet Tanks**

### Testing pH Levels in Portable Toilet Tanks: Simple and Effective Methods

Maintaining proper pH levels in portable toilet tanks is crucial for odor control and waste breakdown. Fortunately, there are several straightforward methods to test pH levels that don't require extensive technical knowledge or expensive equipment.

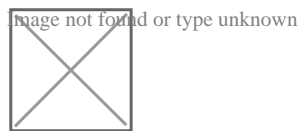
The most basic approach involves using pH test strips, which are readily available at most hardware stores and online retailers. These paper strips change color when dipped into the tank solution, and the resulting color can be matched against a chart to determine the pH level. While not as precise as electronic meters, test strips are cost-effective and sufficiently accurate for most purposes.

Another practical method is using a digital pH meter, which provides more accurate readings. These handheld devices are simple to operate – just dip the probe into the tank solution and wait for the reading to stabilize. While slightly more expensive than test strips, digital meters offer the advantage of reusability and precise measurements.

For a quick assessment, liquid pH indicators can be added directly to a small sample of the tank solution. These indicators change color

based on the pH level, providing immediate results. However, its important to note that this method should only be used with a sample taken from the tank, not directly in the tank itself.

Regular testing, regardless of the method chosen, should be performed at least weekly to ensure optimal conditions. The ideal pH range for portable toilet tanks typically falls between 6.5 and 7.5. If levels fall outside this range, appropriate chemical treatments can be added to restore balance.



Remember to always wear protective gloves and follow safety precautions when testing pH levels, as youre dealing with waste material. These simple testing methods help maintain proper sanitation and extend the service life of portable toilet facilities.

### **Natural Solutions for Balancing pH in Porta Potties**

Balancing the pH levels in portable toilet tanks is crucial for maintaining a hygienic and odor-free environment. While chemical solutions are commonly used, theres a growing interest in natural

alternatives that are both environmentally friendly and effective. Here are some natural solutions that can help balance the pH in porta potties.

First, consider using vinegar, which is a mild acid with a pH level of around 2.4. Adding a small amount of white vinegar to the tank can help neutralize alkaline waste, bringing the pH closer to neutral. This not only helps in reducing odors but also inhibits bacterial growth without harsh chemicals. However, it's important to use vinegar sparingly, as too much can tilt the balance too acidic.

Another natural option is baking soda, which has a pH of about 8.4. Baking soda can be sprinkled into the tank to counteract overly acidic conditions, promoting a more balanced environment. Its gentle alkalinity helps to neutralize acids from urine and other waste products while also acting as a deodorizer. Just like with vinegar, moderation is key; excessive use could make the solution too alkaline.

Enzyme-based cleaners offer another green approach. These cleaners contain natural enzymes that break down organic waste, effectively reducing odors and helping maintain pH balance by converting waste

into less harmful substances. They work well because they mimic nature's own decomposition process, making them efficient without disrupting the ecological balance.

Lastly, incorporating beneficial microorganisms like those found in compost starter or certain types of soil can be beneficial. These microbes consume waste materials, aiding in decomposition and naturally balancing pH through their metabolic processes. This method not only helps with pH balance but also contributes to breaking down waste into simpler compounds that are less odorous.

When implementing these natural solutions, it's vital to monitor the pH regularly with test strips designed for this purpose. Adjustments should be made based on these readings to ensure the environment remains within an optimal range for comfort and hygiene. By choosing these natural methods, users not only promote health and cleanliness but also contribute positively to environmental sustainability by reducing reliance on synthetic chemicals.

### **Commercial Products for pH Control in Rental Units**

Commercial Products for pH Control in Rental Units

Managing pH levels in portable toilet tanks requires reliable commercial products specifically designed for the rental industry. Several trusted manufacturers offer effective solutions that help maintain optimal pH balance while controlling odors and breaking down waste.

Most professional-grade pH control products come in either liquid or drop-in tablet form. Popular options include enzyme-based treatments that naturally digest waste while maintaining proper pH levels, and chemical treatments containing quaternary ammonium compounds that quickly neutralize acids and bases. Many of these products are colored blue or green to provide visual confirmation of proper treatment levels in the tank.

Leading brands like Walex, PolyPortables, and Safe-T-Fresh offer concentrated formulations that are both cost-effective and efficient. These products typically combine pH balancing agents with powerful deodorizers and waste digesters in a single solution. Most are designed to work effectively in extreme temperatures and remain stable during transport.

For optimal results, rental companies should choose products specifically formulated for their climate and usage conditions. Factors like temperature, humidity, and service intervals all affect how well pH control products perform. Many suppliers offer guidance on product selection and can recommend appropriate dosing schedules based on specific operational needs.

When selecting pH control products, its important to consider environmental regulations and disposal requirements in your area. Many modern formulations are biodegradable and environmentally friendly while still providing excellent pH control and waste treatment performance.

#### **Preventative Measures to Maintain Optimal pH Levels**

Lets talk about keeping those portable toilet tanks from turning into stinky science experiments, shall we? Im talking about pH balance, that delicate dance between too acidic and too alkaline. Ignoring it is like ignoring the engine light in your car – eventually, somethings going to seize up, and in this case, that something is likely to be a nose-wrinkling, potentially corrosive, and definitely unpleasant mess.

So, what's a conscientious portable toilet owner to do? Preventative measures, my friends, are the name of the game. Think of it like brushing your teeth – a little effort regularly prevents a whole lot of trouble down the line.

First up, and this is a big one, use the right chemicals. I'm not talking about grabbing any old cleaner off the shelf. We need specialized portable toilet chemicals. These are formulated not only to break down waste and control odors, but also to help maintain a proper pH. Read the labels! Follow the instructions! It's not rocket science, but it is important.

Secondly, regular cleaning and flushing. Seems obvious, right? But a quick rinse isn't enough. We're talking about actually emptying the tank and giving it a good scrub, especially if it's been sitting unused for a while. This prevents buildup that can throw off the pH.

Third, consider the environment. Extreme heat or cold can affect the chemical reactions happening inside the tank. If possible, store the portable toilet in a shaded area or a climate-controlled environment when not in use.

Finally, and this might sound a little extra, but you can actually test the pH levels yourself with readily available kits. This allows you to proactively adjust the chemical treatments as needed, ensuring that your portable toilet remains a relatively happy and odor-free place.

Basically, a little bit of proactive care goes a long way. By taking these preventative measures, you can keep your portable toilet tanks balanced, hygienic, and, dare I say, almost pleasant. And trust me, everyone will thank you for it.

**Meet us at Facebook**



## **Social signals:**

## **How to reach us:**

### **About Fresh water**

Fresh water or freshwater is any kind of naturally taking place liquid or frozen water having reduced concentrations of dissolved salts and other total dissolved solids. The term excludes salt water and briny water, yet it does consist of non-salty mineral-rich waters, such as chalybeate springtimes. Fresh water might incorporate frozen and meltwater in ice sheets, ice caps, glaciers, snowfields and icebergs, all-natural rainfalls such as rains, snowfall, hail/sleet and graupel, and surface area drainages that develop inland bodies of water such as wetlands, fish ponds, lakes, rivers, streams, as well as groundwater included in aquifers, below ground rivers and lakes. Water is important to the survival of all living organisms. Several microorganisms can prosper on seawater, yet the terrific bulk of vascular plants and the majority of insects, amphibians, reptiles, creatures and birds require fresh water to survive. Fresh water is the water source that is of one of the most and prompt use to humans. Fresh water is not constantly safe and clean water, that is, water risk-free to consume alcohol by human beings. Much of the planet's fresh water (on the surface and groundwater) is to a considerable level improper for human intake without treatment.

Fresh water can conveniently come to be polluted by human activities or because of naturally taking place procedures, such as erosion. Fresh water makes up less than 3% of the world's water sources, and simply 1% of that is easily available. Around 70% of the globe's freshwater books are iced up in Antarctica. Simply 3% of it is removed for human usage. Agriculture utilizes roughly two thirds of all fresh water removed from the setting. Fresh water is a renewable and variable, but limited natural deposit. Fresh water is restored via the procedure of the natural water cycle, in which water from seas, lakes, forests, land, rivers and tanks vaporizes, creates clouds, and returns inland as rainfall. In your area, nonetheless, if even more fresh water is consumed with human tasks than is naturally recovered, this might cause reduced fresh water schedule (or water deficiency) from surface area and below ground sources and can trigger major damage to surrounding and linked environments. Water contamination additionally reduces the schedule of fresh water. Where offered water resources are limited, humans have created modern technologies like desalination and wastewater reusing to stretch the available supply further. Nonetheless, given the high price (both resources and running expenses) and – specifically for desalination – energy requirements, those remain mainly specific niche applications. A non-sustainable choice is using so-called "fossil water" from underground aquifers. As a few of those aquifers developed numerous thousands or perhaps numerous years ago when local climates were wetter (e. g. from one of the Green Sahara periods) and are not significantly restored under existing weather conditions – a minimum of contrasted to drawdown, these aquifers form essentially non-renewable sources comparable to peat or lignite, which are also constantly formed in the existing era however orders of magnitude slower than they are mined.

.

## **About Flush toilet**

A flush commode (also called a flushing toilet, water storage room (WC); see likewise bathroom names) is a toilet that throws away human waste (i. e., pee and feces) by accumulating it in a bowl and after that making use of the force of water to carry it ("flush" it) via a drain to an additional area for therapy, either nearby or at a common facility. Flush bathrooms can be created for resting or crouching (frequently regionally differentiated). Many modern-day sewer treatment systems are likewise made to process specifically designed toilet paper, and there is increasing rate of interest for flushable wet wipes. Porcelain (sometimes with vitreous china) is a prominent product for these toilets, although public or institutional ones may be steel or modern various materials of commodes. Flush bathrooms are a kind of plumbing fixture, and generally include a bend called a catch (S-, U-, J-, or P-shaped) that creates water to gather in the commode bowl --- to hold the waste and function as a seal versus poisonous sewage system gases. Urban and country flush commodes are linked to a sewage system that communicates wastewater to a sewer therapy plant; rurally, a sewage-disposal tank or composting system is primarily utilized. The opposite of a flush commode is a dry bathroom, which uses no water for flushing. Associated gadgets are urinals, which largely dispose of urine, and bidets, which use water to cleanse the rectum, perineum, and vulva after making use of the commode.

## **About sustainability**

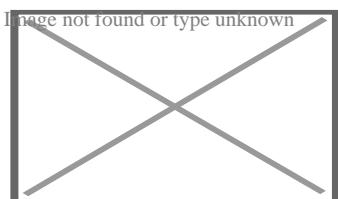
Sustainability is a social goal for people to co-exist in the world over an extended period of time. Interpretations of this term are contested and have actually differed with literary works, context, and time. Sustainability typically has three dimensions (or pillars): ecological, financial, and social. Numerous interpretations highlight the environmental dimension. This can consist of resolving vital environmental issues,

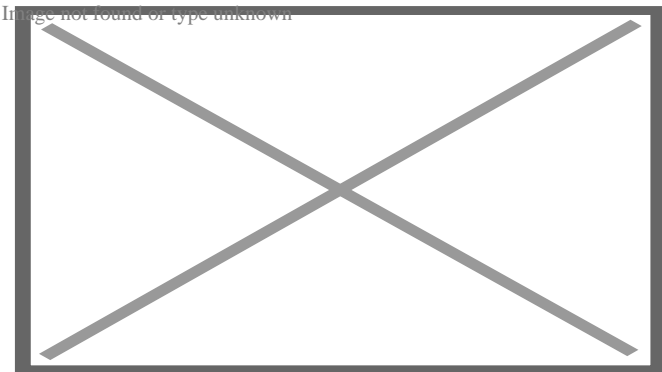
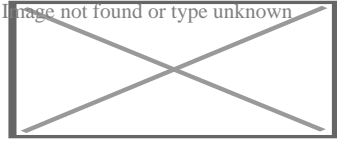
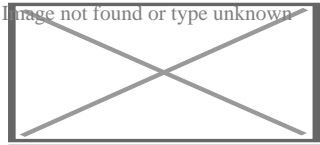
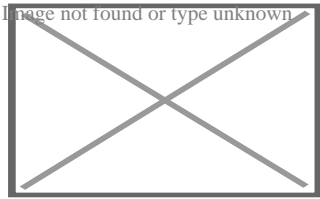
including climate adjustment and biodiversity loss. The idea of sustainability can guide choices at the international, nationwide, organizational, and specific levels. An associated principle is that of lasting development, and the terms are typically utilized to imply the very same thing. UNESCO distinguishes both similar to this: "Sustainability is commonly taken a long-term goal (i. e. a much more lasting globe), while lasting development describes the many procedures and paths to achieve it. " Information around the economic measurement of sustainability are controversial. Scholars have actually reviewed this under the concept of weak and solid sustainability. For example, there will certainly always be tension between the ideas of "well-being and prosperity for all" and environmental conservation, so compromises are necessary. It would be preferable to locate ways that different financial growth from hurting the setting. This implies utilizing less resources each of output even while growing the economic situation. This decoupling decreases the ecological effect of financial growth, such as air pollution. Doing this is difficult. Some professionals say there is no proof that such a decoupling is happening at the needed scale. It is challenging to gauge sustainability as the principle is complicated, contextual, and dynamic. Indicators have been created to cover the environment, culture, or the economic climate however there is no fixed interpretation of sustainability signs. The metrics are developing and consist of signs, benchmarks and audits. They include sustainability standards and qualification systems like Fairtrade and Organic. They also entail indices and bookkeeping systems such as corporate sustainability reporting and Triple Bottom Line accounting. It is essential to resolve numerous obstacles to sustainability to attain a sustainability change or sustainability transformation. 34 Some barriers emerge from nature and its intricacy while others are external to the principle of sustainability. As an example, they can arise from the leading institutional frameworks in countries. Worldwide problems of sustainability are tough to deal with as they require international solutions. The United Nations writes, "Today, there are almost 140 developing nations in the world seeking

ways of fulfilling their development needs, but with the raising threat of climate adjustment, concrete efforts must be made to guarantee growth today does not negatively affect future generations" UN Sustainability. Existing international companies such as the UN and WTO are seen as ineffective in implementing present worldwide policies. One factor for this is the absence of suitable approving mechanisms:â€â€ 135-- 145 â€ Governments are not the only sources of activity for sustainability. As an example, company groups have tried to incorporate eco-friendly interest in economic task, looking for lasting business. Spiritual leaders have emphasized the demand for caring for nature and ecological stability. Individuals can likewise live even more sustainably. Some people have slammed the concept of sustainability. One factor of objection is that the concept is vague and just a buzzword. Another is that sustainability might be a difficult goal. Some experts have actually mentioned that "no country is supplying what its people require without transgressing the biophysical worldly boundaries":â€â€ 11 â€

## About air conditioning

This article is about cooling of air. For the Curved Air album, see Air Conditioning (album). For a similar device capable of both cooling and heating, see Heat pump. "a/c" redirects here. For the abbreviation used in banking and book-keeping, see Account (disambiguation). For other uses, see AC.





There are various types of air conditioners. Popular examples include:

Window-mounted air conditioner

(China, 2023); Ceiling-mounted cassette air conditioner (China, 2023);

Wall-mounted air conditioner (Japan, 2020); Ceiling-mounted console (Also

called ceiling suspended) air conditioner (China, 2023); and portable air conditioner (Vatican City, 2018).

**Air conditioning**, often abbreviated as **A/C** (US) or **air con** (UK),<sup>[1]</sup> is the process of removing heat from an enclosed space to achieve a more comfortable interior temperature, and in some cases, also controlling the humidity of internal air. Air conditioning can be achieved using a mechanical 'air conditioner' or through other

methods, such as passive cooling and ventilative cooling.<sup>[2]</sup><sup>[3]</sup> Air conditioning is a member of a family of systems and techniques that provide heating, ventilation, and air conditioning (HVAC).<sup>[4]</sup> Heat pumps are similar in many ways to air conditioners but use a reversing valve, allowing them to both heat and cool an enclosed space.<sup>[5]</sup>

Air conditioners, which typically use vapor-compression refrigeration, range in size from small units used in vehicles or single rooms to massive units that can cool large buildings.<sup>[6]</sup> Air source heat pumps, which can be used for heating as well as cooling, are becoming increasingly common in cooler climates.

Air conditioners can reduce mortality rates due to higher temperature.<sup>[7]</sup> According to the International Energy Agency (IEA) 1.6 billion air conditioning units were used globally in 2016.<sup>[8]</sup> The United Nations called for the technology to be made more sustainable to mitigate climate change and for the use of alternatives, like passive cooling, evaporative cooling, selective shading, windcatchers, and better thermal insulation.

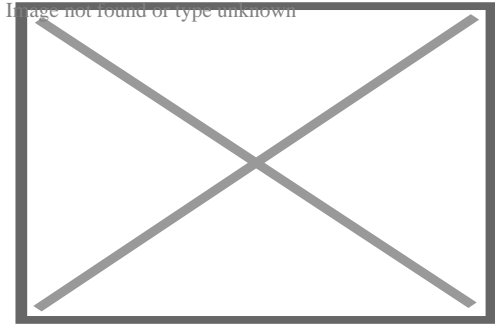
## History

[edit]

Air conditioning dates back to prehistory.<sup>[9]</sup> Double-walled living quarters, with a gap between the two walls to encourage air flow, were found in the ancient city of Hamoukar, in modern Syria.<sup>[10]</sup> Ancient Egyptian buildings also used a wide variety of passive air-conditioning techniques.<sup>[11]</sup> These became widespread from the Iberian Peninsula through North Africa, the Middle East, and Northern India.<sup>[12]</sup>

Passive techniques remained widespread until the 20th century when they fell out of fashion and were replaced by powered air conditioning. Using information from engineering studies of traditional buildings, passive techniques are being revived and

modified for 21st-century architectural designs.<sup>[13]</sup><sup>[12]</sup>



An array of air conditioner condenser units outside a commercial office building

Air conditioners allow the building's indoor environment to remain relatively constant, largely independent of changes in external weather conditions and internal heat loads. They also enable deep plan buildings to be created and have allowed people to live comfortably in hotter parts of the world.<sup>[14]</sup>

## Development

[edit]

## Preceding discoveries

[edit]

In 1558, Giambattista della Porta described a method of chilling ice to temperatures far below its freezing point by mixing it with potassium nitrate (then called "nitre") in his popular science book *Natural Magic*.<sup>[15]</sup><sup>[16]</sup><sup>[17]</sup> In 1620, Cornelis Drebbel demonstrated "Turning Summer into Winter" for James I of England, chilling part of the Great Hall of Westminster Abbey with an apparatus of troughs and vats.<sup>[18]</sup> Drebbel's contemporary Francis Bacon, like della Porta a believer in science communication, may not have been present at the demonstration, but in a book published later the

same year, he described it as "experiment of artificial freezing" and said that "Nitre (or rather its spirit) is very cold, and hence nitre or salt when added to snow or ice intensifies the cold of the latter, the nitre by adding to its cold, but the salt by supplying activity to the cold of the snow."<sup>[15]</sup>

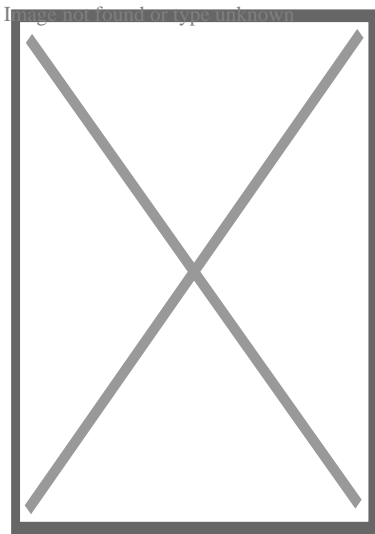
In 1758, Benjamin Franklin and John Hadley, a chemistry professor at the University of Cambridge, conducted experiments applying the principle of evaporation as a means to cool an object rapidly. Franklin and Hadley confirmed that the evaporation of highly volatile liquids (such as alcohol and ether) could be used to drive down the temperature of an object past the freezing point of water. They experimented with the bulb of a mercury-in-glass thermometer as their object. They used a bellows to speed up the evaporation. They lowered the temperature of the thermometer bulb down to  $-14^{\circ}\text{C}$  ( $7^{\circ}\text{F}$ ) while the ambient temperature was  $18^{\circ}\text{C}$  ( $64^{\circ}\text{F}$ ). Franklin noted that soon after they passed the freezing point of water  $0^{\circ}\text{C}$  ( $32^{\circ}\text{F}$ ), a thin film of ice formed on the surface of the thermometer's bulb and that the ice mass was about 6 mm (1/4 in) thick when they stopped the experiment upon reaching  $-14^{\circ}\text{C}$  ( $7^{\circ}\text{F}$ ). Franklin concluded: "From this experiment, one may see the possibility of freezing a man to death on a warm summer's day."<sup>[19]</sup>

The 19th century included many developments in compression technology. In 1820, English scientist and inventor Michael Faraday discovered that compressing and liquefying ammonia could chill air when the liquefied ammonia was allowed to evaporate.<sup>[20]</sup> In 1842, Florida physician John Gorrie used compressor technology to create ice, which he used to cool air for his patients in his hospital in Apalachicola, Florida. He hoped to eventually use his ice-making machine to regulate the temperature of buildings.<sup>[20]</sup><sup>[21]</sup> He envisioned centralized air conditioning that could cool entire cities. Gorrie was granted a patent in 1851,<sup>[22]</sup> but following the death of his main backer, he was not able to realize his invention.<sup>[23]</sup> In 1851, James

Harrison created the first mechanical ice-making machine in Geelong, Australia, and was granted a patent for an ether vapor-compression refrigeration system in 1855 that produced three tons of ice per day.<sup>[24]</sup> In 1860, Harrison established a second ice company. He later entered the debate over competing against the American advantage of ice-refrigerated beef sales to the United Kingdom.<sup>[24]</sup>

## First devices

[edit]



Willis Carrier, who is credited with building the first modern electrical air conditioning unit

Electricity made the development of effective units possible. In 1901, American inventor Willis H. Carrier built what is considered the first modern electrical air conditioning unit.<sup>[25]</sup><sup>[26]</sup><sup>[27]</sup><sup>[28]</sup> In 1902, he installed his first air-conditioning system in the Sackett-Wilhelms Lithographing & Publishing Company in Brooklyn, New York.<sup>[29]</sup> His invention controlled both the temperature and humidity, which helped maintain consistent paper dimensions and ink alignment at the printing plant. Later, together with six other employees, Carrier formed The Carrier Air Conditioning

Company of America, a business that in 2020, employed 53,000 people and was valued at \$18.6 billion.<sup>[30]</sup><sup>[31]</sup>

In 1906, Stuart W. Cramer of Charlotte, North Carolina, was exploring ways to add moisture to the air in his textile mill. Cramer coined the term "air conditioning" in a patent claim which he filed that year, where he suggested that air conditioning was analogous to "water conditioning", then a well-known process for making textiles easier to process.<sup>[32]</sup> He combined moisture with ventilation to "condition" and change the air in the factories, thus controlling the humidity that is necessary in textile plants. Willis Carrier adopted the term and incorporated it into the name of his company.<sup>[33]</sup>

Domestic air conditioning soon took off. In 1914, the first domestic air conditioning was installed in Minneapolis in the home of Charles Gilbert Gates. It is, however, possible that the considerable device (c. 2.1 m × 1.8 m × 6.1 m; 7 ft × 6 ft × 20 ft) was never used, as the house remained uninhabited<sup>[20]</sup> (Gates had already died in October 1913.)

In 1931, H.H. Schultz and J.Q. Sherman developed what would become the most common type of individual room air conditioner: one designed to sit on a window ledge. The units went on sale in 1932 at US\$10,000 to \$50,000 (the equivalent of \$200,000 to \$1,200,000 in 2024.)<sup>[20]</sup> A year later, the first air conditioning systems for cars were offered for sale.<sup>[34]</sup> Chrysler Motors introduced the first practical semi-portable air conditioning unit in 1935,<sup>[35]</sup> and Packard became the first automobile manufacturer to offer an air conditioning unit in its cars in 1939.<sup>[36]</sup>

## Further development

[edit]

Innovations in the latter half of the 20th century allowed more ubiquitous air conditioner use. In 1945, Robert Sherman of Lynn, Massachusetts, invented a portable, in-window air conditioner that cooled, heated, humidified, dehumidified, and filtered the air.<sup>[37]</sup> The first inverter air conditioners were released in 1980–1981.<sup>[38]</sup><sup>[39]</sup>

In 1954, Ned Cole, a 1939 architecture graduate from the University of Texas at Austin, developed the first experimental "suburb" with inbuilt air conditioning in each house. 22 homes were developed on a flat, treeless track in northwest Austin, Texas, and the community was christened the 'Austin Air-Conditioned Village.' The residents were subjected to a year-long study of the effects of air conditioning led by the nation's premier air conditioning companies, builders, and social scientists. In addition, researchers from UT's Health Service and Psychology Department studied the effects on the "artificially cooled humans." One of the more amusing discoveries was that each family reported being troubled with scorpions, the leading theory being that scorpions sought cool, shady places. Other reported changes in lifestyle were that mothers baked more, families ate heavier foods, and they were more apt to choose hot drinks.<sup>[40]</sup><sup>[41]</sup>

Air conditioner adoption tends to increase above around \$10,000 annual household income in warmer areas.<sup>[42]</sup> Global GDP growth explains around 85% of increased air condition adoption by 2050, while the remaining 15% can be explained by climate change.<sup>[42]</sup>

As of 2016, an estimated 1.6 billion air conditioning units were used worldwide, with over half of them in China and the United States, and with a total cooling capacity of 11,675 gigawatts.<sup>[8]</sup><sup>[43]</sup> The International Energy Agency predicted in 2018 that the number of air conditioning units would grow to around 4 billion units by 2050 and that the total cooling capacity would grow to around 23,000 GW, with the biggest increases in India and China.<sup>[8]</sup> Between 1995 and 2004, the proportion of urban

households in China with air conditioners increased from 8% to 70%.<sup>[44]</sup> As of 2015, nearly 100 million homes, or about 87% of US households, had air conditioning systems.<sup>[45]</sup> In 2019, it was estimated that 90% of new single-family homes constructed in the US included air conditioning, ranging from 99% in the South to 62% in the West.<sup>[46]</sup><sup>[47]</sup>

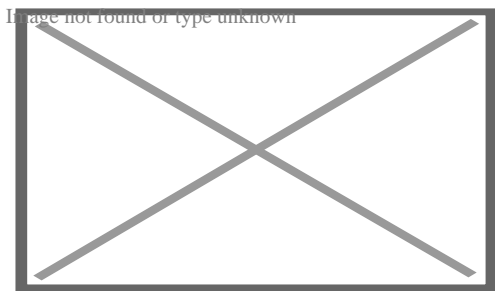
## Operation

[edit]

## Operating principles

[edit]

Main article: Vapor-compression refrigeration



A simple stylized diagram of the refrigeration cycle: 1) condensing coil, 2) expansion valve, 3) evaporator coil, 4) compressor

Cooling in traditional air conditioner systems is accomplished using the vapor-compression cycle, which uses a refrigerant's forced circulation and phase change between gas and liquid to transfer heat.<sup>[48]</sup><sup>[49]</sup> The vapor-compression cycle can occur within a unitary, or packaged piece of equipment, or within a chiller that is connected to terminal cooling equipment (such as a fan coil unit in an air handler) on its evaporator side and heat rejection equipment such as a cooling tower on its condenser side. An air source heat pump shares many components with an air conditioning system, but includes a reversing valve, which allows the unit to be used

to heat as well as cool a space.<sup>[50]</sup>

Air conditioning equipment will reduce the absolute humidity of the air processed by the system if the surface of the evaporator coil is significantly cooler than the dew point of the surrounding air. An air conditioner designed for an occupied space will typically achieve a 30% to 60% relative humidity in the occupied space.<sup>[51]</sup>

Most modern air-conditioning systems feature a dehumidification cycle during which the compressor runs. At the same time, the fan is slowed to reduce the evaporator temperature and condense more water. A dehumidifier uses the same refrigeration cycle but incorporates both the evaporator and the condenser into the same air path; the air first passes over the evaporator coil, where it is cooled<sup>[52]</sup> and dehumidified, before passing over the condenser coil, where it is warmed again before it is released back into the room.<sup>[citation needed]</sup>

Free cooling can sometimes be selected when the external air is cooler than the internal air. In this case, the compressor does not need to be used, resulting in high cooling efficiencies for these times. This may also be combined with seasonal thermal energy storage.<sup>[53]</sup>

## Heating

[edit]

Main article: Heat pump

Some air conditioning systems can reverse the refrigeration cycle and act as an air source heat pump, thus heating instead of cooling the indoor environment. They are also commonly referred to as "reverse cycle air conditioners". The heat pump is significantly more energy-efficient than electric resistance heating, because it moves

energy from air or groundwater to the heated space and the heat from purchased electrical energy. When the heat pump is in heating mode, the indoor evaporator coil switches roles and becomes the condenser coil, producing heat. The outdoor condenser unit also switches roles to serve as the evaporator and discharges cold air (colder than the ambient outdoor air).

Most air source heat pumps become less efficient in outdoor temperatures lower than 4 °C or 40 °F.<sup>[54]</sup> This is partly because ice forms on the outdoor unit's heat exchanger coil, which blocks air flow over the coil. To compensate for this, the heat pump system must temporarily switch back into the regular air conditioning mode to switch the outdoor evaporator coil *back* to the condenser coil, to heat up and defrost. Therefore, some heat pump systems will have electric resistance heating in the indoor air path that is activated only in this mode to compensate for the temporary indoor air cooling, which would otherwise be uncomfortable in the winter.

Newer models have improved cold-weather performance, with efficient heating capacity down to -14 °F (-26 °C).<sup>[55][54][56]</sup> However, there is always a chance that the humidity that condenses on the heat exchanger of the outdoor unit could freeze, even in models that have improved cold-weather performance, requiring a defrosting cycle to be performed.

The icing problem becomes much more severe with lower outdoor temperatures, so heat pumps are sometimes installed in tandem with a more conventional form of heating, such as an electrical heater, a natural gas, heating oil, or wood-burning fireplace or central heating, which is used instead of or in addition to the heat pump during harsher winter temperatures. In this case, the heat pump is used efficiently during milder temperatures, and the system is switched to the conventional heat source when the outdoor temperature is lower.

## Performance

[edit]

Main articles: coefficient of performance, Seasonal energy efficiency ratio, and European seasonal energy efficiency ratio

The coefficient of performance (COP) of an air conditioning system is a ratio of useful heating or cooling provided to the work required.<sup>[57]</sup><sup>[58]</sup> Higher COPs equate to lower operating costs. The COP usually exceeds 1; however, the exact value is highly dependent on operating conditions, especially absolute temperature and relative temperature between sink and system, and is often graphed or averaged against expected conditions.<sup>[59]</sup> Air conditioner equipment power in the U.S. is often described in terms of "tons of refrigeration", with each approximately equal to the cooling power of one short ton (2,000 pounds (910 kg) of ice melting in a 24-hour period. The value is equal to 12,000 BTU<sub>IT</sub> per hour, or 3,517 watts.<sup>[60]</sup> Residential central air systems are usually from 1 to 5 tons (3.5 to 18 kW) in capacity.<sup>[citation needed]</sup>

The efficiency of air conditioners is often rated by the seasonal energy efficiency ratio (SEER), which is defined by the Air Conditioning, Heating and Refrigeration Institute in its 2008 standard AHRI 210/240, *Performance Rating of Unitary Air-Conditioning and Air-Source Heat Pump Equipment*.<sup>[61]</sup> A similar standard is the European seasonal energy efficiency ratio (ESEER).<sup>[citation needed]</sup>

Efficiency is strongly affected by the humidity of the air to be cooled. Dehumidifying the air before attempting to cool it can reduce subsequent cooling costs by as much as 90 percent. Thus, reducing dehumidifying costs can materially affect overall air conditioning costs.<sup>[62]</sup>

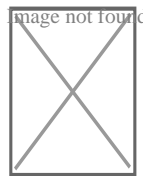
## Control system

[edit]

## Wireless remote control

[edit]

Main articles: Remote control and Infrared blaster

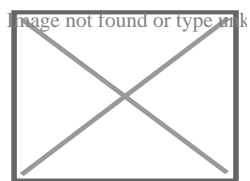


A

wireless

remote

controller

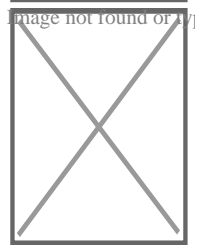
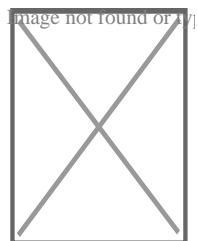


The infrared

transmitting

LED on the

remote



The infrared receiver

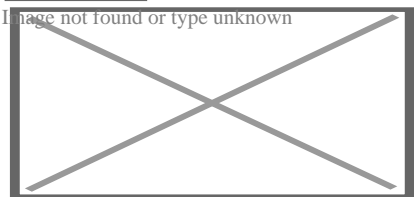
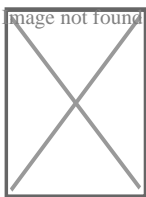
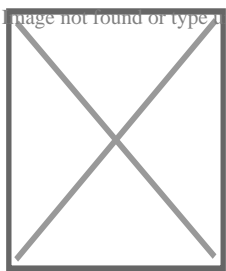
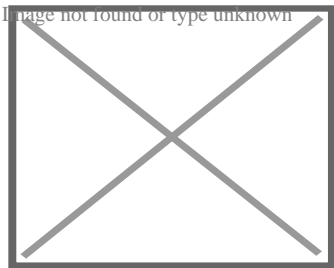
on the air conditioner

This type of controller uses an infrared LED to relay commands from a remote control to the air conditioner. The output of the infrared LED (like that of any infrared remote) is invisible to the human eye because its wavelength is beyond the range of visible light (940 nm). This system is commonly used on mini-split air conditioners because it is simple and portable. Some window and ducted central air conditioners uses it as well.

**Wired controller**

[edit]

Main article: Thermostat



Several wired controllers  
(Indonesia, 2024)

A wired controller, also called a "wired thermostat," is a device that controls an air conditioner by switching heating or cooling on or off. It uses different sensors to measure temperatures and actuate control operations. Mechanical thermostats commonly use bimetallic strips, converting a temperature change into mechanical displacement, to actuate control of the air conditioner. Electronic thermostats, instead, use a thermistor or other semiconductor sensor, processing temperature change as electronic signals to control the air conditioner.

These controllers are usually used in hotel rooms because they are permanently installed into a wall and hard-wired directly into the air conditioner unit, eliminating the need for batteries.

## Types

[edit]

Types	Typical Capacity*	Air supply	Mounting	Typical application
Mini-split	small – large	Direct	Wall	Residential
Window	very small – small	Direct	Window	Residential
Portable	very small – small	Direct / Ducted	Floor	Residential, remote areas
Ducted (individual)	small – very large	Ducted	Ceiling	Residential, commercial
Ducted (central)	medium – very large	Ducted	Ceiling	Residential, commercial
Ceiling suspended	medium – large	Direct	Ceiling	Commercial

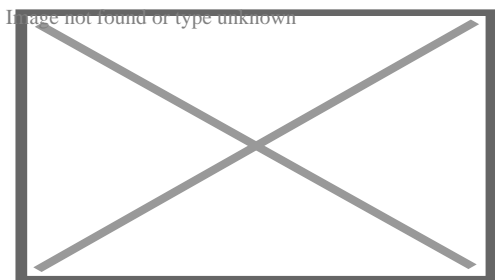
Cassette	medium – large	Direct / Ducted	Ceiling	Commercial
Floor standing	medium – large	Direct / Ducted	Floor	Commercial
Packaged	very large	Direct / Ducted	Floor	Commercial
Packaged RTU (Rooftop Unit)	very large	Ducted	Rooftop	Commercial

\* where the typical capacity is in kilowatt as follows:

- very small: <1.5 kW
- small: 1.5–3.5 kW
- medium: 4.2–7.1 kW
- large: 7.2–14 kW
- very large: >14 kW

## Mini-split and multi-split systems

[edit]



Evaporator, indoor unit, or terminal, side of a ductless split-type air conditioner

Ductless systems (often mini-split, though there are now ducted mini-split) typically supply conditioned and heated air to a single or a few rooms of a building, without ducts and in a decentralized manner.<sup>[63]</sup> Multi-zone or multi-split systems are a common application of ductless systems and allow up to eight rooms (zones or locations) to be conditioned independently from each other, each with its indoor unit and simultaneously from a single outdoor unit.

The first mini-split system was sold in 1961 by Toshiba in Japan, and the first wall-mounted mini-split air conditioner was sold in 1968 in Japan by Mitsubishi Electric, where small home sizes motivated their development. The Mitsubishi model was the first air conditioner with a cross-flow fan.<sup>[64]</sup><sup>[65]</sup><sup>[66]</sup> In 1969, the first mini-split air conditioner was sold in the US.<sup>[67]</sup> Multi-zone ductless systems were invented by Daikin in 1973, and variable refrigerant flow systems (which can be thought of as larger multi-split systems) were also invented by Daikin in 1982. Both were first sold in Japan.<sup>[68]</sup> Variable refrigerant flow systems when compared with central plant cooling from an air handler, eliminate the need for large cool air ducts, air handlers, and chillers; instead cool refrigerant is transported through much smaller pipes to the indoor units in the spaces to be conditioned, thus allowing for less space above dropped ceilings and a lower structural impact, while also allowing for more individual and independent temperature control of spaces. The outdoor and indoor units can be spread across the building.<sup>[69]</sup> Variable refrigerant flow indoor units can also be turned off individually in unused spaces.<sup>[citation needed]</sup> The lower start-up power of VRF's DC inverter compressors and their inherent DC power requirements also allow VRF solar-powered heat pumps to be run using DC-providing solar panels.

## **Ducted central systems**

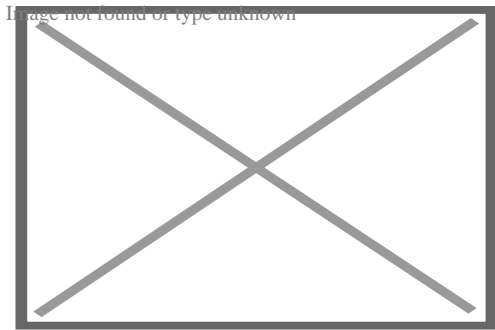
[edit]

Split-system central air conditioners consist of two heat exchangers, an outside unit (the condenser) from which heat is rejected to the environment and an internal heat exchanger (the evaporator, or Fan Coil Unit, FCU) with the piped refrigerant being circulated between the two. The FCU is then connected to the spaces to be cooled by ventilation ducts.<sup>[70]</sup> Floor standing air conditioners are similar to this type of air conditioner but sit within spaces that need cooling.

