- **Estimating Labor Expenses for Repair Services**
  Estimating Labor Expenses for Repair Services Comparing Replacement Part Prices for Various Systems Reviewing Maintenance Plan Rates in Detail Exploring Payment Arrangements for Major Overhauls Analyzing Long Term Savings with Efficient Upgrades Investigating Seasonal Discounts from Service Providers Understanding Monthly Budgeting for HVAC Projects Balancing Initial Spending with Potential Savings Evaluating Total Costs for System Retrofits Preparing for Unexpected Repair Fees Weighing Return on Investment for Modern Equipment Identifying Hidden Expenses in Older Units
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mechanical system, mobile home HVAC units can experience issues that require repair services. Understanding the common repair services and estimating labor expenses is vital for homeowners to manage costs effectively.

Mobile home HVAC systems often face unique challenges due to their compact design and specific requirements. Mobile home owners should explore financing options for energy-efficient upgrades **replacing hvac system in mobile home** temperature. Common repairs typically include fixing refrigerant leaks, replacing faulty thermostats, addressing blower motor issues, cleaning or replacing filters, and repairing or replacing ductwork. Each of these tasks requires specific expertise and can vary significantly in terms of labor intensity.

Refrigerant leaks are among the most frequent issues encountered in mobile home HVAC systems. Detecting and sealing leaks requires specialized equipment and knowledge of refrigerants' handling protocols. Labor costs for this service can vary depending on the complexity of the leak's location and severity.

Thermostat malfunctions are another common problem that can disrupt the efficient operation of an HVAC system. Replacing or recalibrating a thermostat is usually straightforward but demands precision to ensure accurate temperature regulation within the home. The cost of labor here is generally moderate since it involves minimal time for skilled technicians.

Blower motor problems can lead to inadequate airflow or complete system failure if not addressed promptly. Repairing or replacing a blower motor involves diagnosing electrical components and may require disassembling parts of the unit for access. This task is more labor-intensive than others, often resulting in higher labor expenses.

Filter maintenance is essential yet frequently overlooked in mobile home HVAC systems. Clogged filters reduce efficiency and strain other components over time. Cleaning or replacing filters is typically less costly in terms of both parts and labor compared to other repairs but should be done regularly to prevent larger issues.

Lastly, ductwork repairs are critical as damaged ducts can lead to significant energy loss and reduced system performance. Repairing or replacing sections of ductwork involves assessing accessibility within tight spaces typical of mobile homes, making this task potentially more arduous. Consequently, labor costs for duct repairs might be higher due to the intricacies involved.

Estimating labor expenses for these repair services depends on several factors including geographic location, technician expertise, complexity of the issue at hand, and travel distance for service providers specializing in mobile home systems. Homeowners should seek detailed quotes from multiple professionals to ensure fair pricing while also considering warranties or guarantees offered by different companies.

In conclusion, understanding common repair services needed for mobile home HVAC systems empowers homeowners with knowledge necessary not only for budgeting potential expenses but also ensuring timely interventions that prolong their system's lifespan. By recognizing typical issues like refrigerant leaks or blower motor failures alongside associated labor costs involved in addressing them efficiently through professional assistance becomes paramount towards sustaining an optimal indoor climate year-round without undue financial burdens impacting household economics adversely over time!

Estimating labor expenses for repair services, particularly in the niche of mobile home HVAC repairs, involves navigating a complex web of factors. Understanding these influences is crucial for homeowners and service providers alike to ensure fair pricing and efficient project management.

Firstly, geographic location plays a significant role in shaping labor costs. In urban areas with a high cost of living, skilled technicians demand higher wages compared to those in rural settings. This disparity arises from the need to align salaries with local economic conditions, impacting overall repair costs.

The complexity and scope of the HVAC repair job itself also heavily influence labor expenses. Simple tasks such as thermostat replacements might require less time and expertise than intricate issues like ductwork repairs or system overhauls. Technicians must assess each situation to determine the necessary level of skill and time commitment, which directly affects the final labor charge.

Another pivotal factor is the level of expertise required for specific repairs. Experienced technicians who possess specialized knowledge in mobile home HVAC systems often command higher fees due to their proficiency and ability to deliver quality work efficiently.

Investing in seasoned professionals can sometimes lead to long-term savings by preventing recurring issues that may arise from substandard repairs.

Seasonal demand fluctuations further complicate labor cost estimations. During peak seasons-typically extreme summer or winter months-there's an increased demand for HVAC services as systems are pushed to their limits. This surge can lead to longer wait times and potentially higher rates due to the scarcity of available technicians.

Furthermore, industry regulations and licensing requirements can impact labor expenses. Compliance with safety standards and obtaining necessary permits may add additional layers of responsibility-and consequently cost-to a repair job. Ensuring that all work adheres to these regulations is vital not only for legal compliance but also for ensuring safety and reliability.

Lastly, evolving technologies within the HVAC industry introduce new variables into labor cost calculations. As systems become more advanced, continuous training becomes essential for technicians to stay updated on new models and methods. The investment in ongoing education can result in greater efficiency but may also be reflected in higher service charges.

In conclusion, estimating labor costs for mobile home HVAC repairs demands consideration of multiple interrelated factors including geographic location, job complexity, technician expertise, seasonal demand variations, regulatory requirements, and technological advancements. By understanding these elements, both consumers and service providers can navigate repair projects with greater clarity and confidence, ultimately leading to fairer pricing structures and satisfactory outcomes for all parties involved.

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Steps to Accurately Estimate Labor Expenses for HVAC Repair Services

Estimating labor expenses for HVAC repair services is a crucial aspect of running a successful business in the heating, ventilation, and air conditioning industry. Accurate estimations not only ensure profitability but also help maintain customer satisfaction by providing transparent and fair pricing. To achieve precise labor expense estimates, one must follow a structured approach that considers various factors influencing the cost of labor.

Firstly, it is essential to understand the scope of work involved in each repair service. This involves assessing the specific issues with the HVAC system and determining the complexity of repairs required. A thorough diagnosis can help identify whether it's a simple fix or if extensive work is needed. By clearly defining the scope, you can better estimate how much time and effort will be required from your technicians.

Once the scope is established, calculating the time needed to complete each task is crucial. Experienced technicians often have benchmarks for how long common repairs should take, but it's important to consider any unique aspects of each job that might extend this timeframe. Additionally, factoring in potential delays such as waiting for parts or dealing with unforeseen complications ensures a more accurate estimate.

The next step involves considering the skill level and experience of your technicians. Labor rates may vary depending on whether junior technicians or seasoned experts are assigned to a job. More experienced workers might complete tasks faster or handle complex issues more efficiently, so balancing their involvement based on job requirements can optimize costs without compromising quality.

Furthermore, geographical location plays a significant role in labor expense estimation. Wages for HVAC technicians can differ widely across regions due to varying living costs and market competition. Being aware of these local variations allows businesses to set competitive yet sustainable pricing structures.

It's also vital to incorporate overhead costs into your estimates. These include expenses related to transportation, equipment maintenance, insurance, and other operational aspects that support your workforce but aren't directly linked to hours worked on-site. Allocating these costs proportionately across jobs helps maintain comprehensive financial planning.

Lastly, always factor in contingency allowances for unexpected scenarios during repairs-such as discovering additional issues or encountering adverse weather conditions-that could necessitate extra time or resources beyond initial projections. Building in a buffer ensures you're prepared for such eventualities without straining your budget.

In conclusion, accurately estimating labor expenses for HVAC repair services requires meticulous attention to detail and consideration of multiple influencing factors-from job scope and technician expertise to regional wage differences and overhead allocations. By adopting this systematic approach, businesses can achieve reliable estimates that promote operational efficiency while nurturing trust with clients through transparent pricing strategies.

Tools and Software for Estimating Labor Costs in Mobile Home HVAC Repairs

Estimating labor costs for mobile home HVAC repairs is a critical task that requires precision and efficiency. This process is crucial not only for maintaining profitability in a repair business but also for ensuring customer satisfaction through transparent pricing. Today, the intersection of technology and traditional craftsmanship has provided an arsenal of tools and software designed to streamline this estimation process. These tools help businesses accurately assess labor expenses, leading to more reliable service delivery.

At the forefront of these technological advancements are dedicated cost-estimation software programs that cater specifically to the HVAC industry. Such software solutions often come with pre-loaded databases containing standard labor rates, job descriptions, and time estimates for various repair tasks. By utilizing these databases, technicians can quickly generate accurate quotes without having to manually calculate each component of the job from scratch.

One notable example is cloud-based platforms that offer real-time updates on material costs and labor rates. These platforms allow HVAC professionals to adjust their estimates based on current market conditions, which is invaluable given the fluctuating prices in today's economy. Additionally, they provide easy access via mobile devices or tablets, enabling technicians to offer accurate estimates directly at the client's location.