## Central plant cooling

[edit]

See also: Chiller



Industrial air conditioner cooling towers on top of the shopping mall *Passage* in Linz, Austria

Large central cooling plants may use intermediate coolant such as chilled water pumped into air handlers or fan coil units near or in the spaces to be cooled which then duct or deliver cold air into the spaces to be conditioned, rather than ducting cold air directly to these spaces from the plant, which is not done due to the low density and heat capacity of air, which would require impractically large ducts. The chilled water is cooled by chillers in the plant, which uses a refrigeration cycle to cool water, often transferring its heat to the atmosphere even in liquid-cooled chillers through the use of cooling towers. Chillers may be air- or liquid-cooled.<sup>[71]</sup><sup>[72]</sup>

## Portable units

[edit]

A portable system has an indoor unit on wheels connected to an outdoor unit via flexible pipes, similar to a permanently fixed installed unit (such as a ductless split air conditioner).

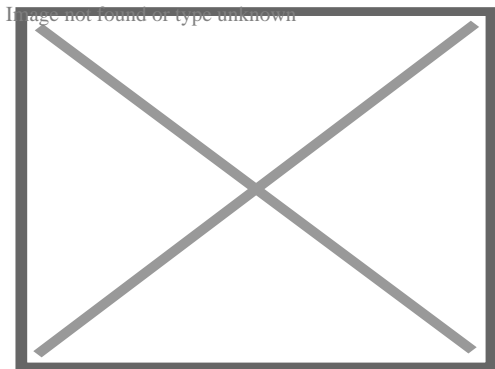
Hose systems, which can be *monoblock* or *air-to-air*, are vented to the outside via air ducts. The *monoblock* type collects the water in a bucket or tray and stops when full. The *air-to-air* type re-evaporates the water, discharges it through the ducted hose, and can run continuously. Many but not all portable units draw indoor air and expel it outdoors through a single duct, negatively impacting their overall cooling efficiency.

Many portable air conditioners come with heat as well as a dehumidification function.  
[<sup>73</sup>]

## Window unit and packaged terminal

[edit]

Main article: Packaged terminal air conditioner



Through-the-wall PTAC units, University Motor Inn, Philadelphia

The packaged terminal air conditioner (PTAC), through-the-wall, and window air conditioners are similar. These units are installed on a window frame or on a wall opening. The unit usually has an internal partition separating its indoor and outdoor sides, which contain the unit's condenser and evaporator, respectively. PTAC systems may be adapted to provide heating in cold weather, either directly by using an electric strip, gas, or other heaters, or by reversing the refrigerant flow to heat the interior and draw heat from the exterior air, converting the air conditioner into a heat pump. They may be installed in a wall opening with the help of a special sleeve on the wall and a custom grill that is flush with the wall and window air conditioners can also be installed in a window, but without a custom grill.<sup>[74]</sup>

**Packaged air conditioner**

[edit]

Packaged air conditioners (also known as self-contained units)<sup>[75]</sup><sup>[76]</sup> are central systems that integrate into a single housing all the components of a split central system, and deliver air, possibly through ducts, to the spaces to be cooled. Depending on their construction they may be outdoors or indoors, on roofs (rooftop units),<sup>[77]</sup><sup>[78]</sup> ] draw the air to be conditioned from inside or outside a building and be water or air-cooled. Often, outdoor units are air-cooled while indoor units are liquid-cooled using a cooling tower.<sup>[70]</sup><sup>[79]</sup><sup>[80]</sup><sup>[81]</sup><sup>[82]</sup><sup>[83]</sup>

**Types of compressors**

[edit]

Compressor types	Common applications	Typical capacity	Efficiency	Durability	Repairability
------------------	---------------------	------------------	------------	------------	---------------

			very low (small capacity)		
Reciprocating	Refrigerator, Walk-in freezer, portable air conditioners	small – large	medium (large capacity)	very low	medium
Rotary vane	Residential mini splits	small	low	low	easy
Scroll	Commercial and central systems, VRF	medium	medium	medium	easy
Rotary screw	Commercial chiller	medium – large	medium	medium	hard
Centrifugal	Commercial chiller	very large	medium	high	hard
Maglev Centrifugal	Commercial chiller	very large	high	very high	very hard

## Reciprocating

[edit]

Main article: Reciprocating compressor

This compressor consists of a crankcase, crankshaft, piston rod, piston, piston ring, cylinder head and valves. <sup>[*citation needed*]</sup>

## Scroll

[edit]

Main article: Scroll compressor

This compressor uses two interleaving scrolls to compress the refrigerant.<sup>[84]</sup> it consists of one fixed and one orbiting scrolls. This type of compressor is more efficient because it has 70 percent less moving parts than a reciprocating compressor. <sup>[citation needed]</sup>

## **Screw**

[edit]

Main article: Rotary-screw compressor

This compressor use two very closely meshing spiral rotors to compress the gas. The gas enters at the suction side and moves through the threads as the screws rotate. The meshing rotors force the gas through the compressor, and the gas exits at the end of the screws. The working area is the inter-lobe volume between the male and female rotors. It is larger at the intake end, and decreases along the length of the rotors until the exhaust port. This change in volume is the compression. <sup>[citation needed]</sup>

## **Capacity modulation technologies**

[edit]

There are several ways to modulate the cooling capacity in refrigeration or air conditioning and heating systems. The most common in air conditioning are: on-off cycling, hot gas bypass, use or not of liquid injection, manifold configurations of multiple compressors, mechanical modulation (also called digital), and inverter technology. <sup>[citation needed]</sup>

## **Hot gas bypass**

[edit]

Hot gas bypass involves injecting a quantity of gas from discharge to the suction side. The compressor will keep operating at the same speed, but due to the bypass, the refrigerant mass flow circulating with the system is reduced, and thus the cooling capacity. This naturally causes the compressor to run uselessly during the periods when the bypass is operating. The turn down capacity varies between 0 and 100%.<sup>[85]</sup>

## **Manifold configurations**

[edit]

Several compressors can be installed in the system to provide the peak cooling capacity. Each compressor can run or not in order to stage the cooling capacity of the unit. The turn down capacity is either 0/33/66 or 100% for a trio configuration and either 0/50 or 100% for a tandem.<sup>[citation needed]</sup>

## **Mechanically modulated compressor**

[edit]

This internal mechanical capacity modulation is based on periodic compression process with a control valve, the two scroll set move apart stopping the compression for a given time period. This method varies refrigerant flow by changing the average time of compression, but not the actual speed of the motor. Despite an excellent turndown ratio – from 10 to 100% of the cooling capacity, mechanically modulated scrolls have high energy consumption as the motor continuously runs.<sup>[citation needed]</sup>

## **Variable-speed compressor**

[edit]

Main article: Inverter compressor

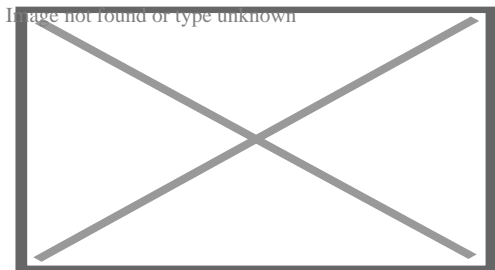
This system uses a variable-frequency drive (also called an Inverter) to control the speed of the compressor. The refrigerant flow rate is changed by the change in the speed of the compressor. The turn down ratio depends on the system configuration and manufacturer. It modulates from 15 or 25% up to 100% at full capacity with a single inverter from 12 to 100% with a hybrid tandem. This method is the most efficient way to modulate an air conditioner's capacity. It is up to 58% more efficient than a fixed speed system.<sup>*[citation needed]*</sup>

## Impact

[edit]

## Health effects

[edit]



Rooftop condenser unit fitted on top of an Osaka Municipal Subway 10 series subway carriage. Air conditioning has become increasingly prevalent on public transport vehicles as a form of climate control, and to ensure passenger comfort and drivers' occupational safety and health.

In hot weather, air conditioning can prevent heat stroke, dehydration due to excessive sweating, electrolyte imbalance, kidney failure, and other issues due to hyperthermia.

[<sup>8</sup>][<sup>86</sup>] Heat waves are the most lethal type of weather phenomenon in the United States.[<sup>87</sup>][<sup>88</sup>] A 2020 study found that areas with lower use of air conditioning correlated with higher rates of heat-related mortality and hospitalizations.[<sup>89</sup>] The August 2003 France heatwave resulted in approximately 15,000 deaths, where 80% of the victims were over 75 years old. In response, the French government required all retirement homes to have at least one air-conditioned room at 25 °C (77 °F) per floor during heatwaves.[<sup>8</sup>]

Air conditioning (including filtration, humidification, cooling and disinfection) can be used to provide a clean, safe, hypoallergenic atmosphere in hospital operating rooms and other environments where proper atmosphere is critical to patient safety and well-being. It is sometimes recommended for home use by people with allergies, especially mold.[<sup>90</sup>][<sup>91</sup>] However, poorly maintained water cooling towers can promote the growth and spread of microorganisms such as *Legionella pneumophila*, the infectious agent responsible for Legionnaires' disease. As long as the cooling tower is kept clean (usually by means of a chlorine treatment), these health hazards can be avoided or reduced. The state of New York has codified requirements for registration, maintenance, and testing of cooling towers to protect against Legionella.[<sup>92</sup>]

## **Economic effects**

[edit]

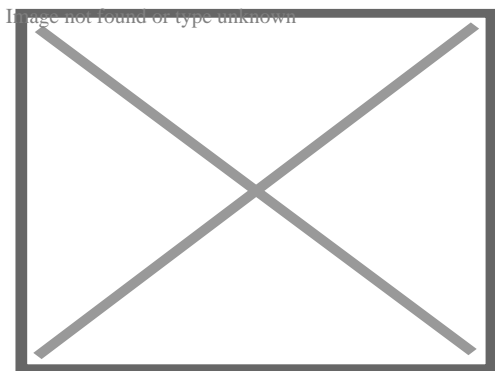
First designed to benefit targeted industries such as the press as well as large factories, the invention quickly spread to public agencies and administrations with studies with claims of increased productivity close to 24% in places equipped with air conditioning.[<sup>93</sup>]

Air conditioning caused various shifts in demography, notably that of the United States starting from the 1970s. In the US, the birth rate was lower in the spring than during other seasons until the 1970s but this difference then declined since then.<sup>[94]</sup> As of 2007, the Sun Belt contained 30% of the total US population while it was inhabited by 24% of Americans at the beginning of the 20th century.<sup>[95]</sup> Moreover, the summer mortality rate in the US, which had been higher in regions subject to a heat wave during the summer, also evened out.<sup>[7]</sup>

The spread of the use of air conditioning acts as a main driver for the growth of global demand of electricity.<sup>[96]</sup> According to a 2018 report from the International Energy Agency (IEA), it was revealed that the energy consumption for cooling in the United States, involving 328 million Americans, surpasses the combined energy consumption of 4.4 billion people in Africa, Latin America, the Middle East, and Asia (excluding China).<sup>[8]</sup> A 2020 survey found that an estimated 88% of all US households use AC, increasing to 93% when solely looking at homes built between 2010 and 2020.<sup>[97]</sup>

## Environmental effects

[edit]



Air conditioner farm in the facade of a building in Singapore

Air conditioning uses a massive amount of energy, leading to more carbon emissions. Space cooling including air conditioning accounted globally for 2021 terawatt-hours

of energy usage in 2016 with around 99% in the form of electricity, according to a 2018 report on air-conditioning efficiency by the International Energy Agency.<sup>[8]</sup> The report predicts an increase of electricity usage due to space cooling to around 6200 TWh by 2050,<sup>[8]</sup><sup>[98]</sup> and that with the progress currently seen, greenhouse gas emissions attributable to space cooling will double from 1,135 million tons (2016) to 2,070 million tons.<sup>[8]</sup> There is some push to increase the energy efficiency of air conditioners. United Nations Environment Programme (UNEP) and the IEA found that if air conditioners could be twice as effective as now, 460 billion tons of GHG could be cut over 40 years.<sup>[99]</sup> The UNEP and IEA also recommended legislation to decrease the use of hydrofluorocarbons, better building insulation, and more sustainable temperature-controlled food supply chains going forward.<sup>[99]</sup>

Refrigerants have also caused and continue to cause serious environmental issues, including ozone depletion and climate change, as several countries have not yet ratified the Kigali Amendment to reduce the consumption and production of hydrofluorocarbons.<sup>[100]</sup> CFCs and HCFCs refrigerants such as R-12 and R-22, respectively, used within air conditioners have caused damage to the ozone layer,<sup>[101]</sup> and hydrofluorocarbon refrigerants such as R-410A and R-404A, which were designed to replace CFCs and HCFCs, are instead exacerbating climate change.<sup>[102]</sup> Both issues happen due to the venting of refrigerant to the atmosphere, such as during repairs. HFO refrigerants, used in some if not most new equipment, solve both issues with an ozone damage potential (ODP) of zero and a much lower global warming potential (GWP) in the single or double digits vs. the three or four digits of hydrofluorocarbons.<sup>[103]</sup>

Hydrofluorocarbons would have raised global temperatures by around 0.3–0.5 °C (0.5–0.9 °F) by 2100 without the Kigali Amendment. With the Kigali Amendment, the increase of global temperatures by 2100 due to hydrofluorocarbons is predicted to be

around 0.06 °C (0.1 °F).<sup>[104]</sup>

Alternatives to continual air conditioning include passive cooling, passive solar cooling, natural ventilation, operating shades to reduce solar gain, using trees, architectural shades, windows (and using window coatings) to reduce solar gain.<sup>[citation ne</sup>

## **Social effects**

[edit]

Socioeconomic groups with a household income below around \$10,000 tend to have a low air conditioning adoption,<sup>[42]</sup> which worsens heat-related mortality.<sup>[7]</sup> The lack of cooling can be hazardous, as areas with lower use of air conditioning correlate with higher rates of heat-related mortality and hospitalizations.<sup>[89]</sup> Premature mortality in NYC is projected to grow between 47% and 95% in 30 years, with lower-income and vulnerable populations most at risk.<sup>[89]</sup> Studies on the correlation between heat-related mortality and hospitalizations and living in low socioeconomic locations can be traced in Phoenix, Arizona,<sup>[105]</sup> Hong Kong,<sup>[106]</sup> China,<sup>[106]</sup> Japan,<sup>[107]</sup> and Italy.<sup>[108]</sup><sup>[109]</sup> Additionally, costs concerning health care can act as another barrier, as the lack of private health insurance during a 2009 heat wave in Australia, was associated with heat-related hospitalization.<sup>[109]</sup>

Disparities in socioeconomic status and access to air conditioning are connected by some to institutionalized racism, which leads to the association of specific marginalized communities with lower economic status, poorer health, residing in hotter neighborhoods, engaging in physically demanding labor, and experiencing limited access to cooling technologies such as air conditioning.<sup>[109]</sup> A study overlooking Chicago, Illinois, Detroit, and Michigan found that black households were half as likely to have central air conditioning units when compared to their white

counterparts.<sup>[110]</sup> Especially in cities, Redlining creates heat islands, increasing temperatures in certain parts of the city.<sup>[109]</sup> This is due to materials heat-absorbing building materials and pavements and lack of vegetation and shade coverage.<sup>[111]</sup> There have been initiatives that provide cooling solutions to low-income communities, such as public cooling spaces.<sup>[8]</sup><sup>[111]</sup>

## **Other techniques**

[edit]

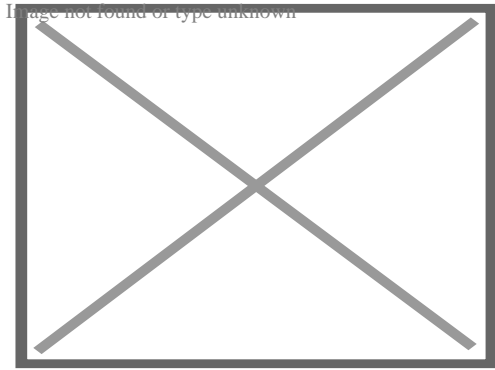
Buildings designed with passive air conditioning are generally less expensive to construct and maintain than buildings with conventional HVAC systems with lower energy demands.<sup>[112]</sup> While tens of air changes per hour, and cooling of tens of degrees, can be achieved with passive methods, site-specific microclimate must be taken into account, complicating building design.<sup>[12]</sup>

Many techniques can be used to increase comfort and reduce the temperature in buildings. These include evaporative cooling, selective shading, wind, thermal convection, and heat storage.<sup>[113]</sup>

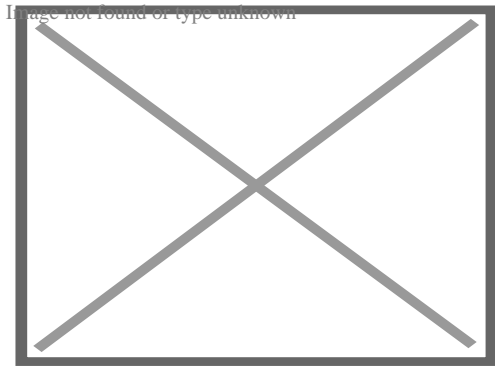
## **Passive ventilation**

[edit]

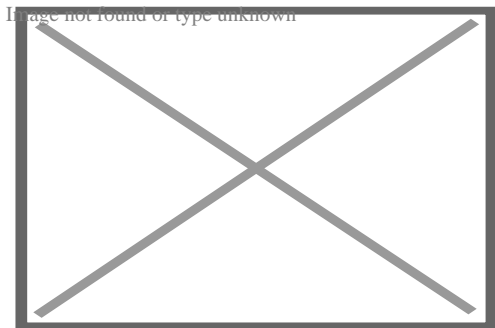
This section is an excerpt from Passive ventilation.[edit]



The ventilation system of a regular earthship



Dogtrot houses are designed to maximise natural ventilation.



A roof turbine ventilator, colloquially known as a 'Whirly Bird', is an application of wind driven ventilation.

Passive ventilation is the process of supplying air to and removing air from an indoor space without using mechanical systems. It refers to the flow of external air to an indoor space as a result of pressure differences arising from natural forces.

There are two types of natural ventilation occurring in buildings: *wind driven ventilation* and *buoyancy-driven ventilation*. Wind driven ventilation arises from the different

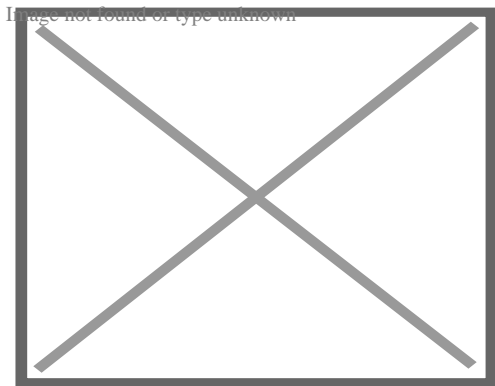
pressures created by wind around a building or structure, and openings being formed on the perimeter which then permit flow through the building. Buoyancy-driven ventilation occurs as a result of the directional buoyancy force that results from temperature differences between the interior and exterior.<sup>[114]</sup>

Since the internal heat gains which create temperature differences between the interior and exterior are created by natural processes, including the heat from people, and wind effects are variable, naturally ventilated buildings are sometimes called "breathing buildings".

## Passive cooling

[edit]

This section is an excerpt from Passive cooling.<sup>[edit]</sup>



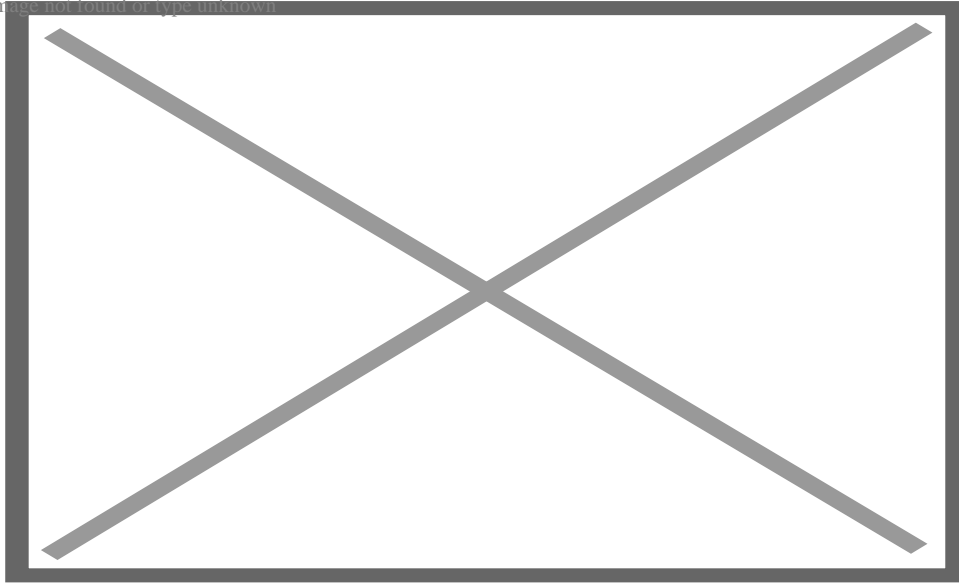
A traditional Iranian solar cooling design using a wind tower

Passive cooling is a building design approach that focuses on heat gain control and heat dissipation in a building in order to improve the indoor thermal comfort with low or no energy consumption.<sup>[115]</sup><sup>[116]</sup> This approach works either by preventing heat from entering the interior (heat gain prevention) or by removing heat from the building (natural cooling).<sup>[117]</sup>

Natural cooling utilizes on-site energy, available from the natural environment, combined with the architectural design of building components (e.g. building envelope), rather than mechanical systems to dissipate heat.<sup>[118]</sup> Therefore, natural cooling depends not only on the architectural design of the building but on how the site's natural resources are used as heat sinks (i.e. everything that absorbs or dissipates heat). Examples of on-site heat sinks are the upper atmosphere (night sky), the outdoor air (wind), and the earth/soil.

Passive cooling is an important tool for design of buildings for climate change adaptation – reducing dependency on energy-intensive air conditioning in warming environments.<sup>[119][120]</sup>

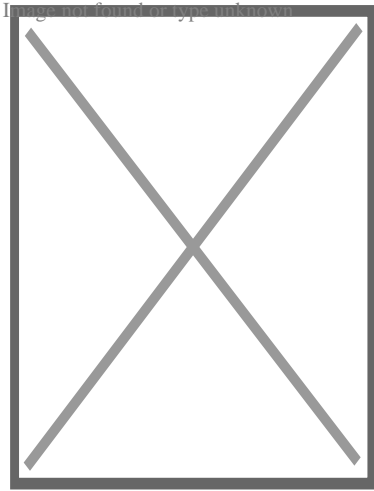
Image not found or type unknown



A pair of short windcatchers (*malqaf*) used in traditional architecture; wind is forced down on the windward side and leaves on the leeward side (*cross-ventilation*). In the absence of wind, the circulation can be driven with evaporative cooling in the inlet (which is also designed to catch dust). In the center, a *shuksheika* (roof lantern vent), used to shade the qa'a below while allowing hot air rise out of it (*stack effect*).<sup>[11]</sup>

## Daytime radiative cooling

[edit]



Passive daytime radiative cooling (PDRC) surfaces are high in solar reflectance and heat emittance, cooling with zero energy use or pollution.<sup>[121]</sup>

Passive daytime radiative cooling (PDRC) surfaces reflect incoming solar radiation and heat back into outer space through the infrared window for cooling during the daytime. Daytime radiative cooling became possible with the ability to suppress solar heating using photonic structures, which emerged through a study by Raman et al. (2014).<sup>[122]</sup> PDRCs can come in a variety of forms, including paint coatings and films, that are designed to be high in solar reflectance and thermal emittance.<sup>[121]</sup><sup>[123]</sup>

PDRC applications on building roofs and envelopes have demonstrated significant decreases in energy consumption and costs.<sup>[123]</sup> In suburban single-family residential areas, PDRC application on roofs can potentially lower energy costs by 26% to 46%.<sup>[124]</sup> PDRCs are predicted to show a market size of ~\$27 billion for indoor space cooling by 2025 and have undergone a surge in research and development since the 2010s.<sup>[125]</sup><sup>[126]</sup>

## Fans

[edit]

Main article: Ceiling fan

Hand fans have existed since prehistory. Large human-powered fans built into buildings include the punkah.

The 2nd-century Chinese inventor Ding Huan of the Han dynasty invented a rotary fan for air conditioning, with seven wheels 3 m (10 ft) in diameter and manually powered by prisoners.<sup>[127]</sup> In 99, in 151, in 233 and in 47, Emperor Xuanzong (r. 712–762) of the Tang dynasty (618–907) had the Cool Hall (*Liang Dian* 凉殿) built in the imperial palace, which the *Tang Yulin* describes as having water-powered fan wheels for air conditioning as well as rising jet streams of water from fountains. During the subsequent Song dynasty (960–1279), written sources mentioned the air conditioning rotary fan as even more widely used.<sup>[127]</sup> In 134, in 151 and in 151

## Thermal buffering

[edit]

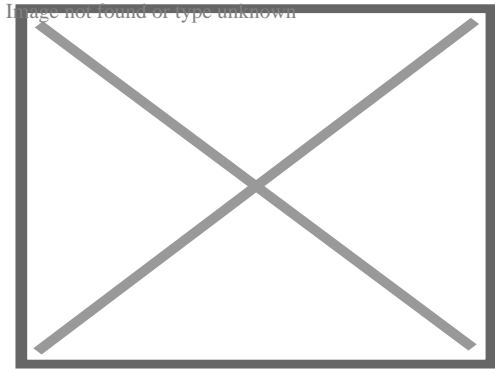
In areas that are cold at night or in winter, heat storage is used. Heat may be stored in earth or masonry; air is drawn past the masonry to heat or cool it.<sup>[13]</sup>

In areas that are below freezing at night in winter, snow and ice can be collected and stored in ice houses for later use in cooling.<sup>[13]</sup> This technique is over 3,700 years old in the Middle East.<sup>[128]</sup> Harvesting outdoor ice during winter and transporting and storing for use in summer was practiced by wealthy Europeans in the early 1600s,<sup>[15]</sup> and became popular in Europe and the Americas towards the end of the 1600s.<sup>[129]</sup> This practice was replaced by mechanical compression-cycle icemakers.

## Evaporative cooling

[edit]

Main article: Evaporative cooler



An evaporative cooler

In dry, hot climates, the evaporative cooling effect may be used by placing water at the air intake, such that the draft draws air over water and then into the house. For this reason, it is sometimes said that the fountain, in the architecture of hot, arid climates, is like the fireplace in the architecture of cold climates.<sup>[1]</sup> Evaporative cooling also makes the air more humid, which can be beneficial in a dry desert climate.<sup>[130]</sup>

Evaporative coolers tend to feel as if they are not working during times of high humidity, when there is not much dry air with which the coolers can work to make the air as cool as possible for dwelling occupants. Unlike other types of air conditioners, evaporative coolers rely on the outside air to be channeled through cooler pads that cool the air before it reaches the inside of a house through its air duct system; this cooled outside air must be allowed to push the warmer air within the house out through an exhaust opening such as an open door or window.<sup>[131]</sup>

**See also**

[edit]

- Air conditioning paradox
- Air filter
- Air purifier
- Cleanroom
- Crankcase heater
- Energy recovery ventilation
- Indoor air quality
- Particulates

## References

[edit]

1. <sup>▲</sup> "Air Con". *Cambridge Dictionary*. Archived from the original on May 3, 2022. Retrieved January 6, 2023.
2. <sup>▲</sup> *Dissertation Abstracts International: The humanities and social sciences*. A. University Microfilms. 2005. p. 3600.
3. <sup>▲</sup> *1993 ASHRAE Handbook: Fundamentals*. ASHRAE. 1993. ISBN 978-0-910110-97-6.
4. <sup>▲</sup> *Enteria, Napoleon; Sawachi, Takao; Saito, Kiyoshi (January 31, 2023). Variable Refrigerant Flow Systems: Advances and Applications of VRF*. Springer Nature. p. 46. ISBN 978-981-19-6833-4.
5. <sup>▲</sup> *Agencies, United States Congress House Committee on Appropriations Subcommittee on Dept of the Interior and Related (1988). Department of the Interior and Related Agencies Appropriations for 1989: Testimony of public witnesses, energy programs, Institute of Museum Services, National Endowment for the Arts, National Endowment for the Humanities*. U.S. Government Printing Office. p. 629.
6. <sup>▲</sup> "Earth Tubes: Providing the freshest possible air to your building". *Earth Rangers Centre for Sustainable Technology Showcase*. Archived from the original on January 28, 2021. Retrieved May 12, 2021.
7. <sup>▲</sup> **a b c** Barreca, Alan; Clay, Karen; Deschenes, Olivier; Greenstone, Michael; Shapiro, Joseph S. (February 2016). "Adapting to Climate Change: The Remarkable Decline in the

US Temperature-Mortality Relationship over the Twentieth Century". *Journal of Political Economy*. **124** (1): 105–159. doi:10.1086/684582.

8. ^ **a b c d e f g h i j** International Energy Agency (May 15, 2018). *The Future of Cooling - Opportunities for energy-efficient air conditioning (PDF) (Report)*. Archived (PDF) from the original on June 26, 2024. Retrieved July 1, 2024.
9. ^ Laub, Julian M. (1963). *Air Conditioning & Heating Practice*. Holt, Rinehart and Winston. p. 367. ISBN 978-0-03-011225-6. cite book: ISBN / Date incompatibility (help)
10. ^ "Air-conditioning found at 'oldest city in the world'". *The Independent*. June 24, 2000. Archived from the original on December 8, 2023. Retrieved December 9, 2023.
11. ^ **a b c** Mohamed, Mady A.A. (January 2010). Lehmann, S.; Waer, H.A.; Al-Qawasmi, J. (eds.). *Traditional Ways of Dealing with Climate in Egypt. The Seventh International Conference of Sustainable Architecture and Urban Development (SAUD 2010)*. Amman, Jordan: The Center for the Study of Architecture in Arab Region (CSAAR Press). pp. 247–266. Archived from the original on May 13, 2021. Retrieved May 12, 2021.
12. ^ **a b c** Ford, Brian (September 2001). "Passive downdraught evaporative cooling: principles and practice". *Architectural Research Quarterly*. **5** (3): 271–280. doi:10.1017/S1359135501001312.
13. ^ **a b c** Attia, Shady; Herde, André de (June 22–24, 2009). *Designing the Malqaf for Summer Cooling in Low-Rise Housing, an Experimental Study*. 26th Conference on Passive and Low Energy Architecture (PLEA2009). Quebec City. Archived from the original on May 13, 2021. Retrieved May 12, 2021 – via ResearchGate.
14. ^ "Heating, Ventilation and Air-Conditioning Systems, Part of Indoor Air Quality Design Tools for Schools". US EPA. October 17, 2014. Archived from the original on July 5, 2022. Retrieved July 5, 2022.
15. ^ **a b c** Shachtman, Tom (1999). "Winter in Summer". *Absolute zero and the conquest of cold*. Boston: Houghton Mifflin Harcourt. ISBN 978-0395938881. OCLC 421754998. Archived from the original on May 13, 2021. Retrieved May 12, 2021.
16. ^ Porta, Giambattista Della (1584). *Magiae naturalis (PDF)*. London. LCCN 09023451. Archived (PDF) from the original on May 13, 2021. Retrieved May 12, 2021. "In our method I shall observe what our ancestors have said; then I shall show by my own experience, whether they be true or false"
17. ^ Beck, Leonard D. (October 1974). "Things Magical in the collections of the Rare Book and Special Collections Division" (PDF). *Library of Congress Quarterly Journal*. **31**: 208–234. Archived (PDF) from the original on March 24, 2021. Retrieved May 12, 2021.
18. ^ Laszlo, Pierre (2001). *Salt: Grain of Life*. Columbia University Press. p. 117. ISBN 978-0231121989. OCLC 785781471. "Cornelius Drebbel air conditioning."

19. ^ Franklin, Benjamin (June 17, 1758). "The Montgomery Family: An historical and photographic perspective". Letter to John Lining. Archived from the original on February 25, 2021. Retrieved May 12, 2021.
20. ^ **a b c d** Green, Amanda (January 1, 2015). "The Cool History of the Air Conditioner". *Popular Mechanics*. Archived from the original on April 10, 2021. Retrieved May 12, 2021.
21. ^ "John Gorrie". *Encyclopædia Britannica*. September 29, 2020. Archived from the original on March 13, 2021. Retrieved May 12, 2021.
22. ^ Gorrie, John "Improved process for the artificial production of ice" U.S. Patent no. 8080 (Issued: May 6, 1851).
23. ^ Wright, E. Lynne (2009). *It Happened in Florida: Remarkable Events That Shaped History*. Rowman & Littlefield. pp. 13–. ISBN 978-0762761692.
24. ^ **a b** Bruce-Wallace, L. G. (1966). "Harrison, James (1816–1893)". *Australian Dictionary of Biography*. Vol. 1. Canberra: National Centre of Biography, Australian National University. ISBN 978-0-522-84459-7. ISSN 1833-7538. OCLC 70677943. Retrieved May 12, 2021.
25. ^ Palermo, Elizabeth (May 1, 2014). "Who Invented Air Conditioning?". *livescience.com*. Archived from the original on January 16, 2021. Retrieved May 12, 2021.
26. ^ Varrasi, John (June 6, 2011). "Global Cooling: The History of Air Conditioning". *American Society of Mechanical Engineers*. Archived from the original on March 8, 2021. Retrieved May 12, 2021.
27. ^ Simha, R. V. (February 2012). "Willis H Carrier". *Resonance*. **17** (2): 117–138. doi:10.1007/s12045-012-0014-y. ISSN 0971-8044. S2CID 116582893.
28. ^ Gullledge III, Charles; Knight, Dennis (February 11, 2016). "Heating, Ventilating, Air-Conditioning, And Refrigerating Engineering". *National Institute of Building Sciences*. Archived from the original on April 20, 2021. Retrieved May 12, 2021. "Though he did not actually invent air-conditioning nor did he take the first documented scientific approach to applying it, Willis Carrier is credited with integrating the scientific method, engineering, and business of this developing technology and creating the industry we know today as air-conditioning."
29. ^ "Willis Carrier – 1876–1902". *Carrier Global*. Archived from the original on February 27, 2021. Retrieved May 12, 2021.
30. ^ "Carrier Reports First Quarter 2020 Earnings". *Carrier Global* (Press release). May 8, 2020. Archived from the original on January 24, 2021. Retrieved May 12, 2021.
31. ^ "Carrier Becomes Independent, Publicly Traded Company, Begins Trading on New York Stock Exchange". *Carrier Global* (Press release). April 3, 2020. Archived from the original on February 25, 2021. Retrieved May 12, 2021.

32. ▲ Cramer, Stuart W. "Humidifying and air conditioning apparatus" U.S. Patent no. 852,823 (filed: April 18, 1906; issued: May 7, 1907).
- See also: Cramer, Stuart W. (1906) "Recent development in air conditioning" in: *Proceedings of the Tenth Annual Convention of the American Cotton Manufacturers Association Held at Asheville, North Carolina May 16–17, 1906*. Charlotte, North Carolina, USA: Queen City Publishing Co. pp. 182–211.
33. ▲ US patent US808897A, Carrier, Willis H., "Apparatus for treating air", published January 2, 1906, issued January 2, 1906 and Buffalo Forge Company "No. 808,897 Patented Jan. 2, 1906: H. W. Carrier: Apparatus for Treating Air" (PDF). Archived (PDF) from the original on December 5, 2019. Retrieved May 12, 2021.
34. ▲ "First Air-Conditioned Auto". *Popular Science*. Vol. 123, no. 5. November 1933. p. 30. ISSN 0161-7370. Archived from the original on April 26, 2021. Retrieved May 12, 2021.
35. ▲ "Room-size air conditioner fits under window sill". *Popular Mechanics*. Vol. 63, no. 6. June 1935. p. 885. ISSN 0032-4558. Archived from the original on November 22, 2016. Retrieved May 12, 2021.
36. ▲ "Michigan Fast Facts and Trivia". *50states.com*. Archived from the original on June 18, 2017. Retrieved May 12, 2021.
37. ▲ US patent US2433960A, Sherman, Robert S., "Air conditioning apparatus", published January 6, 1948, issued January 6, 1948
38. ▲ "IEEE milestones (39) Inverter Air Conditioners, 1980–1981" (PDF). March 2021. Archived (PDF) from the original on January 21, 2024. Retrieved February 9, 2024.
39. ▲ "Inverter Air Conditioners, 1980–1981 IEEE Milestone Celebration Ceremony" (PDF). March 16, 2021. Archived (PDF) from the original on January 21, 2024. Retrieved February 9, 2024.
40. ▲ Seale, Avrel (August 7, 2023). "Texas alumnus and his alma mater central to air-conditioned homes". *UT News*. Retrieved November 13, 2024.
41. ▲ "Air Conditioned Village". *Atlas Obscura*. Retrieved November 13, 2024.
42. ▲ **a b c** Davis, Lucas; Gertler, Paul; Jarvis, Stephen; Wolfram, Catherine (July 2021). "Air conditioning and global inequality". *Global Environmental Change*. **69**: 102299. Bibcode:2021GEC....6902299D. doi:10.1016/j.gloenvcha.2021.102299.
43. ▲ Pierre-Louis, Kendra (May 15, 2018). "The World Wants Air-Conditioning. That Could Warm the World". *The New York Times*. Archived from the original on February 16, 2021.

Retrieved May 12, 2021.