Moreover, many of these software tools integrate with scheduling applications and inventory management systems. This integration ensures that businesses not only estimate costs accurately but also manage their resources efficiently. For instance, by knowing exactly what parts are available in stock or need ordering before starting a project, companies can avoid unnecessary delays or additional trips-factors that could otherwise inflate labor costs.

For smaller businesses or independent contractors who might find comprehensive software solutions financially burdensome or overly complex, there are simpler tools like spreadsheets enhanced with macros and custom formulas tailored to specific needs. While these may lack some features of specialized software, they still offer a significant step up from manual calculations by reducing human error and saving time.

Ultimately, regardless of whether one opts for advanced software or a more straightforward toolset like customized spreadsheets, the key lies in understanding how to effectively leverage these technologies within one's existing workflow. Training team members on how to use new tools efficiently is as vital as choosing the right tool itself; even the most sophisticated system will underperform if users do not operate it correctly.

In conclusion, leveraging modern tools and software for estimating labor costs in mobile home HVAC repairs represents an essential evolution in enhancing operational efficiency and accuracy within this field. As technology continues to advance at a rapid pace, staying updated on new developments will be crucial for any business aiming to maintain competitiveness while delivering exceptional service quality. By embracing these innovations thoughtfully and strategically integrating them into everyday operations, HVAC professionals can ensure better financial health for their businesses while providing clear value propositions to their clients.

Case Studies: Examples of Labor Cost Estimation in Various Repair Scenarios

Estimating labor expenses for repair services is an essential component of project management and financial planning. It involves understanding the intricacies of task requirements, time management, and resource allocation. To illustrate the nuances of labor cost estimation, we can examine case studies from various repair scenarios. These examples will provide insight into how professionals approach this complex task across different industries.

Consider a scenario in the automotive repair industry. A car owner brings in a vehicle with a malfunctioning transmission. The service advisor must estimate the labor costs to provide an accurate quote to the customer. This involves evaluating the complexity of the repair, determining the number of hours required by skilled technicians, and considering additional factors such as potential delays due to parts availability or unexpected complications. By referencing historical data on similar repairs and consulting with experienced staff, the advisor estimates that it will take approximately 10 hours at a rate of $80 per hour, resulting in a labor cost estimation of $800.

In another setting, imagine a home appliance repair technician tasked with fixing a broken washing machine. Unlike automotive repairs, appliance repairs often involve traveling to customers' homes, which adds travel time to labor costs. The technician assesses that it will take roughly three hours to diagnose and resolve the issue onsite. With an hourly rate of $60 and including travel time charges, the technician estimates a total labor expense of around $220 for this job.

A third example can be drawn from commercial building maintenance. Suppose an HVAC system in an office complex requires urgent repairs before winter sets in. Estimating labor costs for such large-scale projects demands careful consideration of project timelines and coordination among multiple teams-for instance, electricians and plumbers may need to collaborate on certain tasks. Project managers break down each phase: initial assessment (2 hours), ordering parts (no charge), installation (8 hours), testing (2 hours). With specialists charging $100 per hour on average due to their expertise level and urgency premium fees applied during peak seasons like winter preparation times-labor costs could reach approximately $1,200.

These case studies demonstrate that estimating labor expenses is both an art and science; it requires technical knowledge paired with strategic foresight about possible hurdles along every unique pathway towards successful completion within budget constraints without compromising quality standards expected by clients relying upon these vital services rendered efficiently yet effectively when needed most urgently!

Tips for Managing and Reducing Labor Expenses Without Compromising Quality

In the realm of repair services, managing and reducing labor expenses while maintaining quality is a crucial balance that businesses must strike to remain competitive and profitable. Labor costs are often one of the largest expenses for service providers, so developing strategies to estimate and control these costs without compromising on quality can lead to significant advantages.

The first step in effectively estimating labor expenses is understanding the scope of work involved in each repair service. This involves a detailed assessment of the tasks required for each job, which enables businesses to allocate appropriate time and resources. By breaking down tasks into smaller components, managers can better predict how long each aspect will take and assign staff accordingly. Utilizing historical data from past projects can also provide valuable insights into average timeframes and help set realistic expectations.

Technology plays a pivotal role in enhancing both estimation accuracy and operational efficiency. Implementing project management software or specialized industry tools can streamline processes by offering real-time tracking of labor hours, enabling more accurate forecasting of future needs. Additionally, investing in training for employees on new technologies or techniques can improve their productivity and reduce the time spent on each job, ultimately lowering labor costs over time.

Another key strategy is optimizing workforce scheduling. Efficiently scheduling skilled technicians ensures that they are neither overburdened nor underutilized, which helps maintain high-quality service delivery. Cross-training employees to handle multiple types of repairs increases flexibility and allows businesses to adapt quickly to varying workloads without incurring additional hiring costs.

Outsourcing certain non-core activities can also be an effective way to manage labor expenses without affecting quality. By entrusting routine or administrative tasks to external specialists, businesses can focus their internal resources on core competencies that directly impact customer satisfaction.

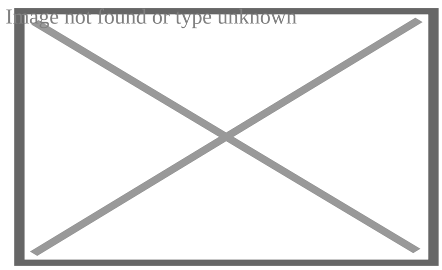
Moreover, fostering a culture of continuous improvement within the workforce encourages innovation in problem-solving approaches and process optimization. Encouraging employees to suggest improvements not only boosts morale but also leads to more efficient methods that save both time and money.

Finally, performance-based incentives can motivate employees to work efficiently while maintaining high standards. Linking part of their compensation to performance metrics related to quality and efficiency ensures that they have a vested interest in delivering superior results promptly.

In conclusion, estimating labor expenses accurately is foundational for managing costs effectively in repair services. By leveraging technology, optimizing scheduling practices, investing in employee training, considering strategic outsourcing, promoting continuous improvement initiatives, and employing performance-based incentives, businesses can reduce labor expenses without sacrificing quality. These strategies collectively ensure that companies remain competitive while delivering exceptional value to their customers.

About Thermal comfort

This article is about comfort zones in building construction. For other uses, see Comfort zone (disambiguation).



A thermal image of human

Thermal comfort is the condition of mind that expresses subjective satisfaction with the thermal environment.[1] The human body can be viewed as a heat engine where food is the input energy. The human body will release excess heat into the environment, so the body can continue to operate. The heat transfer is proportional to temperature difference. In cold environments, the body loses more heat to the environment and in hot environments the body does not release enough heat. Both the hot and cold scenarios lead to discomfort.[2] Maintaining this standard of thermal comfort for occupants of buildings or other enclosures is one of the important goals of HVAC (heating, ventilation, and air conditioning) design engineers.

Thermal neutrality is maintained when the heat generated by human metabolism is allowed to dissipate, thus maintaining thermal equilibrium with the surroundings. The main factors that influence thermal neutrality are those that determine heat gain and loss, namely metabolic rate, clothing insulation, air temperature, mean radiant temperature, air speed and relative humidity. Psychological parameters, such as individual expectations, and physiological parameters also affect thermal neutrality.[3] Neutral temperature is the temperature that can lead to thermal neutrality and it may vary greatly between individuals and depending on factors such as activity level, clothing, and humidity. People are highly sensitive to even small differences in environmental temperature. At 24 °C, a difference of 0.38 °C can be detected between the temperature of two rooms.[4]

The Predicted Mean Vote (PMV) model stands among the most recognized thermal comfort models. It was developed using principles of heat balance and experimental data collected in a controlled climate chamber under steady state conditions.[5] The adaptive model, on the other hand, was developed based on hundreds of field studies with the idea that occupants dynamically interact with their environment. Occupants control their thermal environment by means of clothing, operable windows, fans, personal heaters, and sun shades.[3][6] The PMV model can be applied to air-conditioned buildings, while the adaptive model can be applied only to buildings where no mechanical systems have been installed.[1] There is no consensus about which comfort model should be applied for buildings that are partially air-conditioned spatially or temporally.

Thermal comfort calculations in accordance with the ANSI/ASHRAE Standard 55,[1] the ISO 7730 Standard[7] and the EN 16798-1 Standard[8] can be freely performed with either the CBE Thermal Comfort Tool for ASHRAE 55,[9] with the Python package pythermalcomfort[10] or with the R package comf.

Significance

[edit]

Satisfaction with the thermal environment is important because thermal conditions are potentially life-threatening for humans if the core body temperature reaches conditions of hyperthermia, above 37.5–38.3 °C (99.5–100.9 °F),[11][12] or hypothermia, below 35.0 °C (95.0 °F).[13] Buildings modify the conditions of the external environment and reduce the effort that the human body needs to do in order to stay stable at a normal human body temperature, important for the correct functioning of human physiological processes.