44. ▲ Carroll, Rory (October 26, 2015). "How America became addicted to air conditioning". *The Guardian*. Los Angeles. Archived from the original on March 13, 2021. Retrieved May 12, 2021.
45. ▲ Lester, Paul (July 20, 2015). "History of Air Conditioning". United States Department of Energy. Archived from the original on June 5, 2020. Retrieved May 12, 2021.
46. ▲ Cornish, Cheryl; Cooper, Stephen; Jenkins, Salima. *Characteristics of New Housing (Report)*. United States Census Bureau. Archived from the original on April 11, 2021. Retrieved May 12, 2021.
47. ▲ "Central Air Conditioning Buying Guide". Consumer Reports. March 3, 2021. Archived from the original on May 9, 2021. Retrieved May 12, 2021.
48. ▲ Petchers, Neil (2003). *Combined Heating, Cooling & Power Handbook: Technologies & Applications : an Integrated Approach to Energy Resource Optimization*. The Fairmont Press. p. 737. ISBN 978-0-88173-433-1.
49. ▲ Krarti, Moncef (December 1, 2020). *Energy Audit of Building Systems: An Engineering Approach, Third Edition*. CRC Press. p. 370. ISBN 978-1-000-25967-4.
50. ▲ "What is a Reversing Valve". Samsung India. Archived from the original on February 22, 2019. Retrieved May 12, 2021.
51. ▲ "Humidity and Comfort" (PDF). DriSteem. Archived from the original (PDF) on May 16, 2018. Retrieved May 12, 2021.
52. ▲ Perryman, Oliver (April 19, 2021). "Dehumidifier vs Air Conditioning". *Dehumidifier Critic*. Archived from the original on May 13, 2021. Retrieved May 12, 2021.
53. ▲ Snijders, Aart L. (July 30, 2008). "Aquifer Thermal Energy Storage (ATES) Technology Development and Major Applications in Europe" (PDF). Toronto and Region Conservation Authority. Arnhem: IFTech International. Archived (PDF) from the original on March 8, 2021. Retrieved May 12, 2021.
54. ▲ a b "Cold Climate Air Source Heat Pump" (PDF). Minnesota Department of Commerce, Division of Energy Resources. Archived (PDF) from the original on January 2, 2022. Retrieved March 29, 2022.
55. ▲ "Even in Frigid Temperatures, Air-Source Heat Pumps Keep Homes Warm From Alaska Coast to U.S. Mass Market". nrel.gov. Archived from the original on April 10, 2022. Retrieved March 29, 2022.
56. ▲ "Heat Pumps: A Practical Solution for Cold Climates". RMI. December 10, 2020. Archived from the original on March 31, 2022. Retrieved March 28, 2022.

57. ▲ "TEM Instruction Sheet" (PDF). TE Technology. March 14, 2012. Archived from the original (PDF) on January 24, 2013. Retrieved May 12, 2021.
58. ▲ "Coefficient of Performance (COP) heat pumps". Grundfos. November 18, 2020. Archived from the original on May 3, 2021. Retrieved May 12, 2021.
59. ▲ "Unpotted HP-199-1.4-0.8 at a hot-side temperature of 25 °C" (PDF). TE Technology. Archived from the original (PDF) on January 7, 2009. Retrieved February 9, 2024.
60. ▲ Newell, David B.; Tiesinga, Eite, eds. (August 2019). *The International System of Units (SI)* (PDF). National Institute of Standards and Technology. doi:10.6028/NIST.SP.330-2019 . Archived (PDF) from the original on April 22, 2021. Retrieved May 13, 2021.
61. ▲ ANSI/AHRI 210/240-2008: 2008 Standard for Performance Rating of Unitary Air-Conditioning & Air-Source Heat Pump Equipment (PDF). Air Conditioning, Heating and Refrigeration Institute. 2012. Archived from the original on March 29, 2018. Retrieved May 13, 2021.
62. ▲ Baraniuk, Chris. "Cutting-Edge Technology Could Massively Reduce the Amount of Energy Used for Air Conditioning". *Wired*. ISSN 1059-1028. Retrieved July 18, 2024.
63. ▲ "M-Series Contractor Guide" (PDF). Mitsubishi-pro.com. p. 19. Archived (PDF) from the original on March 18, 2021. Retrieved May 12, 2021.
64. ▲ "ã, ¨ã, ¢ã, 3ãf3ã•@æ´â•2ã•¨ãf´ãfYãf,, | èª¿ã•1ã, ^ã•†â@¶lé»ã•¨çœ•ã,¨ãf• | ã,ãffã,°ç%¨^ çœ•ã,¨ãf•â@¶lé»» de ã,1ãfžãf¼ãf¨ãf©ã,ããf•i¼^ã,€è^-è²jâ>£æ³•äºº â@¶lé»»è£½â“•â”ã¼ši¼%o ã!ã¼ã•†i¼•ã,1ãfžãf¼ãf¨ãf©ã,ããf•shouene-kaden.net. Archived from the original on September 7, 2022. Retrieved January 21, 2024.
65. ▲ "Air conditioner | History". Toshiba Carrier. April 2016. Archived from the original on March 9, 2021. Retrieved May 12, 2021.
66. ▲ "1920s–1970s | History". Mitsubishi Electric. Archived from the original on March 8, 2021. Retrieved May 12, 2021.
67. ▲ Wagner, Gerry (November 30, 2021). "The Duct Free Zone: History of the Mini Split". *HPAC Magazine*. Retrieved February 9, 2024.
68. ▲ "History of Daikin Innovation". Daikin. Archived from the original on June 5, 2020. Retrieved May 12, 2021.
69. ▲ Feit, Justin (December 20, 2017). "The Emergence of VRF as a Viable HVAC Option". *buildings.com*. Archived from the original on December 3, 2020. Retrieved May 12, 2021.
70. ▲ **a b** "Central Air Conditioning". United States Department of Energy. Archived from the original on January 30, 2021. Retrieved May 12, 2021.
71. ▲ Kreith, Frank; Wang, Shan K.; Norton, Paul (April 20, 2018). *Air Conditioning and Refrigeration Engineering*. CRC Press. ISBN 978-1-351-46783-4.

72. ▲ Wang, Shan K. (November 7, 2000). *Handbook of Air Conditioning and Refrigeration*. McGraw-Hill Education. ISBN 978-0-07-068167-5.
73. ▲ Hleborodova, Veronika (August 14, 2018). "Portable Vs Split System Air Conditioning | Pros & Cons". *Canstar Blue*. Archived from the original on March 9, 2021. Retrieved May 12, 2021.
74. ▲ Kamins, Toni L. (July 15, 2013). "Through-the-Wall Versus PTAC Air Conditioners: A Guide for New Yorkers". *Brick Underground*. Archived from the original on January 15, 2021. Retrieved May 12, 2021.
75. ▲ "Self-Contained Air Conditioning Systems". *Daikin Applied Americas*. 2015. Archived from the original on October 30, 2020. Retrieved May 12, 2021.
76. ▲ "LSWU/LSWD Vertical Water-Cooled Self-Contained Unit Engineering Guide" (PDF). *Johnson Controls*. April 6, 2018. Archived (PDF) from the original on May 13, 2021. Retrieved May 12, 2021.
77. ▲ "Packaged Rooftop Unit" (PDF). *Carrier Global*. 2016. Archived (PDF) from the original on May 13, 2021. Retrieved May 12, 2021.
78. ▲ "Packaged Rooftop Air Conditioners" (PDF). *Trane Technologies*. November 2006. Archived (PDF) from the original on May 13, 2021. Retrieved May 12, 2021.
79. ▲ "What is Packaged Air Conditioner? Types of Packged Air Condtioners". *Bright Hub Engineering*. January 13, 2010. Archived from the original on February 22, 2018. Retrieved May 12, 2021.
80. ▲ Evans, Paul (November 11, 2018). "RTU Rooftop Units explained". *The Engineering Mindset*. Archived from the original on January 15, 2021. Retrieved May 12, 2021.
81. ▲ "water-cooled – Johnson Supply". *studylib.net*. 2000. Archived from the original on May 13, 2021. Retrieved May 12, 2021.
82. ▲ "Water Cooled Packaged Air Conditioners" (PDF). *Japan: Daikin*. May 2, 2003. Archived (PDF) from the original on June 19, 2018. Retrieved May 12, 2021.
83. ▲ "Water Cooled Packaged Unit" (PDF). *Daikin*. Archived (PDF) from the original on May 13, 2021. Retrieved May 12, 2021.
84. ▲ Lun, Y. H. Venus; Tung, S. L. Dennis (November 13, 2019). *Heat Pumps for Sustainable Heating and Cooling*. *Springer Nature*. p. 25. ISBN 978-3-030-31387-6.
85. ▲ Ghanbariannaeeni, Ali; Ghazanfarihashemi, Ghazalehsadat (June 2012). "Bypass Method For Recip Compressor Capacity Control". *Pipeline and Gas Journal*. **239** (6). Archived from the original on August 12, 2014. Retrieved February 9, 2024.
86. ▲ "Heat Stroke (Hyperthermia)". *Harvard Health*. January 2, 2019. Archived from the original on January 29, 2021. Retrieved May 13, 2021.

87. ▲ "Weather Related Fatality and Injury Statistics". National Weather Service. 2021. Archived from the original on August 24, 2022. Retrieved August 24, 2022.
88. ▲ "Extreme Weather: A Guide to Surviving Flash Floods, Tornadoes, Hurricanes, Heat Waves, Snowstorms Tsunamis and Other Natural Disasters". Reference Reviews. **26** (8): 41. October 19, 2012. doi:10.1108/09504121211278322. ISSN 0950-4125. Archived from the original on January 21, 2024. Retrieved December 9, 2023.
89. ▲ **a b c** Gamarro, Harold; Ortiz, Luis; González, Jorge E. (August 1, 2020). "Adapting to Extreme Heat: Social, Atmospheric, and Infrastructure Impacts of Air-Conditioning in Megacities—The Case of New York City". *Journal of Engineering for Sustainable Buildings and Cities*. **1** (3). doi:10.1115/1.4048175. ISSN 2642-6641. S2CID 222121944.
90. ▲ Spiegelman, Jay; Friedman, Herman; Blumstein, George I. (September 1, 1963). "The effects of central air conditioning on pollen, mold, and bacterial concentrations". *Journal of Allergy*. **34** (5): 426–431. doi:10.1016/0021-8707(63)90007-8. ISSN 0021-8707. PMID 14066385.
91. ▲ Portnoy, Jay M.; Jara, David (February 1, 2015). "Mold allergy revisited". *Annals of Allergy, Asthma & Immunology*. **114** (2): 83–89. doi:10.1016/j.anai.2014.10.004. ISSN 1081-1206. PMID 25624128.
92. ▲ "Subpart 4-1 – Cooling Towers". New York Codes, Rules and Regulations. June 7, 2016. Archived from the original on May 13, 2021. Retrieved May 13, 2021.
93. ▲ Nordhaus, William D. (February 10, 2010). "Geography and macroeconomics: New data and new findings". *Proceedings of the National Academy of Sciences*. **103** (10): 3510–3517. doi:10.1073/pnas.0509842103. ISSN 0027-8424. PMC 1363683. PMID 16473945.
94. ▲ Barreca, Alan; Deschenes, Olivier; Guldi, Melanie (2018). "Maybe next month? Temperature shocks and dynamic adjustments in birth rates". *Demography*. **55** (4): 1269–1293. doi:10.1007/s13524-018-0690-7. PMC 7457515. PMID 29968058.
95. ▲ Glaeser, Edward L.; Tobio, Kristina (January 2008). "The Rise of the Sunbelt". *Southern Economic Journal*. **74** (3): 609–643. doi:10.1002/j.2325-8012.2008.tb00856.x.
96. ▲ Sherman, Peter; Lin, Haiyang; McElroy, Michael (2018). "Projected global demand for air conditioning associated with extreme heat and implications for electricity grids in poorer countries". *Energy and Buildings*. **268**: 112198. doi:10.1016/j.enbuild.2022.112198. ISSN 0378-7788. S2CID 248979815.
97. ▲ *Air Filters Used in Air Conditioning and General Ventilation Part 1: Methods of Test for Atmospheric Dust Spot Efficiency and Synthetic Dust Weight Arrestance (Withdrawn Standard)*. British Standards Institution. March 29, 1985. BS 6540-1:1985.
98. ▲ Mutschler, Robin; Rüdisüli, Martin; Heer, Philipp; Eggimann, Sven (April 15, 2021). "Benchmarking cooling and heating energy demands considering climate change, population growth and cooling device uptake". *Applied Energy*. **288**: 116636.

99. ^ **a b** "Climate-friendly cooling could cut years of Greenhouse Gas Emissions and save US\$ trillions: UN". *Climate Change and Law Collection*. doi:10.1163/9789004322714\_cclc\_2020-0252-0973.
100. ^ Gerretsen, Isabelle (December 8, 2020). "How your fridge is heating up the planet". *BBC Future*. Archived from the original on May 10, 2021. Retrieved May 13, 2021.
101. ^ *Encyclopedia of Energy*: Ph-S. Elsevier. 2004. ISBN 978-0121764821.
102. ^ Corberan, J.M. (2016). "New trends and developments in ground-source heat pumps". *Advances in Ground-Source Heat Pump Systems*. pp. 359–385. doi:10.1016/B978-0-08-100311-4.00013-3. ISBN 978-0-08-100311-4.
103. ^ Roselli, Carlo; Sasso, Maurizio (2021). *Geothermal Energy Utilization and Technologies 2020*. MDPI. ISBN 978-3036507040.
104. ^ "Cooling Emissions and Policy Synthesis Report: Benefits of cooling efficiency and the Kigali Amendment, United Nations Environment Programme - International Energy Agency, 2020" (PDF).
105. ^ Harlan, Sharon L.; Declet-Barreto, Juan H.; Stefanov, William L.; Petitti, Diana B. (February 2013). "Neighborhood Effects on Heat Deaths: Social and Environmental Predictors of Vulnerability in Maricopa County, Arizona". *Environmental Health Perspectives*. **121** (2): 197–204. Bibcode:2013EnvHP.121..197H. doi:10.1289/ehp.1104625. ISSN 0091-6765. PMC 3569676. PMID 23164621.
106. ^ **a b** Chan, Emily Ying Yang; Goggins, William B; Kim, Jacqueline Jakyoung; Griffiths, Sian M (April 2012). "A study of intracity variation of temperature-related mortality and socioeconomic status among the Chinese population in Hong Kong". *Journal of Epidemiology and Community Health*. **66** (4): 322–327. doi:10.1136/jech.2008.085167. ISSN 0143-005X. PMC 3292716. PMID 20974839.
107. ^ Ng, Chris Fook Sheng; Ueda, Kayo; Takeuchi, Ayano; Nitta, Hiroshi; Konishi, Shoko; Bagrowicz, Rinako; Watanabe, Chiho; Takami, Akinori (2014). "Sociogeographic Variation in the Effects of Heat and Cold on Daily Mortality in Japan". *Journal of Epidemiology*. **24** (1): 15–24. doi:10.2188/jea.JE20130051. PMC 3872520. PMID 24317342.
108. ^ Stafoggia, Massimo; Forastiere, Francesco; Agostini, Daniele; Biggeri, Annibale; Bisanti, Luigi; Cadum, Ennio; Caranci, Nicola; de'Donato, Francesca; De Lisio, Sara; De Maria, Moreno; Michelozzi, Paola; Miglio, Rossella; Pandolfi, Paolo; Picciotto, Sally; Rognoni, Magda (2006). "Vulnerability to Heat-Related Mortality: A Multicity, Population-Based, Case-Crossover Analysis". *Epidemiology*. **17** (3): 315–323. doi:10.1097/01.ede.0000208477.36665.34. ISSN 1044-3983. JSTOR 20486220. PMID 16570026. S2CID 20283342.

109. ^ **a b c d** Gronlund, Carina J. (September 2014). "Racial and Socioeconomic Disparities in Heat-Related Health Effects and Their Mechanisms: a Review". *Current Epidemiology Reports*. **1** (3): 165–173. doi:10.1007/s40471-014-0014-4. PMC 4264980. PMID 25512891.
110. ^ O'Neill, M. S. (May 11, 2005). "Disparities by Race in Heat-Related Mortality in Four US Cities: The Role of Air Conditioning Prevalence". *Journal of Urban Health: Bulletin of the New York Academy of Medicine*. **82** (2): 191–197. doi:10.1093/jurban/jti043. PMC 3456567. PMID 15888640.
111. ^ **a b** Sampson, Natalie R.; Gronlund, Carina J.; Buxton, Miatta A.; Catalano, Linda; White-Newsome, Jalonne L.; Conlon, Kathryn C.; O'Neill, Marie S.; McCormick, Sabrina; Parker, Edith A. (April 1, 2013). "Staying cool in a changing climate: Reaching vulnerable populations during heat events". *Global Environmental Change*. **23** (2): 475–484. Bibcode:2013GEC....23..475S. doi:10.1016/j.gloenvcha.2012.12.011. ISSN 0959-3780. PMC 5784212. PMID 29375195.
112. ^ Niktash, Amirreza; Huynh, B. Phuoc (July 2–4, 2014). *Simulation and Analysis of Ventilation Flow Through a Room Caused by a Two-sided Windcatcher Using a LES Method (PDF)*. World Congress on Engineering. Lecture Notes in Engineering and Computer Science. Vol. 2. London. eISSN 2078-0966. ISBN 978-9881925350. ISSN 2078-0958. Archived (PDF) from the original on April 26, 2018. Retrieved May 13, 2021.
113. ^ Zhang, Chen; Kazanci, Ongun Berk; Levinson, Ronnen; Heiselberg, Per; Olesen, Bjarne W.; Chiesa, Giacomo; Sodagar, Behzad; Ai, Zhengtao; Selkowitz, Stephen; Zinzi, Michele; Mahdavi, Ardeshir (November 15, 2021). "Resilient cooling strategies – A critical review and qualitative assessment". *Energy and Buildings*. **251**: 111312. Bibcode:2021EneBu.25111312Z. doi:10.1016/j.enbuild.2021.111312. hdl:2117/363031. ISSN 0378-7788.
114. ^ Linden, P. F. (1999). "The Fluid Mechanics of Natural Ventilation". *Annual Review of Fluid Mechanics*. **31**: 201–238. Bibcode:1999AnRFM..31..201L. doi:10.1146/annurev.fluid.31.1.201.
115. ^ Santamouris, M.; Asimakoupolos, D. (1996). *Passive cooling of buildings* (1st ed.). London: James & James (Science Publishers) Ltd. ISBN 978-1-873936-47-4.
116. ^ Leo Samuel, D.G.; Shiva Nagendra, S.M.; Maiya, M.P. (August 2013). "Passive alternatives to mechanical air conditioning of building: A review". *Building and Environment*. **66**: 54–64. Bibcode:2013BuEnv..66...54S. doi:10.1016/j.buildenv.2013.04.016.
117. ^ M.j, Limb (January 1, 1998). "BIB 08: An Annotated Bibliography: Passive Cooling Technology for Office Buildings in Hot Dry and Temperate Climates".
118. ^ Niles, Philip; Kenneth, Haggard (1980). *Passive Solar Handbook*. California Energy Resources Conservation. ASIN B001UYRTMM.

119. ^ "Cooling: The hidden threat for climate change and sustainable goals". *phys.org*. Retrieved September 18, 2021.
120. ^ Ford, Brian (September 2001). "Passive downdraught evaporative cooling: principles and practice". *Arq: Architectural Research Quarterly*. **5** (3): 271–280. doi:10.1017/S1359135501001312. ISSN 1474-0516. S2CID 110209529.
121. ^ a b Chen, Meijie; Pang, Dan; Chen, Xingyu; Yan, Hongjie; Yang, Yuan (2022). "Passive daytime radiative cooling: Fundamentals, material designs, and applications". *EcoMat*. **4**. doi:10.1002/eom2.12153. S2CID 240331557. "Passive daytime radiative cooling (PDRC) dissipates terrestrial heat to the extremely cold outer space without using any energy input or producing pollution. It has the potential to simultaneously alleviate the two major problems of energy crisis and global warming."
122. ^ Raman, Aaswath P.; Anoma, Marc Abou; Zhu, Linxiao; Rephaeli, Eden; Fan, Shanhui (November 2014). "Passive radiative cooling below ambient air temperature under direct sunlight". *Nature*. **515** (7528): 540–544. Bibcode:2014Natur.515..540R. doi:10.1038/nature13883. PMID 25428501.
123. ^ a b Bijarniya, Jay Prakash; Sarkar, Jahar; Maiti, Pralay (November 2020). "Review on passive daytime radiative cooling: Fundamentals, recent researches, challenges and opportunities". *Renewable and Sustainable Energy Reviews*. **133**: 110263. Bibcode:2020RSErv.13310263B. doi:10.1016/j.rser.2020.110263. S2CID 224874019.
124. ^ Mokhtari, Reza; Ulpiani, Giulia; Ghasempour, Roghayeh (July 2022). "The Cooling Station: Combining hydronic radiant cooling and daytime radiative cooling for urban shelters". *Applied Thermal Engineering*. **211**: 118493. Bibcode:2022AppTE.21118493M. doi:10.1016/j.applthermaleng.2022.118493.
125. ^ Yang, Yuan; Zhang, Yifan (July 2020). "Passive daytime radiative cooling: Principle, application, and economic analysis". *MRS Energy & Sustainability*. **7** (1). doi:10.1557/mre.2020.18.
126. ^ Miranda, Nicole D.; Renaldi, Renaldi; Khosla, Radhika; McCulloch, Malcolm D. (October 2021). "Bibliometric analysis and landscape of actors in passive cooling research". *Renewable and Sustainable Energy Reviews*. **149**: 111406. Bibcode:2021RSErv.14911406M. doi:10.1016/j.rser.2021.111406.
127. ^ a b Needham, Joseph; Wang, Ling (1991). *Science and Civilisation in China, Volume 4: Physics and Physical Technology, Part 2, Mechanical Engineering*. Cambridge University Press. ISBN 978-0521058032. OCLC 468144152.
128. ^ Dalley, Stephanie (2002). *Mari and Karana: Two Old Babylonian Cities* (2nd ed.). Piscataway, New Jersey: Gorgias Press. p. 91. ISBN 978-1931956024. OCLC 961899663. Archived from the original on January 29, 2021. Retrieved May 13, 2021.

129. <sup>▲</sup> Nagengast, Bernard (February 1999). "Comfort from a Block of Ice: A History of Comfort Cooling Using Ice" (PDF). *ASHRAE Journal*. **41** (2): 49. ISSN 0001-2491. Archived (PDF) from the original on May 13, 2021. Retrieved May 13, 2021.
130. <sup>▲</sup> Bahadori, Mehdi N. (February 1978). "Passive Cooling Systems in Iranian Architecture". *Scientific American*. **238** (2): 144–154. Bibcode:1978SciAm.238b.144B. doi:10.1038/SCIENTIFICAMERICAN0278-144.
131. <sup>▲</sup> Smith, Shane (2000). *Greenhouse Gardener's Companion: Growing Food and Flowers in Your Greenhouse Or Sunspace*. Illustrated by Marjorie C. Leggitt (illustrated, revised ed.). Golden, Colorado: Fulcrum Publishing. p. 62. ISBN 978-1555914509. OCLC 905564174. Archived from the original on May 13, 2021. Retrieved August 25, 2020.

## External links

[edit]



Wikimedia Commons has media related to ***Air conditioners***.



Look up ***Cassette air conditioner*** in Wiktionary, the free dictionary.



Wikiversity has learning resources about ***Refrigeration and air conditioning***

- U.S. patent 808,897 Carrier's original patent
- U.S. patent 1,172,429
- U.S. patent 2,363,294
- *Scientific American*, "Artificial Cold", 28 August 1880, p. 138
- *Scientific American*, "The Presidential Cold Air Machine", 6 August 1881, p. 84
- v
- t

- e

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

- 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

- 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

**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

**Professions,  
trades,  
and services**

- Architectural acoustics
- Architectural engineering
- Architectural technologist
- Building services engineering
- Building information modeling (BIM)
- Deep energy retrofit
- 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)

**See also**

- ASHRAE Handbook
- Building science
- Fireproofing
- Glossary of HVAC terms
- Warm Spaces
- World Refrigeration Day
- Template:Fire protection
- Template:Home automation
- Template:Solar energy

- v
- t
- e

Home appliances

- Air conditioner
- Air fryer
- Air ioniser
- Air purifier
- Barbecue grill
- Blender
  - Immersion blender
- Bread machine
- Bug zapper
- Coffee percolator
- Clothes dryer
  - combo
- Clothes iron
- Coffeemaker
- Dehumidifier
- Dishwasher
  - drying cabinet
- Domestic robot
- Deep fryer
- Electric blanket
- Electric drill
- Electric kettle
- Electric knife
- Electric water boiler
- Electric heater
- Electric shaver
- Electric toothbrush
- Epilator
- Espresso machine
- Evaporative cooler

**See also**

- Appliance plug
- Appliance recycling

- **v**

- **t**

- **e**

Roofs

## Roof shapes

- Arched roof
- Barrel roof
- Board roof
- Bochkha roof
- Bow roof
- Butterfly roof
- Clerestory
- Conical roof
- Dome
- Flat roof
- Gable roof
- Gablet roof
- Gambrel roof
- Half-hipped roof
- Hip roof
- Onion dome
- Mansard roof
- Pavilion roof
- Rhombic roof
- Ridged roof
- Saddle roof
- Sawtooth roof
- Shed roof
- Tented roof

## Cross-gabled roof

Image not found or type unknown

- Air conditioning unit
- Attic
- Catslide
- Chimney
- Collar beam
- Dormer
- Eaves
- Flashing
- Gable
- Green roof
- Gutter
- Hanging beam
- Joist
- Lightning rod
- Loft
- Purlin

## **Roof elements**

- Rafter
- Ridge vent
- Roof batten
- Roof garden
- Roofline
- Roof ridge
- Roof sheeting
- Roof tiles
- Roof truss
- Roof window
- Shingles
- Skylight
- Soffit
- Solar panels

- v
- t
- e

## Electronics

### **Branches**

- Analogue electronics
- Digital electronics
- Electronic engineering
- Instrumentation
- Microelectronics
- Optoelectronics
- Power electronics
- Printed electronics
- Semiconductor
- Schematic capture
- Thermal management

- 2020s in computing
- Atomtronics
- Bioelectronics
- List of emerging electronics
- Failure of electronic components
- Flexible electronics

**Advanced  
topics**

- Low-power electronics
- Molecular electronics
- Nanoelectronics
- Organic electronics
- Photonics
- Piezotronics
- Quantum electronics
- Spintronics

**Electronic  
equipment**

- Air conditioner
- Central heating
- Clothes dryer
- Computer/Notebook
- Camera
- Dishwasher
- Freezer
- Home robot
- Home cinema
- Home theater PC
- Information technology
- Cooker
- Microwave oven
- Mobile phone
- Networking hardware
- Portable media player
- Radio
- Refrigerator
- Robotic vacuum cleaner
- Tablet
- Telephone
- Television
- Water heater
- Video game console
- Washing machine

- Audio equipment
- Automotive electronics
- Avionics
- Control system
- Data acquisition
- e-book
- e-health
- Electromagnetic warfare
- Electronics industry
- Embedded system
- Home appliance
- Home automation
- Integrated circuit

## **Applications**

- Home appliance
  - Consumer electronics
  - Major appliance
  - Small appliance
- Marine electronics
- Microwave technology
- Military electronics
- Multimedia
- Nuclear electronics
- Open-source hardware
- Radar and Radio navigation
- Radio electronics
- Terahertz technology
- Wired and Wireless Communications

- Germany

**Authority control databases: National**

Image not found or type unknown  
**Edit this at Wikidata**

## About Water

For other uses, see Water (disambiguation). "H2O" redirects here. For other uses, see H2O (disambiguation).

### Water

The water molecule has this basic geometric structure

Image not found or type unknown

The water molecule has this basic geometric structure

### Hydrogen, H

Ball-and-stick model of a water molecule

Image not found or type unknown

Ball-and-stick model of a water molecule

Space filling model of a water molecule

Image not found or type unknown

Space filling model of a water molecule

**O**xygen, O

A drop of water falling towards water in a glass

Image not found or type unknown

A drop of water falling towards water in a glass

Names Preferred IUPAC name

Water

Systematic IUPAC name

Oxidane (not in common use)<sup>[3]</sup>

Other names

- Hydrogen oxide
- Hydrogen hydroxide ( $\text{H}_2\text{O}$  or HOH)
- Hydroxylic acid
- Dihydrogen monoxide (DHMO) (parody name<sup>[1]</sup>)
- Dihydrogen oxide
- Hydric acid
- Hydrohydroxic acid
- Hydroxic acid
- Hydroxoic acid
- Hydrol<sup>[2]</sup>
- $\text{H}_2\text{O}$ -Oxidodihydrogen

- <sup>1</sup>~~X~~-Hydroxylhydrogen(0)
- Aqua
- Neutral liquid
- Oxygen dihydride (may be considered incorrect)

## Identifiers

- 7732-18-5 Image not found or type unknown  
check

## CAS Number

- Interactive image

## 3D model (JSmol)

## Beilstein Reference 3587155

- CHEBI:15377 Image not found or type unknown  
check

## ChEBI

- ChEMBL1098659 Image not found or type unknown  
check

## ChEMBL

- 937 Image not found or type unknown  
check

ChemSpider

- DB09145

DrugBank

ECHA InfoCard100.028.902 Image not found or type unknown  
[Edit this at Wikidata](#)

- 231-791-2

EC Number

Gmelin Reference <sub>117</sub>

- C00001

KEGG

- 962

PubChem CID

- ZC0110000

RTECS number

- 059QF0K00R Image not found or type unknown  
[check](#)

UNII

- DTXSID6026296  [Edit this at Wikidata](#)

## CompTox Dashboard (EPA)

### InChI

---

InChI=1S/H2O/h1H2  [check](#)

Key: XLYOFNOQVPJJNP-UHFFFAOYSA-N  [check](#)

### SMILES

---

O

### Properties

#### Chemical formula

H

<sup>2</sup>OMolar mass18.01528(33) g/molAppearanceAlmost colorless or white crystalline solid, almost colorless liquid, with a hint of blue, colorless gas<sup>[4]</sup>OdorOdorless

- Liquid (1 atm, VSMOW):
  - 0.999 842 83(84) g/mL at 0 °C<sup>[5]</sup>
  - 0.999 974 95(84) g/mL at 3.983 035(670) °C (temperature of maximum density, often 4 °C)<sup>[5]</sup>
  - 0.997 047 02(83) g/mL at 25 °C<sup>[5]</sup>
  - 0.961 887 91(96) g/mL at 95 °C<sup>[6]</sup>
- Solid:
  - 0.9167 g/mL at 0 °C<sup>[7]</sup>

Density

Melting point  $0.00\text{ }^{\circ}\text{C}$  ( $32.00\text{ }^{\circ}\text{F}$ ;  $273.15\text{ K}$ ) [<sup>b</sup>] Boiling point  $99.98\text{ }^{\circ}\text{C}$  ( $211.96\text{ }^{\circ}\text{F}$ ;  $373.13\text{ K}$ ) [<sup>17</sup>] [<sup>b</sup>] Solubility Poorly soluble in haloalkanes, aliphatic and aromatic hydrocarbons, ethers. [<sup>8</sup>]

Improved solubility in carboxylates, alcohols, ketones, amines.

Miscible with methanol, ethanol, propanol, isopropanol, acetone, glycerol, 1,4-dioxane, tetrahydrofuran, sulfolane, acetaldehyde, dimethylformamide, dimethoxyethane, dimethyl sulfoxide, acetonitrile.

Partially miscible with diethyl ether, methyl ethyl ketone, dichloromethane, ethyl acetate, bromine. Vapor pressure  $3.1690\text{ kilopascals}$  or  $0.031276\text{ atm}$  at  $25\text{ }^{\circ}\text{C}$  [<sup>9</sup>] Acidity ( $\text{p}K_{\text{a}}$ )  $13.995$  [<sup>10</sup>] [<sup>11</sup>] [<sup>a</sup>] Basicity ( $\text{p}K_{\text{b}}$ )  $13.995$  Conjugate acid Hydronium  $\text{H}_3\text{O}^{+}$  ( $\text{p}K_{\text{a}} = 0$ ) Conjugate base Hydroxide  $\text{OH}^{-}$  ( $\text{p}K_{\text{b}} = 0$ ) Thermal conductivity  $0.6065\text{ W}/(\text{m}\cdot\text{K})$  [<sup>14</sup>]

Refractive index ( $n_{\text{D}}$ )

$1.3330$  ( $20\text{ }^{\circ}\text{C}$ ) [<sup>15</sup>] Viscosity  $0.890\text{ mPa}\cdot\text{s}$  ( $0.890\text{ cP}$ ) [<sup>16</sup>] Structure

Crystal structure

Hexagonal

Point group

$\text{C}_{2v}$

Molecular shape

Bent

Dipole moment

$1.8546\text{ D}$  [<sup>18</sup>] Thermochemistry

Heat capacity (C)

$$75.385 \pm 0.05 \text{ J/(mol}\cdot\text{K)} [^{17}]$$

Std molar

entropy ( $S_{298}^\circ$ )

$$69.95 \pm 0.03 \text{ J/(mol}\cdot\text{K)} [^{17}]$$

Std enthalpy of

formation ( $\Delta_f H_{298}^\circ$ )

$$-285.83 \pm 0.04 \text{ kJ/mol} [^8] [^{17}]$$

Gibbs free energy ( $\Delta_f G^\circ$ )

$$-237.24 \text{ kJ/mol} [^8] \text{ Hazards } \mathbf{Occupational\ safety\ and\ health\ (OHS/OSH):}$$

Main hazards

Drowning

Avalanche (as snow)

Water intoxication **NFPA 704** (fire diamond)

NFPA 704 four-colored diamond

Image not found or type unknown

0

0

0

Flash pointNon-flammableRelated compounds

- Hydrogen sulfide
- Hydrogen selenide
- Hydrogen telluride
- Hydrogen polonide
- Hydrogen peroxide

Other anions

- Acetone
- Ethanol
- Methanol
- Hydrogen fluoride
- Ammonia

Related solvents

Supplementary data pageWater (data page)

Except where otherwise noted, data are given for materials in their standard state (at 25 °C [77 °F], 100 kPa).

verify (what is ?)  
check check  
Infobox references

**Water** is an inorganic compound with the chemical formula  $\text{H}_2\text{O}$ . It is a transparent, tasteless, odorless,<sup>[C]</sup> and nearly colorless chemical substance. It is the main

constituent of Earth's hydrosphere and the fluids of all known living organisms (in which it acts as a solvent<sup>[20]</sup>). It is vital for all known forms of life, despite not providing food energy or organic micronutrients. Its chemical formula,

H<sub>2</sub>O, indicates that each of its molecules contains one oxygen and two hydrogen atoms, connected by covalent bonds. The hydrogen atoms are attached to the oxygen atom at an angle of 104.45°.<sup>[21]</sup> In liquid form,

H<sub>2</sub>O is also called "water" at standard temperature and pressure.

Because Earth's environment is relatively close to water's triple point, water exists on Earth as a solid, a liquid, and a gas.<sup>[22]</sup> It forms precipitation in the form of rain and aerosols in the form of fog. Clouds consist of suspended droplets of water and ice, its solid state. When finely divided, crystalline ice may precipitate in the form of snow. The gaseous state of water is steam or water vapor.

Water covers about 71.0% of the Earth's surface, with seas and oceans making up most of the water volume (about 96.5%).<sup>[23]</sup> Small portions of water occur as groundwater (1.7%), in the glaciers and the ice caps of Antarctica and Greenland (1.7%), and in the air as vapor, clouds (consisting of ice and liquid water suspended in air), and precipitation (0.001%).<sup>[24][25]</sup> Water moves continually through the water cycle of evaporation, transpiration (evapotranspiration), condensation, precipitation, and runoff, usually reaching the sea.

Water plays an important role in the world economy. Approximately 70% of the fresh water used by humans goes to agriculture.<sup>[26]</sup> Fishing in salt and fresh water bodies has been, and continues to be, a major source of food for many parts of the world, providing 6.5% of global protein.<sup>[27]</sup> Much of the long-distance trade of commodities (such as oil, natural gas, and manufactured products) is transported by boats

through seas, rivers, lakes, and canals. Large quantities of water, ice, and steam are used for cooling and heating in industry and homes. Water is an excellent solvent for a wide variety of substances, both mineral and organic; as such, it is widely used in industrial processes and in cooking and washing. Water, ice, and snow are also central to many sports and other forms of entertainment, such as swimming, pleasure boating, boat racing, surfing, sport fishing, diving, ice skating, snowboarding, and skiing.

**Etymology**

[edit]

The word *water* comes from Old English ***wæter***, from Proto-Germanic *\*watar* (source also of Old Saxon *watar*, Old Frisian *wetir*, Dutch *water*, Old High German *wazzar*, German *Wasser*, *vatn*, Gothic *𐍄𐍅𐍂𐍄* *waþar*), from Proto-Indo-European *\*wod-or*, suffixed form of root *\*wed-* ('water'; 'wet').<sup>[28]</sup> Also cognate, through the Indo-European root, with Greek *ἵδωρ*, from Ancient Greek *ἡδω*, whence English 'hydro-'), Russian *во́да* (*vodá*), Irish *uisce*, and Albanian *ujë*.

**History**

[edit]

Main articles: Origin of water on Earth § History of water on Earth, and Properties of water § History

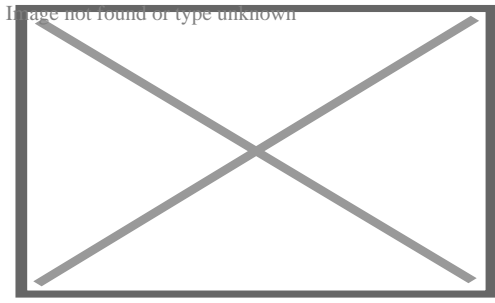
**On Earth**

[edit]

This section is an excerpt from Origin of water on Earth § History of water on Earth.[edit]

One factor in estimating when water appeared on Earth is that water is continually being lost to space.  $\text{H}_2\text{O}$  molecules in the atmosphere are broken up by photolysis, and the resulting free hydrogen atoms can sometimes escape Earth's gravitational pull. When the Earth was younger and less massive, water would have been lost to space more easily.<sup>[29]</sup> Lighter elements like hydrogen and helium are expected to leak from the atmosphere continually, but isotopic ratios of heavier noble gases in the modern atmosphere suggest that even the heavier elements in the early atmosphere were subject to significant losses.<sup>[30]</sup> In particular, xenon is useful for calculations of water loss over time. Not only is it a noble gas (and therefore is not removed from the atmosphere through chemical reactions with other elements), but comparisons between the abundances of its nine stable isotopes in the modern atmosphere reveal that the Earth lost at least one ocean of water, a volume of water approximately equal to modern ocean volume, early in its history. This is likely to have occurred between the Hadean and Archean eons in cataclysmic events such as the moon forming impact.<sup>[31]</sup>

Any water on Earth during the latter part of its accretion would have been disrupted by the Moon-forming impact (~4.5 billion years ago), which likely vaporized much of Earth's crust and upper mantle and created a rock-vapor atmosphere around the young planet.<sup>[32][33]</sup> The rock vapor would have condensed within two thousand years, leaving behind hot volatiles which probably resulted in a majority carbon dioxide atmosphere with hydrogen and water vapor. Afterward, liquid water oceans may have existed despite the surface temperature of 230 °C (446 °F) due to the increased atmospheric pressure of the  $\text{CO}_2$  atmosphere.<sup>[34]</sup> As the cooling continued, most  $\text{CO}_2$  was removed from the atmosphere by subduction and dissolution in ocean water, but levels oscillated wildly as new surface and mantle cycles appeared.<sup>[35]</sup>



This pillow basalt on the seafloor near Hawaii was formed when magma extruded underwater. Other, much older pillow basalt formations provide evidence for large bodies of water long ago in Earth's history.