The Roman writer Vitruvius actually linked this purpose to the birth of architecture.[14] David Linden also suggests that the reason why we associate tropical beaches with paradise is because in those environments is where human bodies need to do less metabolic effort to maintain their core temperature.[15] Temperature not only supports human life; coolness and warmth have also become in different cultures a symbol of protection, community and even the sacred.[16]

In building science studies, thermal comfort has been related to productivity and health. Office workers who are satisfied with their thermal environment are more productive.[17][18] The combination of high temperature and high relative humidity reduces thermal comfort and indoor air quality.[19]

Although a single static temperature can be comfortable, people are attracted by thermal changes, such as campfires and cool pools. Thermal pleasure is caused by varying thermal sensations from a state of unpleasantness to a state of pleasantness, and the scientific term for it is positive thermal alliesthesia.[20] From a state of thermal neutrality or comfort any change will be perceived as unpleasant.[21] This challenges the assumption that mechanically controlled buildings should deliver uniform temperatures and comfort, if it is at the cost of excluding thermal pleasure.[22]

Influencing factors

[edit]

Since there are large variations from person to person in terms of physiological and psychological satisfaction, it is hard to find an optimal temperature for everyone in a given space. Laboratory and field data have been collected to define conditions that will be found comfortable for a specified percentage of occupants.[1]

There are numerous factors that directly affect thermal comfort that can be grouped in two categories:

1. **Personal factors** – characteristics of the occupants such as metabolic rate and clothing level
2. **Environmental factors** – which are conditions of the thermal environment, specifically air temperature, mean radiant temperature, air speed and humidity

Even if all these factors may vary with time, standards usually refer to a steady state to study thermal comfort, just allowing limited temperature variations.

Personal factors

[edit]

Metabolic rate

[edit]
Main article: Metabolic rate

People have different metabolic rates that can fluctuate due to activity level and environmental conditions.[23][24][25] ASHRAE 55-2017 defines metabolic rate as the rate of transformation of chemical energy into heat and mechanical work by metabolic activities of an individual, per unit of skin surface area.[1]
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Metabolic rate is expressed in units of met, equal to 58.2 W/m^2 (18.4 Btu/h·ft^2). One met is equal to the energy produced per unit surface area of an average person seated at rest.

ASHRAE 55 provides a table of metabolic rates for a variety of activities. Some common values are 0.7 met for sleeping, 1.0 met for a seated and quiet position, 1.2–1.4 met for light activities standing, 2.0 met or more for activities that involve movement, walking, lifting heavy loads or operating machinery. For intermittent activity, the standard states that it is permissible to use a time-weighted average metabolic rate if individuals are performing activities that vary over a period of one hour or less. For longer periods, different metabolic rates must be considered.[1]

According to ASHRAE Handbook of Fundamentals, estimating metabolic rates is complex, and for levels above 2 or 3 met – especially if there are various ways of performing such activities – the accuracy is low. Therefore, the standard is not applicable for activities with an average level higher than 2 met. Met values can also be determined more accurately than the tabulated ones, using an empirical equation that takes into account the rate of respiratory oxygen consumption and carbon dioxide production. Another physiological yet less accurate method is related to the heart rate, since there is a relationship between the latter and oxygen consumption.[26]

The Compendium of Physical Activities is used by physicians to record physical activities. It has a different definition of met that is the ratio of the metabolic rate of the activity in question to a resting metabolic rate.[27] As the formulation of the concept is different from the one that ASHRAE uses, these met values cannot be used directly in PMV calculations, but it opens up a new way of quantifying physical activities.

Food and drink habits may have an influence on metabolic rates, which indirectly influences thermal preferences. These effects may change depending on food and drink intake.[28]

Body shape is another factor that affects metabolic rate and hence thermal comfort. Heat dissipation depends on body surface area. The surface area of an average person is 1.8 m^2 (19 ft^2).[1] A tall and skinny person has a larger surface-to-volume ratio, can dissipate heat more easily, and can tolerate higher temperatures more than a person with a rounded body shape.[28]

Clothing insulation

[edit]
Main article: Clothing insulation

The amount of thermal insulation worn by a person has a substantial impact on thermal comfort, because it influences the heat loss and consequently the thermal balance. Layers of insulating clothing prevent heat loss and can either help keep a person warm or lead to overheating. Generally, the thicker the garment is, the greater insulating ability it has. Depending on the type of material the clothing is made out of, air movement and relative humidity can decrease the insulating ability of the material.[29][30]

1 clo is equal to 0.155 m^2·K/W (0.88 °F·ft^2·h/Btu). This corresponds to trousers, a long sleeved shirt, and a jacket. Clothing insulation values for other common ensembles or single garments can be found in ASHRAE 55.[1]

Skin wetness

[edit]

Skin wetness is defined as "the proportion of the total skin surface area of the body covered with sweat".[31] The wetness of skin in different areas also affects perceived thermal comfort. Humidity can increase wetness in different areas of the body, leading to a perception of discomfort. This is usually localized in different parts of the body, and local thermal comfort limits for skin wetness differ by locations of the body.[32] The extremities are much more sensitive to thermal discomfort from wetness than the trunk of the body. Although local thermal discomfort can be caused by wetness, the thermal comfort of the whole body will not be affected by the wetness of certain parts.

Environmental factors

[edit]

Air temperature

[edit]
Main article: Dry-bulb temperature

The air temperature is the average temperature of the air surrounding the occupant, with respect to location and time. According to ASHRAE 55 standard, the spatial average takes into account the ankle, waist and head levels, which vary for seated or standing occupants. The temporal average is based on three-minutes intervals with at least 18 equally spaced points in time. Air temperature is measured with a dry-bulb thermometer and for this reason it is also known as dry-bulb temperature.

Mean radiant temperature

[edit]
Main article: Mean radiant temperature

The radiant temperature is related to the amount of radiant heat transferred from a surface, and it depends on the material's ability to absorb or emit heat, or its emissivity. The mean radiant temperature depends on the temperatures and emissivities of the surrounding surfaces as well as the view factor, or the amount of the surface that is “seen” by the object. So the mean radiant temperature experienced by a person in a room with the sunlight streaming in varies based on how much of their body is in the sun.

Air speed

[edit]

Air speed is defined as the rate of air movement at a point, without regard to direction. According to ANSI/ASHRAE Standard 55, it is the average speed of the air surrounding a representative occupant, with respect to location and time. The spatial average is for three heights as defined for average air temperature. For an occupant moving in a space the sensors shall follow the movements of the occupant. The air speed is averaged over an interval not less than one and not greater than three minutes. Variations that occur over a period greater than three minutes shall be treated as multiple different air speeds.[33]

Relative humidity

[edit]
Main article: Relative humidity

Relative humidity (RH) is the ratio of the amount of water vapor in the air to the amount of water vapor that the air could hold at the specific temperature and pressure. While the human body has thermoreceptors in the skin that enable perception of temperature, relative humidity is detected indirectly. Sweating is an effective heat loss mechanism that relies on evaporation from the skin. However at high RH, the air has close to the maximum water vapor that it can hold, so evaporation, and therefore heat loss, is decreased. On the other hand, very dry environments (RH < 20–30%) are also uncomfortable because of their effect on the mucous membranes. The recommended level of indoor humidity is in the range of 30–60% in air conditioned buildings,[34][35] but new standards such as the adaptive model allow lower and higher humidity, depending on the other factors involved in thermal comfort.