Geological evidence also helps constrain the time frame for liquid water existing on Earth. A sample of pillow basalt (a type of rock formed during an underwater eruption) was recovered from the Isua Greenstone Belt and provides evidence that water existed on Earth 3.8 billion years ago.<sup>[36]</sup> In the Nuvvuagittuq Greenstone Belt, Quebec, Canada, rocks dated at 3.8 billion years old by one study<sup>[37]</sup> and 4.28 billion years old by another<sup>[38]</sup> show evidence of the presence of water at these ages.<sup>[36]</sup> If oceans existed earlier than this, any geological evidence has yet to be discovered (which may be because such potential evidence has been destroyed by geological processes like crustal recycling). More recently, in August 2020, researchers reported that sufficient water to fill the oceans may have always been on the Earth since the beginning of the planet's formation.<sup>[39][40][41]</sup>

Unlike rocks, minerals called zircons are highly resistant to weathering and geological processes and so are used to understand conditions on the very early Earth.

Mineralogical evidence from zircons has shown that liquid water and an atmosphere must have existed  $4.404 \pm 0.008$  billion years ago, very soon after the formation of Earth.<sup>[42][43][44][45]</sup> This presents somewhat of a paradox, as the cool early Earth hypothesis suggests temperatures were cold enough to freeze water between about 4.4 billion and 4.0 billion years ago.<sup>[46]</sup> Other studies of zircons found in Australian Hadean rock point to the existence of plate tectonics as early as 4 billion years ago.<sup>[</sup>

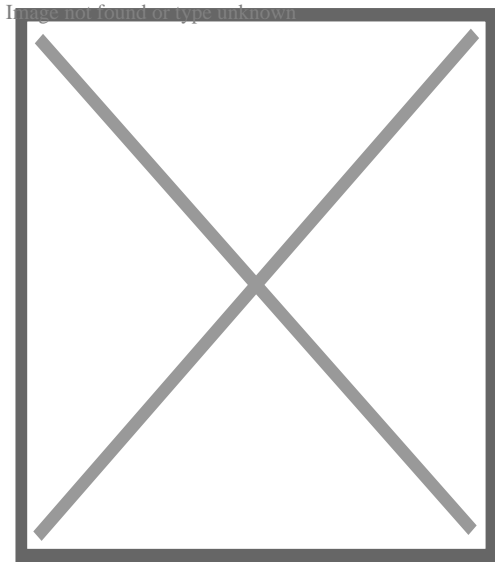
<sup>47]</sup> If true, that implies that rather than a hot, molten surface and an atmosphere full of carbon dioxide, early Earth's surface was much as it is today (in terms of thermal insulation). The action of plate tectonics traps vast amounts of CO<sub>2</sub>, thereby reducing greenhouse effects, leading to a much cooler surface temperature and the formation of solid rock and liquid water.<sup>[48]</sup>

## Properties

[edit]

Main article: Properties of water

See also: Water (data page) and Water model



A water molecule consists of two hydrogen atoms and one oxygen atom.

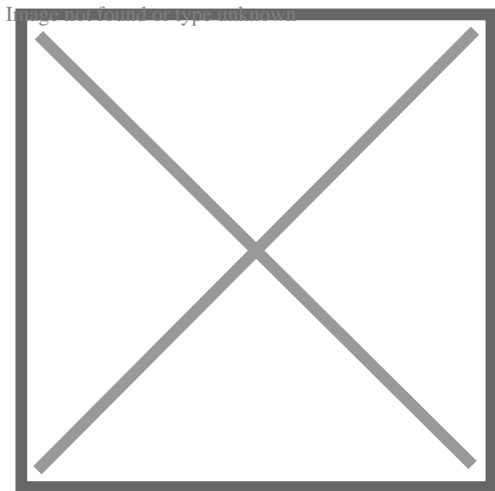
Water (

H<sub>2</sub>O) is a polar inorganic compound. At room temperature it is a tasteless and odorless liquid, nearly colorless with a hint of blue. The simplest hydrogen chalcogenide, it is by far the most studied chemical compound and is sometimes described as the "universal solvent" for its ability to dissolve more substances than any other liquid,<sup>[49]</sup><sup>[50]</sup> though it is poor at dissolving nonpolar substances.<sup>[51]</sup> This

allows it to be the "solvent of life":<sup>[52]</sup> indeed, water as found in nature almost always includes various dissolved substances, and special steps are required to obtain chemically pure water. Water is the only common substance to exist as a solid, liquid, and gas in normal terrestrial conditions.<sup>[53]</sup>

## States

[edit]



The three common states of matter

Along with *oxidane*, *water* is one of the two official names for the chemical compound  $\text{H}_2\text{O}$ ;<sup>[54]</sup> it is also the liquid phase of  $\text{H}_2\text{O}$ .<sup>[55]</sup> The other two common states of matter of water are the solid phase, ice, and the gaseous phase, water vapor or steam. The addition or removal of heat can cause phase transitions: freezing (water to ice), melting (ice to water), vaporization (water to vapor), condensation (vapor to water), sublimation (ice to vapor) and deposition (vapor to ice).<sup>[56]</sup>

## Density

[edit]

See also: Frost weathering

Water is one of only a few common naturally occurring substances which, for some temperature ranges, become less dense as they cool, and the only known naturally occurring substance which does so while liquid. In addition it is unusual as it becomes significantly less dense as it freezes, though it is not unique in that respect.<sup>[d]</sup>

At 1 atm pressure, it reaches its maximum density of  $999.972 \text{ kg/m}^3$  ( $62.4262 \text{ lb/cu ft}$ ) at  $3.98 \text{ }^{\circ}\text{C}$  ( $39.16 \text{ }^{\circ}\text{F}$ ).<sup>[58]</sup><sup>[59]</sup>

Below that temperature, but above the freezing point of  $0 \text{ }^{\circ}\text{C}$  ( $32 \text{ }^{\circ}\text{F}$ ), it expands becoming less dense until it reaches freezing point, reaching a density in its liquid phase of  $999.8 \text{ kg/m}^3$  ( $62.4155 \text{ lb/cu ft}$ ).

Once it freezes and becomes ice, it expands by about 9%, with a density of  $917 \text{ kg/m}^3$  ( $57.25 \text{ lb/cu ft}$ ).<sup>[60]</sup><sup>[61]</sup> This expansion can exert enormous pressure, bursting pipes and cracking rocks.<sup>[62]</sup> As a solid, it displays the usual behavior of contracting and becoming more dense as it cools. These unusual thermal properties have important consequences for life on earth.

In a lake or ocean, water at  $4 \text{ }^{\circ}\text{C}$  ( $39 \text{ }^{\circ}\text{F}$ ) sinks to the bottom, and ice forms on the surface, floating on the liquid water. This ice insulates the water below, preventing it from freezing solid. Without this protection, most aquatic organisms residing in lakes would perish during the winter.<sup>[63]</sup> In addition, this anomalous behavior is an important part of the thermohaline circulation which distributes heat around the planet's oceans.

## Magnetism

[edit]

Water is a diamagnetic material.<sup>[64]</sup> Though interaction is weak, with superconducting magnets it can attain a notable interaction.<sup>[64]</sup>

## Phase transitions

[edit]

At a pressure of one atmosphere (atm), ice melts or water freezes (solidifies) at 0 °C (32 °F) and water boils or vapor condenses at 100 °C (212 °F). However, even below the boiling point, water can change to vapor at its surface by evaporation (vaporization throughout the liquid is known as boiling). Sublimation and deposition also occur on surfaces.<sup>[56]</sup> For example, frost is deposited on cold surfaces while snowflakes form by deposition on an aerosol particle or ice nucleus.<sup>[65]</sup> In the process of freeze-drying, a food is frozen and then stored at low pressure so the ice on its surface sublimates.<sup>[66]</sup>

The melting and boiling points depend on pressure. A good approximation for the rate of change of the melting temperature with pressure is given by the Clausius–Clapeyron relation:

$$\frac{dT}{dP} = \frac{T}{L} (v_L - v_S)$$

Image not found or type unknown

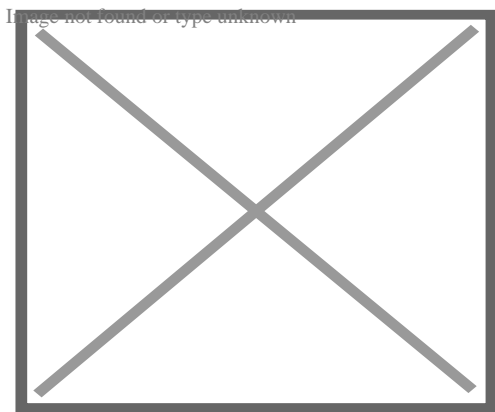
where  $v_L$  and  $v_S$  are the molar volumes of the liquid and solid phases, and  $L$  is the molar latent heat of melting. In most substances, the volume increases when melting occurs, so the melting temperature increases with pressure. However, because ice is less dense than water, the melting temperature decreases.<sup>[57]</sup> In glaciers, pressure melting can occur under sufficiently thick volumes of ice, resulting in subglacial lakes.<sup>[67][68]</sup>

The Clausius–Clapeyron relation also applies to the boiling point, but with the liquid/gas transition the vapor phase has a much lower density than the liquid phase, so the boiling point increases with pressure.<sup>[69]</sup> Water can remain in a liquid state at high temperatures in the deep ocean or underground. For example, temperatures exceed 205 °C (401 °F) in Old Faithful, a geyser in Yellowstone National Park.<sup>[70]</sup> In hydrothermal vents, the temperature can exceed 400 °C (752 °F).<sup>[71]</sup>

At sea level, the boiling point of water is 100 °C (212 °F). As atmospheric pressure decreases with altitude, the boiling point decreases by 1 °C every 274 meters. High-altitude cooking takes longer than sea-level cooking. For example, at 1,524 metres (5,000 ft), cooking time must be increased by a fourth to achieve the desired result.<sup>[72]</sup> Conversely, a pressure cooker can be used to decrease cooking times by raising the boiling temperature.<sup>[73]</sup> In a vacuum, water will boil at room temperature.<sup>[74]</sup>

## Triple and critical points

[edit]



Phase diagram of water

On a pressure/temperature phase diagram (see figure), there are curves separating solid from vapor, vapor from liquid, and liquid from solid. These meet at a single point called the triple point, where all three phases can coexist. The triple point is at a

temperature of 273.16 K (0.01 °C; 32.02 °F) and a pressure of 611.657 pascals (0.00604 atm; 0.0887 psi);<sup>[75]</sup> it is the lowest pressure at which liquid water can exist. Until 2019, the triple point was used to define the Kelvin temperature scale.<sup>[76]</sup><sup>[77]</sup>

The water/vapor phase curve terminates at 647.096 K (373.946 °C; 705.103 °F) and 22.064 megapascals (3,200.1 psi; 217.75 atm).<sup>[78]</sup> This is known as the critical point. At higher temperatures and pressures the liquid and vapor phases form a continuous phase called a supercritical fluid. It can be gradually compressed or expanded between gas-like and liquid-like densities; its properties (which are quite different from those of ambient water) are sensitive to density. For example, for suitable pressures and temperatures it can mix freely with nonpolar compounds, including most organic compounds. This makes it useful in a variety of applications including high-temperature electrochemistry and as an ecologically benign solvent or catalyst in chemical reactions involving organic compounds. In Earth's mantle, it acts as a solvent during mineral formation, dissolution and deposition.<sup>[79]</sup><sup>[80]</sup>

## Phases of ice and water

[edit]

Main article: Ice

The normal form of ice on the surface of Earth is ice I<sub>h</sub>, a phase that forms crystals with hexagonal symmetry. Another with cubic crystalline symmetry, ice I<sub>c</sub>, can occur in the upper atmosphere.<sup>[81]</sup> As the pressure increases, ice forms other crystal structures. As of 2024, twenty have been experimentally confirmed and several more are predicted theoretically.<sup>[82]</sup> The eighteenth form of ice, ice XVIII, a face-centred-cubic, superionic ice phase, was discovered when a droplet of water was subject to a shock wave that raised the water's pressure to millions of atmospheres and its

temperature to thousands of degrees, resulting in a structure of rigid oxygen atoms in which hydrogen atoms flowed freely.<sup>[83]</sup><sup>[84]</sup> When sandwiched between layers of graphene, ice forms a square lattice.<sup>[85]</sup>

The details of the chemical nature of liquid water are not well understood; some theories suggest that its unusual behavior is due to the existence of two liquid states.<sup>[59]</sup><sup>[86]</sup><sup>[87]</sup><sup>[88]</sup>

## **Taste and odor**

[edit]

Pure water is usually described as tasteless and odorless, although humans have specific sensors that can feel the presence of water in their mouths,<sup>[89]</sup><sup>[90]</sup> and frogs are known to be able to smell it.<sup>[91]</sup> However, water from ordinary sources (including mineral water) usually has many dissolved substances that may give it varying tastes and odors. Humans and other animals have developed senses that enable them to evaluate the potability of water to avoid water that is too salty or putrid.<sup>[92]</sup>

## **Color and appearance**

[edit]

Main article: Color of water

See also: Electromagnetic absorption by water

Pure water is visibly blue due to absorption of light in the region c. 600–800 nm.<sup>[93]</sup>

The color can be easily observed in a glass of tap-water placed against a pure white background, in daylight. The principal absorption bands responsible for the color are overtones of the O–H stretching vibrations. The apparent intensity of the color

increases with the depth of the water column, following Beer's law. This also applies, for example, with a swimming pool when the light source is sunlight reflected from the pool's white tiles.

In nature, the color may also be modified from blue to green due to the presence of suspended solids or algae.

In industry, near-infrared spectroscopy is used with aqueous solutions as the greater intensity of the lower overtones of water means that glass cuvettes with short path-length may be employed. To observe the fundamental stretching absorption spectrum of water or of an aqueous solution in the region around  $3,500\text{ cm}^{-1}$  ( $2.85\text{ }\mu\text{m}$ ) [94] a path length of about  $25\text{ }\mu\text{m}$  is needed. Also, the cuvette must be both transparent around  $3500\text{ cm}^{-1}$  and insoluble in water; calcium fluoride is one material that is in common use for the cuvette windows with aqueous solutions.

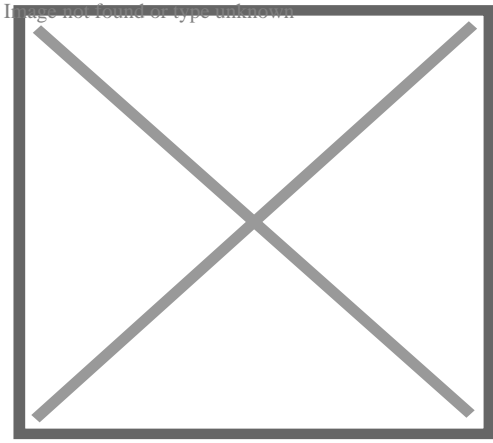
The Raman-active fundamental vibrations may be observed with, for example, a 1 cm sample cell.

Aquatic plants, algae, and other photosynthetic organisms can live in water up to hundreds of meters deep, because sunlight can reach them. Practically no sunlight reaches the parts of the oceans below 1,000 metres (3,300 ft) of depth.

The refractive index of liquid water ( $1.333$  at  $20\text{ }^{\circ}\text{C}$  ( $68\text{ }^{\circ}\text{F}$ )) is much higher than that of air ( $1.0$ ), similar to those of alkanes and ethanol, but lower than those of glycerol ( $1.473$ ), benzene ( $1.501$ ), carbon disulfide ( $1.627$ ), and common types of glass ( $1.4$  to  $1.6$ ). The refraction index of ice ( $1.31$ ) is lower than that of liquid water.

## **Molecular polarity**

[edit]



Tetrahedral structure of water

In a water molecule, the hydrogen atoms form a  $104.5^\circ$  angle with the oxygen atom. The hydrogen atoms are close to two corners of a tetrahedron centered on the oxygen. At the other two corners are *lone pairs* of valence electrons that do not participate in the bonding. In a perfect tetrahedron, the atoms would form a  $109.5^\circ$  angle, but the repulsion between the lone pairs is greater than the repulsion between the hydrogen atoms.<sup>[95]</sup><sup>[96]</sup> The O–H bond length is about 0.096 nm.<sup>[97]</sup>

Other substances have a tetrahedral molecular structure, for example methane ( $\text{CH}_4$ ) and hydrogen sulfide ( $\text{H}_2\text{S}$ ). However, oxygen is more electronegative than most other elements, so the oxygen atom has a negative partial charge while the hydrogen atoms are partially positively charged. Along with the bent structure, this gives the molecule an electrical dipole moment and it is classified as a polar molecule.<sup>[98]</sup>

Water is a good polar solvent, dissolving many salts and hydrophilic organic molecules such as sugars and simple alcohols such as ethanol. Water also dissolves many gases, such as oxygen and carbon dioxide—the latter giving the fizz of carbonated beverages, sparkling wines and beers. In addition, many substances in living organisms, such as proteins, DNA and polysaccharides, are dissolved in water. The interactions between water and the subunits of these biomacromolecules shape

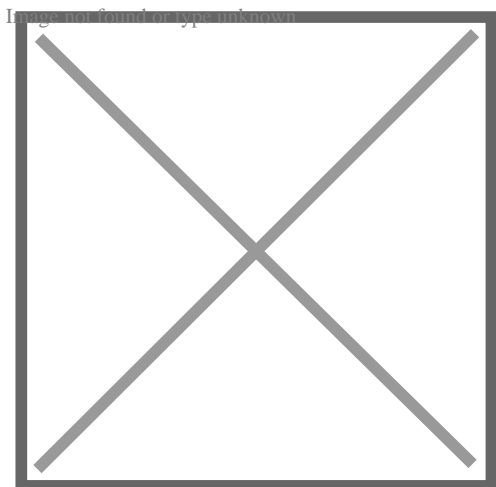
protein folding, DNA base pairing, and other phenomena crucial to life (hydrophobic effect).

Many organic substances (such as fats and oils and alkanes) are hydrophobic, that is, insoluble in water. Many inorganic substances are insoluble too, including most metal oxides, sulfides, and silicates.

## Hydrogen bonding

[edit]

See also: Chemical bonding of water

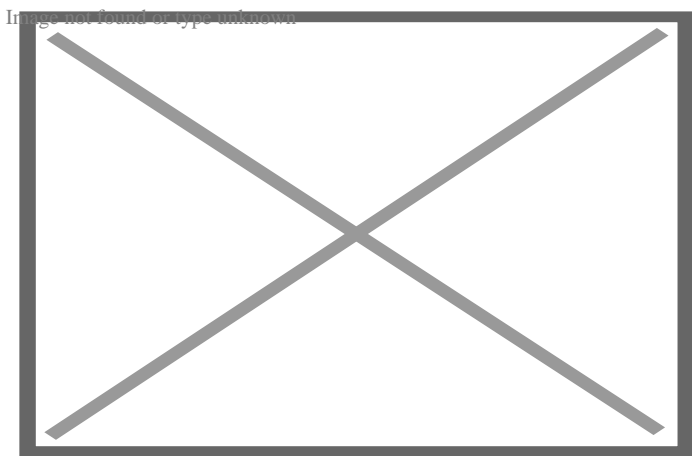


Model of hydrogen bonds (1) between molecules of water

Because of its polarity, a molecule of water in the liquid or solid state can form up to four hydrogen bonds with neighboring molecules. Hydrogen bonds are about ten times as strong as the Van der Waals force that attracts molecules to each other in most liquids. This is the reason why the melting and boiling points of water are much higher than those of other analogous compounds like hydrogen sulfide. They also explain its exceptionally high specific heat capacity (about  $4.2 \text{ J}/(\text{g}\cdot\text{K})$ ), heat of fusion (about  $333 \text{ J/g}$ ), heat of vaporization ( $2257 \text{ J/g}$ ), and thermal conductivity (between  $0.561$  and  $0.679 \text{ W}/(\text{m}\cdot\text{K})$ ). These properties make water more effective at moderating

Earth's climate, by storing heat and transporting it between the oceans and the atmosphere. The hydrogen bonds of water are around 23 kJ/mol (compared to a covalent O–H bond at 492 kJ/mol). Of this, it is estimated that 90% is attributable to electrostatics, while the remaining 10% is partially covalent.<sup>[99]</sup>

These bonds are the cause of water's high surface tension<sup>[100]</sup> and capillary forces. The capillary action refers to the tendency of water to move up a narrow tube against the force of gravity. This property is relied upon by all vascular plants, such as trees.<sup>[citation needed]</sup>



Specific heat capacity of water<sup>[101]</sup>

## Self-ionization

[edit]

Main article: Self-ionization of water

Water is a weak solution of hydronium hydroxide—there is an equilibrium 



2

H

2


O
⇌

H

3


O

+

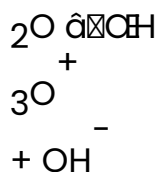

+

OH

−




{\displaystyle 2\mathrm {H\_{2}O} \rightleftharpoons \mathrm {H\_{3}O^{+}} +\mathrm {OH^{-}} }



, in combination with solvation of the resulting hydronium and hydroxide ions.

## Electrical conductivity and electrolysis

[edit]

Pure water has a low electrical conductivity, which increases with the dissolution of a small amount of ionic material such as common salt.

Liquid water can be split into the elements hydrogen and oxygen by passing an electric current through it—a process called electrolysis. The decomposition requires more energy input than the heat released by the inverse process (285.8 kJ/mol, or 15.9 MJ/kg).<sup>[102]</sup>

## Mechanical properties

[edit]

Liquid water can be assumed to be incompressible for most purposes: its compressibility ranges from 4.4 to  $5.1 \times 10^{-10} \text{ Pa}^{-1}$  in ordinary conditions.<sup>[103]</sup> Even in oceans at 4 km depth, where the pressure is 400 atm, water suffers only a 1.8% decrease in volume.<sup>[104]</sup>

The viscosity of water is about  $10^{-3} \text{ Pa}\cdot\text{s}$  or 0.01 poise at 20 °C (68 °F), and the speed of sound in liquid water ranges between 1,400 and 1,540 metres per second (4,600 and 5,100 ft/s) depending on temperature. Sound travels long distances in water with little attenuation, especially at low frequencies (roughly 0.03 dB/km for 1 kHz), a property that is exploited by cetaceans and humans for communication and environment sensing (sonar).<sup>[105]</sup>

## Reactivity

[edit]

Metallic elements which are more electropositive than hydrogen, particularly the alkali metals and alkaline earth metals such as lithium, sodium, calcium, potassium and caesium displace hydrogen from water, forming hydroxides and releasing hydrogen. At high temperatures, carbon reacts with steam to form carbon monoxide and hydrogen.<sup>[*citation needed*]</sup>

## **On Earth**

[edit]

Main articles: Hydrology and Water distribution on Earth

Hydrology is the study of the movement, distribution, and quality of water throughout the Earth. The study of the distribution of water is hydrography. The study of the distribution and movement of groundwater is hydrogeology, of glaciers is glaciology, of inland waters is limnology and distribution of oceans is oceanography. Ecological processes with hydrology are in the focus of ecohydrology.

The collective mass of water found on, under, and over the surface of a planet is called the hydrosphere. Earth's approximate water volume (the total water supply of the world) is 1.386 billion cubic kilometres (333 million cubic miles).<sup>[<sup>24</sup>]</sup>

Liquid water is found in bodies of water, such as an ocean, sea, lake, river, stream, canal, pond, or puddle. The majority of water on Earth is seawater. Water is also present in the atmosphere in solid, liquid, and vapor states. It also exists as groundwater in aquifers.

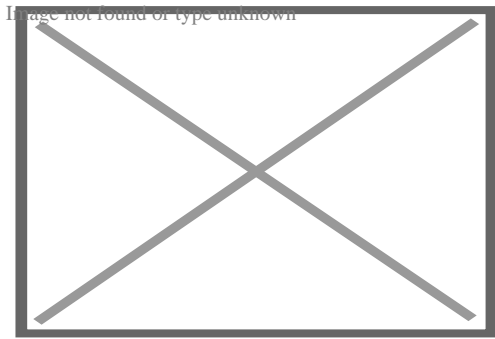
Water is important in many geological processes. Groundwater is present in most rocks, and the pressure of this groundwater affects patterns of faulting. Water in the

mantle is responsible for the melt that produces volcanoes at subduction zones. On the surface of the Earth, water is important in both chemical and physical weathering processes. Water, and to a lesser but still significant extent, ice, are also responsible for a large amount of sediment transport that occurs on the surface of the earth. Deposition of transported sediment forms many types of sedimentary rocks, which make up the geologic record of Earth history.

## Water cycle

[edit]

Main article: Water cycle



Water cycle

The water cycle (known scientifically as the hydrologic cycle) is the continuous exchange of water within the hydrosphere, between the atmosphere, soil water, surface water, groundwater, and plants.

Water moves perpetually through each of these regions in the *water cycle* consisting of the following transfer processes:

- evaporation from oceans and other water bodies into the air and transpiration from land plants and animals into the air.
- precipitation, from water vapor condensing from the air and falling to the earth or ocean.

- runoff from the land usually reaching the sea.

Most water vapors found mostly in the ocean returns to it, but winds carry water vapor over land at the same rate as runoff into the sea, about 47 Tt per year while evaporation and transpiration happening in land masses also contribute another 72 Tt per year. Precipitation, at a rate of 119 Tt per year over land, has several forms: most commonly rain, snow, and hail, with some contribution from fog and dew.<sup>[106]</sup> Dew is small drops of water that are condensed when a high density of water vapor meets a cool surface. Dew usually forms in the morning when the temperature is the lowest, just before sunrise and when the temperature of the earth's surface starts to increase.<sup>[107]</sup> Condensed water in the air may also refract sunlight to produce rainbows.

Water runoff often collects over watersheds flowing into rivers. Through erosion, runoff shapes the environment creating river valleys and deltas which provide rich soil and level ground for the establishment of population centers. A flood occurs when an area of land, usually low-lying, is covered with water which occurs when a river overflows its banks or a storm surge happens. On the other hand, drought is an extended period of months or years when a region notes a deficiency in its water supply. This occurs when a region receives consistently below average precipitation either due to its topography or due to its location in terms of latitude.

## **Water resources**

[edit]

Main article: Water resources

Water resources are natural resources of water that are potentially useful for humans, <sup>[108]</sup> for example as a source of drinking water supply or irrigation water. Water

occurs as both "stocks" and "flows". Water can be stored as lakes, water vapor, groundwater or aquifers, and ice and snow. Of the total volume of global freshwater, an estimated 69 percent is stored in glaciers and permanent snow cover; 30 percent is in groundwater; and the remaining 1 percent in lakes, rivers, the atmosphere, and biota.<sup>[109]</sup> The length of time water remains in storage is highly variable: some aquifers consist of water stored over thousands of years but lake volumes may fluctuate on a seasonal basis, decreasing during dry periods and increasing during wet ones. A substantial fraction of the water supply for some regions consists of water extracted from water stored in stocks, and when withdrawals exceed recharge, stocks decrease. By some estimates, as much as 30 percent of total water used for irrigation comes from unsustainable withdrawals of groundwater, causing groundwater depletion.<sup>[110]</sup>

## **Seawater and tides**

[edit]

Main articles: Seawater and Tides

Seawater contains about 3.5% sodium chloride on average, plus smaller amounts of other substances. The physical properties of seawater differ from fresh water in some important respects. It freezes at a lower temperature (about -1.9 °C (28.6 °F)) and its density increases with decreasing temperature to the freezing point, instead of reaching maximum density at a temperature above freezing. The salinity of water in major seas varies from about 0.7% in the Baltic Sea to 4.0% in the Red Sea. (The Dead Sea, known for its ultra-high salinity levels of between 30 and 40%, is really a salt lake.)

Tides are the cyclic rising and falling of local sea levels caused by the tidal forces of the Moon and the Sun acting on the oceans. Tides cause changes in the depth of the marine and estuarine water bodies and produce oscillating currents known as tidal

streams. The changing tide produced at a given location is the result of the changing positions of the Moon and Sun relative to the Earth coupled with the effects of Earth rotation and the local bathymetry. The strip of seashore that is submerged at high tide and exposed at low tide, the intertidal zone, is an important ecological product of ocean tides.

The Bay of Fundy at high tide and low tide

High tide

o

Image not found or type unknown

High tide

Low tide

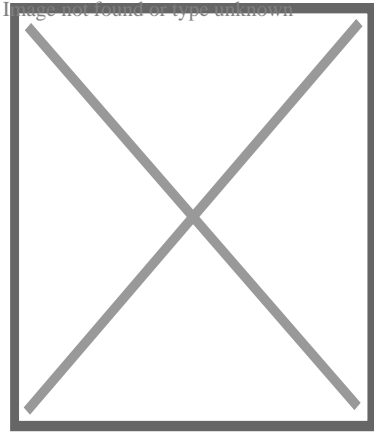
o

Image not found or type unknown

Low tide

## Effects on life

[edit]



## Overview of photosynthesis (green) and respiration (red)

From a biological standpoint, water has many distinct properties that are critical for the proliferation of life. It carries out this role by allowing organic compounds to react in ways that ultimately allow replication. All known forms of life depend on water.

Water is vital both as a solvent in which many of the body's solutes dissolve and as an essential part of many metabolic processes within the body. Metabolism is the sum total of anabolism and catabolism. In anabolism, water is removed from molecules (through energy requiring enzymatic chemical reactions) to grow larger molecules (e.g., starches, triglycerides, and proteins for storage of fuels and information). In catabolism, water is used to break bonds to generate smaller molecules (e.g., glucose, fatty acids, and amino acids to be used for fuels for energy use or other purposes). Without water, these particular metabolic processes could not exist.

Water is fundamental to both photosynthesis and respiration. Photosynthetic cells use the sun's energy to split off water's hydrogen from oxygen.<sup>[111]</sup> In the presence of sunlight, hydrogen is combined with CO<sub>2</sub> (absorbed from air or water) to form glucose and release oxygen.<sup>[112]</sup> All living cells use such fuels and oxidize the hydrogen and carbon to capture the sun's energy and reform water and CO<sub>2</sub> in the process (cellular respiration).

Water is also central to acid-base neutrality and enzyme function. An acid, a hydrogen ion ( $\text{H}^+$ ), that is, a proton donor, can be neutralized by a base, a proton acceptor such as a hydroxide ion ( $\text{OH}^-$ ) to form water. Water is considered to be neutral, with a pH (the negative log of the hydrogen ion concentration) of 7 in an ideal state. Acids have pH values less than 7 while bases have values greater than 7.

## **Aquatic life forms**

[edit]

Further information: Hydrobiology, Marine life, and Aquatic plant

Earth's surface waters are filled with life. The earliest life forms appeared in water; nearly all fish live exclusively in water, and there are many types of marine mammals, such as dolphins and whales. Some kinds of animals, such as amphibians, spend portions of their lives in water and portions on land. Plants such as kelp and algae grow in the water and are the basis for some underwater ecosystems. Plankton is generally the foundation of the ocean food chain.

Aquatic vertebrates must obtain oxygen to survive, and they do so in various ways. Fish have gills instead of lungs, although some species of fish, such as the lungfish, have both. Marine mammals, such as dolphins, whales, otters, and seals need to surface periodically to breathe air. Some amphibians are able to absorb oxygen through their skin. Invertebrates exhibit a wide range of modifications to survive in poorly oxygenated waters including breathing tubes (see insect and mollusc siphons) and gills (*Carcinus*). However, as invertebrate life evolved in an aquatic habitat most have little or no specialization for respiration in water.

Some of the biodiversity of a coral reef

o

Image not found or type unknown

Some of the biodiversity  
of a coral reef

Some marine diatoms – a key phytoplankton group

o

Image not found or type unknown

Some marine diatoms –  
a key phytoplankton  
group

Squat lobster and Alvinocarididae shrimp at the Von Damm hydrothermal field survive

o

Image not found or type unknown

Squat lobster and  
Alvinocarididae shrimp  
at the Von Damm

hydrothermal field  
survive by altered water  
chemistry.

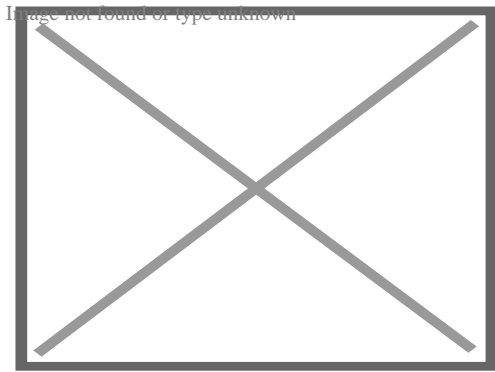
## Effects on human civilization

[edit]

This section **needs additional citations for verification**. Please help improve



this article by adding citations to reliable sources in this section. Unsourced material may be challenged and removed. *(May 2018) (Learn how and when to remove this message)*



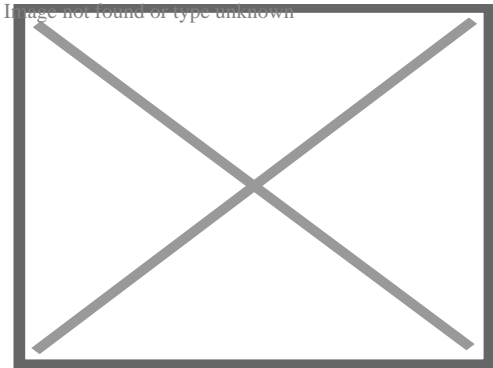
Water fountain

Civilization has historically flourished around rivers and major waterways; Mesopotamia, one of the so-called cradles of civilization, was situated between the major rivers Tigris and Euphrates; the ancient society of the Egyptians depended entirely upon the Nile. The early Indus Valley civilization (c. 3300 BCE – c. 1300 BCE) developed along the Indus River and tributaries that flowed out of the Himalayas. Rome was also founded on the banks of the Italian river Tiber. Large metropolises like Rotterdam, London, Montreal, Paris, New York City, Buenos Aires, Shanghai, Tokyo, Chicago, and Hong Kong owe their success in part to their easy accessibility via water and the resultant expansion of trade. Islands with safe water ports, like Singapore, have flourished for the same reason. In places such as North Africa and the Middle

East, where water is more scarce, access to clean drinking water was and is a major factor in human development.

## Health and pollution

[edit]



An environmental science program – a student from Iowa State University sampling water

Water fit for human consumption is called drinking water or potable water. Water that is not potable may be made potable by filtration or distillation, or by a range of other methods. More than 660 million people do not have access to safe drinking water.<sup>[113]</sup>  
]]<sup>[114]</sup>

Water that is not fit for drinking but is not harmful to humans when used for swimming or bathing is called by various names other than potable or drinking water, and is sometimes called safe water, or "safe for bathing". Chlorine is a skin and mucous membrane irritant that is used to make water safe for bathing or drinking. Its use is highly technical and is usually monitored by government regulations (typically 1 part per million (ppm) for drinking water, and 1–2 ppm of chlorine not yet reacted with impurities for bathing water). Water for bathing may be maintained in satisfactory microbiological condition using chemical disinfectants such as chlorine or ozone or by the use of ultraviolet light.

Water reclamation is the process of converting wastewater (most commonly sewage, also called municipal wastewater) into water that can be reused for other purposes. There are 2.3 billion people who reside in nations with water scarcities, which means that each individual receives less than 1,700 cubic metres (60,000 cu ft) of water annually. 380 billion cubic metres ( $13 \times 10^{12}$  cu ft) of municipal wastewater are produced globally each year.<sup>[115]</sup><sup>[116]</sup><sup>[117]</sup>

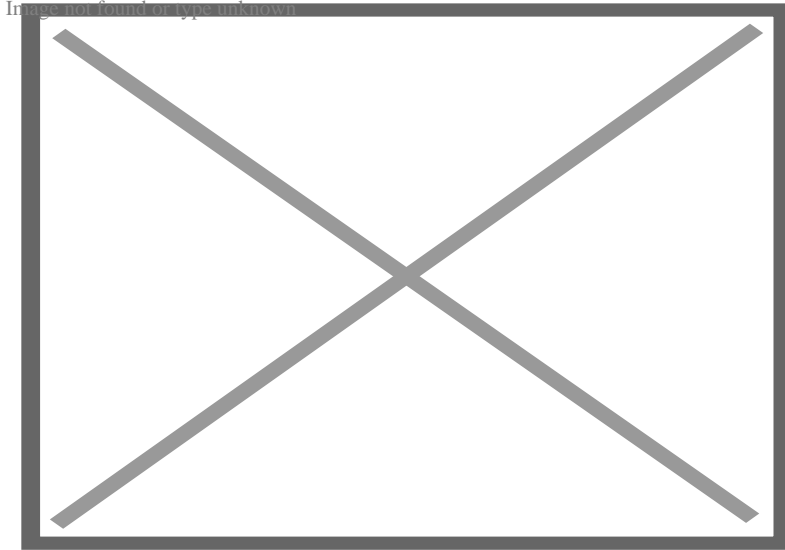
Freshwater is a renewable resource, recirculated by the natural hydrologic cycle, but pressures over access to it result from the naturally uneven distribution in space and time, growing economic demands by agriculture and industry, and rising populations. Currently, nearly a billion people around the world lack access to safe, affordable water. In 2000, the United Nations established the Millennium Development Goals for water to halve by 2015 the proportion of people worldwide without access to safe water and sanitation. Progress toward that goal was uneven, and in 2015 the UN committed to the Sustainable Development Goals of achieving universal access to safe and affordable water and sanitation by 2030. Poor water quality and bad sanitation are deadly; some five million deaths a year are caused by water-related diseases. The World Health Organization estimates that safe water could prevent 1.4 million child deaths from diarrhea each year.<sup>[118]</sup>

In developing countries, 90% of all municipal wastewater still goes untreated into local rivers and streams.<sup>[119]</sup> Some 50 countries, with roughly a third of the world's population, also suffer from medium or high water scarcity and 17 of these extract more water annually than is recharged through their natural water cycles.<sup>[120]</sup> The strain not only affects surface freshwater bodies like rivers and lakes, but it also degrades groundwater resources.