Recently, the effects of low relative humidity and high air velocity were tested on humans after bathing. Researchers found that low relative humidity engendered thermal discomfort as well as the sensation of dryness and itching. It is recommended to keep relative humidity levels higher in a bathroom than other rooms in the house for optimal conditions.[36]

Various types of apparent temperature have been developed to combine air temperature and air humidity. For higher temperatures, there are quantitative scales, such as the heat index. For lower temperatures, a related interplay was identified only qualitatively:

- High humidity and low temperatures cause the air to feel chilly.[37]
- Cold air with high relative humidity "feels" colder than dry air of the same temperature because high humidity in cold weather increases the conduction of heat from the body.[38]

There has been controversy over why damp cold air feels colder than dry cold air. Some believe it is because when the humidity is high, our skin and clothing become moist and are better conductors of heat, so there is more cooling by conduction.[39]

The influence of humidity can be exacerbated with the combined use of fans (forced convection cooling).[40]

Natural ventilation

[edit]
Main article: Natural ventilation

Many buildings use an HVAC unit to control their thermal environment. Other buildings are naturally ventilated (or would have cross ventilation) and do not rely on mechanical systems to provide thermal comfort. Depending on the climate, this can drastically reduce energy consumption. It is sometimes seen as a risk, though, since indoor temperatures can be too extreme if the building is poorly designed. Properly designed, naturally ventilated buildings keep indoor conditions within the range where opening windows and using fans in the summer, and wearing extra clothing in the winter, can keep people thermally comfortable.[41]

Models and indices

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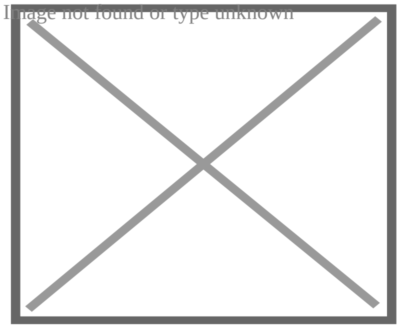
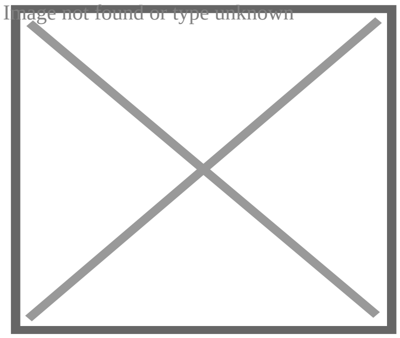
There are several different models or indices that can be used to assess thermal comfort conditions indoors as described below.

PMV/PPD method

[edit]



Psychrometric Chart



Temperature-relative humidity chart

Two alternative representations of thermal comfort for the PMV/PPD method

The PMV/PPD model was developed by P.O. Fanger using heat-balance equations and empirical studies about skin temperature to define comfort. Standard thermal comfort surveys ask subjects about their thermal sensation on a seven-point scale from cold (?3) to hot (+3). Fanger's equations are used to calculate the predicted mean vote (PMV) of a group of subjects for a particular combination of air temperature, mean radiant temperature, relative humidity, air speed, metabolic rate, and clothing insulation.[5] PMV equal to zero is representing thermal neutrality, and the comfort zone is defined by the combinations of the six parameters for which the PMV is within the recommended limits (?0.5 < PMV < +0.5).[1] Although predicting the thermal sensation of a population is an important step in determining what conditions are comfortable, it is more useful to consider whether or not people will be satisfied. Fanger developed another equation to relate the PMV to the Predicted Percentage of Dissatisfied (PPD). This relation was based on studies that surveyed subjects in a chamber where the indoor conditions could be precisely controlled.[5]

The PMV/PPD model is applied globally but does not directly take into account the adaptation mechanisms and outdoor thermal conditions.[3][42][43]

ASHRAE Standard 55-2017 uses the PMV model to set the requirements for indoor thermal conditions. It requires that at least 80% of the occupants be satisfied.[1]

The CBE Thermal Comfort Tool for ASHRAE 55[9] allows users to input the six comfort parameters to determine whether a certain combination complies with ASHRAE 55. The results are displayed on a psychrometric or a temperature-relative humidity chart and indicate the ranges of temperature and relative humidity that will be comfortable with the given the values input for the remaining four parameters.[44]

The PMV/PPD model has a low prediction accuracy.[45] Using the world largest thermal comfort field survey database,[46] the accuracy of PMV in predicting occupant's thermal sensation was only 34%, meaning that the thermal sensation is correctly predicted one out of three times. The PPD was overestimating subject's thermal unacceptability outside the thermal neutrality ranges (-1?PMV?1). The PMV/PPD accuracy varies strongly between ventilation strategies, building types and climates.[45]

Elevated air speed method

[edit]

ASHRAE 55 2013 accounts for air speeds above 0.2 metres per second (0.66 ft/s) separately than the baseline model. Because air movement can provide direct cooling to people, particularly if they are not wearing much clothing, higher temperatures can be more comfortable than the PMV model predicts. Air speeds up to 0.8 m/s (2.6 ft/s) are allowed without local control, and 1.2 m/s is possible with local control. This elevated air movement increases the maximum temperature for an office space in the summer to 30 °C from 27.5 °C (86.0–81.5 °F).[1]

Virtual Energy for Thermal Comfort

[edit]

"Virtual Energy for Thermal Comfort" is the amount of energy that will be required to make a non-air-conditioned building relatively as comfortable as one with air-conditioning. This is based on the assumption that the home will eventually install air-conditioning or heating.[47] Passive design improves thermal comfort in a building, thus reducing demand for heating or cooling. In many developing countries, however, most occupants do not currently heat or cool, due to economic constraints, as well as climate conditions which border lines comfort conditions such as cold winter nights in Johannesburg (South Africa) or warm summer days in San Jose, Costa Rica. At the same time, as incomes rise, there is a strong tendency to introduce cooling and heating systems. If we recognize and reward passive design features that improve thermal comfort today, we diminish the risk of having to install HVAC systems in the future, or we at least ensure that such systems will be smaller and less frequently used. Or in case the heating or cooling system is not installed due to high cost, at least people should not suffer from discomfort indoors. To provide an example, in San Jose, Costa Rica, if a house were being designed with high level of glazing and small opening sizes, the internal temperature would easily rise above 30 °C (86 °F) and natural ventilation would not be enough to remove the internal heat gains and solar gains. This is why Virtual Energy for Comfort is important.

World Bank's assessment tool the EDGE software (Excellence in Design for Greater Efficiencies) illustrates the potential issues with discomfort in buildings and has created the concept of Virtual Energy for Comfort which provides for a way to present potential thermal discomfort. This approach is used to award for design solutions which improves thermal comfort even in a fully free running building. Despite the inclusion of requirements for overheating in CIBSE, overcooling has not been assessed. However, overcooling can be an issue, mainly in the developing world, for example in cities such as Lima (Peru), Bogota, and Delhi, where cooler indoor temperatures can occur frequently. This may be a new area for research and design guidance for reduction of discomfort.

Cooling Effect

[edit]

ASHRAE 55-2017 defines the Cooling Effect (CE) at elevated air speed (above 0.2 metres per second (0.66 ft/s)) as the value that, when subtracted from both the air temperature and the mean radiant temperature, yields the same SET value under still air (0.1 m/s) as in the first SET calculation under elevated air speed.[1]

$$\displaystyle SET(t_a,t_r,v,met,clo,RH)=SET(t_a-CE,t_r-CE,v=0.1,met,clo,RH)$$

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The CE can be used to determine the PMV adjusted for an environment with elevated air speed using the adjusted temperature, the adjusted radiant temperature and still air (0.2 metres per second (0.66 ft/s)). Where the adjusted temperatures are equal to the original air and mean radiant temperatures minus the CE.

Local thermal discomfort

[edit]

Avoiding local thermal discomfort, whether caused by a vertical air temperature difference between the feet and the head, by an asymmetric radiant field, by local convective cooling (draft), or by contact with a hot or cold floor, is essential to providing acceptable thermal comfort. People are generally more sensitive to local discomfort when their thermal sensation is cooler than neutral, while they are less sensitive to it when their body is warmer than neutral.[33]

Radiant temperature asymmetry

[edit]

Large differences in the thermal radiation of the surfaces surrounding a person may cause local discomfort or reduce acceptance of the thermal conditions. ASHRAE Standard 55 sets limits on the allowable temperature differences between various surfaces. Because people are more sensitive to some asymmetries than others, for example that of a warm ceiling versus that of hot and cold vertical surfaces, the limits depend on which surfaces are involved. The ceiling is not allowed to be more than +5 °C (9.0 °F) warmer, whereas a wall may be up to +23 °C (41 °F) warmer than the other surfaces.[1]

Draft

[edit]

While air movement can be pleasant and provide comfort in some circumstances, it is sometimes unwanted and causes discomfort. This unwanted air movement is called "draft" and is most prevalent when the thermal sensation of the whole body is cool. People are most likely to feel a draft on uncovered body parts such as their head, neck, shoulders, ankles, feet, and legs, but the sensation also depends on the air speed, air temperature, activity, and clothing.[1]

Floor surface temperature

[edit]

Floors that are too warm or too cool may cause discomfort, depending on footwear. ASHRAE 55 recommends that floor temperatures stay in the range of 19–29 °C (66–84 °F) in spaces where occupants will be wearing lightweight shoes.[1]

Standard effective temperature

[edit]

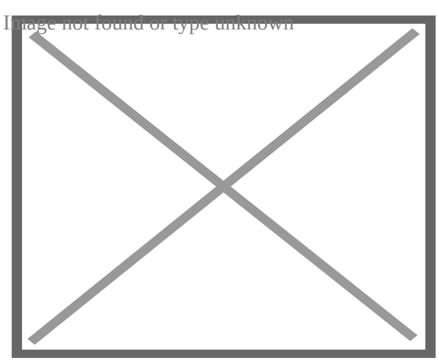
Standard effective temperature (SET) is a model of human response to the thermal environment. Developed by A.P. Gagge and accepted by ASHRAE in 1986,[48] it is also referred to as the Pierce Two-Node model.[49] Its calculation is similar to PMV because it is a comprehensive comfort index based on heat-balance equations that incorporates the personal factors of clothing and metabolic rate. Its fundamental difference is it takes a two-node method to represent human physiology in measuring skin temperature and skin wettedness.[48]

The SET index is defined as the equivalent dry bulb temperature of an isothermal environment at 50% relative humidity in which a subject, while wearing clothing standardized for activity concerned, would have the same heat stress (skin temperature) and thermoregulatory strain (skin wettedness) as in the actual test environment.[48]

Research has tested the model against experimental data and found it tends to overestimate skin temperature and underestimate skin wettedness.[49][50] Fountain and Huizenga (1997) developed a thermal sensation prediction tool that computes SET.[51] The SET index can also be calculated using either the CBE Thermal Comfort Tool for ASHRAE 55,[9] the Python package pythermalcomfort,[10] or the R package comf.