## **Human uses**

[edit]

Further information: Water supply



Total water withdrawals for agricultural, industrial and municipal purposes per capita, measured in cubic metres (m<sup>3</sup>) per year in 2010<sup>[121]</sup>

## Agriculture

[edit]

The most substantial human use of water is for agriculture, including irrigated agriculture, which accounts for as much as 80 to 90 percent of total human water consumption.<sup>[122]</sup> In the United States, 42% of freshwater withdrawn for use is for irrigation, but the vast majority of water "consumed" (used and not returned to the environment) goes to agriculture.<sup>[123]</sup>

Access to fresh water is often taken for granted, especially in developed countries that have built sophisticated water systems for collecting, purifying, and delivering water, and removing wastewater. But growing economic, demographic, and climatic pressures are increasing concerns about water issues, leading to increasing competition for fixed water resources, giving rise to the concept of peak water.<sup>[124]</sup> As

populations and economies continue to grow, consumption of water-thirsty meat expands, and new demands rise for biofuels or new water-intensive industries, new water challenges are likely.<sup>[125]</sup>

An assessment of water management in agriculture was conducted in 2007 by the International Water Management Institute in Sri Lanka to see if the world had sufficient water to provide food for its growing population.<sup>[126]</sup> It assessed the current availability of water for agriculture on a global scale and mapped out locations suffering from water scarcity. It found that a fifth of the world's people, more than 1.2 billion, live in areas of physical water scarcity, where there is not enough water to meet all demands. A further 1.6 billion people live in areas experiencing economic water scarcity, where the lack of investment in water or insufficient human capacity make it impossible for authorities to satisfy the demand for water. The report found that it would be possible to produce the food required in the future, but that continuation of today's food production and environmental trends would lead to crises in many parts of the world. To avoid a global water crisis, farmers will have to strive to increase productivity to meet growing demands for food, while industries and cities find ways to use water more efficiently.<sup>[127]</sup>

Water scarcity is also caused by production of water intensive products. For example, cotton: 1 kg of cotton—equivalent of a pair of jeans—requires 10.9 cubic metres (380 cu ft) water to produce. While cotton accounts for 2.4% of world water use, the water is consumed in regions that are already at a risk of water shortage. Significant environmental damage has been caused: for example, the diversion of water by the former Soviet Union from the Amu Darya and Syr Darya rivers to produce cotton was largely responsible for the disappearance of the Aral Sea.<sup>[128]</sup>

## Water requirement per tonne of food product

○

Image not found or type unknown

Water  
requirement per  
tonne of food  
product

○

Water distribution  
in subsurface drip  
irrigation  
Irrigation of field crops

○

Image not found or type unknown

Irrigation of field  
crops

**As a scientific standard**

[edit]

On 7 April 1795, the gram was defined in France to be equal to "the absolute weight of a volume of pure water equal to a cube of one-hundredth of a meter, and at the temperature of melting ice".<sup>[129]</sup> For practical purposes though, a metallic reference standard was required, one thousand times more massive, the kilogram. Work was therefore commissioned to determine precisely the mass of one liter of water. In spite of the fact that the decreed definition of the gram specified water at 0 °C (32 °F)—a highly reproducible *temperature*—the scientists chose to redefine the standard and to perform their measurements at the temperature of highest water *density*, which was measured at the time as 4 °C (39 °F).<sup>[130]</sup>

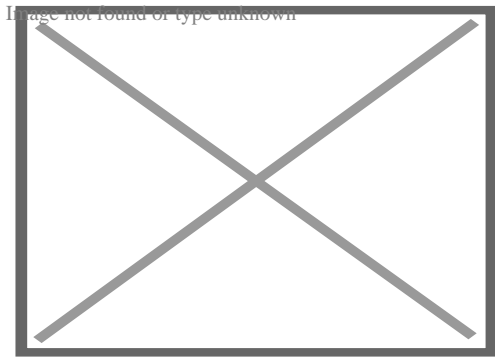
The Kelvin temperature scale of the SI system was based on the triple point of water, defined as exactly 273.16 K (0.01 °C; 32.02 °F), but as of May 2019 is based on the Boltzmann constant instead. The scale is an absolute temperature scale with the same increment as the Celsius temperature scale, which was originally defined according to the boiling point (set to 100 °C (212 °F)) and melting point (set to 0 °C (32 °F)) of water.

Natural water consists mainly of the isotopes hydrogen-1 and oxygen-16, but there is also a small quantity of heavier isotopes oxygen-18, oxygen-17, and hydrogen-2 (deuterium). The percentage of the heavier isotopes is very small, but it still affects the properties of water. Water from rivers and lakes tends to contain less heavy isotopes than seawater. Therefore, standard water is defined in the Vienna Standard Mean Ocean Water specification.

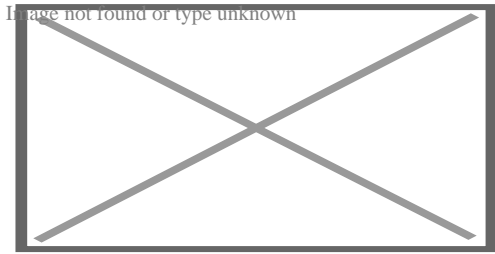
## **For drinking**

[edit]

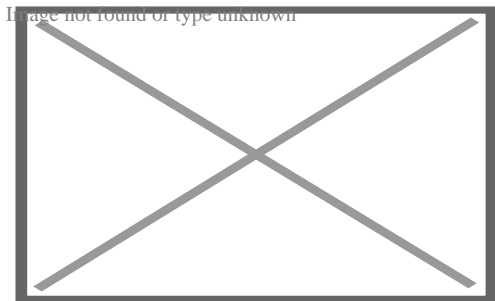
Main article: Drinking water



A young girl drinking bottled water



Water availability: the fraction of the population using improved water sources by country



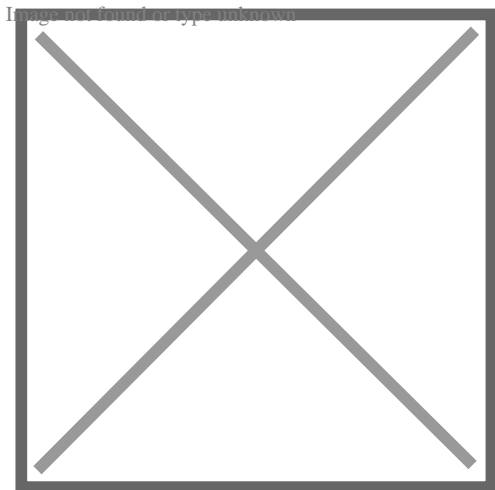
Roadside fresh water outlet from glacier, Nubra

The human body contains from 55% to 78% water, depending on body size.<sup>[131]</sup><sup>[user-generated]</sup>

To function properly, the body requires between one and seven litres (0.22 and 1.54 imp gal; 0.26 and 1.85 US gal)<sup>[citation needed]</sup> of water per day to avoid dehydration; the precise amount depends on the level of activity, temperature, humidity, and other factors. Most of this is ingested through foods or beverages other than drinking straight water. It is not clear how much water intake is needed by healthy people, though the British Dietetic Association advises that 2.5 liters of total water daily is the minimum to maintain proper hydration, including 1.8 liters (6 to 7

glasses) obtained directly from beverages.[<sup>132</sup>] Medical literature favors a lower consumption, typically 1 liter of water for an average male, excluding extra requirements due to fluid loss from exercise or warm weather.[<sup>133</sup>]

Healthy kidneys can excrete 0.8 to 1 liter of water per hour, but stress such as exercise can reduce this amount. People can drink far more water than necessary while exercising, putting them at risk of water intoxication (hyperhydration), which can be fatal.[<sup>134</sup>][<sup>135</sup>] The popular claim that "a person should consume eight glasses of water per day" seems to have no real basis in science.[<sup>136</sup>] Studies have shown that extra water intake, especially up to 500 millilitres (18 imp fl oz; 17 US fl oz) at mealtime, was associated with weight loss.[<sup>137</sup>][<sup>138</sup>][<sup>139</sup>][<sup>140</sup>][<sup>141</sup>][<sup>142</sup>] Adequate fluid intake is helpful in preventing constipation.[<sup>143</sup>]



Hazard symbol for non-potable water

An original recommendation for water intake in 1945 by the Food and Nutrition Board of the U.S. National Research Council read: "An ordinary standard for diverse persons is 1 milliliter for each calorie of food. Most of this quantity is contained in prepared foods."[<sup>144</sup>] The latest dietary reference intake report by the U.S. National Research Council in general recommended, based on the median total water intake from US survey data (including food sources): 3.7 litres (0.81 imp gal; 0.98 US gal) for men and

2.7 litres (0.59 imp gal; 0.71 US gal) of water total for women, noting that water contained in food provided approximately 19% of total water intake in the survey.<sup>[145]</sup>

Specifically, pregnant and breastfeeding women need additional fluids to stay hydrated. The US Institute of Medicine recommends that, on average, men consume 3 litres (0.66 imp gal; 0.79 US gal) and women 2.2 litres (0.48 imp gal; 0.58 US gal); pregnant women should increase intake to 2.4 litres (0.53 imp gal; 0.63 US gal) and breastfeeding women should get 3 liters (12 cups), since an especially large amount of fluid is lost during nursing.<sup>[146]</sup> Also noted is that normally, about 20% of water intake comes from food, while the rest comes from drinking water and beverages (caffeinated included). Water is excreted from the body in multiple forms; through urine and feces, through sweating, and by exhalation of water vapor in the breath. With physical exertion and heat exposure, water loss will increase and daily fluid needs may increase as well.

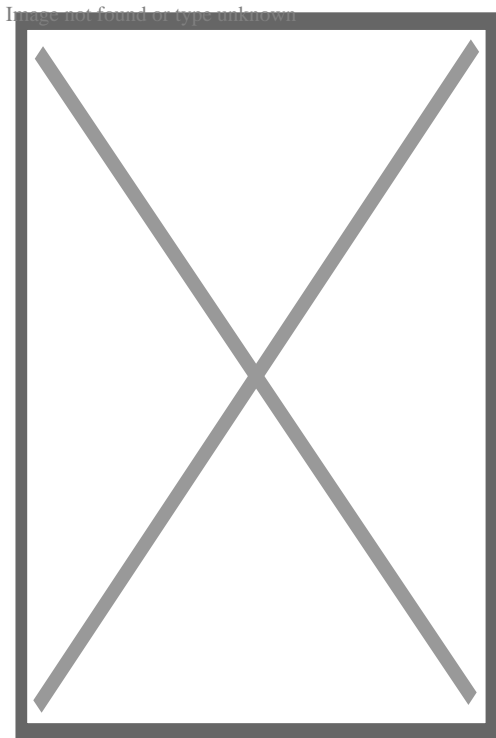
Humans require water with few impurities. Common impurities include metal salts and oxides, including copper, iron, calcium and lead,<sup>[147]</sup> *[full citation needed]* and harmful bacteria, such as *Vibrio*. Some solutes are acceptable and even desirable for taste enhancement and to provide needed electrolytes.<sup>[148]</sup>

The single largest (by volume) freshwater resource suitable for drinking is Lake Baikal in Siberia.<sup>[149]</sup>

## **Washing**

[edit]

This section is an excerpt from Washing.<sup>[edit]</sup>



A woman washes her hands with soap and water.

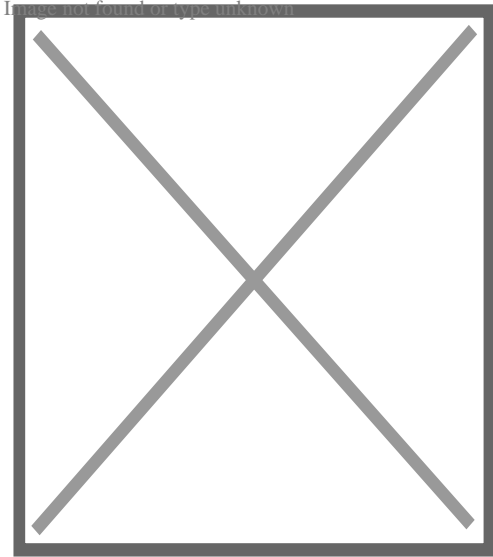
Washing is a method of cleaning, usually with water and soap or detergent. Regularly washing and then rinsing both body and clothing is an essential part of good hygiene and health.<sup>[150]</sup><sup>[151]</sup><sup>[152]</sup>

Often people use soaps and detergents to assist in the emulsification of oils and dirt particles so they can be washed away. The soap can be applied directly, or with the aid of a washcloth or assisted with sponges or similar cleaning tools.

In social contexts, washing refers to the act of bathing, or washing different parts of the body, such as hands, hair, or faces. Excessive washing may damage the hair, causing dandruff, or cause rough skin/skin lesions.<sup>[153]</sup><sup>[154]</sup> Some washing of the body is done ritually in religions like Christianity and Judaism, as an act of purification.

Washing can also refer to washing objects. For example, washing of clothing or other cloth items, like bedsheets, or washing dishes or cookwear. Keeping objects clean,

especially if they interact with food or the skin, can help with sanitation. Other kinds of washing focus on maintaining cleanliness and durability of objects that get dirty, such washing one's car, by lathering the exterior with car soap, or washing tools used in a dirty process.



A private home washing machine

## Transportation

[edit]

These paragraphs are an excerpt from Maritime transport.[edit]

Maritime transport (or ocean transport) or more generally waterborne transport, is the transport of people (passengers) or goods (cargo) via waterways. Freight transport by watercraft has been widely used throughout recorded history, as it provides a higher-capacity mode of transportation for passengers and cargo than land transport, the latter typically being more costly per unit payload due to it being affected by terrain conditions and road/rail infrastructures. The advent of aviation

during the 20th century has diminished the importance of sea travel for passengers, though it is still popular for short trips and pleasure cruises. Transport by watercraft is much cheaper than transport by aircraft or land vehicles (both road and rail),<sup>[155]</sup> but is significantly slower for longer journeys and heavily dependent on adequate port facilities. Maritime transport accounts for roughly 80% of international trade, according to UNCTAD in 2020.

Maritime transport can be realized over any distance as long as there are connecting bodies of water that are navigable to boats, ships or barges such as oceans, lakes, rivers and canals. Shipping may be for commerce, recreation, or military purposes, and is an important aspect of logistics in human societies since early shipbuilding and river engineering were developed, leading to canal ages in various civilizations. While extensive inland shipping is less critical today, the major waterways of the world including many canals are still very important and are integral parts of worldwide economies. Particularly, especially any material can be moved by water; however, water transport becomes impractical when material delivery is time-critical such as various types of perishable produce. Still, water transport is highly cost effective with regular schedulable cargoes, such as trans-oceanic shipping of consumer products – and especially for heavy loads or bulk cargos, such as coal, coke, ores or grains. Arguably, the Industrial Revolution had its first impacts where cheap water transport by canal, navigations, or shipping by all types of watercraft on natural waterways supported cost-effective bulk transport.

Containerization revolutionized maritime transport starting in the 1970s. "General cargo" includes goods packaged in boxes, cases, pallets, and barrels. When a cargo is carried in more than one mode, it is intermodal or co-modal.

## **Chemical uses**

[edit]

Water is widely used in chemical reactions as a solvent or reactant and less commonly as a solute or catalyst. In inorganic reactions, water is a common solvent, dissolving many ionic compounds, as well as other polar compounds such as ammonia and compounds closely related to water. In organic reactions, it is not usually used as a reaction solvent, because it does not dissolve the reactants well and is amphoteric (acidic *and* basic) and nucleophilic. Nevertheless, these properties are sometimes desirable. Also, acceleration of Diels–Alder reactions by water has been observed. Supercritical water has recently been a topic of research. Oxygen-saturated supercritical water combusts organic pollutants efficiently.

## Heat exchange

[edit]

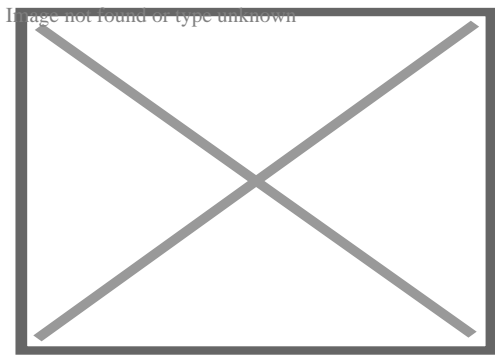
Water and steam are a common fluid used for heat exchange, due to its availability and high heat capacity, both for cooling and heating. Cool water may even be naturally available from a lake or the sea. It is especially effective to transport heat through vaporization and condensation of water because of its large latent heat of vaporization. A disadvantage is that metals commonly found in industries such as steel and copper are oxidized faster by untreated water and steam. In almost all thermal power stations, water is used as the working fluid (used in a closed-loop between boiler, steam turbine, and condenser), and the coolant (used to exchange the waste heat to a water body or carry it away by evaporation in a cooling tower). In the United States, cooling power plants is the largest use of water.<sup>[156]</sup>

In the nuclear power industry, water can also be used as a neutron moderator. In most nuclear reactors, water is both a coolant and a moderator. This provides

something of a passive safety measure, as removing the water from the reactor also slows the nuclear reaction down. However other methods are favored for stopping a reaction and it is preferred to keep the nuclear core covered with water so as to ensure adequate cooling.

## Fire considerations

[edit]



Water is used for fighting wildfires.

Water has a high heat of vaporization and is relatively inert, which makes it a good fire extinguishing fluid. The evaporation of water carries heat away from the fire. It is dangerous to use water on fires involving oils and organic solvents because many organic materials float on water and the water tends to spread the burning liquid.

Use of water in fire fighting should also take into account the hazards of a steam explosion, which may occur when water is used on very hot fires in confined spaces, and of a hydrogen explosion, when substances which react with water, such as certain metals or hot carbon such as coal, charcoal, or coke graphite, decompose the water, producing water gas.

The power of such explosions was seen in the Chernobyl disaster, although the water involved in this case did not come from fire-fighting but from the reactor's own water

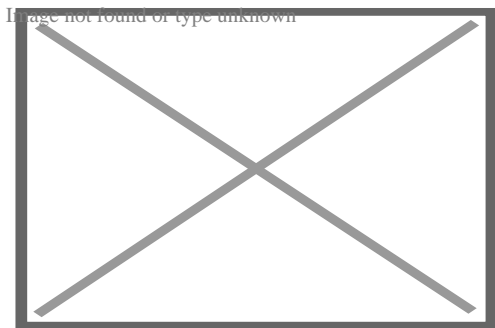
cooling system. A steam explosion occurred when the extreme overheating of the core caused water to flash into steam. A hydrogen explosion may have occurred as a result of a reaction between steam and hot zirconium.

Some metallic oxides, most notably those of alkali metals and alkaline earth metals, produce so much heat in reaction with water that a fire hazard can develop. The alkaline earth oxide quicklime, also known as calcium oxide, is a mass-produced substance that is often transported in paper bags. If these are soaked through, they may ignite as their contents react with water.<sup>[157]</sup>

## Recreation

[edit]

Main article: Water sport (recreation)



San Andrés island, Colombia

Humans use water for many recreational purposes, as well as for exercising and for sports. Some of these include swimming, waterskiing, boating, surfing and diving. In addition, some sports, like ice hockey and ice skating, are played on ice. Lakesides, beaches and water parks are popular places for people to go to relax and enjoy recreation. Many find the sound and appearance of flowing water to be calming, and fountains and other flowing water structures are popular decorations. Some keep fish and other flora and fauna inside aquariums or ponds for show, fun, and

companionship. Humans also use water for snow sports such as skiing, sledding, snowmobiling or snowboarding, which require the water to be at a low temperature either as ice or crystallized into snow.

## **Water industry**

[edit]

The water industry provides drinking water and wastewater services (including sewage treatment) to households and industry. Water supply facilities include water wells, cisterns for rainwater harvesting, water supply networks, and water purification facilities, water tanks, water towers, water pipes including old aqueducts. Atmospheric water generators are in development.

Drinking water is often collected at springs, extracted from artificial borings (wells) in the ground, or pumped from lakes and rivers. Building more wells in adequate places is thus a possible way to produce more water, assuming the aquifers can supply an adequate flow. Other water sources include rainwater collection. Water may require purification for human consumption. This may involve the removal of undissolved substances, dissolved substances and harmful microbes. Popular methods are filtering with sand which only removes undissolved material, while chlorination and boiling kill harmful microbes. Distillation does all three functions. More advanced techniques exist, such as reverse osmosis. Desalination of abundant seawater is a more expensive solution used in coastal arid climates.

The distribution of drinking water is done through municipal water systems, tanker delivery or as bottled water. Governments in many countries have programs to distribute water to the needy at no charge.

Reducing usage by using drinking (potable) water only for human consumption is another option. In some cities such as Hong Kong, seawater is extensively used for flushing toilets citywide to conserve freshwater resources.

Polluting water may be the biggest single misuse of water; to the extent that a pollutant limits other uses of the water, it becomes a waste of the resource, regardless of benefits to the polluter. Like other types of pollution, this does not enter standard accounting of market costs, being conceived as externalities for which the market cannot account. Thus other people pay the price of water pollution, while the private firms' profits are not redistributed to the local population, victims of this pollution. Pharmaceuticals consumed by humans often end up in the waterways and can have detrimental effects on aquatic life if they bioaccumulate and if they are not biodegradable.

Municipal and industrial wastewater are typically treated at wastewater treatment plants. Mitigation of polluted surface runoff is addressed through a variety of prevention and treatment techniques.

A water-carrier in India, 1882. In many places where running water is not available, water

o

Image not found or type unknown

A water-carrier in India,  
1882. In many places  
where running water is  
not available, water has

to be transported by  
people.

A manual water pump in China

o

Image not found or type unknown

A manual water pump in  
China

Water purification facility

o

Image not found or type unknown

Water purification facility

Reverse osmosis (RO) desalination plant in Barcelona, Spain

o

Image not found or type unknown

Reverse osmosis (RO)  
desalination plant in  
Barcelona, Spain

## Industrial applications

[edit]

Many industrial processes rely on reactions using chemicals dissolved in water, suspension of solids in water slurries or using water to dissolve and extract substances, or to wash products or process equipment. Processes such as mining, chemical pulping, pulp bleaching, paper manufacturing, textile production, dyeing, printing, and cooling of power plants use large amounts of water, requiring a dedicated water source, and often cause significant water pollution.

Water is used in power generation. Hydroelectricity is electricity obtained from hydropower. Hydroelectric power comes from water driving a water turbine connected to a generator. Hydroelectricity is a low-cost, non-polluting, renewable energy source. The energy is supplied by the motion of water. Typically a dam is constructed on a river, creating an artificial lake behind it. Water flowing out of the lake is forced through turbines that turn generators.

Image not found or type unknown



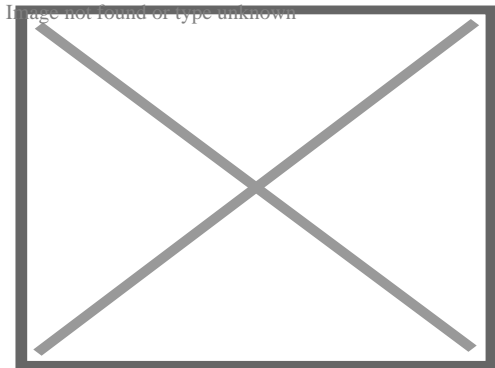
Three Gorges Dam is the largest hydro-electric power station in the world.

Pressurized water is used in water blasting and water jet cutters. High pressure water guns are used for precise cutting. It works very well, is relatively safe, and is not harmful to the environment. It is also used in the cooling of machinery to prevent overheating, or prevent saw blades from overheating.

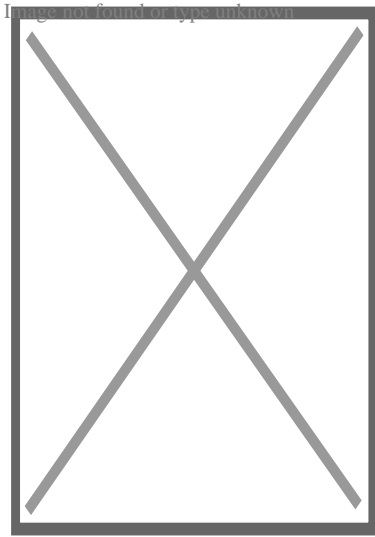
Water is also used in many industrial processes and machines, such as the steam turbine and heat exchanger, in addition to its use as a chemical solvent. Discharge of untreated water from industrial uses is pollution. Pollution includes discharged solutes (chemical pollution) and discharged coolant water (thermal pollution). Industry requires pure water for many applications and uses a variety of purification techniques both in water supply and discharge.

## **Food processing**

[edit]



Water can be used to cook foods such as noodles.



Sterile water for injection

Boiling, steaming, and simmering are popular cooking methods that often require immersing food in water or its gaseous state, steam.<sup>[158]</sup> Water is also used for dishwashing. Water also plays many critical roles within the field of food science.

Solutes such as salts and sugars found in water affect the physical properties of water. The boiling and freezing points of water are affected by solutes, as well as air pressure, which is in turn affected by altitude. Water boils at lower temperatures with the lower air pressure that occurs at higher elevations. One mole of sucrose (sugar) per kilogram of water raises the boiling point of water by 0.51 °C (0.918 °F), and one mole of salt per kg raises the boiling point by 1.02 °C (1.836 °F); similarly, increasing the number of dissolved particles lowers water's freezing point.<sup>[159]</sup>

Solutes in water also affect water activity that affects many chemical reactions and the growth of microbes in food.<sup>[160]</sup> Water activity can be described as a ratio of the vapor pressure of water in a solution to the vapor pressure of pure water.<sup>[159]</sup> Solutes in water lower water activity—this is important to know because most bacterial growth ceases at low levels of water activity.<sup>[160]</sup> Not only does microbial growth affect the safety of food, but also the preservation and shelf life of food.

Water hardness is also a critical factor in food processing and may be altered or treated by using a chemical ion exchange system. It can dramatically affect the quality of a product, as well as playing a role in sanitation. Water hardness is classified based on concentration of calcium carbonate the water contains. Water is classified as soft if it contains less than 100 mg/L (UK)<sup>[161]</sup> or less than 60 mg/L (US).<sup>[162]</sup>

According to a report published by the Water Footprint organization in 2010, a single kilogram of beef requires 15 thousand litres ( $3.3 \times 10^3$  imp gal;  $4.0 \times 10^3$  US gal) of water; however, the authors also make clear that this is a global average and circumstantial factors determine the amount of water used in beef production.<sup>[163]</sup>

## **Medical use**

[edit]

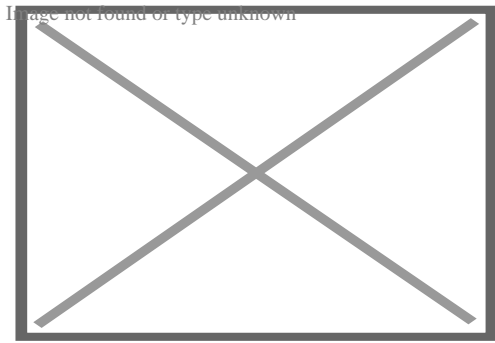
Water for injection is on the World Health Organization's list of essential medicines.<sup>[164]</sup>

## **Distribution in nature**

[edit]

## **In the universe**

[edit]



Band 5 ALMA receiver is an instrument specifically designed to detect water in the universe.<sup>[165]</sup>

Much of the universe's water is produced as a byproduct of star formation. The formation of stars is accompanied by a strong outward wind of gas and dust. When this outflow of material eventually impacts the surrounding gas, the shock waves that are created compress and heat the gas. The water observed is quickly produced in this warm dense gas.<sup>[166]</sup>

On 22 July 2011, a report described the discovery of a gigantic cloud of water vapor containing "140 trillion times more water than all of Earth's oceans combined" around a quasar located 12 billion light years from Earth. According to the researchers, the "discovery shows that water has been prevalent in the universe for nearly its entire existence".<sup>[167]</sup><sup>[168]</sup>

Water has been detected in interstellar clouds within the Milky Way.<sup>[169]</sup> Water probably exists in abundance in other galaxies, too, because its components, hydrogen, and oxygen, are among the most abundant elements in the universe. Based on models of the formation and evolution of the Solar System and that of other star systems, most other planetary systems are likely to have similar ingredients.

## **Water vapor**

[edit]

Water is present as vapor in:

- Atmosphere of the Sun: in detectable trace amounts<sup>[170]</sup>
- Atmosphere of Mercury: 3.4%, and large amounts of water in Mercury's exosphere<sup>[171]</sup>
- Atmosphere of Venus: 0.002%<sup>[172]</sup>
- Earth's atmosphere: 0.40% over full atmosphere, typically 1–4% at surface
- Atmosphere of the Moon: in trace amounts<sup>[173]</sup>
- Atmosphere of Mars: 0.03%<sup>[174]</sup>
- Atmosphere of Ceres<sup>[175]</sup>
- Atmosphere of Jupiter: 0.0004%<sup>[176]</sup> – in ices only; and that of its moon Europa<sup>[177]</sup>
- Atmosphere of Saturn – in ices only; Enceladus: 91%<sup>[178]</sup> and Dione (exosphere)<sup>[citation needed]</sup>
- Atmosphere of Uranus – in trace amounts below 50 bar
- Atmosphere of Neptune – found in the deeper layers<sup>[179]</sup>
- Extrasolar planet atmospheres: including those of HD 189733 b<sup>[180]</sup> and HD 209458 b,<sup>[181]</sup> Tau Boötis b,<sup>[182]</sup> HAT-P-11b,<sup>[183]</sup><sup>[184]</sup> XO-1b, WASP-12b, WASP-17b, and WASP-19b.<sup>[185]</sup>
- Stellar atmospheres: not limited to cooler stars and even detected in giant hot stars such as Betelgeuse, Mu Cephei, Antares and Arcturus.<sup>[184]</sup><sup>[186]</sup>
- Circumstellar disks: including those of more than half of T Tauri stars such as AA Tauri<sup>[184]</sup> as well as TW Hydrae,<sup>[187]</sup><sup>[188]</sup> IRC +10216<sup>[189]</sup> and APM 08279+5255,<sup>[167]</sup><sup>[168]</sup> VY Canis Majoris and S Persei.<sup>[186]</sup>

## Liquid water

[edit]

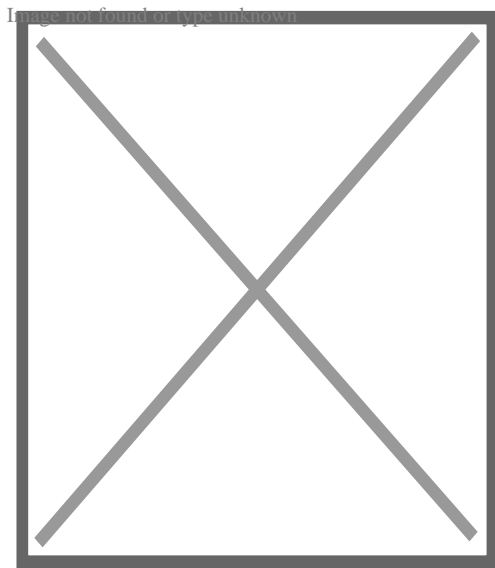
Further information: List of largest lakes and seas in the Solar System and Extraterrestrial liquid water

Liquid water is present on Earth, covering 71% of its surface.<sup>[23]</sup> Liquid water is also occasionally present in small amounts on Mars.<sup>[190]</sup> Scientists believe liquid water is present in the Saturnian moons of Enceladus, as a 10-kilometre thick ocean approximately 30–40 kilometers below Enceladus' south polar surface,<sup>[191]</sup><sup>[192]</sup> and Titan, as a subsurface layer, possibly mixed with ammonia.<sup>[193]</sup> Jupiter's moon Europa has surface characteristics which suggest a subsurface liquid water ocean.<sup>[194]</sup> Liquid water may also exist on Jupiter's moon Ganymede as a layer sandwiched between high pressure ice and rock.<sup>[195]</sup>

## Water ice

[edit]

Water is present as ice on:



Water ice in the Korolev crater on Mars

Mars: under the regolith and at the poles.<sup>[196]</sup><sup>[197]</sup>

- Earth–Moon system: mainly as ice sheets on Earth and in Lunar craters and volcanic rocks<sup>[198]</sup> NASA reported the detection of water molecules by NASA's Moon Mineralogy Mapper aboard the Indian Space Research Organization's Chandrayaan-1 spacecraft in September 2009.<sup>[199]</sup>
- Ceres<sup>[200]</sup><sup>[201]</sup><sup>[202]</sup>
- Jupiter's moons: Europa's surface and also that of Ganymede<sup>[203]</sup> and Callisto<sup>[204]</sup><sup>[205]</sup>
- Saturn: in the planet's ring system<sup>[206]</sup> and on the surface and mantle of Titan<sup>[207]</sup> and Enceladus<sup>[208]</sup>
- Pluto–Charon system<sup>[206]</sup>
- Comets<sup>[209]</sup><sup>[210]</sup> and other related Kuiper belt and Oort cloud objects<sup>[211]</sup>

And is also likely present on:

- Mercury's poles<sup>[212]</sup>
- Tethys<sup>[213]</sup>

## Exotic forms

[edit]

Water and other volatiles probably comprise much of the internal structures of Uranus and Neptune and the water in the deeper layers may be in the form of ionic water in which the molecules break down into a soup of hydrogen and oxygen ions, and deeper still as superionic water in which the oxygen crystallizes, but the hydrogen ions float about freely within the oxygen lattice.<sup>[214]</sup>

## Water and planetary habitability

[edit]

Further information: Water distribution on Earth and Planetary habitability

The existence of liquid water, and to a lesser extent its gaseous and solid forms, on Earth are vital to the existence of life on Earth as we know it. The Earth is located in the habitable zone of the Solar System; if it were slightly closer to or farther from the Sun (about 5%, or about 8 million kilometers), the conditions which allow the three forms to be present simultaneously would be far less likely to exist.<sup>[215]</sup><sup>[216]</sup>

Earth's gravity allows it to hold an atmosphere. Water vapor and carbon dioxide in the atmosphere provide a temperature buffer (greenhouse effect) which helps maintain a relatively steady surface temperature. If Earth were smaller, a thinner atmosphere would allow temperature extremes, thus preventing the accumulation of water except in polar ice caps (as on Mars).<sup>[citation needed]</sup>

The surface temperature of Earth has been relatively constant through geologic time despite varying levels of incoming solar radiation (insolation), indicating that a dynamic process governs Earth's temperature via a combination of greenhouse gases and surface or atmospheric albedo. This proposal is known as the Gaia hypothesis.<sup>[citation needed]</sup>

The state of water on a planet depends on ambient pressure, which is determined by the planet's gravity. If a planet is sufficiently massive, the water on it may be solid even at high temperatures, because of the high pressure caused by gravity, as it was observed on exoplanets Gliese 436 b<sup>[217]</sup> and GJ 1214 b.<sup>[218]</sup>

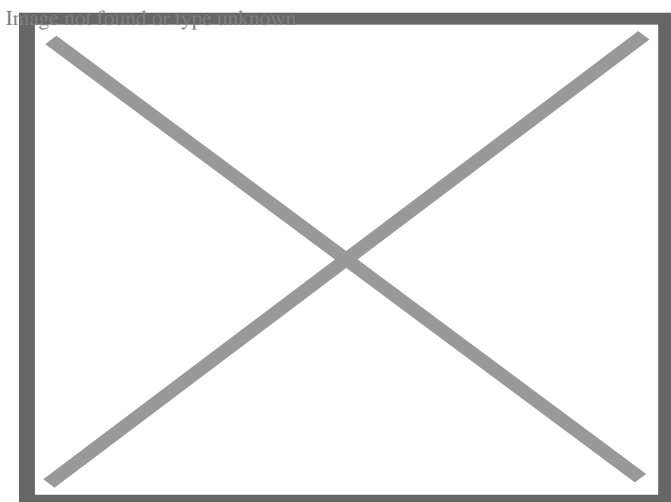
## **Law, politics, and crisis**

[edit]

Main articles: Water law, Water right, and Water scarcity



This section needs to be **updated**. Please help update this article to reflect recent events or newly available information. *(June 2022)*



An estimate of the proportion of people in developing countries with access to potable water 1970–2000

Water politics is politics affected by water and water resources. Water, particularly fresh water, is a strategic resource across the world and an important element in many political conflicts. It causes health impacts and damage to biodiversity.

Access to safe drinking water has improved over the last decades in almost every part of the world, but approximately one billion people still lack access to safe water and over 2.5 billion lack access to adequate sanitation.<sup>[219]</sup> However, some observers have estimated that by 2025 more than half of the world population will be facing water-based vulnerability.<sup>[220]</sup> A report, issued in November 2009, suggests that by 2030, in some developing regions of the world, water demand will exceed supply by 50%.<sup>[221]</sup>

1.6 billion people have gained access to a safe water source since 1990.<sup>[222]</sup> The proportion of people in developing countries with access to safe water is calculated to have improved from 30% in 1970<sup>[223]</sup> to 71% in 1990, 79% in 2000, and 84% in 2004.<sup>[219]</sup>

A 2006 United Nations report stated that "there is enough water for everyone", but that access to it is hampered by mismanagement and corruption.<sup>[224]</sup> In addition, global initiatives to improve the efficiency of aid delivery, such as the Paris Declaration on Aid Effectiveness, have not been taken up by water sector donors as effectively as they have in education and health, potentially leaving multiple donors working on overlapping projects and recipient governments without empowerment to act.<sup>[225]</sup>

The authors of the 2007 Comprehensive Assessment of Water Management in Agriculture cited poor governance as one reason for some forms of water scarcity. Water governance is the set of formal and informal processes through which decisions related to water management are made. Good water governance is primarily about knowing what processes work best in a particular physical and socioeconomic context. Mistakes have sometimes been made by trying to apply 'blueprints' that work in the developed world to developing world locations and contexts. The Mekong river is one example; a review by the International Water Management Institute of policies in six countries that rely on the Mekong river for water found that thorough and transparent cost-benefit analyses and environmental impact assessments were rarely undertaken. They also discovered that Cambodia's draft water law was much more complex than it needed to be.<sup>[226]</sup>

In 2004, the UK charity WaterAid reported that a child dies every 15 seconds from easily preventable water-related diseases, which are often tied to a lack of adequate sanitation.<sup>[227]</sup><sup>[228]</sup>

Since 2003, the UN World Water Development Report, produced by the UNESCO World Water Assessment Programme, has provided decision-makers with tools for developing sustainable water policies.<sup>[229]</sup> The 2023 report states that two billion people (26% of the population) do not have access to drinking water and 3.6 billion (46%) lack access to safely managed sanitation.<sup>[230]</sup> People in urban areas

(2.4 billion) will face water scarcity by 2050.<sup>[229]</sup> Water scarcity has been described as endemic, due to overconsumption and pollution.<sup>[231]</sup> The report states that 10% of the world's population lives in countries with high or critical water stress. Yet over the past 40 years, water consumption has increased by around 1% per year, and is expected to grow at the same rate until 2050. Since 2000, flooding in the tropics has quadrupled, while flooding in northern mid-latitudes has increased by a factor of 2.5.<sup>[232]</sup> The cost of these floods between 2000 and 2019 was 100,000 deaths and \$650 million.<sup>[229]</sup>

Organizations concerned with water protection include the International Water Association (IWA), WaterAid, Water 1st, and the American Water Resources Association. The International Water Management Institute undertakes projects with the aim of using effective water management to reduce poverty. Water related conventions are United Nations Convention to Combat Desertification (UNCCD), International Convention for the Prevention of Pollution from Ships, United Nations Convention on the Law of the Sea and Ramsar Convention. World Day for Water takes place on 22 March<sup>[233]</sup> and World Oceans Day on 8 June.<sup>[234]</sup>

## **In culture**

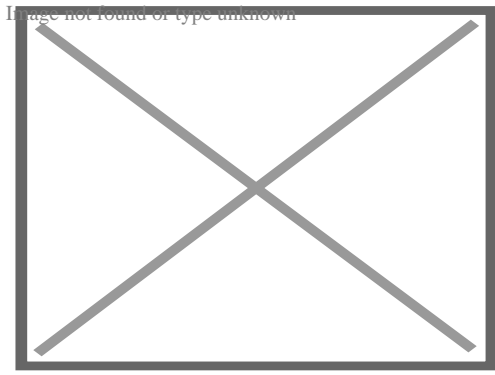
[edit]

## **Religion**

[edit]

Main article: Water and religion

See also: Sacred waters



People come to Inda Abba Hadera spring (Inda Sillasie, Ethiopia) to wash in holy water.