Adaptive comfort model

[edit]



Adaptive chart according to ASHRAE Standard 55-2010

The adaptive model is based on the idea that outdoor climate might be used as a proxy of indoor comfort because of a statistically significant correlation between them. The adaptive hypothesis predicts that contextual factors, such as having access to environmental controls, and past thermal history can influence building occupants' thermal expectations and preferences.[3] Numerous researchers have conducted field studies worldwide in which they survey building occupants about their thermal comfort while taking simultaneous environmental measurements. Analyzing a database of results from 160 of these buildings revealed that occupants of naturally ventilated buildings accept and even prefer a wider range of temperatures than their counterparts in sealed, air-conditioned buildings because their preferred temperature depends on outdoor conditions.[3] These results were incorporated in the ASHRAE 55-2004 standard as the adaptive comfort model. The adaptive chart relates indoor comfort temperature to prevailing outdoor temperature and defines zones of 80% and 90% satisfaction.[1]

The ASHRAE-55 2010 Standard introduced the prevailing mean outdoor temperature as the input variable for the adaptive model. It is based on the arithmetic average of the mean daily outdoor temperatures over no fewer than 7 and no more than 30 sequential days prior to the day in question.[1] It can also be calculated by weighting the temperatures with different coefficients, assigning increasing importance to the most recent temperatures. In case this weighting is used, there is no need to respect the upper limit for the subsequent days. In order to apply the adaptive model, there should be no mechanical cooling system for the space, occupants should be engaged in sedentary activities with metabolic rates of 1–1.3 met, and a prevailing mean temperature of 10–33.5 °C (50.0–92.3 °F).[1]

This model applies especially to occupant-controlled, natural-conditioned spaces, where the outdoor climate can actually affect the indoor conditions and so the comfort zone. In fact, studies by de Dear and Brager showed that occupants in naturally ventilated buildings were tolerant of a wider range of temperatures.[3] This is due to both behavioral and physiological adjustments, since there are different types of adaptive processes.[52] ASHRAE Standard 55-2010 states that differences in recent thermal experiences, changes in clothing, availability of control options, and shifts in occupant expectations can change people's thermal responses.[1]

Adaptive models of thermal comfort are implemented in other standards, such as European EN 15251 and ISO 7730 standard. While the exact derivation methods and results are slightly different from the ASHRAE 55 adaptive standard, they are substantially the same. A larger difference is in applicability. The ASHRAE adaptive standard only applies to buildings without mechanical cooling installed, while EN15251 can be applied to mixed-mode buildings, provided the system is not running.[53]

There are basically three categories of thermal adaptation, namely: behavioral, physiological, and psychological.

Psychological adaptation

[edit]

An individual's comfort level in a given environment may change and adapt over time due to psychological factors. Subjective perception of thermal comfort may be influenced by the memory of previous experiences. Habituation takes place when repeated exposure moderates future expectations, and responses to sensory input. This is an important factor in explaining the difference between field observations and PMV predictions (based on the static model) in naturally ventilated buildings. In these buildings, the relationship with the outdoor temperatures has been twice as strong as predicted.[3]

Psychological adaptation is subtly different in the static and adaptive models. Laboratory tests of the static model can identify and quantify non-heat transfer (psychological) factors that affect reported comfort. The adaptive model is limited to reporting differences (called psychological) between modeled and reported comfort.[*citation needed*]

Thermal comfort as a "condition of mind" is *defined* in psychological terms. Among the factors that affect the condition of mind (in the laboratory) are a sense of control over the temperature, knowledge of the temperature and the appearance of the (test) environment. A thermal test chamber that appeared residential "felt" warmer than one which looked like the inside of a refrigerator.[54]

Physiological adaptation

[edit]
Further information: Thermoregulation

The body has several thermal adjustment mechanisms to survive in drastic temperature environments. In a cold environment the body utilizes vasoconstriction; which reduces blood flow to the skin, skin temperature and heat dissipation. In a warm environment, vasodilation will increase blood flow to the skin, heat transport, and skin temperature and heat dissipation.[55] If there is an imbalance despite the vasomotor adjustments listed above, in a warm environment sweat production will start and provide evaporative cooling. If this is insufficient, hyperthermia will set in, body temperature may reach 40 °C (104 °F), and heat stroke may occur. In a cold environment, shivering will start, involuntarily forcing the muscles to work and increasing the heat production by up to a factor of 10. If equilibrium is not restored, hypothermia can set in, which can be fatal.[55] Long-term adjustments to extreme temperatures, of a few days to six months, may result in cardiovascular and endocrine adjustments. A hot climate may create increased blood volume, improving the effectiveness of vasodilation, enhanced performance of the sweat mechanism, and the readjustment of thermal preferences. In cold or underheated conditions, vasoconstriction can become permanent, resulting in decreased blood volume and increased body metabolic rate.[55]

Behavioral adaptation

[edit]

In naturally ventilated buildings, occupants take numerous actions to keep themselves comfortable when the indoor conditions drift towards discomfort. Operating windows and fans, adjusting blinds/shades, changing clothing, and consuming food and drinks are some of the common adaptive strategies. Among these, adjusting windows is the most common.[56] Those occupants who take these sorts of actions tend to feel cooler at warmer temperatures than those who do not.[57]

The behavioral actions significantly influence energy simulation inputs, and researchers are developing behavior models to improve the accuracy of simulation results. For example, there are many window-opening models that have been developed to date, but there is no consensus over the factors that trigger window opening.[56]

People might adapt to seasonal heat by becoming more nocturnal, doing physical activity and even conducting business at night.

Specificity and sensitivity

[edit]

Individual differences

[edit]
Further information: Cold sensitivity

The thermal sensitivity of an individual is quantified by the descriptor *FS*, which takes on higher values for individuals with lower tolerance to non-ideal thermal conditions.[58] This group includes pregnant women, the disabled, as well as individuals whose age is below fourteen or above sixty, which is considered the adult range. Existing literature provides consistent evidence that sensitivity to hot and cold surfaces usually declines with age. There is also some evidence of a gradual reduction in the effectiveness of the body in thermo-regulation after the age of sixty.[58] This is mainly due to a more sluggish response of the counteraction mechanisms in lower parts of the body that are used to maintain the core temperature of the body at ideal values.[58] Seniors prefer warmer temperatures than young adults (76 vs 72 degrees F or 24.4 vs 22.2 Celsius).[54]

Situational factors include the health, psychological, sociological, and vocational activities of the persons.

Biological sex differences

[edit]

While thermal comfort preferences between sexes seem to be small, there are some average differences. Studies have found males on average report discomfort due to rises in temperature much earlier than females. Males on average also estimate higher levels of their sensation of discomfort than females. One recent study tested males and females in the same cotton clothing, performing mental jobs while using a dial vote to report their thermal comfort to the changing temperature.[59] Many times, females preferred higher temperatures than males. But while females tend to be more sensitive to temperatures, males tend to be more sensitive to relative-humidity levels.[60][61]

An extensive field study was carried out in naturally ventilated residential buildings in Kota Kinabalu, Sabah, Malaysia. This investigation explored the sexes thermal sensitivity to the indoor environment in non-air-conditioned residential buildings. Multiple hierarchical regression for categorical moderator was selected for data analysis; the result showed that as a group females were slightly more sensitive than males to the indoor air temperatures, whereas, under thermal neutrality, it was found that males and females have similar thermal sensation.[62]

Regional differences

[edit]

In different areas of the world, thermal comfort needs may vary based on climate. In China[*where?*] the climate has hot humid summers and cold winters, causing a need for efficient thermal comfort. Energy conservation in relation to thermal comfort has become a large issue in China in the last several decades due to rapid economic and population growth.[63] Researchers are now looking into ways to heat and cool buildings in China for lower costs and also with less harm to the environment.