Water is considered a purifier in most religions. Faiths that incorporate ritual washing (ablution) include Christianity,<sup>[235]</sup> Hinduism, Islam, Judaism, the Rastafari movement, Shinto, Taoism, and Wicca. Immersion (or aspersion or affusion) of a person in water is a central Sacrament of Christianity (where it is called baptism); it is also a part of the practice of other religions, including Islam (*Ghusl*), Judaism (*mikvah*) and Sikhism (*Amrit Sanskar*). In addition, a ritual bath in pure water is performed for the dead in many religions including Islam and Judaism. In Islam, the five daily prayers can be done in most cases after washing certain parts of the body using clean water (*wudu*), unless water is unavailable (see *Tayammum*). In Shinto, water is used in almost all rituals to cleanse a person or an area (e.g., in the ritual of *misogi*).

In Christianity, holy water is water that has been sanctified by a priest for the purpose of baptism, the blessing of persons, places, and objects, or as a means of repelling evil.<sup>[236]</sup><sup>[237]</sup>

In Zoroastrianism, water (𐬀𐬎𐬌) is respected as the source of life.<sup>[238]</sup>

## Philosophy

[edit]

Icosahedron as a part of Spinoza monument in Amsterdam.

Image not found or type unknown

Icosahedron as a part of Spinoza monument in Amsterdam

The Ancient Greek philosopher Empedocles saw water as one of the four classical elements (along with fire, earth, and air), and regarded it as an ylem, or basic substance of the universe. Thales, whom Aristotle portrayed as an astronomer and an engineer, theorized that the earth, which is denser than water, emerged from the water. Thales, a monist, believed further that all things are made from water. Plato believed that the shape of water is an icosahedron – flowing easily compared to the cube-shaped earth.<sup>[239]</sup>

The theory of the four bodily humors associated water with phlegm, as being cold and moist. The classical element of water was also one of the five elements in traditional Chinese philosophy (along with earth, fire, wood, and metal).

Some traditional and popular Asian philosophical systems take water as a role-model. James Legge's 1891 translation of the *Dao De Jing* states, "The highest excellence is like (that of) water. The excellence of water appears in its benefiting all things, and in its occupying, without striving (to the contrary), the low place which all men dislike. Hence (its way) is near to (that of) the Tao" and "There is nothing in the world more soft and weak than water, and yet for attacking things that are firm and strong there is nothing that can take precedence of it—for there is nothing (so

effectual) for which it can be changed."<sup>[240]</sup> *Guanzi* in the "Shui di" 𐀓𐀠𐀗𐀓 chapter further elaborates on the symbolism of water, proclaiming that "man is water" and attributing natural qualities of the people of different Chinese regions to the character of local water resources.<sup>[241]</sup>

## Folklore

[edit]

"Living water" features in Germanic and Slavic folktales as a means of bringing the dead back to life. Note the Grimm fairy-tale ("The Water of Life") and the Russian dichotomy of living [ru] and dead water [ru]. The Fountain of Youth represents a related concept of magical waters allegedly preventing aging.

## Art and activism

[edit]

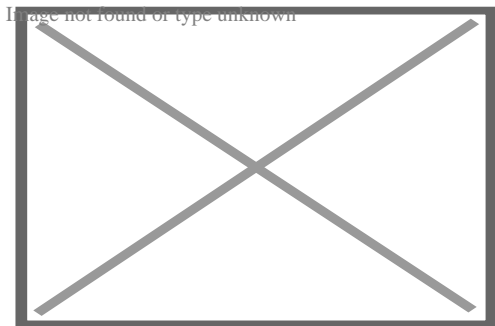
In the significant modernist novel *Ulysses* (1922) by Irish writer James Joyce, the chapter "Ithaca" takes the form of a catechism of 309 questions and answers, one of which is known as the "water hymn".<sup>[242]</sup> 𐀓𐀠𐀗𐀓 According to Richard E. Madtes, the hymn is not merely a "monotonous string of facts", rather, its phrases, like their subject, "ebb and flow, heave and swell, gather and break, until they subside into the calm quiescence of the concluding 'pestilential fens, faded flowerwater, stagnant pools in the waning moon.'"<sup>[242]</sup> 𐀓𐀠𐀗𐀓 The hymn is considered one of the most remarkable passages in Ithaca, and according to literary critic Hugh Kenner, achieves "the improbable feat of raising to poetry all the clutter of footling information that has accumulated in schoolbooks."<sup>[242]</sup> 𐀓𐀠𐀗𐀓 The literary motif of water represents the novel's theme of "everlasting, everchanging life," and the hymn represents the

culmination of the motif in the novel.<sup>[242]</sup> The following is the hymn quoted in full.<sup>[243]</sup>

What in water did Bloom, waterlover, drawer of water, watercarrier returning to the range, admire?

Its universality: its democratic equality and constancy to its nature in seeking its own level: its vastness in the ocean of Mercator's projection: its unplumbed profundity in the Sundam trench of the Pacific exceeding 8,000 fathoms: the restlessness of its waves and surface particles visiting in turn all points of its seaboard: the independence of its units: the variability of states of sea: its hydrostatic quiescence in calm: its hydrokinetic turgidity in neap and spring tides: its subsidence after devastation: its sterility in the circumpolar icecaps, arctic and antarctic: its climatic and commercial significance: its preponderance of 3 to 1 over the dry land of the globe: its indisputable hegemony extending in square leagues over all the region below the subequatorial tropic of Capricorn: the multiseccular stability of its primeval basin: its luteofulvous bed: its capacity to dissolve and hold in solution all soluble substances including millions of tons of the most precious metals: its slow erosions of peninsulas and downwardtending promontories: its alluvial deposits: its weight and volume and density: its imperturbability in lagoons and highland tarns: its gradation of colours in the torrid and temperate and frigid zones: its vehicular ramifications in continental lakecontained streams and confluent oceanflowing rivers with their tributaries and transoceanic currents: gulfstream, north and south equatorial courses: its violence in seaquakes, waterspouts, artesian wells, eruptions, torrents, eddies, freshets, spates, groundswells, watersheds, waterpartings, geysers, cataracts, whirlpools, maelstroms, inundations,

deluges, cloudbursts: its vast circumterrestrial ahorizontal curve: its secrecy in springs, and latent humidity, revealed by rhabdomantic or hygrometric instruments and exemplified by the well by the hole in the wall at Ashtown gate, saturation of air, distillation of dew: the simplicity of its composition, two constituent parts of hydrogen with one constituent part of oxygen: its healing virtues: its buoyancy in the waters of the Dead Sea: its persevering penetrativeness in runnels, gullies, inadequate dams, leaks on shipboard: its properties for cleansing, quenching thirst and fire, nourishing vegetation: its infallibility as paradigm and paragon: its metamorphoses as vapour, mist, cloud, rain, sleet, snow, hail: its strength in rigid hydrants: its variety of forms in loughs and bays and gulfs and bights and guts and lagoons and atolls and archipelagos and sounds and fjords and minches and tidal estuaries and arms of sea: its solidity in glaciers, icebergs, icefloes: its docility in working hydraulic millwheels, turbines, dynamos, electric power stations, bleachworks, tanneries, scutchmills: its utility in canals, rivers, if navigable, floating and graving docks: its potentiality derivable from harnessed tides or watercourses falling from level to level: its submarine fauna and flora (anacoustic, photophobe) numerically, if not literally, the inhabitants of the globe: its ubiquity as constituting 90% of the human body: the noxiousness of its effluvia in lacustrine marshes, pestilential fens, faded flowerwater, stagnant pools in the waning moon.



The vast "water hymn" in James Joyce's novel *Ulysses* is occasioned when the protagonist Leopold Bloom fills a kettle with water from a kitchen faucet.  
[<sup>243</sup>]

Painter and activist Fredericka Foster curated *The Value of Water*, at the Cathedral of St. John the Divine in New York City,<sup>[<sup>244</sup>]</sup> which anchored a year-long initiative by the Cathedral on our dependence on water.<sup>[<sup>245</sup>]</sup><sup>[<sup>246</sup>]</sup> The largest exhibition to ever appear at the Cathedral,<sup>[<sup>247</sup>]</sup> it featured over forty artists, including Jenny Holzer, Robert Longo, Mark Rothko, William Kentridge, April Gornik, Kiki Smith, Pat Steir, Alice Dalton Brown, Teresita Fernandez and Bill Viola.<sup>[<sup>248</sup>]</sup><sup>[<sup>249</sup>]</sup> Foster created Think About Water,<sup>[<sup>250</sup>]</sup> <sup>[full citation needed]</sup> an ecological collective of artists who use water as their subject or medium. Members include Basia Irland,<sup>[<sup>251</sup>]</sup> <sup>[full citation needed]</sup> Aviva Rahmani, Betsy Damon, Diane Burko, Leila Daw, Stacy Levy, Charlotte Côté,<sup>[<sup>252</sup>]</sup> Meridel Rubenstein, and Anna Macleod.

To mark the 10th anniversary of access to water and sanitation being declared a human right by the UN, the charity WaterAid commissioned ten visual artists to show the impact of clean water on people's lives.<sup>[<sup>253</sup>]</sup><sup>[<sup>254</sup>]</sup>

## **Dihydrogen monoxide parody**

[edit]

Main article: Dihydrogen monoxide parody

'Dihydrogen monoxide' is a technically correct but rarely used chemical name of water. This name has been used in a series of hoaxes and pranks that mock scientific illiteracy. This began in 1983, when an April Fools' Day article appeared in a newspaper in Durand, Michigan. The false story consisted of safety concerns about the substance.<sup>[<sup>255</sup>]</sup>














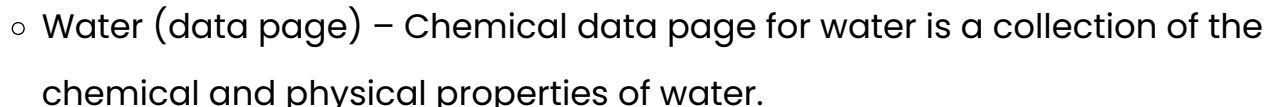

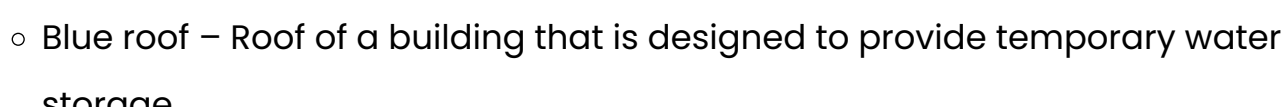


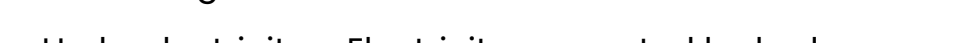
## Music

[edit]

The word "Water" has been used by many Florida based rappers as a sort of catchphrase or adlib. Rappers who have done this include BLP Kosher and Ski Mask the Slump God.<sup>[256]</sup> To go even further some rappers have made whole songs dedicated to the water in Florida, such as the 2023 Danny Towers song "Florida Water".<sup>[257]</sup> Others have made whole songs dedicated to water as a whole, such as XXXTentacion, and Ski Mask the Slump God with their hit song "H2O".

## See also

[edit]

-   
-   
-   
-   
- 
- 
- 
- 
- 
- 
- 

- List of waterfalls
- Marine current power – Extraction of power from ocean currents
- Marine energy – Energy available from oceans
- Mpemba effect – Natural phenomenon that hot water freezes faster than cold
- Oral rehydration therapy – Type of fluid replacement used to prevent and treat dehydration
- Osmotic power – Energy available from the difference in the salt concentration between seawater and river water
- Oxyhydrogen – Explosive mixture of hydrogen and oxygen gases
- Properties of water – Physical and chemical properties of pure water
- Rainwater tank – Container for collecting and storing rainwater
- Thirst – Craving for potable fluids experienced by animals
- Tidal power – Technology to convert the energy from tides into useful forms of power
- Water pinch analysis – systematic technique for reducing water consumption and wastewater generation
- Wave power – Transport of energy by wind waves, and the capture of that energy to do useful work
- Water filter – Device that removes impurities in water
- Water heat recycling – Use of a heat exchanger to recover energy and reuse heat from drain water
- Water recycling shower – Showers that use a basin and a pump to re-use the showering water
- Water-sensitive urban design – Integrated approach to urban water cycle

## **Notes**

[edit]

1. **^** A commonly quoted value of 15.7 used mainly in organic chemistry for the  $pK_a$  of water is incorrect.<sup>[12][13]</sup>
2. **^ a b** Vienna Standard Mean Ocean Water (VSMOW), used for calibration, melts at 273.150089(10) K (0.000089(10) °C, and boils at 373.1339 K (99.9839 °C). Other isotopic compositions melt or boil at slightly different temperatures.
3. **^** see the taste and odor section
4. **^** Other substances with this property include bismuth, silicon, germanium and gallium.<sup>[57]</sup>

## References

[edit]

1. **^** "naming molecular compounds". *www.iun.edu*. Archived from the original on 24 September 2018. Retrieved 1 October 2018. "Sometimes these compounds have generic or common names (e.g., H2O is "water") and they also have systematic names (e.g., H2O, dihydrogen monoxide)."
2. **^** "Definition of Hydrol". Merriam-Webster. Archived from the original on 13 August 2017. Retrieved 21 April 2019.
3. **^** Leigh, Favre & Metanomski 1998, p. 99.
4. **^** Braun CL, Smirnov SN (1 August 1993). "Why is water blue?" (PDF). *Journal of Chemical Education*. **70** (8): 612. Bibcode:1993JChEd..70..612B. doi:10.1021/ed070p612. ISSN 0021-9584. Archived (PDF) from the original on 1 December 2019. Retrieved 13 September 2023.
5. **^ a b c** Tanaka M, Girard G, Davis R, Peuto A, Bignell N (August 2001). "Recommended table for the density of water between 0 C and 40 C based on recent experimental reports". *Metrologia*. **38** (4): 301–309. Bibcode:2001Metro..38..301T. doi:10.1088/0026-1394/38/4/3.
6. **^** Lemmon EW, Bell IH, Huber ML, McLinden MO (1997). "Thermophysical Properties of Fluid Systems". In Linstrom P, Mallard W (eds.). *NIST Chemistry WebBook, NIST Standard Reference Database Number 69*. National Institute of Standards and Technology. doi:10.18434/T4D303. Archived from the original on 23 October 2023. Retrieved 17 October 2023.
7. **^** Lide 2003, Properties of Ice and Supercooled Water in Section 6.

8. ^ **a b c** Anatolievich KR. "Properties of substance: water". Archived from the original on 2 June 2014. Retrieved 1 June 2014.
9. ^ Lide 2003, Vapor Pressure of Water From 0 to 370 °C in Sec. 6.
10. ^ Lide 2003, Chapter 8: Dissociation Constants of Inorganic Acids and Bases.
11. ^ Weingärtner et al. 2016, p. 13.
12. ^ "What is the pKa of Water". University of California, Davis. 9 August 2015. Archived from the original on 14 February 2016. Retrieved 9 April 2016.
13. ^ Silverstein TP, Heller ST (17 April 2017). "pKa Values in the Undergraduate Curriculum: What Is the Real pKa of Water?". *Journal of Chemical Education*. **94** (6): 690–695. Bibcode:2017JChEd..94..690S. doi:10.1021/acs.jchemed.6b00623.
14. ^ Ramires ML, Castro CA, Nagasaka Y, Nagashima A, Assael MJ, Wakeham WA (1 May 1995). "Standard Reference Data for the Thermal Conductivity of Water". *Journal of Physical and Chemical Reference Data*. **24** (3): 1377–1381. Bibcode:1995JPCRD..24.1377R. doi:10.1063/1.555963. ISSN 0047-2689.
15. ^ Lide 2003, 8—Concentrative Properties of Aqueous Solutions: Density, Refractive Index, Freezing Point Depression, and Viscosity.
16. ^ Lide 2003, 6.186.
17. ^ **a b c d** Water in Linstrom, Peter J.; Mallard, William G. (eds.); *NIST Chemistry WebBook*, NIST Standard Reference Database Number 69, National Institute of Standards and Technology, Gaithersburg (MD)
18. ^ Lide 2003, 9—Dipole Moments.
19. ^ GHS: PubChem 962 Archived 2023-07-28 at the Wayback Machine
20. ^ "Water Q&A: Why is water the "universal solvent"?". Water Science School. United States Geological Survey, U.S. Department of the Interior. 20 June 2019. Archived from the original on 6 February 2021. Retrieved 15 January 2021.
21. ^ "10.2: Hybrid Orbitals in Water". Chemistry LibreTexts. 18 March 2020. Archived from the original on 30 July 2022. Retrieved 11 April 2021.
22. ^ Butler J. "The Earth – Introduction – Weathering". University of Houston. Archived from the original on 30 January 2023. Retrieved 30 January 2023. "Note that the Earth environment is close to the triple point and that water, steam and ice can all exist at the surface."

23. ^ **a b** "How Much Water is There on Earth?". Water Science School. United States Geological Survey, U.S. Department of the Interior. 13 November 2019. Archived from the original on 9 June 2022. Retrieved 8 June 2022.
24. ^ **a b** Gleick, P.H., ed. (1993). *Water in Crisis: A Guide to the World's Freshwater Resources*. Oxford University Press. p. 13, Table 2.1 "Water reserves on the earth". Archived from the original on 8 April 2013.
25. ^ Water Vapor in the Climate System Archived 20 March 2007 at the Wayback Machine, Special Report, [AGU], December 1995 (linked 4/2007). Vital Water Archived 20 February 2008 at the Wayback Machine UNEP.
26. ^ Baroni, L., Cenci, L., Tettamanti, M., Berati, M. (2007). "Evaluating the environmental impact of various dietary patterns combined with different food production systems". *European Journal of Clinical Nutrition*. **61** (2): 279–286. doi:10.1038/sj.ejcn.1602522. ISSN 0954-3007. PMID 17035955.
27. ^ Troell M, Naylor RL, Metian M, Beveridge M, Tyedmers PH, Folke C, et al. (16 September 2014). "Does aquaculture add resilience to the global food system?". *Proceedings of the National Academy of Sciences*. **111** (37): 13257–13263. Bibcode:2014PNAS..11113257T. doi:10.1073/pnas.1404067111. ISSN 0027-8424. PMC 4169979. PMID 25136111.
28. ^ "Water (v.)". *www.etymonline.com*. Online Etymology Dictionary. Archived from the original on 2 August 2017. Retrieved 20 May 2017.
29. ^ Luger R, Barnes R (February 2015). "Extreme Water Loss and Abiotic O<sub>2</sub> Buildup on Planets Throughout the Habitable Zones of M Dwarfs". *Astrobiology*. **15** (2): 119–143. arXiv:1411.7412. Bibcode:2015AsBio..15..119L. doi:10.1089/ast.2014.1231. ISSN 1531-1074. PMC 4323125. PMID 25629240.
30. ^ Pepin RO (July 1991). "On the origin and early evolution of terrestrial planet atmospheres and meteoritic volatiles". *Icarus*. **92** (1): 2–79. Bibcode:1991Icar...92....2P. doi:10.1016/0019-1035(91)90036-s. ISSN 0019-1035.
31. ^ Zahnle KJ, Gacesa M, Catling DC (January 2019). "Strange messenger: A new history of hydrogen on Earth, as told by Xenon". *Geochimica et Cosmochimica Acta*. **244**: 56–85. arXiv:1809.06960. Bibcode:2019GeCoA.244...56Z. doi:10.1016/j.gca.2018.09.017. ISSN 0016-7037. S2CID 119079927.
32. ^ Canup RM, Asphaug E (August 2001). "Origin of the Moon in a giant impact near the end of the Earth's formation". *Nature*. **412** (6848): 708–712. Bibcode:2001Natur.412..708C. doi:10.1038/35089010. ISSN 0028-0836. PMID 11507633. S2CID 4413525.
33. ^ Cuk M, Stewart ST (17 October 2012). "Making the Moon from a Fast-Spinning Earth: A Giant Impact Followed by Resonant Despinning". *Science*. **338** (6110): 1047–1052.

Bibcode:2012Sci...338.1047C. doi:10.1126/science.1225542. ISSN 0036-8075.  
PMID 23076099. S2CID 6909122.

34. ▲ Ding C, He Y, Yin J, Yao W, Zhou D, Wang J (18 February 2015). "Study on the Pressure Dependence of Boiling Point, Flashpoint, and Lower Flammability Limit at Low Ambient Pressure". *Industrial & Engineering Chemistry Research*. **54** (6): 1899–1907. doi:10.1021/ie503383a. ISSN 0888-5885.
35. ▲ Sleep NH, Zahnle K, Neuhoﬀ PS (2001). "Initiation of clement surface conditions on the earliest Earth". *Proceedings of the National Academy of Sciences*. **98** (7): 3666–3672. Bibcode:2001PNAS...98.3666S. doi:10.1073/pnas.071045698. PMC 31109. PMID 11259665.
36. ▲ a b Pinti DL, Arndt N (2014), "Oceans, Origin of", *Encyclopedia of Astrobiology*, Springer Berlin Heidelberg, pp. 1–5, doi:10.1007/978-3-642-27833-4\_1098-4, ISBN 978-3-642-27833-4
37. ▲ Cates N, Mojzsis S (March 2007). "Pre-3750 Ma supracrustal rocks from the Nuvvuagittuq supracrustal belt, northern Québec". *Earth and Planetary Science Letters*. **255** (1–2): 9–21. Bibcode:2007E&PSL.255....9C. doi:10.1016/j.epsl.2006.11.034. ISSN 0012-821X.
38. ▲ O'Neil J, Carlson RW, Paquette JL, Francis D (November 2012). "Formation age and metamorphic history of the Nuvvuagittuq Greenstone Belt" (PDF). *Precambrian Research*. 220–221: 23–44. Bibcode:2012PreR..220...23O. doi:10.1016/j.precamres.2012.07.009. ISSN 0301-9268.
39. ▲ Piani, Laurette (28 August 2020). "Earth's water may have been inherited from material similar to enstatite chondrite meteorites". *Science*. **369** (6507): 1110–1113. Bibcode:2020Sci...369.1110P. doi:10.1126/science.aba1948. PMID 32855337. S2CID 221342529. Retrieved 28 August 2020.
40. ▲ Washington University in St. Louis (27 August 2020). "Meteorite study suggests Earth may have been wet since it formed - Enstatite chondrite meteorites, once considered 'dry,' contain enough water to fill the oceans -- and then some". *EurekAlert!*. Retrieved 28 August 2020.
41. ▲ American Association for the Advancement of Science (27 August 2020). "Unexpected abundance of hydrogen in meteorites reveals the origin of Earth's water". *EurekAlert!*. Retrieved 28 August 2020.
42. ▲ Wilde S, Valley J, Peck W, Graham C (2001). "Evidence from detrital zircons for the existence of continental crust and oceans on the Earth 4.4 nGyr ago" (PDF). *Nature*. **409** (6817): 175–8. Bibcode:2001Natur.409..175W. doi:10.1038/35051550. PMID 11196637. S2CID 4319774.

43. ▲ "ANU - Research School of Earth Sciences - ANU College of Science - Harrison". *Ses.anu.edu.au*. Archived from the original on 21 June 2006. Retrieved 20 August 2009.
44. ▲ "ANU - OVC - MEDIA - MEDIA RELEASES - 2005 - NOVEMBER - 181105HARRISONCONTINENTS". *Info.anu.edu.au*. Retrieved 20 August 2009.
45. ▲ "A Cool Early Earth". *Geology.wisc.edu*. Archived from the original on 16 June 2013. Retrieved 20 August 2009.
46. ▲ Valley JW, Peck WH, King EM, Wilde SA (2002). "A cool early Earth". *Geology*. **30** (4): 351. Bibcode:2002Geo....30..351V. doi:10.1130/0091-7613(2002)030<0351:ACEE>2.0.CO;2. ISSN 0091-7613.
47. ▲ Nebel O, Rapp RP, Yaxley GM (1 March 2014). "The role of detrital zircons in Hadean crustal research". *Lithos*. 190–191: 313–327. doi:10.1016/j.lithos.2013.12.010. ISSN 0024-4937.
48. ▲ Chang K (2 December 2008). "A New Picture of the Early Earth". *The New York Times*. Retrieved 20 May 2010.
49. ▲ Greenwood NN, Earnshaw A (1997). *Chemistry of the Elements* (2nd ed.). Butterworth-Heinemann. p. 620. ISBN 978-0-08-037941-8.
50. ▲ "Water, the Universal Solvent". *USGS*. Archived from the original on 9 July 2017. Retrieved 27 June 2017.
51. ▲ "Solvent properties of water". *Khan Academy*.
52. ▲ Reece JB (2013). *Campbell Biology* (10th ed.). Pearson. p. 48. ISBN 978-0-321-77565-8.
53. ▲ Reece JB (2013). *Campbell Biology* (10th ed.). Pearson. p. 44. ISBN 978-0-321-77565-8.
54. ▲ Leigh GJ, Favre HA, Metanomski WV (1998). *Principles of chemical nomenclature: a guide to IUPAC recommendations* (PDF). Oxford: Blackwell Science. ISBN 978-0-86542-685-6. OCLC 37341352. Archived from the original (PDF) on 26 July 2011.
55. ▲ PubChem. "Water". National Center for Biotechnology Information. Archived from the original on 3 August 2018. Retrieved 25 March 2020.
56. ▲ a b Belnay L. "The water cycle" (PDF). *Critical thinking activities. Earth System Research Laboratory*. Archived (PDF) from the original on 20 September 2020. Retrieved 25 March 2020.
57. ▲ a b Oliveira MJ (2017). *Equilibrium Thermodynamics*. Springer. pp. 120–124. ISBN 978-3-662-53207-2. Archived from the original on 8 March 2021. Retrieved 26 March 2020.
58. ▲ "What is Density?". *Mettler Toledo*. Archived from the original on 11 November 2022. Retrieved 11 November 2022.

59. ^ **a b** Ball P (2008). "Water – an enduring mystery". *Nature*. **452** (7185): 291–2. Bibcode:2008Natur.452..291B. doi:10.1038/452291a. PMID 18354466. S2CID 4365814. Archived from the original on 17 November 2016. Retrieved 15 November 2016.
60. ^ Kotz JC, Treichel P, Weaver GC (2005). *Chemistry & Chemical Reactivity*. Thomson Brooks/Cole. ISBN 978-0-534-39597-1.
61. ^ Ben-Naim A, Ben-Naim R, et al. (2011). *Alice's Adventures in Water-land*. doi:10.1142/8068. ISBN 978-981-4338-96-7.
62. ^ Matsuoka N, Murton J (2008). "Frost weathering: recent advances and future directions". *Permafrost and Periglacial Processes*. **19** (2): 195–210. Bibcode:2008PPPr...19..195M. doi:10.1002/ppp.620. S2CID 131395533.
63. ^ Wiltse B. "A Look Under The Ice: Winter Lake Ecology". Ausable River Association. Archived from the original on 19 June 2020. Retrieved 23 April 2020.
64. ^ **a b** Chen Z (21 April 2010). "Measurement of Diamagnetism in Water". hdl:11299/90865. Archived from the original on 8 January 2022. Retrieved 8 January 2022.
65. ^ Wells S (21 January 2017). "The Beauty and Science of Snowflakes". Smithsonian Science Education Center. Archived from the original on 25 March 2020. Retrieved 25 March 2020.
66. ^ Fellows P (2017). "Freeze drying and freeze concentration". *Food processing technology: principles and practice* (4th ed.). Kent: Woodhead Publishing/Elsevier Science. pp. 929–940. ISBN 978-0-08-100523-1. OCLC 960758611.
67. ^ Siegert MJ, Ellis-Evans JC, Tranter M, Mayer C, Petit JR, Salamatin A, et al. (December 2001). "Physical, chemical and biological processes in Lake Vostok and other Antarctic subglacial lakes". *Nature*. **414** (6864): 603–609. Bibcode:2001Natur.414..603S. doi:10.1038/414603a. PMID 11740551. S2CID 4423510.
68. ^ Davies B. "Antarctic subglacial lakes". *AntarcticGlaciers*. Archived from the original on 3 October 2020. Retrieved 25 March 2020.
69. ^ Masterton WL, Hurley CN (2008). *Chemistry: principles and reactions* (6th ed.). Cengage Learning. p. 230. ISBN 978-0-495-12671-3. Archived from the original on 8 March 2021. Retrieved 3 April 2020.
70. ^ Peaco J. "Yellowstone Lesson Plan: How Yellowstone Geysers Erupt". Yellowstone National Park: U.S. National Park Service. Archived from the original on 2 March 2020. Retrieved 5 April 2020.
71. ^ Brahic C. "Found: The hottest water on Earth". *New Scientist*. Archived from the original on 9 May 2020. Retrieved 5 April 2020.

72. ▲ USDA Food Safety and Inspection Service. "High Altitude Cooking and Food Safety" (PDF). Archived from the original (PDF) on 20 January 2021. Retrieved 5 April 2020.
73. ▲ "Pressure Cooking – Food Science". Exploratorium. 26 September 2019. Archived from the original on 19 June 2020. Retrieved 21 April 2020.
74. ▲ Allain R (12 September 2018). "Yes, You Can Boil Water at Room Temperature. Here's How". Wired. Archived from the original on 28 September 2020. Retrieved 5 April 2020.
75. ▲ Murphy DM, Koop T (1 April 2005). "Review of the vapour pressures of ice and supercooled water for atmospheric applications". *Quarterly Journal of the Royal Meteorological Society*. **131** (608): 1540. Bibcode:2005QJRMS.131.1539M. doi:10.1256/qj.04.94. S2CID 122365938. Archived from the original on 18 August 2020. Retrieved 31 August 2020.
76. ▲ International Bureau of Weights and Measures (2006). *The International System of Units (SI) (PDF) (8th ed.)*. Bureau International des Poids et Mesures. p. 114. ISBN 92-822-2213-6. Archived (PDF) from the original on 14 August 2017.
77. ▲ "9th edition of the SI Brochure". BIPM. 2019. Archived from the original on 19 April 2021. Retrieved 20 May 2019.
78. ▲ Wagner W, Pruß A (June 2002). "The IAPWS Formulation 1995 for the Thermodynamic Properties of Ordinary Water Substance for General and Scientific Use". *Journal of Physical and Chemical Reference Data*. **31** (2): 398. doi:10.1063/1.1461829.
79. ▲ Weingärtner H, Franck EU (29 April 2005). "Supercritical Water as a Solvent". *Angewandte Chemie International Edition*. **44** (18): 2672–2692. doi:10.1002/anie.200462468. PMID 15827975.
80. ▲ Adschiri T, Lee YW, Goto M, Takami S (2011). "Green materials synthesis with supercritical water". *Green Chemistry*. **13** (6): 1380. doi:10.1039/c1gc15158d.
81. ▲ Murray BJ, Knopf DA, Bertram AK (2005). "The formation of cubic ice under conditions relevant to Earth's atmosphere". *Nature*. **434** (7030): 202–205. Bibcode:2005Natur.434..202M. doi:10.1038/nature03403. PMID 15758996. S2CID 4427815.
82. ▲ Salzmann CG (14 February 2019). "Advances in the experimental exploration of water's phase diagram". *The Journal of Chemical Physics*. **150** (6): 060901. arXiv:1812.04333. Bibcode:2019JChPh.150f0901S. doi:10.1063/1.5085163. PMID 30770019.
83. ▲ Sokol J (12 May 2019). "A Bizarre Form of Water May Exist All Over the Universe". Wired . Archived from the original on 12 May 2019. Retrieved 1 September 2021.
84. ▲ Millot M, Coppari F, Rygg JR, Barrios AC, Hamel S, Swift DC, et al. (2019). "Nanosecond X-ray diffraction of shock-compressed superionic water ice". *Nature*. **569** (7755). Springer: 251–255. Bibcode:2019Natur.569..251M. doi:10.1038/s41586-019-1114-6. OSTI 1568026.

PMID 31068720. S2CID 148571419. Archived from the original on 9 July 2023. Retrieved 5 March 2024.

85. ▲ Peplow M (25 March 2015). "Graphene sandwich makes new form of ice". *Nature*. doi:10.1038/nature.2015.17175. S2CID 138877465.
86. ▲ Maestro LM, Marqués MI, Camarillo E, Jaque D, Solé JG, Gonzalo JA, et al. (1 January 2016). "On the existence of two states in liquid water: impact on biological and nanoscopic systems" (PDF). *International Journal of Nanotechnology*. **13** (8–9): 667–677. Bibcode:2016IJNT...13..667M. doi:10.1504/IJNT.2016.079670. S2CID 5995302. Archived (PDF) from the original on 15 November 2023. Retrieved 5 March 2024.
87. ▲ Mallamace F, Corsaro C, Stanley HE (18 December 2012). "A singular thermodynamically consistent temperature at the origin of the anomalous behavior of liquid water". *Scientific Reports*. **2** (1): 993. Bibcode:2012NatSR...2..993M. doi:10.1038/srep00993. PMC 3524791. PMID 23251779.
88. ▲ Perakis F, Amann-Winkel K, Lehmkuhler F, Sprung M, Mariedahl D, Sellberg JA, et al. (26 June 2017). "Diffusive dynamics during the high-to-low density transition in amorphous ice". *Proceedings of the National Academy of Sciences of the United States of America*. **13** (8–9): 667–677. Bibcode:2017PNAS..114.8193P. doi:10.1073/pnas.1705303114. PMC 5547632. PMID 28652327.
89. ▲ Zocchi D, Wennemuth G, Oka Y (July 2017). "The cellular mechanism for water detection in the mammalian taste system" (PDF). *Nature Neuroscience*. **20** (7): 927–933. doi:10.1038/nn.4575. PMID 28553944. S2CID 13263401. Archived from the original on 5 March 2024. Retrieved 27 January 2024.
90. ▲ Edmund T. Rolls (2005). *Emotion Explained*. Oxford University Press, Medical. ISBN 978-0198570035.
91. ▲ R. Llinas, W. Precht (2012), *Frog Neurobiology: A Handbook*. Springer Science & Business Media. ISBN 978-3642663161
92. ▲ Candau J (2004). "The Olfactory Experience: constants and cultural variables". *Water Science and Technology*. **49** (9): 11–17. Bibcode:2004WSTec..49...11C. doi:10.2166/wst.2004.0522. PMID 15237601. Archived from the original on 2 October 2016. Retrieved 28 September 2016.
93. ▲ Braun CL, Sergei N. Smirnov (1993). "Why is water blue?". *Journal of Chemical Education*. **70** (8): 612. Bibcode:1993JChEd..70..612B. doi:10.1021/ed070p612. Archived from the original on 20 March 2012. Retrieved 21 April 2007.
94. ▲ Nakamoto K (1997). *Infrared and Raman Spectra of Inorganic and Coordination Compounds, Part A: Theory and Applications in Inorganic Chemistry* (5th ed.). New York: Wiley. p. 170. ISBN 0-471-16394-5.

95. ▲ Ball 2001, p. 168
96. ▲ Franks 2007, p. 10
97. ▲ "Physical Chemistry of Water". Michigan State University. Archived from the original on 20 October 2020. Retrieved 11 September 2020.
98. ▲ Ball 2001, p. 169
99. ▲ Isaacs ED, Shukla A, Platzman PM, Hamann DR, Barbiellini B, Tulk CA (1 March 2000). "Compton scattering evidence for covalency of the hydrogen bond in ice". *Journal of Physics and Chemistry of Solids*. **61** (3): 403–406. Bibcode:2000JPCS...61..403I. doi:10.1016/S0022-3697(99)00325-X.
100. ▲ Campbell NA, Williamson B, Heyden RJ (2006). *Biology: Exploring Life*. Boston: Pearson Prentice Hall. ISBN 978-0-13-250882-7. Archived from the original on 2 November 2014. Retrieved 11 November 2008.
101. ▲ "Heat capacity water online". Desmos (in Russian). Archived from the original on 6 June 2022. Retrieved 3 June 2022.
102. ▲ Ball P (14 September 2007). "Burning water and other myths". *News@nature*. doi:10.1038/news070910-13. S2CID 129704116. Archived from the original on 28 February 2009. Retrieved 14 September 2007.
103. ▲ Fine RA, Millero FJ (1973). "Compressibility of water as a function of temperature and pressure". *Journal of Chemical Physics*. **59** (10): 5529. Bibcode:1973JChPh..59.5529F. doi:10.1063/1.1679903.
104. ▲ Nave R. "Bulk Elastic Properties". *HyperPhysics*. Georgia State University. Archived from the original on 28 October 2007. Retrieved 26 October 2007.
105. ▲ UK National Physical Laboratory, Calculation of absorption of sound in seawater Archived 3 October 2016 at the Wayback Machine. Online site, last accessed on 28 September 2016.
106. ▲ Gleick PH, ed. (1993). *Water in Crisis: A Guide to the World's Freshwater Resources*. Oxford University Press. p. 15, Table 2.3. Archived from the original on 8 April 2013.
107. ▲ Ben-Naim A, Ben-Naim R (2011). *Alice's Adventures in Water-land*. World Scientific Publishing. p. 31. doi:10.1142/8068. ISBN 978-981-4338-96-7.
108. ▲ "water resource". *Encyclopædia Britannica*. Archived from the original on 2 October 2022. Retrieved 17 May 2022.
109. ▲ Gleick PH (1993). *Water in Crisis*. New York: Oxford University Press. p. 13. ISBN 0-19-507627-3.