In tropical areas of Brazil, urbanization is creating urban heat islands (UHI). These are urban areas that have risen over the thermal comfort limits due to a large influx of people and only drop within the comfortable range during the rainy season.[64] Urban heat islands can occur over any urban city or built-up area with the correct conditions.[65][66]

In the hot, humid region of Saudi Arabia, the issue of thermal comfort has been important in mosques, because they are very large open buildings that are used only intermittently (very busy for the noon prayer on Fridays) it is hard to ventilate them properly. The large size requires a large amount of ventilation, which requires a lot of energy since the buildings are used only for short periods of time. Temperature regulation in mosques is a challenge due to the intermittent demand, leading to many mosques being either too hot or too cold. The stack effect also comes into play due to their large size and creates a large layer of hot air above the people in the mosque. New designs have placed the ventilation systems lower in the buildings to provide more temperature control at ground level.[67] New monitoring steps are also being taken to improve efficiency.[68]

Thermal stress

[edit]
Not to be confused with thermal stress on objects, which describes the change materials experience when subject to extreme temperatures.

The concept of thermal comfort is closely related to thermal stress. This attempts to predict the impact of solar radiation, air movement, and humidity for military personnel undergoing training exercises or athletes during competitive events. Several thermal stress indices have been proposed, such as the Predicted Heat Strain (PHS) or the humidex.[69] Generally, humans do not perform well under thermal stress. People's performances under thermal stress is about 11% lower than their performance at normal thermal wet conditions. Also, human performance in relation to thermal stress varies greatly by the type of task which the individual is completing. Some of the physiological effects of thermal heat stress include increased blood flow to the skin, sweating, and increased ventilation.[70][71]

Predicted Heat Strain (PHS)

[edit]

The PHS model, developed by the International Organization for Standardization (ISO) committee, allows the analytical evaluation of the thermal stress experienced by a working subject in a hot environment.[72] It describes a method for predicting the sweat rate and the internal core temperature that the human body will develop in response to the working conditions. The PHS is calculated as a function of several physical parameters, consequently it makes it possible to determine which parameter or group of parameters should be modified, and to what extent, in order to reduce the risk of physiological strains. The PHS model does not predict the physiological response of an individual subject, but only considers standard subjects in good health and fit for the work they perform. The PHS can be determined using either the Python package pythermalcomfort[10] or the R package comf.

American Conference on Governmental Industrial Hygienists (ACGIH) Action Limits and Threshold Limit Values

[edit]

ACGIH has established Action Limits and Threshold Limit Values for heat stress based upon the estimated metabolic rate of a worker and the environmental conditions the worker is subjected to.

This methodology has been adopted by the Occupational Safety and Health Administration (OSHA) as an effective method of assesing heat stress within workplaces.[73]

Research

[edit]

The factors affecting thermal comfort were explored experimentally in the 1970s. Many of these studies led to the development and refinement of ASHRAE Standard 55 and were performed at Kansas State University by Ole Fanger and others. Perceived comfort was found to be a complex interaction of these variables. It was found that the majority of individuals would be satisfied by an ideal set of values. As the range of values deviated progressively from the ideal, fewer and fewer people were satisfied. This observation could be expressed statistically as the percent of individuals who expressed satisfaction by *comfort conditions* and the *predicted mean vote* (PMV). This approach was challenged by the adaptive comfort model, developed from the ASHRAE 884 project, which revealed that occupants were comfortable in a broader range of temperatures.[3]

This research is applied to create Building Energy Simulation (BES) programs for residential buildings. Residential buildings in particular can vary much more in thermal comfort than public and commercial buildings. This is due to their smaller size, the variations in clothing worn, and different uses of each room. The main rooms of concern are bathrooms and bedrooms. Bathrooms need to be at a temperature comfortable for a human with or without clothing. Bedrooms are of importance because they need to accommodate different levels of clothing and also different metabolic rates of people asleep or awake.[74] Discomfort hours is a common metric used to evaluate the thermal performance of a space.

Thermal comfort research in clothing is currently being done by the military. New air-ventilated garments are being researched to improve evaporative cooling in military settings. Some models are being created and tested based on the amount of cooling they provide.[75]

In the last twenty years, researchers have also developed advanced thermal comfort models that divide the human body into many segments, and predict local thermal discomfort by considering heat balance.[76][77][78] This has opened up a new arena of thermal comfort modeling that aims at heating/cooling selected body parts.

Another area of study is the hue-heat hypothesis that states that an environment with warm colors (red, orange yellow hues) will feel warmer in terms of temperature and comfort, while an environment with cold colors (blue, green hues) will feel cooler.[79][80][81] The hue-heat hypothesis has both been investigated scientifically[82] and ingrained in popular culture in the terms warm and cold colors [83]

Medical environments

[edit]

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Whenever the studies referenced tried to discuss the thermal conditions for different groups of occupants in one room, the studies ended up simply presenting comparisons of thermal comfort satisfaction based on the subjective studies. No study tried to reconcile the different thermal comfort requirements of different types of occupants who compulsorily must stay in one room. Therefore, it looks to be necessary to investigate the different thermal conditions required by different groups of occupants in hospitals to reconcile their different requirements in this concept. To reconcile the differences in the required thermal comfort conditions it is recommended to test the possibility of using different ranges of local radiant temperature in one room via a suitable mechanical system.

Although different researches are undertaken on thermal comfort for patients in hospitals, it is also necessary to study the effects of thermal comfort conditions on the quality and the quantity of healing for patients in hospitals. There are also original researches that show the link between thermal comfort for staff and their levels of productivity, but no studies have been produced individually in hospitals in this field.

Therefore, research for coverage and methods individually for this subject is recommended. Also research in terms of cooling and heating delivery systems for patients with low levels of immune-system protection (such as HIV patients, burned patients, etc.) are recommended. There are important areas, which still need to be focused on including thermal comfort for staff and its relation with their productivity, using different heating systems to prevent hypothermia in the patient and to improve the thermal comfort for hospital staff simultaneously.

Finally, the interaction between people, systems and architectural design in hospitals is a field in which require further work needed to improve the knowledge of how to design buildings and systems to reconcile many conflicting factors for the people occupying these buildings.[84]

Personal comfort systems

[edit]

Personal comfort systems (PCS) refer to devices or systems which heat or cool a building occupant personally.[85] This concept is best appreciated in contrast to central HVAC systems which have uniform temperature settings for extensive areas. Personal comfort systems include fans and air diffusers of various kinds (e.g. desk fans, nozzles and slot diffusers, overhead fans, high-volume low-speed fans etc.) and personalized sources of radiant or conductive heat (footwarmers, legwarmers, hot water bottles etc.). PCS has the potential to satisfy individual comfort requirements much better than current HVAC systems, as interpersonal differences in thermal sensation due to age, sex, body mass, metabolic rate, clothing and thermal adaptation can amount to an equivalent temperature variation of 2–5 °C (3,6–9 °F), which is impossible for a central, uniform HVAC system to cater to.[85] Besides, research has shown that the perceived ability to control one's thermal environment tends to widen one's range of tolerable temperatures.[3] Traditionally, PCS devices have been used in isolation from one another. However, it has been proposed by Andersen et al. (2016) that a network of PCS devices which generate well-connected microzones of thermal comfort, and report real-time occupant information and respond to programmatic actuation requests (e.g. a party, a conference, a concert etc.) can combine with occupant-aware building applications to enable new methods of comfort maximization.[86]

See also

[edit]

- ASHRAE
- ANSI/ASHRAE Standard 55
- Air conditioning

- Building insulation
- Cold and heat adaptations in humans
- Heat stress
- Mean radiant temperature
- Mahoney tables
- Povl Ole Fanger
- Psychrometrics
- Ralph G. Nevins
- Room air distribution
- Room temperature
- Ventilative cooling

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- Cold Stress, National Institute for Occupational Safety and Health.