110. ▲ Wada Y, Van Beek LP, Bierkens MF (2012). "Nonsustainable groundwater sustaining irrigation: A global assessment". *Water Resources Research*. **48** (6): W00L06. Bibcode:2012WRR....48.0L06W. doi:10.1029/2011WR010562.
111. ▲ "Catalyst helps split water: Plants". AskNature. Archived from the original on 28 October 2020. Retrieved 10 September 2020.
112. ▲ Hall D (2001). *Photosynthesis, Sixth edition*. University of Cambridge. ISBN 0-521-64497-6. Archived from the original on 5 October 2023. Retrieved 26 August 2023.
113. ▲ "On Water". European Investment Bank. Archived from the original on 14 October 2020. Retrieved 13 October 2020.
114. ▲ Jammi R (13 March 2018). "2.4 billion Without Adequate Sanitation. 600 million Without Safe Water. Can We Fix it by 2030?". World Bank Group. Archived from the original on 14 October 2020. Retrieved 13 October 2020.
115. ▲ "Wastewater resource recovery can fix water insecurity and cut carbon emissions". European Investment Bank. Archived from the original on 29 August 2022. Retrieved 29 August 2022.
116. ▲ "International Decade for Action 'Water for Life' 2005–2015. Focus Areas: Water scarcity". United Nations. Archived from the original on 23 May 2020. Retrieved 29 August 2022.
117. ▲ "The State of the World's Land and Water Resources for Food and Agriculture" (PDF). Archived (PDF) from the original on 31 August 2022. Retrieved 30 August 2022.
118. ▲ "World Health Organization. Safe Water and Global Health". World Health Organization. 25 June 2008. Archived from the original on 24 December 2010. Retrieved 25 July 2010.
119. ▲ UNEP International Environment (2002). *Environmentally Sound Technology for Wastewater and Stormwater Management: An International Source Book*. IWA. ISBN 978-1-84339-008-4. OCLC 49204666.
120. ▲ Ravindranath NH, Sathaye JA (2002). *Climate Change and Developing Countries*. Springer. ISBN 978-1-4020-0104-8. OCLC 231965991.
121. ▲ "Water withdrawals per capita". Our World in Data. Archived from the original on 12 March 2020. Retrieved 6 March 2020.
122. ▲ "WBCSD Water Facts & Trends". Archived from the original on 1 March 2012. Retrieved 25 July 2010.
123. ▲ Dieter CA, Maupin MA, Caldwell RR, Harris MA, Ivahnenko TI, Lovelace JK, et al. (2018). "Estimated use of water in the United States in 2015". Circular. U.S. Geological Survey. p. 76. doi:10.3133/cir1441. Archived from the original on 28 April 2019. Retrieved 21 May 2019.

124. ▲ Gleick PH, Palaniappan M (2010). "Peak Water" (PDF). *Proceedings of the National Academy of Sciences*. **107** (125): 11155–11162. Bibcode:2010PNAS..10711155G. doi: 10.1073/pnas.1004812107. PMC 2895062. PMID 20498082. Archived (PDF) from the original on 8 November 2011. Retrieved 11 October 2011.
125. ▲ United Nations Press Release POP/952 (13 March 2007). "World population will increase by 2.5 billion by 2050". Archived 27 July 2014 at the Wayback Machine
126. ▲ , Molden, D. (Ed). *Water for food, Water for life: A Comprehensive Assessment of Water Management in Agriculture*. Earthscan/IWMI, 2007.
127. ▲ Chartres, C. and Varma, S. (2010) *Out of water. From Abundance to Scarcity and How to Solve the World's Water Problems*. FT Press (US).
128. ▲ Chapagain AK, Hoekstra AY, Savenije HH, Guatam R (September 2005). "The Water Footprint of Cotton Consumption" (PDF). IHE Delft Institute for Water Education. Archived (PDF) from the original on 26 March 2019. Retrieved 24 October 2019.
129. ▲ "Décret relatif aux poids et aux mesures" [Decree relating to weights and measures] (in French). 18 germinal an 3 (7 April 1795). Archived 25 February 2013 at the Wayback Machine. quartier-rural.org
130. ▲ here "L'Histoire Du Mètre, La Détermination De L'Unité De Poids" Archived 25 July 2013 at the Wayback Machine. histoire.du.metre.free.fr
131. ▲ "Re: What percentage of the human body is composed of water?" Archived 25 November 2007 at the Wayback Machine Jeffrey Utz, M.D., The MadSci Network
132. ▲ "Healthy Water Living". *BBC Health*. Archived from the original on 1 January 2007. Retrieved 1 February 2007.
133. ▲ Rhoades RA, Tanner GA (2003). *Medical Physiology* (2nd ed.). Baltimore: Lippincott Williams & Wilkins. ISBN 978-0-7817-1936-0. OCLC 50554808.
134. ▲ Noakes TD, Goodwin N, Rayner BL, et al. (1985). "Water intoxication: a possible complication during endurance exercise". *Medicine and Science in Sports and Exercise*. **17** (3): 370–375. doi:10.1249/00005768-198506000-00012. PMID 4021781.
135. ▲ Noakes TD, Goodwin N, Rayner BL, Branken T, Taylor RK (2005). "Water intoxication: a possible complication during endurance exercise, 1985". *Wilderness and Environmental Medicine*. **16** (4): 221–227. doi:10.1580/1080-6032(2005)16[221:WIAPCD]2.0.CO;2. PMID 16366205. S2CID 28370290.

136. ▲ Valtin H (2002). "'Drink at least eight glasses of water a day.' Really? Is there scientific evidence for '8 × 8'?" (PDF). *American Journal of Physiology. Regulatory, Integrative and Comparative Physiology*. **283** (5): R993 – R1004. doi:10.1152/ajpregu.00365.2002. PMID 12376390. S2CID 2256436. Archived from the original (PDF) on 22 February 2019.
137. ▲ Stookey JD, Constant F, Popkin BM, Gardner CD (November 2008). "Drinking water is associated with weight loss in overweight dieting women independent of diet and activity". *Obesity*. **16** (11): 2481–2488. doi:10.1038/oby.2008.409. PMID 18787524. S2CID 24899383.
138. ▲ "Drink water to curb weight gain? Clinical trial confirms effectiveness of simple appetite control method". *Science Daily*. 23 August 2010. Archived from the original on 7 July 2017. Retrieved 14 May 2017.
139. ▲ Dubnov-Raz G, Constantini NW, Yariv H, Nice S, Shapira N (October 2011). "Influence of water drinking on resting energy expenditure in overweight children". *International Journal of Obesity*. **35** (10): 1295–1300. doi:10.1038/ijo.2011.130. PMID 21750519. S2CID 27561994.
140. ▲ Dennis EA, Dengo AL, Comber DL, et al. (February 2010). "Water consumption increases weight loss during a hypocaloric diet intervention in middle-aged and older adults". *Obesity*. **18** (2): 300–307. doi:10.1038/oby.2009.235. PMC 2859815. PMID 19661958.
141. ▲ Vij VA, Joshi AS (September 2013). "Effect of 'water induced thermogenesis' on body weight, body mass index and body composition of overweight subjects". *Journal of Clinical and Diagnostic Research*. **7** (9): 1894–1896. doi:10.7860/JCDR/2013/5862.3344. PMC 3809630. PMID 24179891.
142. ▲ Muckelbauer R, Sarganas G, Grüneis A, Müller-Nordhorn J (August 2013). "Association between water consumption and body weight outcomes: a systematic review". *The American Journal of Clinical Nutrition*. **98** (2): 282–299. doi:10.3945/ajcn.112.055061. PMID 23803882. S2CID 12265434.
143. ▲ "Water, Constipation, Dehydration, and Other Fluids". Archived 4 March 2015 at the Wayback Machine. *Science Daily*. Retrieved on 28 September 2015.
144. ▲ Food and Nutrition Board, National Academy of Sciences. *Recommended Dietary Allowances. National Research Council, Reprint and Circular Series, No. 122. 1945. pp. 3–18.*
145. ▲ Institute of Medicine, Food Nutrition Board, Standing Committee on the Scientific Evaluation of Dietary Reference Intakes, Panel on Dietary Reference Intakes for Electrolytes and Water (2005). *4 Water | Dietary Reference Intakes for Water, Potassium, Sodium, Chloride, and Sulfate. The National Academies Press.* doi:10.17226/10925. ISBN 978-0-309-09169-5. Archived from the original on 13 January 2017. Retrieved 11 January

2017.

146. ▲ "Water: How much should you drink every day?". Mayo Clinic. Archived from the original on 4 December 2010. Retrieved 25 July 2010.
147. ▲ *Conquering Chemistry* (4th ed.), 2008
148. ▲ Maton A, Hopkins J, McLaughlin CW, Johnson S, Warner MQ, LaHart D, et al. (1993). *Human Biology and Health*. Englewood Cliffs, New Jersey: Prentice Hall. ISBN 978-0-13-981176-0. OCLC 32308337.
149. ▲ Unesco (2006). *Water: a shared responsibility*. Berghahn Books. p. 125. ISBN 978-1-84545-177-6.
150. ▲ Bockmühl DP, Schages J, Rehberg L (2019). "Laundry and textile hygiene in healthcare and beyond". *Microbial Cell*. **6** (7): 299–306. doi:10.15698/mic2019.07.682. ISSN 2311-2638. PMC 6600116. PMID 31294042.
151. ▲ Moyer MW (23 October 2023). "Do You Really Need to Shower Every Day?". *The New York Times*. ISSN 0362-4331. Retrieved 22 April 2024.
152. ▲ Hadaway A (2 January 2020). "Handwashing: Clean Hands Save Lives". *Journal of Consumer Health on the Internet*. **24** (1): 43–49. doi:10.1080/15398285.2019.1710981. ISSN 1539-8285.
153. ▲ Ettinger J (22 October 2018). "You Probably Wash Your Hair Way Too Much (Really!)". *Organic Authority*. Retrieved 22 April 2024.
154. ▲ Petersen EE (7 December 2005). *Infections in Obstetrics and Gynecology: Textbook and Atlas*. Thieme. pp. 6–13. ISBN 978-3-13-161511-4.
155. ▲ Stopford M (1 January 1997). *Maritime Economics*. Psychology Press. p. 10. ISBN 9780415153102.
156. ▲ "Water Use in the United States", *National Atlas*. Archived 14 August 2009 at the Wayback Machine
157. ▲ "Material Safety Data Sheet: Quicklime" (PDF). Lhoist North America. 6 August 2012. Archived (PDF) from the original on 5 July 2016. Retrieved 24 October 2019.
158. ▲ Duff LB (1916). *A Course in Household Arts: Part I*. Whitcomb & Barrows. Archived from the original on 14 April 2021. Retrieved 3 December 2017.
159. ▲ **a b** Vaclavik VA, Christian EW (2007). *Essentials of Food Science*. Springer. ISBN 978-0-387-69939-4. Archived from the original on 14 April 2021. Retrieved 31 August 2020.
160. ▲ **a b** DeMan JM (1999). *Principles of Food Chemistry*. Springer. ISBN 978-0-8342-1234-3. Archived from the original on 14 April 2021. Retrieved 31 August 2020.

161. ▲ *"Map showing the rate of hardness in mg/L as Calcium carbonate in England and Wales"* (PDF). DEFRA Drinking Water Inspectorate. 2009. Archived (PDF) from the original on 29 May 2015. Retrieved 18 May 2015.
162. ▲ *"Water hardness"*. US Geological Service. 8 April 2014. Archived from the original on 18 May 2015. Retrieved 18 May 2015.
163. ▲ Mekonnen MM, Hoekstra AY (December 2010). *The green, blue and grey water footprint of farm animals and animal products, Value of Water (PDF) (Report)*. Research Report Series. Vol. 1. UNESCO – IHE Institute for Water Education. Archived (PDF) from the original on 27 May 2014. Retrieved 30 January 2014.
164. ▲ *"WHO Model List of Essential Medicines"* (PDF). World Health Organization. October 2013. Archived (PDF) from the original on 23 April 2014. Retrieved 22 April 2014.
165. ▲ *"ALMA Greatly Improves Capacity to Search for Water in Universe"*. Archived from the original on 23 July 2015. Retrieved 20 July 2015.
166. ▲ Melnick, Gary, Harvard-Smithsonian Center for Astrophysics and Neufeld, David, Johns Hopkins University quoted in: *"Discover of Water Vapor Near Orion Nebula Suggests Possible Origin of H<sub>2</sub>O in Solar System (sic)"*. The Harvard University Gazette. 23 April 1998. Archived from the original on 16 January 2000. *"Space Cloud Holds Enough Water to Fill Earth's Oceans 1 Million Times"*. Headlines@Hopkins, JHU. 9 April 1998. Archived from the original on 9 November 2007. Retrieved 21 April 2007. *"Water, Water Everywhere: Radio telescope finds water is common in universe"*. The Harvard University Gazette. 25 February 1999. Archived from the original on 19 May 2011. Retrieved 19 September 2010. (archive link)
167. ▲ **a b** Clavin W, Buis A (22 July 2011). *"Astronomers Find Largest, Most Distant Reservoir of Water"*. NASA. Archived from the original on 24 July 2011. Retrieved 25 July 2011.
168. ▲ **a b** Staff (22 July 2011). *"Astronomers Find Largest, Oldest Mass of Water in Universe"*. Space.com. Archived from the original on 29 October 2011. Retrieved 23 July 2011.
169. ▲ Bova B (2009). *Faint Echoes, Distant Stars: The Science and Politics of Finding Life Beyond Earth*. Zondervan. ISBN 978-0-06-185448-4. Archived from the original on 14 April 2021. Retrieved 31 August 2020.
170. ▲ Solanki S, Livingston W, Ayres T (1994). *"New Light on the Heart of Darkness of the Solar Chromosphere"* (PDF). Science. **263** (5143): 64–66. Bibcode:1994Sci...263...64S. doi:10.1126/science.263.5143.64. PMID 17748350. S2CID 27696504. Archived from the original (PDF) on 7 March 2019.
171. ▲ *"MESSENGER Scientists 'Astonished' to Find Water in Mercury's Thin Atmosphere"*. Planetary Society. 3 July 2008. Archived from the original on 6 April 2010. Retrieved 5 July

2008.

172. ▲ Bertaux JL, Vandaele, Ann-Carine, Korablev O, Villard E, Fedorova A, Fussen D, et al. (2007). "A warm layer in Venus' cryosphere and high-altitude measurements of HF, HCl, H<sub>2</sub>O and HDO" (PDF). *Nature*. **450** (7170): 646–649. Bibcode:2007Natur.450..646B. doi:10.1038/nature05974. hdl:2268/29200. PMID 18046397. S2CID 4421875. Archived (PDF) from the original on 7 September 2022. Retrieved 8 October 2022.
173. ▲ Sridharan R, Ahmed S, Dasa TP, Sreelatha P, Pradeepkumara P, Naika N, et al. (2010). "'Direct' evidence for water (H<sub>2</sub>O) in the sunlit lunar ambience from CHACE on MIP of Chandrayaan I". *Planetary and Space Science*. **58** (6): 947. Bibcode:2010P&SS...58..947S. doi:10.1016/j.pss.2010.02.013.
174. ▲ Rapp, Donald (2012). *Use of Extraterrestrial Resources for Human Space Missions to Moon or Mars*. Springer. p. 78. ISBN 978-3-642-32762-9. Archived from the original on 15 July 2016. Retrieved 9 February 2016.
175. ▲ Küppers M, O'Rourke L, Bockelée-Morvan D, Zakharov V, Lee S, Von Allmen P, et al. (23 January 2014). "Localized sources of water vapour on the dwarf planet (1) Ceres". *Nature*. **505** (7484): 525–527. Bibcode:2014Natur.505..525K. doi:10.1038/nature12918. PMID 24451541. S2CID 4448395.
176. ▲ Atreya SK, Wong AS (2005). "Coupled Clouds and Chemistry of the Giant Planets – A Case for Multiprobes" (PDF). *Space Science Reviews*. **116** (1–2): 121–136. Bibcode:2005SSRv..116..121A. doi:10.1007/s11214-005-1951-5. hdl:2027.42/43766. S2CID 31037195. Archived (PDF) from the original on 22 July 2011. Retrieved 1 April 2014 .
177. ▲ Cook JR, Gutro R, Brown D, Harrington J, Fohn J (12 December 2013). "Hubble Sees Evidence of Water Vapor at Jupiter Moon". NASA. Archived from the original on 15 December 2013. Retrieved 12 December 2013.
178. ▲ Hansen, C.J., Stewart AI, Colwell J, Hendrix A, Pryor W, et al. (2006). "Enceladus' Water Vapor Plume" (PDF). *Science*. **311** (5766): 1422–1425. Bibcode:2006Sci...311.1422H. doi:10.1126/science.1121254. PMID 16527971. S2CID 2954801. Archived from the original (PDF) on 18 February 2020.
179. ▲ Hubbard W (1997). "Neptune's Deep Chemistry". *Science*. **275** (5304): 1279–1280. doi:10.1126/science.275.5304.1279. PMID 9064785. S2CID 36248590.
180. ▲ Water Found on Distant Planet Archived 16 July 2007 at the Wayback Machine 12 July 2007 By Laura Blue, *Time*
181. ▲ Water Found in Extrasolar Planet's Atmosphere Archived 30 December 2010 at the Wayback Machine – Space.com

182. ▲ Lockwood AC, Johnson JA, Bender CF, Carr JS, Barman T, Richert AJ, et al. (2014). "Near-IR Direct Detection of Water Vapor in Tau Boo B". *The Astrophysical Journal*. **783** (2): L29. arXiv:1402.0846. Bibcode:2014ApJ...783L..29L. doi:10.1088/2041-8205/783/2/L29. S2CID 8463125.
183. ▲ Clavin W, Chou F, Weaver D, Villard, Johnson M (24 September 2014). "NASA Telescopes Find Clear Skies and Water Vapor on Exoplanet". NASA. Archived from the original on 14 January 2017. Retrieved 24 September 2014.
184. ▲ **a b c** Arnold Hanslmeier (2010). *Water in the Universe*. Springer Science & Business Media. pp. 159—. ISBN 978-90-481-9984-6. Archived from the original on 15 July 2016. Retrieved 9 February 2016.
185. ▲ "Hubble Traces Subtle Signals of Water on Hazy Worlds". NASA. 3 December 2013. Archived from the original on 6 December 2013. Retrieved 4 December 2013.
186. ▲ **a b** Andersson, Jonas (June 2012). Water in stellar atmospheres "Is a novel picture required to explain the atmospheric behavior of water in red giant stars?" Archived 13 February 2015 at the Wayback Machine Lund Observatory, Lund University, Sweden
187. ▲ Herschel Finds Oceans of Water in Disk of Nearby Star Archived 19 February 2015 at the Wayback Machine. Nasa.gov (20 October 2011). Retrieved on 28 September 2015.
188. ▲ "JPL". NASA Jet Propulsion Laboratory (JPL). Archived from the original on 4 June 2012.
189. ▲ Lloyd, Robin. "Water Vapor, Possible Comets, Found Orbiting Star", 11 July 2001, Space.com. Retrieved 15 December 2006. Archived 23 May 2009 at the Wayback Machine
190. ▲ "NASA Confirms Evidence That Liquid Water Flows on Today's Mars". NASA. 28 September 2015. Archived from the original on 28 September 2015. Retrieved 22 June 2020.
191. ▲ Platt J, Bell B (3 April 2014). "NASA Space Assets Detect Ocean inside Saturn Moon". NASA. Archived from the original on 3 April 2014. Retrieved 3 April 2014.
192. ▲ Iess L, Stevenson DJ, Parisi M, Hemingway D, Jacobson R, Lunine JJ, et al. (4 April 2014). "The Gravity Field and Interior Structure of Enceladus" (PDF). *Science*. **344** (6179): 78–80. Bibcode:2014Sci...344...78I. doi:10.1126/science.1250551. PMID 24700854. S2CID 28990283. Archived (PDF) from the original on 2 December 2017. Retrieved 14 July 2019.

193. ▲ Dunaeva, A.N., Kronrod, V.A., Kuskov, O.L. (2013). "Numerical Models of Titan's Interior with Subsurface Ocean" (PDF). *44th Lunar and Planetary Science Conference (2013) (1719): 2454*. Bibcode:2013LPI....44.2454D. Archived (PDF) from the original on 23 March 2014. Retrieved 23 March 2014.
194. ▲ Tritt CS (2002). "Possibility of Life on Europa". *Milwaukee School of Engineering*. Archived from the original on 9 June 2007. Retrieved 10 August 2007.
195. ▲ Dunham, Will. (3 May 2014) Jupiter's moon Ganymede may have 'club sandwich' layers of ocean | Reuters Archived 3 May 2014 at the Wayback Machine. In.reuters.com. Retrieved on 28 September 2015.
196. ▲ Carr M (1996). *Water on Mars*. New York: Oxford University Press. p. 197.
197. ▲ Bibring JP, Langevin Y, Poulet F, Gendrin A, Gondet B, Berthé M, et al. (2004). "Perennial Water Ice Identified in the South Polar Cap of Mars" (PDF). *Nature*. **428** (6983): 627–630. Bibcode:2004Natur.428..627B. doi:10.1038/nature02461. PMID 15024393. S2CID 4373206.
198. ▲ Versteckt in Glasperlen: Auf dem Mond gibt es Wasser – Wissenschaft – Archived 10 July 2008 at the Wayback Machine Der Spiegel – Nachrichten
199. ▲ Water Molecules Found on the Moon Archived 27 September 2009 at the Wayback Machine, NASA, 24 September 2009
200. ▲ McCord T, Sotin C (21 May 2005). "Ceres: Evolution and current state" (PDF). *Journal of Geophysical Research: Planets*. **110** (E5): E05009. Bibcode:2005JGRE..110.5009M. doi:10.1029/2004JE002244. Archived (PDF) from the original on 18 July 2021. Retrieved 5 March 2024.
201. ▲ Thomas P, Parker J, McFadden L (2005). "Differentiation of the asteroid Ceres as revealed by its shape". *Nature*. **437** (7056): 224–226. Bibcode:2005Natur.437..224T. doi:10.1038/nature03938. PMID 16148926. S2CID 17758979.
202. ▲ Carey B (7 September 2005). "Largest Asteroid Might Contain More Fresh Water than Earth". *SPACE.com*. Archived from the original on 18 December 2010. Retrieved 16 August 2006.
203. ▲ Chang K (12 March 2015). "Suddenly, It Seems, Water Is Everywhere in Solar System". *New York Times*. Archived from the original on 12 August 2018. Retrieved 12 March 2015.
204. ▲ Kuskov O, Kronrod, V.A. (2005). "Internal structure of Europa and Callisto". *Icarus*. **177** (2): 550–369. Bibcode:2005Icar..177..550K. doi:10.1016/j.icarus.2005.04.014.

205. ▲ Showman AP, Malhotra R (1 October 1999). "The Galilean Satellites" (PDF). *Science*. **286** (5437): 77–84. doi:10.1126/science.286.5437.77. PMID 10506564. S2CID 9492520. Archived from the original (PDF) on 12 April 2020.
206. ▲ a b Sparrow G (2006). *The Solar System*. Thunder Bay Press. ISBN 978-1-59223-579-7.
207. ▲ Tobie G, Grasset O, Lunine JI, Mocquet A, Sotin C (2005). "Titan's internal structure inferred from a coupled thermal-orbital model". *Icarus*. **175** (2): 496–502. Bibcode:2005Icar..175..496T. doi:10.1016/j.icarus.2004.12.007.
208. ▲ Verbisser A, French R, Showalter M, Helfenstein P (9 February 2007). "Enceladus: Cosmic Graffiti Artist Caught in the Act". *Science*. **315** (5813): 815. Bibcode:2007Sci...315..815V. doi:10.1126/science.1134681. PMID 17289992. S2CID 21932253. (supporting online material, table S1)
209. ▲ Greenberg JM (1998). "Making a comet nucleus". *Astronomy and Astrophysics*. **330**: 375. Bibcode:1998A&A...330..375G.
210. ▲ "Dirty Snowballs in Space". *Starryskies*. Archived from the original on 29 January 2013. Retrieved 15 August 2013.
211. ▲ E.L. Gibb, M.J. Mumma, N. Dello Russo, M.A. DiSanti, K. Magee-Sauer (2003). "Methane in Oort Cloud comets". *Icarus*. **165** (2): 391–406. Bibcode:2003Icar..165..391G. doi:10.1016/S0019-1035(03)00201-X.
212. ▲ NASA, "MESSENGER Finds New Evidence for Water Ice at Mercury's Poles Archived 30 November 2012 at the Wayback Machine", NASA, 29 November 2012.
213. ▲ Thomas P, Burns J, Helfenstein P, Squyres S, Veverka J, Porco C, et al. (October 2007). "Shapes of the saturnian icy satellites and their significance" (PDF). *Icarus*. **190** (2): 573–584. Bibcode:2007Icar..190..573T. doi:10.1016/j.icarus.2007.03.012. Archived (PDF) from the original on 27 September 2011. Retrieved 15 December 2011.
214. ▲ Weird water lurking inside giant planets Archived 15 April 2015 at the Wayback Machine, *New Scientist*, 1 September 2010, Magazine issue 2776.
215. ▲ Ehlers, E., Krafft, T, eds. (2001). "J.C.I. Dooge. "Integrated Management of Water Resources"". *Understanding the Earth System: compartments, processes, and interactions*. Springer. p. 116.
216. ▲ "Habitable Zone". *The Encyclopedia of Astrobiology, Astronomy and Spaceflight*. Archived from the original on 23 May 2007. Retrieved 26 April 2007.
217. ▲ Shiga D (6 May 2007). "Strange alien world made of "hot ice"". *New Scientist*. Archived from the original on 6 July 2008. Retrieved 28 March 2010.

218. ^ Aguilar, David A. (16 December 2009). "Astronomers Find Super-Earth Using Amateur, Off-the-Shelf Technology". *Harvard-Smithsonian Center for Astrophysics*. Archived from the original on 7 April 2012. Retrieved 28 March 2010.
219. ^ **a b** "MDG Report 2008" (PDF). Archived (PDF) from the original on 27 August 2010. Retrieved 25 July 2010.
220. ^ Kulshreshtha SN (1998). "A Global Outlook for Water Resources to the Year 2025". *Water Resources Management*. **12** (3): 167–184. Bibcode:1998WatRM..12..167K. doi:10.1023/A:1007957229865. S2CID 152322295.
221. ^ "Charting Our Water Future: Economic frameworks to inform decision-making" (PDF). Archived from the original (PDF) on 5 July 2010. Retrieved 25 July 2010.
222. ^ "The Millennium Development Goals Report". Archived 27 August 2010 at the Wayback Machine, United Nations, 2008
223. ^ Lomborg B (2001). *The Skeptical Environmentalist* (PDF). Cambridge University Press. p. 22. ISBN 978-0-521-01068-9. Archived from the original (PDF) on 25 July 2013.
224. ^ UNESCO, (2006), "Water, a shared responsibility. The United Nations World Water Development Report 2". Archived 6 January 2009 at the Wayback Machine
225. ^ Welle, Katharina; Evans, Barbara; Tucker, Josephine; and Nicol, Alan (2008). "Is water lagging behind on Aid Effectiveness?" Archived 27 July 2011 at the Wayback Machine
226. ^ "Search Results". *International Water Management Institute (IWMI)*. Archived from the original on 5 June 2013. Retrieved 3 March 2016.
227. ^ Burrows G (24 March 2004). "Clean water to fight poverty". *The Guardian*. Archived from the original on 16 February 2024. Retrieved 16 February 2024.
228. ^ Morris K (20 March 2004). "'Silent emergency' of poor water and sanitation". *Medicine and Health Policy*. **363** (9413): 954. doi:10.1016/S0140-6736(04)15825-X. PMID 15046114. S2CID 29128993. Archived from the original on 22 February 2024. Retrieved 16 February 2024.
229. ^ **a b c** "Home | UN World Water Development Report 2023". *www.unesco.org*. Archived from the original on 5 June 2023. Retrieved 5 June 2023.
230. ^ "UN World Water Development Report 2023". *www.rural21.com*. 29 March 2023. Archived from the original on 5 June 2023. Retrieved 5 June 2023.
231. ^ "UN warns 'vampiric' water use leading to 'imminent' global crisis". *France 24*. 22 March 2023. Archived from the original on 5 June 2023. Retrieved 5 June 2023.

232. ▲ "New UN report paints stark picture of huge changes needed to deliver safe drinking water to all people". ABC News. 22 March 2023. Archived from the original on 5 June 2023. Retrieved 5 June 2023.
233. ▲ "World Water Day". United Nations. Archived from the original on 9 September 2020. Retrieved 10 September 2020.
234. ▲ "About". World Oceans Day Online Portal. Archived from the original on 20 September 2020. Retrieved 10 September 2020.
235. ▲ Z Wahrman M (2016). *The Hand Book: Surviving in a Germ-Filled World*. University Press of New England. pp. 46–48. ISBN 978-1-61168-955-6. "Water plays a role in other Christian rituals as well. ... In the early days of Christianity, two to three centuries after Christ, the lavabo (Latin for "I wash myself"), a ritual handwashing vessel and bowl, was introduced as part of Church service."
236. ▲ Chambers's encyclopædia, Lippincott & Co (1870). p. 394.
237. ▲ Altman, Nathaniel (2002) *Sacred water: the spiritual source of life*. pp. 130–133. ISBN 1-58768-013-0.
238. ▲ "ÄB i. The concept of water in ancient Iran". [www.iranicaonline.org](http://www.iranicaonline.org). Encyclopedia Iranica. Archived from the original on 16 May 2018. Retrieved 19 September 2018.
239. ▲ Lindberg, D. (2008). *The beginnings of western science: The European scientific tradition in a philosophical, religious, and institutional context, prehistory to A.D. 1450* (2nd ed.). Chicago: University of Chicago Press.
240. ▲ *Tao Te Ching*. Archived from the original on 12 July 2010. Retrieved 25 July 2010 – via Internet Sacred Text Archive Home.
241. ▲ "Guanzi : Shui Di". Chinese Text Project. Archived 6 November 2014 at archive.today. Retrieved on 28 September 2015.
242. ▲ **a b c d** Madtes RE (1983). *The "Ithaca" chapter of Joyce's "Ulysses"*. Ann Arbor, Michigan: UMI Research Press. ISBN 0835714608.
243. ▲ **a b** Joyce J (1933). Wegner C (ed.). *Ulysses*. Vol. 2. Hamburg: The Odyssey Press. pp. 668–670.
244. ▲ Vartanian H (3 October 2011). "Manhattan Cathedral Explores Water in Art". Hyperallergic. Archived from the original on 3 February 2021. Retrieved 14 December 2020 .
245. ▲ Kowalski JA (6 October 2011). "The Cathedral of St. John the Divine and The Value of Water". [huffingtonpost.com](http://huffingtonpost.com). Huffington Post. Archived from the original on 6 August 2015.

Retrieved 14 December 2020.

246. ▲ Foster F. "The Value of Water at St John the Divine". *vimeo.com*. Sara Karl. Archived from the original on 1 March 2021. Retrieved 14 December 2020.
247. ▲ Miller T. "The Value of Water Exhibition". *UCLA Art Science Center*. Archived from the original on 3 February 2021. Retrieved 14 December 2020.
248. ▲ Madel R (6 December 2017). "Through Art, the Value of Water Expressed". *Huffington Post*. Archived from the original on 1 December 2020. Retrieved 16 December 2020.
249. ▲ Cotter M (4 October 2011). "Manhattan Cathedral Examines 'The Value of Water' in a New Star-Studded Art Exhibition". *Inhabitat*. Archived from the original on 8 July 2019. Retrieved 14 December 2020.
250. ▲ "Think About Water". Archived from the original on 26 November 2020. Retrieved 15 December 2020.
251. ▲ "Basia Irland". Archived from the original on 14 October 2021. Retrieved 19 August 2021.
252. ▲ "Influential Figures Dr. Charlotte Cote". *Tseshaht First Nation [c]“išaaĖ”atá, ʔ*. Archived from the original on 19 August 2021. Retrieved 19 August 2021.
253. ▲ "10 years of the human rights to water and sanitation". *United Nations. UN – Water Family News*. 27 February 2020. Archived from the original on 19 August 2021. Retrieved 19 August 2021.
254. ▲ "Water is sacred": 10 visual artists reflect on the human right to water". *The Guardian*. 4 August 2020. Archived from the original on 19 August 2021. Retrieved 19 August 2021.
255. ▲ "dihydrogen monoxide". March 2018. Archived from the original on 2 May 2018. Retrieved 2 May 2018.
256. ▲ "What Does Water Mean In Rap? (EXPLAINED)". *Lets Learn Slang*. 27 December 2021. Archived from the original on 6 August 2023. Retrieved 6 August 2023.
257. ▲ Danny Towers, DJ Scheme & Ski Mask the Slump God (Ft. Luh Tyler) – Florida Water, archived from the original on 6 August 2023, retrieved 6 August 2023

## Works cited

[edit]

- Ball P (2001). *Life's matrix : a biography of water*. Farrar, Straus, and Giroux. ISBN 978-0-520-23008-8.

- *Franks F (2007). Water : a matrix of life (2nd ed.). Royal Society of Chemistry. ISBN 978-1-84755-234-1.*
- *Lide DR (2003). CRC Handbook of Chemistry and Physics. CRC Handbook (84th ed.). CRC Press. ISBN 978-0-8493-0484-2. Archived from the original on 4 February 2024. Retrieved 14 December 2023.*
- *Weingärtner H, Teermann I, Borchers U, Balsaa P, Lutze HV, Schmidt TC, et al. (2016). "Water, 1. Properties, Analysis, and Hydrological Cycle". Ullmann's Encyclopedia of Industrial Chemistry. Wiley-VCH Verlag GmbH & Co. KGaA. doi:10.1002/14356007.a28\_001.pub3. ISBN 978-3-527-30673-2.*

## Further reading

[edit]








- Debenedetti, PG., and HE Stanley, "Supercooled and Glassy Water", *Physics Today* **56** (6), pp. 40–46 (2003). Downloadable PDF (1.9 MB) Archived 1 November 2018 at the Wayback Machine
- Gleick, PH., (editor), *The World's Water: The Biennial Report on Freshwater Resources*. Island Press, Washington, D.C. (published every two years, beginning in 1998.) The World's Water, Island Press Archived 26 February 2009 at the Wayback Machine
- *Jones OA, Lester JN, Voulvoulis N (2005). "Pharmaceuticals: a threat to drinking water?". Trends in Biotechnology. 23 (4): 163–167. doi:10.1016/j.tibtech.2005.02.001. PMID 15780706.*
- Journal of Contemporary Water Research & Education Archived 3 March 2016 at the Wayback Machine
- Postel, S., *Last Oasis: Facing Water Scarcity*. W.W. Norton and Company, New York. 1992
- Reisner, M., *Cadillac Desert: The American West and Its Disappearing Water*. Penguin Books, New York. 1986.
- United Nations World Water Development Report Archived 22 February 2009 at the Wayback Machine. Produced every three years.