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Heating, ventilation, and air conditioning

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

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

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

Components

- Grille

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

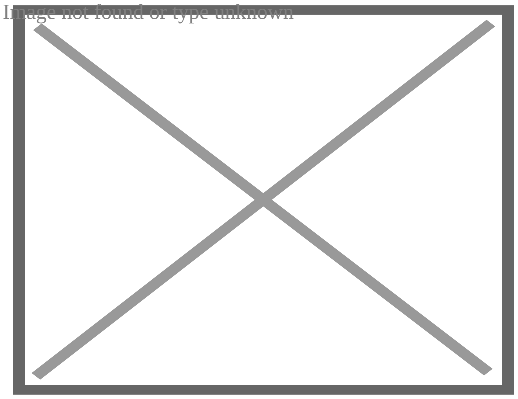
See also

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

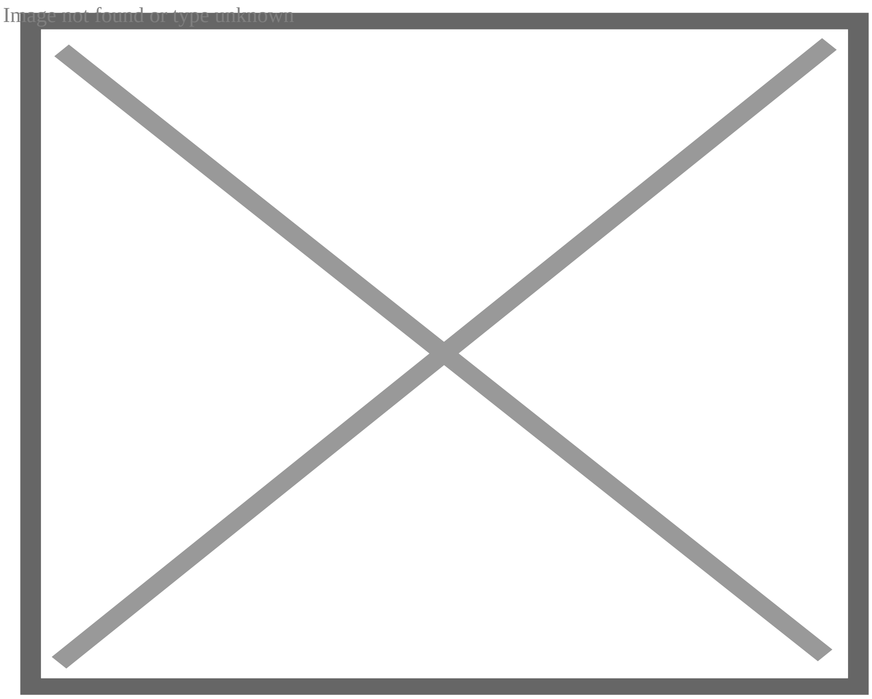
Authority control databases: National Germany Image not found or type unknown **Edit this at Wikidata**

About Air pollution

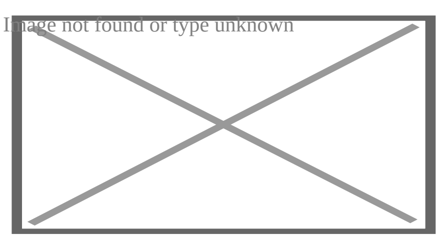
"Bad air quality" and "Air quality" redirect here. For the obsolete medical theory, see Miasma theory. For the measurement of air pollution, see Air quality index. For the qualities of air, see Atmosphere of Earth.



Air pollution from a coking oven



2016 Environmental Performance Index – darker colors indicate lower concentrations of fine particulate matter and nitrogen dioxide, as well as better indoor air quality.



Deaths from air pollution per 100,000 inhabitants (IHME, 2019)

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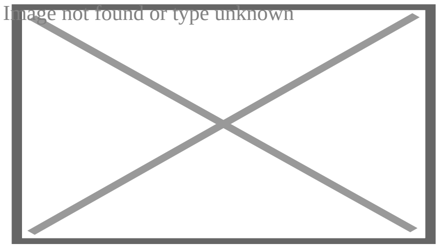
Part of a series on



Air pollution from a factory

Air

- Acid rain
- Air quality index
- Atmospheric dispersion modeling
- Chlorofluorocarbon
- Combustion
- Exhaust gas
- Haze
- Global dimming
- Global distillation
- Indoor air quality
- Non-exhaust emissions
- Ozone depletion
- Particulates
- Persistent organic pollutant
- Smog
- Soot
- Volatile organic compound

Biological

- Biological hazard
- Genetic
- Illegal logging
- Introduced species
  - Invasive species

Digital

- Information

Electromagnetic

- Light
  - Ecological
  - Overillumination
- Radio spectrum

Natural

- Ozone
- Radium and radon in the environment
- Volcanic ash
- Wildfire

Noise

- Transportation
- Health effects from noise
- Marine mammals and sonar
- Noise barrier
- Noise control
- Soundproofing

Radiation

- Actinides
- Bioremediation
- Depleted uranium
- Nuclear fission
- Nuclear fallout
- Plutonium
- Poisoning
- Radioactivity
- Uranium
- Radioactive waste

Soil

- Agricultural
- Land degradation
- Bioremediation
- Defecation
- Electrical resistance heating
- Illegal mining
- Soil guideline values
- Phytoremediation

Solid waste

- Advertising mail
- Biodegradable waste
- Brown waste
- Electronic waste
- Foam food container
- Food waste
- Green waste
- Hazardous waste
- Industrial waste
- Litter
- Mining
- Municipal solid waste
- Nanomaterials
- Plastic
- Packaging waste
- Post-consumer waste
- Waste management

Space

- Space debris

Thermal

- Urban heat island

Visual

- Air travel
- Advertising clutter
- Overhead power lines
- Traffic signs
- Urban blight
- Vandalism

War

- Chemical warfare
- Herbicidal warfare
  - Agent Orange
- Nuclear holocaust
  - Nuclear fallout
  - Nuclear famine
  - Nuclear winter
- Scorched earth
- Unexploded ordnance
- War and environmental law

Water

- Agricultural wastewater
- Biosolids
- Diseases
- Eutrophication
- Firewater
- Freshwater
- Groundwater
- Hypoxia
- Industrial wastewater
- Marine
- Monitoring
- Nonpoint source
- Nutrient
- Ocean acidification
- Oil spill
- Pharmaceuticals
- Freshwater salinization
- Septic tanks
- Sewage
- Shipping
- Sludge
- Stagnation
- Sulfur water
- Surface runoff
- Turbidity
- Urban runoff
- Water quality
- Wastewater

Topics

- History
- Pollutants
    - Heavy metals
    - Paint

Misc

- Area source
- Brain health and pollution
- Debris
- Dust
- Garbology
- Legacy
- Midden
- Point source
- Waste
  - Toxic

Lists

- Diseases
- Law by country
- Most polluted cities
- Least polluted cities by PM2.5
- Treaties
- Most polluted rivers

Categories

- By country

- Image not found or type unknown icon Environment portal
- Image not found or type unknown icon Ecology portal

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Part of a series on

Weather

Temperate and polar seasons

- Winter
- Spring
- Summer
- Autumn

Tropical seasons

- Dry season
  - Harmattan
- Wet season

Storms

- Cloud
  - Cumulonimbus cloud
  - Arcus cloud
- Downburst
  - Microburst
  - Heat burst
  - Derecho
- Lightning
  - Volcanic lightning
- Thunderstorm
  - Air-mass thunderstorm
  - Thundersnow
  - Dry thunderstorm
- Mesocyclone
  - Supercell
- Tornado
  - Anticyclonic tornado
  - Landspout
  - Waterspout
- Dust devil
- Fire whirl
- Anticyclone
- Cyclone
- Polar low
- Extratropical cyclone
  - European windstorm
  - Nor'easter
- Subtropical cyclone
- Tropical cyclone
  - Atlantic hurricane
  - Typhoon
- Storm surge
- Dust storm
  - Simoom
  - Haboob
- Monsoon
  - Amihan
- Gale
- Sirocco
- Firestorm
- Winter storm
  - Ice storm
  - Blizzard
  - Ground blizzard
  - Snow squall

Precipitation

- Drizzle
  - Freezing
- Graupel
- Hail
  - Megacryometeor
- Ice pellets
- Diamond dust
- Rain
  - Freezing
- Cloudburst
- Snow
  - Rain and snow mixed
  - Snow grains
  - Snow roller
  - Slush

Topics

- Air pollution
- Atmosphere
-
  - Chemistry
  - Convection
  - Physics
  - River
- Climate
- Cloud
  - Physics
- Fog
  - Mist
  - Season
- Cold wave
- Heat wave
- Jet stream
- Meteorology
- Severe weather
  - List
  - Extreme
  - Severe weather terminology
    - Canada
    - Japan
    - United States
- Weather forecasting
- Weather modification

Glossaries

- Meteorology
- Climate change
- Tornado terms
- Tropical cyclone terms

icon Image not found or type unknown Weather portal

Air pollution is the contamination of air due to the presence of substances called pollutants in the atmosphere that are harmful to the health of humans and other living beings, or cause damage to the climate or to materials.[1] It is also the contamination of the indoor or outdoor environment either by chemical, physical, or biological agents that alters the natural features of the atmosphere.[1] There are many different types of air pollutants, such as gases (including ammonia, carbon monoxide, sulfur dioxide, nitrous oxides, methane and chlorofluorocarbons), particulates (both organic and inorganic) and biological molecules. Air pollution can cause diseases, allergies, and even death to humans; it can also cause harm to other living organisms such as animals and crops, and may damage the natural environment (for example, climate change, ozone depletion or habitat degradation) or built environment (for example, acid rain).[2] Air pollution can be caused by both human activities[3] and natural phenomena.[4]