- St. Fleur, Nicholas. The Water in Your Glass Might Be Older Than the Sun Archived 15 January 2017 at the Wayback Machine. "The water you drink is older than the planet you're standing on." *The New York Times* (15 April 2016)

## External links

[edit]

## **water** at Wikipedia's sister projects

-  not found or type unknown **Definitions from Wiktionary**
  -  not found or type unknown **Media from Commons**
  -  not found or type unknown **News from Wikinews**
  -  not found or type unknown **Quotations from Wikiquote**
  -  not found or type unknown **Texts from Wikisource**
  -  not found or type unknown **Textbooks from Wikibooks**
  -  not found or type unknown **Resources from Wikiversity**
- 
- The World's Water Data Page
  - FAO Comprehensive Water Database, AQUASTAT
  - The Water Conflict Chronology: Water Conflict Database Archived 16 January 2013 at the Wayback Machine
  - Water science school (USGS)
  - Portal to The World Bank's strategy, work and associated publications on water resources
  - America Water Resources Association Archived 24 March 2018 at the Wayback Machine
  - Water on the web

- Water structure and science Archived 28 December 2014 at the Wayback Machine
  - "Why water is one of the weirdest things in the universe", *Ideas*, BBC, Video, 3:16 minutes, 2019
  - The chemistry of water Archived 19 June 2020 at the Wayback Machine (NSF special report)
  - The International Association for the Properties of Water and Steam
  - *H2O: The Molecule That Made Us*, a 2020 PBS documentary
- 
- v
  - t
  - e

Water

## Overviews

- Outline
- Data
- Model
- Properties

## States

- Liquid
- Ice
- Vapor
- Steam
  - superheated

Water droplet

Image not found or type unknown

Water  
droplet

## **Forms**

- Deuterium-depleted
- Semiheavy
- Heavy
- Tritiated
- Doubly labeled water
- Hydronium

## **On Earth**

- Cycle
- Distribution
- Hydrosphere
  - Hydrology
  - Hydrobiology
- Origin
- Pollution
- Resources
  - management
  - policy
- Supply

- Extraterrestrial liquid water
  - Asteroidal water
  - Planetary oceanography
  - Ocean world
  - Hycean planet
  - List of Candidates
- Specific
  - Europa
  - Mars
  - Moon
  - Enceladus

## Extraterrestrial

- Stratification
  - Ocean stratification
  - Lake stratification
- Ocean temperature

## Physical parameters

-  **Portal** Image not found or type unknown
-  **Category** Image not found or type unknown
-  **Commons** Image not found or type unknown
-  **Wiktionary** Image not found or type unknown

- v
- t
- e

## Food chemistry

- Additives
- Carbohydrates
- Coloring
- Enzymes
- Essential fatty acids
- Flavors
- Fortification
- Lipids
- "Minerals" (Chemical elements)
- Proteins
- Vitamins
- Water

○ v

○ t

○ e

## Natural resources

## **Air**

- Ambient standards (US)
- Index
- Pollution /  
quality
  - Indoor
  - Law
    - Clean Air Act (US)
  - Ozone depletion

- Airshed
- Emissions
  - Trading
  - Deforestation (REDD)

## **Energy**

- Bio
- Law
- Resources
- Fossil fuels (gas, peak coal, peak gas, peak oil)
- Geothermal
- Hydro
- Nuclear
- Solar
  - sunlight
  - shade
- Wind

- Agricultural
  - arable
    - peak farmland
- Degradation
- Field
- Landscape
  - cityscape
  - seascape
  - soundscape
  - viewshed
- Law
  - property
- Management
  - habitat conservation
- Minerals
  - gemstone
  - industrial
  - ore
    - metal
  - mining
    - law
    - sand
  - peak
    - copper
    - phosphorus
  - rights
- Soil
  - conservation
  - fertility
  - health

## **Land**

- Biodiversity
- Bioprospecting
  - biopiracy
- Biosphere
- Bushfood
- Bushmeat
- Fisheries
  - climate change
  - law
  - management
- Forests
  - genetic resources
  - law
  - management
  - non-timber products
- Game
  - law
- Marine conservation
- Meadow
- Pasture
- Plants
  - FAO Plant Treaty
  - food
  - genetic resources
  - gene banks
  - herbal medicines
  - UPOV Convention
  - wood
- Rangeland
- Seed bank

## **Life**

## Water

### Types / location

- Aquifer
  - storage and recovery
- Drinking
- Fresh
- Groundwater
  - pollution
  - recharge
  - remediation
- Hydrosphere
- Ice
  - bergs
  - glacial
  - polar
- Irrigation
  - *huerta*
- Marine
- Rain
  - harvesting
- Stormwater
- Surface water
- Sewage
  - reclaimed water
- Watershed
- Desalination
- Floods
- Law
- Leaching
- Sanitation

- Commons
  - enclosure
  - global
  - land
  - tragedy of
- Economics
  - ecological
  - land
- Ecosystem services
- Exploitation
  - overexploitation
  - Earth Overshoot Day
- Management
  - adaptive
- Natural capital
  - accounting
  - good
- Natural heritage

## **Related**

- Nature reserve
  - remnant natural area
- Systems ecology
- Urban ecology
- Wilderness
- Common-pool
- Conflict (perpetuation)
- Curse
- Resource
  - Depletion
  - Extraction

-  Category

- **v**

- **t**

- **e**

Molecules detected in outer space

- Aluminium monochloride
- Aluminium monofluoride
- Aluminium(II) oxide
- Argonium
- Carbon cation
- Carbon monophosphide
- Carbon monosulfide
- Carbon monoxide
- Cyano radical
- Diatomic carbon
- Fluoromethylidynium
- Helium hydride ion
- Hydrogen chloride
- Hydrogen fluoride
- Hydrogen (molecular)
- Hydroxyl radical
- Imidogen

**Diatomic**

- Iron(II) oxide
- Magnesium monohydride
- Methylidyne radical
- Nitric oxide
- Nitrogen (molecular)
- Oxygen (molecular)
- Phosphorus monoxide
- Phosphorus mononitride
- Potassium chloride
- Silicon carbide
- Silicon monoxide
- Silicon monosulfide

**Deuterated  
molecules**

- Ammonia
- Ammonium ion
- Formaldehyde
- Formyl radical
- Heavy water
- Hydrogen cyanide
- Hydrogen deuteride
- Hydrogen isocyanide
- $\text{N}_2\text{D}^+$
- Propyne
- Trihydrogen cation

**Unconfirmed**

- Anthracene
- Dihydroxyacetone
- Glycine
- Graphene
- $\text{H}_2\text{NCO}^+$
- Hemolithin
- Linear  $\text{C}_5$
- Methoxyethane
- Naphthalene cation
- Phosphine
- Pyrene
- Silylidyne

- Abiogenesis
- Astrobiology
- Astrochemistry
- Atomic and molecular astrophysics
- Chemical formula
- Circumstellar dust
- Circumstellar envelope
- Cosmic dust
- Cosmic ray
- Cosmochemistry
- Diffuse interstellar band
- Earliest known life forms
- Extraterrestrial life
- Extraterrestrial liquid water
- Forbidden mechanism
- Homochirality

## **Related**

- Intergalactic dust
- Interplanetary medium
- Interstellar medium
- Iron–sulfur world theory
- Kerogen
- Molecules in stars
- Nexus for Exoplanet System Science
- Organic compound
- Outer space
- PAH world hypothesis
- Photodissociation region
- Polycyclic aromatic hydrocarbon (PAH)
- Pseudo-panspermia
- RNA world hypothesis

-  **Category: Astrochemistry**
-  **Outer space portal**
-  **Astronomy portal**
-  **Chemistry portal**

## Authority control databases **Edit this at Wikidata**

### National

- Germany
- United States
- France
- BnF data
- Japan
- Czech Republic
- Spain
- Israel

### Other

- NARA
- Åslâm Ansiklopedisi

## About Wastewater

Wastewater (or drainage) is water generated after the use of freshwater, raw water, alcohol consumption water or saline water in a variety of calculated applications or processes.:â€â€1 â€ An additional definition of wastewater is "Utilized water from any kind of combination of domestic, industrial, business or agricultural activities,

surface drainage/ storm water, and any type of sewage system inflow or drain infiltration".

175 In daily usage, wastewater is typically a basic synonym for sewage (likewise called domestic wastewater or local wastewater), which is wastewater that is created by a community of people. As a common term, wastewater might also explain water including contaminants collected in other settings, such as:

Industrial wastewater: waterborne waste produced from a variety of commercial procedures, such as making operations, mineral removal, power generation, or water and wastewater treatment. Cooling water, is released with potential thermal contamination after usage to condense vapor or reduce equipment temperature levels by transmission or evaporation. Leachate: precipitation containing contaminants liquified while percolating through ores, basic materials, items, or solid waste. Return circulation: the flow of water lugging suspended dirt, pesticide deposits, or liquified minerals and nutrients from irrigated cropland. Surface runoff: the flow of water occurring on the ground surface area when excess rainwater, stormwater, meltwater, or other resources, can no longer completely rapidly penetrate the soil. Urban overflow, consisting of water utilized for exterior cleansing task and landscape watering in densely booming locations produced by urbanization. Agricultural wastewater: animal husbandry wastewater produced from constrained animal operations.

.

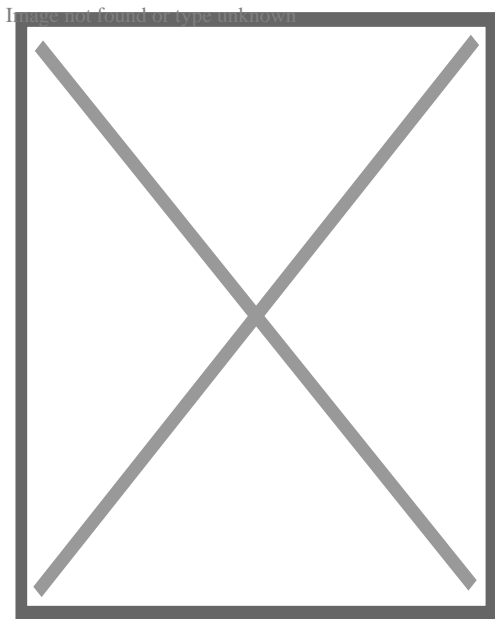
## **About health**

Health and wellness has a selection of definitions, which have been used for different purposes with time. As a whole, it refers to physical and psychological wellness, particularly that connected with normal functioning of the human body, lacking of condition, pain (including psychological pain), or injury. Health and wellness can be advertised by urging healthy tasks, such as routine physical exercise and sufficient

sleep, and by decreasing or staying clear of unhealthy activities or circumstances, such as cigarette smoking or too much tension. Some aspects influencing wellness are due to private options, such as whether to take part in a high-risk habits, while others are due to architectural reasons, such as whether the society is prepared in a manner that makes it simpler or tougher for individuals to obtain needed health care solutions. Still, other elements are beyond both specific and group choices, such as genetic disorders.

.

### About Ventilative cooling



A sash window with two sashes that can be adjusted to control airflows and temperatures

**Ventilative cooling** is the use of natural or mechanical ventilation to cool indoor spaces.<sup>[1]</sup> The use of outside air reduces the cooling load and the energy consumption of these systems, while maintaining high quality indoor conditions; passive ventilative cooling may eliminate energy consumption. Ventilative cooling strategies are applied in a wide range of buildings and may even be critical to realize

renovated or new high efficient buildings and zero-energy buildings (ZEBs).[<sup>2</sup>]  
Ventilation is present in buildings mainly for air quality reasons. It can be used additionally to remove both excess heat gains, as well as increase the velocity of the air and thereby widen the thermal comfort range.[<sup>3</sup>] Ventilative cooling is assessed by long-term evaluation indices.[<sup>4</sup>] Ventilative cooling is dependent on the availability of appropriate external conditions and on the thermal physical characteristics of the building.

## **Background**

[edit]

In the last years, overheating in buildings has been a challenge not only during the design stage but also during the operation. The reasons are:[<sup>5</sup>][<sup>6</sup>]

- High performance energy standards which reduce heating demand in heating dominated climates. Mainly refer to increase of the insulation levels and restriction on infiltration rates
- The occurrence of higher outdoor temperatures during the cooling season, because of the climate change and the heat island effect not considered at the design phase
- Internal heat gains and occupancy behavior were not calculated with accuracy during the design phase (gap in performance).

In many post-occupancy comfort studies overheating is a frequently reported problem not only during the summer months but also during the transitions periods, also in temperate climates.

## **Potentials and limitations**

[edit]

The effectiveness of ventilative cooling has been investigated by many researchers and has been documented in many post occupancy assessments reports.<sup>[7][8][9]</sup> The system cooling effectiveness (natural or mechanical ventilation) depends on the air flow rate that can be established, the thermal capacity of the construction and the heat transfer of the elements. During cold periods the cooling power of outdoor air is large. The risk of draughts is also important. During summer and transition months outdoor air cooling power might not be enough to compensate overheating indoors during daytime and application of ventilative cooling will be limited only during the night period. The night ventilation may remove effectively accumulated heat gains (internal and solar) during daytime in the building constructions.<sup>[10]</sup> For the assessment of the cooling potential of the location simplified methods have been developed.<sup>[11][12][13][14]</sup> These methods use mainly building characteristics information, comfort range indices and local climate data. In most of the simplified methods the thermal inertia is ignored.

The critical limitations for ventilative cooling are:

- Impact of global warming
- Impact of urban environment
- Outdoor noise levels
- Outdoor air pollution<sup>[15]</sup>
- Pets and insects
- Security issues
- Locale limitations

## **Existing regulations**

[edit]

Ventilative cooling requirements in regulations are complex. Energy performance calculations in many countries worldwide do not explicitly consider ventilative cooling. The available tools used for energy performance calculations are not suited to model the impact and effectiveness of ventilative cooling, especially through annual and monthly calculations.<sup>[16]</sup>

## **Case studies**

[edit]

A large number of buildings using ventilative cooling strategies have already been built around the world.<sup>[17]</sup><sup>[18]</sup><sup>[19]</sup> Ventilative cooling can be found not only in traditional, pre-air-condition architecture, but also in temporary European and international low energy buildings. For these buildings passive strategies are priority. When passive strategies are not enough to achieve comfort, active strategies are applied. In most cases for the summer period and the transition months, automatically controlled natural ventilation is used. During the heating season, mechanical ventilation with heat recovery is used for indoor air quality reasons. Most of the buildings present high thermal mass. User behavior is crucial element for successful performance of the method.

## **Building components and control strategies**

[edit]

Building components of ventilative cooling are applied on all three levels of climate-sensitive building design, i.e. site design, architectural design and technical interventions . A grouping of these components follows:<sup>[1]</sup><sup>[20]</sup>

- Airflow guiding ventilation components (windows, rooflights, doors, dampers and grills, fans, flaps, louvres, special effect vents)

- Airflow enhancing ventilation building components (chimneys, atria, venturi ventilators, wind catchers, wind towers and scoops, double facades, ventilated walls)
- Passive cooling building components (convective components, evaporative components, phase change components)
- Actuators (chain, linear, rotary)
- Sensors (temperature, humidity, air flow, radiation, CO<sub>2</sub>, rain, wind)

Control strategies in ventilative cooling solutions have to control the magnitude and the direction, of air flows in space and time.<sup>[1]</sup> Effective control strategies ensure high indoor comfort levels and minimum energy consumption. Strategies in a lot of cases include temperature and CO<sub>2</sub> monitoring.<sup>[21]</sup> In many buildings in which occupants had learned how to operate the systems, energy use reduction was achieved. Main control parameters are operative (air and radiant) temperature (both peak, actual or average), occupancy, carbon dioxide concentration and humidity levels.<sup>[21]</sup> Automation is more effective than personal control.<sup>[1]</sup> Manual control or manual override of automatic control are very important as it affects user acceptance and appreciation of the indoor climate positively (also cost).<sup>[22]</sup> The third option is that operation of facades is left to personal control of the inhabitants, but the building automation system gives active feedback and specific advises.

## **Existing methods and tools**

[edit]

Building design is characterized by different detailed design levels. In order to support the decision-making process towards ventilative cooling solutions, airflow models with different resolution are used. Depending on the detail resolution required, airflow models can be grouped into two categories:<sup>[1]</sup>

- Early stage modelling tools, which include empirical models, monozone model, bidimensional airflow network models;and
- Detailed modelling tools, which include airflow network models, coupled BES-AFN models, zonal models, Computational Fluid Dynamic, coupled CFD-BES-AFN models.

Existing literature includes reviews of available methods for airflow modelling.[<sup>9</sup>][<sup>23</sup>][<sup>24</sup>][<sup>25</sup>][<sup>26</sup>][<sup>27</sup>][<sup>28</sup>]

## **IEA EBC Annex 62**

[edit]

Annex 62 'ventilative cooling' was a research project of the Energy in Buildings and Communities Programme (EBC) of the International Energy Agency (IEA), with a four-year working phase (2014–2018).[<sup>29</sup>] The main goal was to make ventilative cooling an attractive and energy efficient cooling solution to avoid overheating of both new and renovated buildings. The results from the Annex facilitate better possibilities for prediction and estimation of heat removal and overheating risk – for both design purposes and for energy performance calculation. The documented performance of ventilative cooling systems through analysis of case studies aimed to promote the use of this technology in future high performance and conventional buildings.[<sup>30</sup>] To fulfill the main goal the Annex had the following targets for the research and development work:

- To develop and evaluate suitable design methods and tools for prediction of cooling need, ventilative cooling performance and risk of overheating in buildings.
- To develop guidelines for an energy-efficient reduction of the risk of overheating by ventilative cooling solutions and for design and operation of ventilative

cooling in both residential and commercial buildings.

- To develop guidelines for integration of ventilative cooling in energy performance calculation methods and regulations including specification and verification of key performance indicators.
- To develop instructions for improvement of the ventilative cooling capacity of existing systems and for development of new ventilative cooling solutions including their control strategies.
- To demonstrate the performance of ventilative cooling solutions through analysis and evaluation of well-documented case studies.

The Annex 62 research work was divided in three subtasks.

- **Subtask A** "Methods and Tools" analyses, developed and evaluated suitable design methods and tools for prediction of cooling need, ventilative cooling performance and risk of overheating in buildings. The subtask also gave guidelines for integration of ventilative cooling in energy performance calculation methods and regulation including specification and verification of key performance indicators.
- **Subtask B** "Solutions" investigated the cooling performance of existing mechanical, natural and hybrid ventilation systems and technologies and typical comfort control solutions as a starting point for extending the boundaries for their use. Based upon these investigations the subtask also developed recommendations for new kinds of flexible and reliable ventilative cooling solutions that create comfort under a wide range of climatic conditions.
- **Subtask C** "Case studies" demonstrated the performance of ventilative cooling through analysis and evaluation of well-documented case studies.

**See also**

[edit]

- Air conditioning
- Architectural engineering
- Glossary of HVAC
- Green building
- Heating, Ventilation and Air-Conditioning
- Indoor air quality
- Infiltration (HVAC)
- International Energy Agency Energy in Buildings and Communities Programme
- Mechanical engineering
- Mixed Mode Ventilation
- Passive cooling
- Room air distribution
- Sick building syndrome
- Sustainable refurbishment
- Thermal comfort
- Thermal mass
- Venticool
- Ventilation (architecture)

## References

[edit]

1. <sup>^</sup> **a b c d e** P. Heiselberg, M. Kolokotroni. "Ventilative Cooling. State of the art review". Department of Civil Engineering. Aalborg University, Denmark. 2015
2. <sup>^</sup> venticool, the international platform for ventilative cooling. "What is ventilative cooling?". Retrieved June 2018

3. ▲ F. Nicol, M. Wilson. "An overview of the European Standard EN 15251".  
Proceedings of Conference: Adapting to Change: New Thinking on Comfort.  
Cumberland Lodge, Windsor, UK, 9–11 April 2010.
4. ▲ S. Carlucci, L. Pagliano. "A review of indices for the long-term evaluation of the  
general thermal comfort conditions in buildings". *Energy and Buildings* 53:194–  
205 · October 2012
5. ▲ AECOM "Investigation of overheating in homes". Department for Communities  
and Local Government, UK. ISBN 978-1-4098-3592-9. July 2012
6. ▲ NHBC Foundation. "Overheating in new homes. A review of the evidence".  
ISBN 978-1-84806-306-8. 6 December 2012.
7. ▲ H. Awbi. "Ventilation Systems: Design and Performance". Taylor & Francis.  
ISBN 978-0419217008. 2008.
8. ▲ M. Santamouris, P. Wouters. "Building Ventilation: The State of the Art".  
Routledge. ISBN 978-1844071302. 2006
9. ▲ **a b** F. Allard. "Natural Ventilation in Buildings: A Design Handbook". Earthscan  
Publications Ltd. ISBN 978-1873936726. 1998
10. ▲ M. Santamouris, D. Kolokotsa. "Passive cooling dissipation techniques for  
buildings and other structures: The state of the art". *Energy and Building* 57: 74–  
94. 2013
11. ▲ C. Ghiaus. "Potential for free-cooling by ventilation". *Solar Energy* 80: 402–413.  
2006
12. ▲ N. Artmann, P. Heiselberg. "Climatic potential for passive cooling of buildings by  
night-time ventilation in Europe". *Applied Energy*. 84 (2): 187–201. 2006
13. ▲ A. Belleri, T. Psomas, P. Heiselberg, Per. "Evaluation Tool of Climate Potential for  
Ventilative Cooling". 36th AIVC Conference "Effective ventilation in high  
performance buildings", Madrid, Spain, 23–24 September 2015. p 53–66. 2015
14. ▲ R. Yao, K. Steemers, N. Baker. "Strategic design and analysis method of natural  
ventilation for summer cooling". *Build Serv Eng Res Technol*. 26 (4). 2005

15. ▲ Belias, Evangelos; Licina, Dusan (2023). "Influence of outdoor air pollution on European residential ventilative cooling potential". *Energy and Buildings*. **289**. doi: 10.1016/j.enbuild.2023.113044.
16. ▲ M. Kapsalaki, F.R. Carrié. "Overview of provisions for ventilative cooling within 8 European building energy performance regulations". venticool, the international platform for ventilative cooling. 2015.
17. ▲ P. Holzer, T. Psomas, P. O'Sullivan. "International ventilation cooling application database". CLIMA 2016 : Proceedings of the 12th REHVA World Congress, 22–25 May 2016, Aalborg, Denmark. 2016
18. ▲ venticool, the international platform for ventilative cooling. "Ventilative Cooling Application Database". Retrieved June 2018
19. ▲ P. O'Sullivan, A. O' Donovan. Ventilative Cooling Case Studies. Aalborg University, Denmark. 2018
20. ▲ P. Holzer, T.Psomas. Ventilative cooling sourcebook. Aalborg University, Denmark. 2018
21. ▲ **a b** P. Heiselberg (ed.). "Ventilative Cooling Design Guide". Aalborg University, Denmark. 2018
22. ▲ R.G. de Dear, G.S. Brager. "Thermal Comfort in Naturally Ventilated Buildings: Revisions to ASHRAE Standard 55". *Energy and Buildings*. 34 (6).2002
23. ▲ M. Caciolo, D. Marchio, P. Stabat. "Survey of the existing approaches to assess and design natural ventilation and need for further developments" 11th International IBPSA Conference, Glasgow. 2009.
24. ▲ Q. Chen. "Ventilation performance prediction for buildings: A method overview and recent applications". *Building and Environment*, 44(4), 848–858. 2009
25. ▲ A. Delsante, T. A. Vik. "Hybrid ventilation – State of the art review," IEA-ECBCS Annex 35. 1998.
26. ▲ J. Zhai, M. Krarti, M.H Johnson. "Assess and implement natural and hybrid ventilation models in whole-building energy simulations," Department of Civil, Environmental and Architectural Engineering, University of Colorado, ASHRAE TRP–

1456. 2010.

27. ▲ A. Foucquier, S. Robert, F. Suard, L. Stéphan, A. Jay. "State of the art in building modelling and energy performances prediction: A review," *Renewable and Sustainable Energy Reviews*, vol. 23. pp. 272–288. 2013.
28. ▲ J. Hensen "Integrated building airflow simulation". *Advanced Building Simulation*. pp. 87–118. Taylor & Francis. 2004
29. ▲ International Energy Agency's Energy in Buildings and Communities Programme, "EBC Annex 62 Ventilative Cooling Archived 2016-03-17 at the Wayback Machine", Retrieved June 2018
30. ▲ venticool, the international platform for ventilative cooling. "About Annex 62". Retrieved June 2018

## **About toilet**

A bathroom is an item of hygienic hardware that accumulates human waste (pee and feces) and sometimes bathroom tissue, usually for disposal. Flush commodes use water, while completely dry or non-flush toilets do not. They can be made for a resting setting popular in Europe and North America with a commode seat, with additional considerations for those with handicaps, or for a crouching position more popular in Asia, referred to as a squat commode. In urban locations, flush bathrooms are normally linked to a drain system; in isolated locations, to a sewage-disposal tank. The waste is called blackwater and the mixed effluent, consisting of various other sources, is sewage. Dry bathrooms are attached to a pit, removable container, composting chamber, or various other storage and treatment device, consisting of pee diversion with a urine-diverting toilet. "Toilet" or "commodes" is likewise widely used for areas consisting of just one or even more toilets and hand-basins. Bathroom is an older word for commode. The technology utilized for modern commodes differs. Toilets are generally constructed from ceramic (porcelain), concrete, plastic, or

timber. Newer toilet modern technologies consist of double flushing, low flushing, commode seat warming, self-cleaning, women rest rooms and waterless rest rooms. Japan is recognized for its commode technology. Aircraft commodes are specifically developed to operate in the air. The demand to preserve rectal health post-defecation is widely acknowledged and bathroom tissue (typically held by a toilet roll holder), which might additionally be used to clean the vulva after urination, is widely made use of (as well as bidets). In private homes, depending on the area and design, the toilet may exist in the exact same shower room as the sink, tub, and shower. An additional alternative is to have one room for body cleaning (also called "washroom") and a different one for the toilet and handwashing sink (commode room). Public bathrooms (restrooms) consist of one or more bathrooms (and frequently single urinals or trough urinals) which are readily available for use by the public. Products like urinal blocks and bathroom obstructs assistance keep the scent and cleanliness of bathrooms. Commode seat covers are in some cases used. Portable toilets (regularly chemical "porta johns") may be generated for large and short-lived celebrations. Historically, hygiene has been an issue from the earliest phases of human negotiations. However, lots of bad homes in developing nations make use of really basic, and frequently unclean, bathrooms --- and nearly one billion individuals have no accessibility to a toilet in any way; they should openly excrete and urinate. These problems can bring about the spread of illness transmitted through the fecal-oral path, or the transmission of waterborne illness such as cholera and dysentery. As a result, the United Nations Sustainable Growth Goal 6 intends to "accomplish access to adequate and equitable cleanliness and health for all and end open defecation".

## **About hygiene**

Hygiene is a set of techniques done to preserve health and wellness. According to the World Health Organization (WHO), "Health refers to problems and techniques that help to preserve health and wellness and stop the spread of illness." Personal hygiene refers to preserving the body's sanitation. Health tasks can be organized into the following: home and day-to-day hygiene, personal hygiene, clinical health, rest health, and food health. Home and daily health consists of hand cleaning, respiratory system health, food hygiene at home, health in the kitchen area, hygiene in the washroom, laundry hygiene, and medical hygiene in the house. And likewise ecological hygiene in the culture to prevent all type of microorganisms from penetrating into our homes. Many individuals relate health with "tidiness", however hygiene is a broad term. It consists of such personal routine options as just how often to shower or bath, laundry hands, trim finger nails, and wash clothes. It also includes attention to keeping surface areas in the home and work environment clean, including washroom facilities. Adherence to routine health methods is often considered a socially responsible and commendable habits, while neglecting proper hygiene can be perceived as unclean or unhygienic, and may be taken into consideration socially unacceptable or disrespectful, while additionally presenting a risk to public health and wellness.

.

## **About Sewage**

Sewer (or domestic sewage, residential wastewater, community wastewater) is a type of wastewater that is produced by a neighborhood of people. It is usually carried with a drain system. 175 Sewage contains wastewater discharged from homes and from industrial, institutional and public centers that exist in the locality. 10 Sub-types of sewage are greywater (from sinks, tubs, showers,

dish washers, and garments washers) and blackwater (the water used to flush commodes, integrated with the human waste that it flushes away). Sewage likewise includes soaps and cleaning agents. Food waste may exist from dishwashing, and food amounts may be raised where garbage disposal devices are utilized. In areas where toilet tissue is made use of rather than bidets, that paper is likewise contributed to the sewage. Sewer includes macro-pollutants and micro-pollutants, and might also integrate some community solid waste and toxins from industrial wastewater. Sewage usually travels from a structure's plumbing either into a drain, which will lug it in other places, or into an onsite sewer facility. Collection of sewage from numerous families together typically occurs in either hygienic drains or integrated sewage systems. The former is created to leave out stormwater streams whereas the last is designed to additionally take stormwater. The production of sewage usually represents the water consumption. A series of factors affect water intake and hence the sewer flowrates each. These include: Water availability (the opposite of water shortage), water choices, climate (warmer climates might lead to higher water consumption), neighborhood dimension, financial degree of the neighborhood, level of industrialization, metering of house usage, water price and water pressure. 20 The main parameters in sewage that are measured to evaluate the sewer toughness or high quality as well as treatment options include: solids, signs of raw material, nitrogen, phosphorus, and indicators of fecal contamination. 33 These can be taken into consideration to be the primary macro-pollutants in sewer. Sewer has microorganisms which stem from fecal matter. The adhering to four types of pathogens are found in sewage: pathogenic microorganisms, viruses, protozoa (in the kind of cysts or oocysts) and helminths (in the type of eggs). In order to quantify the raw material, indirect approaches are typically utilized: generally the Biochemical Oxygen Demand (BOD) and the Chemical Oxygen Need (COD). 36 Monitoring of sewer consists of collection and transportation for release right into the atmosphere, after a treatment level that is compatible with the local needs for

discharge right into water bodies, onto soil or for reuse applications.:â€â€ 156 â€

Disposal options consist of dilution (self-purification of water bodies, making use of their assimilative ability if possible), marine outfalls, land disposal and sewer farms. All disposal options may run risks of triggering water pollution.

.

## **About Royal Porta Johns**

## **Driving Directions in Plymouth County**

---

### **Driving Directions**

42.057192898441, -71.129962582483

Starting Point

Royal Porta Johns

Destination

[Open in Google Maps](#)

### **Driving Directions**

42.021681054325, -70.994779412929

Starting Point

Royal Porta Johns

Destination

[Open in Google Maps](#)

### **Driving Directions**

42.049536121253, -70.921156963921

Starting Point

Royal Porta Johns

Destination

[Open in Google Maps](#)

### **Driving Directions**

42.017156066986, -70.98743331883

Starting Point

Royal Porta Johns

Destination

[Open in Google Maps](#)

### **Driving Directions**

41.998477555725, -71.083750301447

Starting Point

Royal Porta Johns

Destination

[Open in Google Maps](#)

### **Driving Directions**

42.11137217518, -71.074721196873

Starting Point

Royal Porta Johns

Destination

[Open in Google Maps](#)

### **Driving Directions**

41.991622235639, -71.033942274495

Starting Point

Royal Porta Johns

Destination

[Open in Google Maps](#)

### **Driving Directions**

42.101911608886, -71.08021216269

Starting Point

Royal Porta Johns

Destination

[Open in Google Maps](#)

### **Driving Directions**

41.940215630626, -71.12080827318

Starting Point

Royal Porta Johns

Destination

[Open in Google Maps](#)

## Driving Directions

41.992776220847, -70.982857925563

## Starting Point

## Royal Porta Johns

Destination

[Open in Google Maps](#)

### Google Maps Location

<https://www.google.com/maps/place/Royal+Porta+Johns/@42.07558806286,->

70.985620603074,25.2z/data=!4m6!3m5!1s0x89e48f0bdb75549d:0x9ac1c8405242e765!8m2!3d42

71.0537696!16s%2F

Click below to open this location on Google Maps

[Open in Google Maps](#)

### Google Maps Location

<https://www.google.com/maps/place/Royal+Porta+Johns/@42.121264166174,-71.032834761485,25.2z/data=!4m6!3m5!1s0x89e48f0bdb75549d:0x9ac1c8405242e765!8m2!3d42.0710537696!16s%2F>

Click below to open this location on Google Maps

[Open in Google Maps](https://www.google.com/maps/place/Royal+Porta+Johns/@42.121264166174,-71.032834761485,25.2z/data=!4m6!3m5!1s0x89e48f0bdb75549d:0x9ac1c8405242e765!8m2!3d42.0710537696!16s%2F)

### Google Maps Location

<https://www.google.com/maps/place/Royal+Porta+Johns/@42.003687040962,-70.972960957357,25.2z/data=!4m6!3m5!1s0x89e48f0bdb75549d:0x9ac1c8405242e765!8m2!3d42.0710537696!16s%2F>

Click below to open this location on Google Maps

[Open in Google Maps](https://www.google.com/maps/place/Royal+Porta+Johns/@42.003687040962,-70.972960957357,25.2z/data=!4m6!3m5!1s0x89e48f0bdb75549d:0x9ac1c8405242e765!8m2!3d42.0710537696!16s%2F)

### Google Maps Location

<https://www.google.com/maps/place/Royal+Porta+Johns/@42.028218387814,-70.976558945871,25.2z/data=!4m6!3m5!1s0x89e48f0bdb75549d:0x9ac1c8405242e765!8m2!3d42.0710537696!16s%2F>

Click below to open this location on Google Maps

[Open in Google Maps](https://www.google.com/maps/place/Royal+Porta+Johns/@42.028218387814,-70.976558945871,25.2z/data=!4m6!3m5!1s0x89e48f0bdb75549d:0x9ac1c8405242e765!8m2!3d42.0710537696!16s%2F)

### Google Maps Location

<https://www.google.com/maps/place/Royal+Porta+Johns/@42.081613424355,-71.05239643919,25.2z/data=!4m6!3m5!1s0x89e48f0bdb75549d:0x9ac1c8405242e765!8m2!3d42.0710537696!16s%2F>

Click below to open this location on Google Maps

[Open in Google Maps](#)

**Google Maps Location**

<https://www.google.com/maps/place/Royal+Porta+Johns/@41.95517988369,-71.024040697865,25.2z/data=!4m6!3m5!1s0x89e48f0bdb75549d:0x9ac1c8405242e765!8m2!3d42.0710537696!16s%2F>

Click below to open this location on Google Maps

[Open in Google Maps](#)

**Google Maps Location**

<https://www.google.com/maps/place/Royal+Porta+Johns/@42.031367052841,-71.03811562689,25.2z/data=!4m6!3m5!1s0x89e48f0bdb75549d:0x9ac1c8405242e765!8m2!3d42.0710537696!16s%2F>

Click below to open this location on Google Maps

[Open in Google Maps](#)

**Google Maps Location**

<https://www.google.com/maps/place/Royal+Porta+Johns/@41.967226876267,-71.02486031676,25.2z/data=!4m6!3m5!1s0x89e48f0bdb75549d:0x9ac1c8405242e765!8m2!3d42.0710537696!16s%2F>

Click below to open this location on Google Maps

[Open in Google Maps](#)

**Google Maps Location**

<https://www.google.com/maps/place/Royal+Porta+Johns/@41.979416462412,-71.164472167531,25.2z/data=!4m6!3m5!1s0x89e48f0bdb75549d:0x9ac1c8405242e765!8m2!3d42.071.0537696!16s%2F>

Click below to open this location on Google Maps

[Open in Google Maps](#)

#### **Google Maps Location**

<https://www.google.com/maps/place/Royal+Porta+Johns/@42.044247352494,-71.152683864117,25.2z/data=!4m6!3m5!1s0x89e48f0bdb75549d:0x9ac1c8405242e765!8m2!3d42.071.0537696!16s%2F>

Click below to open this location on Google Maps

[Open in Google Maps](#)

#### **Google Maps Location**

<https://www.google.com/maps/dir/?api=1&origin=42.031367052841,-71.03811562689&destination=Royal+Porta+Johns%2C+400+West+St%2C+West+Bridgewater%2C>

Click below to open this location on Google Maps

[Open in Google Maps](#)

#### **Google Maps Location**

<https://www.google.com/maps/dir/?api=1&origin=42.010826225495,-70.935601156785&destination=Royal+Porta+Johns%2C+400+West+St%2C+West+Bridgewater%2C>

Click below to open this location on Google Maps

[Open in Google Maps](#)

#### **Google Maps Location**

[https://www.google.com/maps/dir/?api=1&origin=42.094107688628,-](https://www.google.com/maps/dir/?api=1&origin=42.094107688628,-70.998610012566&destination=Royal+Porta+Johns%2C+400+West+St%2C+West+Bridgewater%2C)

[70.998610012566&destination=Royal+Porta+Johns%2C+400+West+St%2C+West+Bridgewater%2C](https://www.google.com/maps/dir/?api=1&origin=42.094107688628,-70.998610012566&destination=Royal+Porta+Johns%2C+400+West+St%2C+West+Bridgewater%2C)

Click below to open this location on Google Maps

[Open in Google Maps](#)

#### **Google Maps Location**

[https://www.google.com/maps/dir/?api=1&origin=42.119162887671,-](https://www.google.com/maps/dir/?api=1&origin=42.119162887671,-71.069650437354&destination=Royal+Porta+Johns%2C+400+West+St%2C+West+Bridgewater%2C)

[71.069650437354&destination=Royal+Porta+Johns%2C+400+West+St%2C+West+Bridgewater%2C](https://www.google.com/maps/dir/?api=1&origin=42.119162887671,-71.069650437354&destination=Royal+Porta+Johns%2C+400+West+St%2C+West+Bridgewater%2C)

Click below to open this location on Google Maps

[Open in Google Maps](#)

#### **Google Maps Location**

[https://www.google.com/maps/dir/?api=1&origin=42.112630239887,-](https://www.google.com/maps/dir/?api=1&origin=42.112630239887,-71.066436661126&destination=Royal+Porta+Johns%2C+400+West+St%2C+West+Bridgewater%2C)

[71.066436661126&destination=Royal+Porta+Johns%2C+400+West+St%2C+West+Bridgewater%2C](https://www.google.com/maps/dir/?api=1&origin=42.112630239887,-71.066436661126&destination=Royal+Porta+Johns%2C+400+West+St%2C+West+Bridgewater%2C)

Click below to open this location on Google Maps

[Open in Google Maps](#)

#### **Google Maps Location**

[https://www.google.com/maps/dir/?api=1&origin=41.992776220847,-](https://www.google.com/maps/dir/?api=1&origin=41.992776220847,-70.982857925563&destination=Royal+Porta+Johns%2C+400+West+St%2C+West+Bridgewater%2C)

[70.982857925563&destination=Royal+Porta+Johns%2C+400+West+St%2C+West+Bridgewater%2C](https://www.google.com/maps/dir/?api=1&origin=41.992776220847,-70.982857925563&destination=Royal+Porta+Johns%2C+400+West+St%2C+West+Bridgewater%2C)

Click below to open this location on Google Maps

[Open in Google Maps](#)

#### **Google Maps Location**

[https://www.google.com/maps/dir/?api=1&origin=42.06073374085,-](https://www.google.com/maps/dir/?api=1&origin=42.06073374085,-70.972860731764&destination=Royal+Porta+Johns%2C+400+West+St%2C+West+Bridgewater%2C)

[70.972860731764&destination=Royal+Porta+Johns%2C+400+West+St%2C+West+Bridgewater%2C](https://www.google.com/maps/dir/?api=1&origin=42.06073374085,-70.972860731764&destination=Royal+Porta+Johns%2C+400+West+St%2C+West+Bridgewater%2C)

Click below to open this location on Google Maps

[Open in Google Maps](#)

**Google Maps Location**

[https://www.google.com/maps/dir/?api=1&origin=41.954668785966,-](https://www.google.com/maps/dir/?api=1&origin=41.954668785966,-71.131095094454&destination=Royal+Porta+Johns%2C+400+West+St%2C+West+Bridgewater%2C)

[71.131095094454&destination=Royal+Porta+Johns%2C+400+West+St%2C+West+Bridgewater%2C](https://www.google.com/maps/dir/?api=1&origin=41.954668785966,-71.131095094454&destination=Royal+Porta+Johns%2C+400+West+St%2C+West+Bridgewater%2C)

Click below to open this location on Google Maps

[Open in Google Maps](#)

**Google Maps Location**

[https://www.google.com/maps/dir/?api=1&origin=42.017480326511,-](https://www.google.com/maps/dir/?api=1&origin=42.017480326511,-71.060981727885&destination=Royal+Porta+Johns%2C+400+West+St%2C+West+Bridgewater%2C)

[71.060981727885&destination=Royal+Porta+Johns%2C+400+West+St%2C+West+Bridgewater%2C](https://www.google.com/maps/dir/?api=1&origin=42.017480326511,-71.060981727885&destination=Royal+Porta+Johns%2C+400+West+St%2C+West+Bridgewater%2C)

Click below to open this location on Google Maps

[Open in Google Maps](#)

**Google Maps Location**

[https://www.google.com/maps/dir/?api=1&origin=42.039162790759,-](https://www.google.com/maps/dir/?api=1&origin=42.039162790759,-70.917607648104&destination=Royal+Porta+Johns%2C+400+West+St%2C+West+Bridgewater%2C)

[70.917607648104&destination=Royal+Porta+Johns%2C+400+West+St%2C+West+Bridgewater%2C](https://www.google.com/maps/dir/?api=1&origin=42.039162790759,-70.917607648104&destination=Royal+Porta+Johns%2C+400+West+St%2C+West+Bridgewater%2C)

Click below to open this location on Google Maps

[Open in Google Maps](#)

Royal Porta Johns

Phone : 17744442014

City : West Bridgewater

State : MA

Zip : 02379

Address : 400, West Street

[Google Business Profile](#)

Company Website : <https://royalportajohns.com/>

#### USEFUL LINKS

---

[porta potty rental near me](#)

[portable restroom rental near me](#)

[portable toilet rental near me](#)

[portable toilet rental](#)

[portable restroom cleaning](#)

[Sitemap](#)

[Privacy Policy](#)

[About Us](#)

---