Air quality is closely related to the Earth's climate and ecosystems globally. Many of the contributors of air pollution are also sources of greenhouse emission i.e., burning of fossil fuel.[1]

Air pollution is a significant risk factor for a number of pollution-related diseases, including respiratory infections, heart disease, chronic obstructive pulmonary disease (COPD), stroke, and lung cancer.[5] Growing evidence suggests that air pollution exposure may be associated with reduced IQ scores, impaired cognition,[6] increased risk for psychiatric disorders such as depression[7] and detrimental perinatal health.[8] The human health effects of poor air quality are far reaching, but principally affect the body's respiratory system and the cardiovascular system.[9][10] Individual reactions to air pollutants depend on the type of pollutant a person is exposed to,[11][12] the degree of exposure, and the individual's health status and genetics.[13]

Air pollution is the largest environmental risk factor for disease and premature death[5][14] and the fourth largest risk factor overall for human health.[15] Air pollution causes the premature deaths of around 7 million people worldwide each year,[5] or a global mean loss of life expectancy (LLE) of 2.9 years,[16] and there has been no significant change in the number of deaths caused by all forms of pollution since at least 2015.[14][17][18] Outdoor air pollution attributable to fossil fuel use alone causes ~3.61 million deaths annually,[19] making it one of the top contributors to human death.[5] Anthropogenic ozone causes around 470,000 premature deaths a year and fine particulate ($PM_{2.5}$)

pollution around another 2.1 million.[20] The scope of the air pollution crisis is large: In 2018, WHO estimated that "9 out of 10 people breathe air containing high levels of pollutants."[21] Although the health consequences are extensive, the way the problem is handled is considered largely haphazard[22][21][23] or neglected.[14]

The World Bank has estimated that welfare losses (premature deaths) and productivity losses (lost labour) caused by air pollution cost the world economy $5 trillion per year.[24][25][26] The costs of air pollution are generally an externality to the contemporary economic system and most human activity, although they are sometimes recovered through monitoring, legislation, and regulation.[27][28]

Many different technologies and strategies are available for reducing air pollution.[29] Although a majority of countries have air pollution laws, according to UNEP, 43 percent of countries lack a legal definition of air pollution, 31 percent lack outdoor air quality standards, 49 percent restrict their definition to outdoor pollution only, and just 31 percent have laws for tackling pollution originating from outside their borders.[30] National air quality laws have often been highly effective, notably the 1956 Clean Air Act in Britain and the US Clean Air Act, introduced in 1963.[31][32] Some of these efforts have been successful at the international level, such as the Montreal Protocol,[33] which reduced the release of harmful ozone depleting chemicals, and the 1985 Helsinki Protocol,[34] which reduced sulfur emissions,[35] while others, such as international action on climate change,[36][37][38] have been less successful.

Sources of air pollution

[edit]

There are many different sources of air pollution. Some air pollutants (such as nitrogen oxides) originate mainly from human activities,[39] while some (notably radon gas) come mostly from natural sources.[40] However, many air pollutants (including dust and sulfur dioxide) come from a mixture of natural and human sources.[41]

Anthropogenic (human-made) sources

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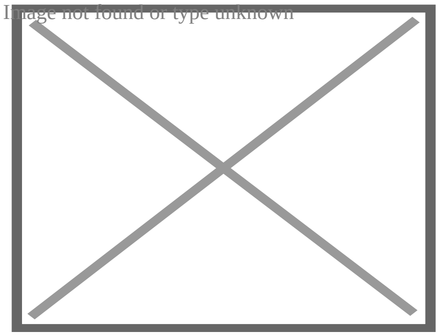
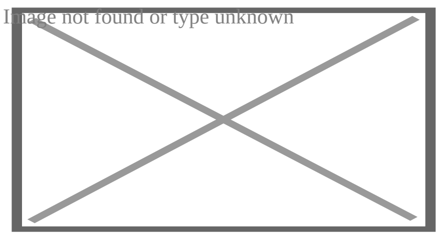
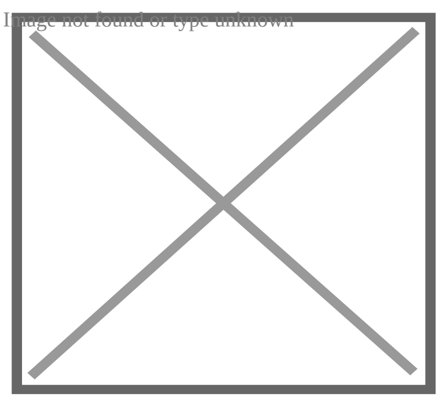


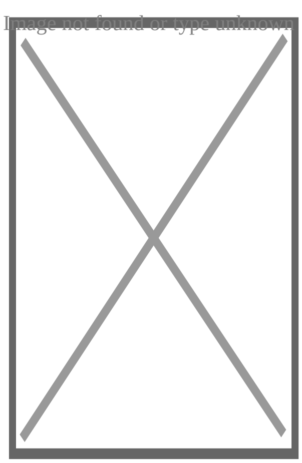
Demolition of the cooling towers of a power station, Athlone, Cape Town, South Africa, 2010



Controlled burning of a field outside of Statesboro, Georgia, US, in preparation for spring planting



Smoking of fish over an open fire in Ghana, 2018



Burning of joss paper in a Chinese temple in Hong Kong

- Stationary sources include:
  - fossil-fuel power plants and biomass power plants both have smoke stacks (see for example environmental impact of the coal industry)[42]
    - Oil and gas sites that have methane leaks[43][44][45][46]
  - burning of traditional biomass such as wood, crop waste and dung. (In developing and poor countries,[47] traditional biomass burning is the major source of air pollutants.[48][49] It is also the main source of particulate pollution in many developed areas including the UK & New South Wales.[50][51] Its pollutants include PAHs.[52])
  - manufacturing facilities (factories)[53]
    - a 2014 study found that in China equipment-, machinery-, and devices-manufacturing and construction sectors contributed more than 50% of air pollutant emissions.[54][*better source needed*] This high emission is due to high emission intensity and high emission factors in its industrial structure.[55]
  - construction[56][57]
  - renovation[58]
  - waste incineration (incinerators as well as open and uncontrolled fires of mismanaged waste, making up about a fourth of municipal solid terrestrial waste)[59][60]
  - furnaces and other types of fuel-burning heating devices[61]
- Mobile sources include motor vehicles, trains (particularly diesel locomotives and DMUs), marine vessels and aircraft[62] as well as rockets and re-entry of components and debris.[63] The air pollution externality of cars enters the air from the exhaust gas and car tires (including microplastics[64]). Road vehicles make a significant amount of all air pollution (typically, for example, around a third to a half of all nitrogen dioxide emissions)[65][66][67] and are a major driver of climate change.[68][69]
- Agriculture and forest management strategies using controlled burns. Practices like slash-and-burn in forests like the Amazon cause large air pollution with the deforestation.[70] Controlled or prescribed burning is a practice used in forest management, agriculture, prairie restoration, and greenhouse gas reduction.[71] Foresters can use controlled fire as a tool because fire is a natural feature of both forest and grassland ecology.[72][73] Controlled burning encourages the sprouting of some desirable forest trees, resulting in a forest renewal.[74]

There are also sources from processes other than combustion:

- Fumes from paint, hair spray, varnish, aerosol sprays and other solvents. These can be substantial; emissions from these sources was estimated to account for almost half of pollution from volatile organic compounds in the Los Angeles basin in the 2010s.[75]
- Waste deposition in landfills produces methane[76] and open burning of waste releases harmful substances.[77]

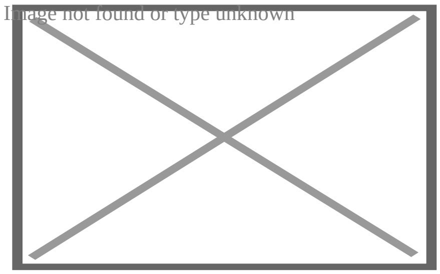
- Nuclear weapons, toxic gases, germ warfare, and rocketry are examples of military resources.[78]
- Agricultural emissions and emissions from meat production or livestock contribute substantially to air pollution[79][80]
    - Fertilized farmland may be a major source of nitrogen oxides.[81]

Mean acidifying emissions (air pollution) of different foods per 100g of protein[82]

Food Types	Acidifying Emissions (g SO_2eq per 100g protein)
Beef	343.6
Cheese	165.5
Pork	142.7
Lamb and mutton	139.0
Farmed crustaceans	133.1
Poultry	102.4
Farmed fish	65.9
Eggs	53.7
Groundnuts	22.6
Peas	8.5
Tofu	6.7

Natural sources

[edit]

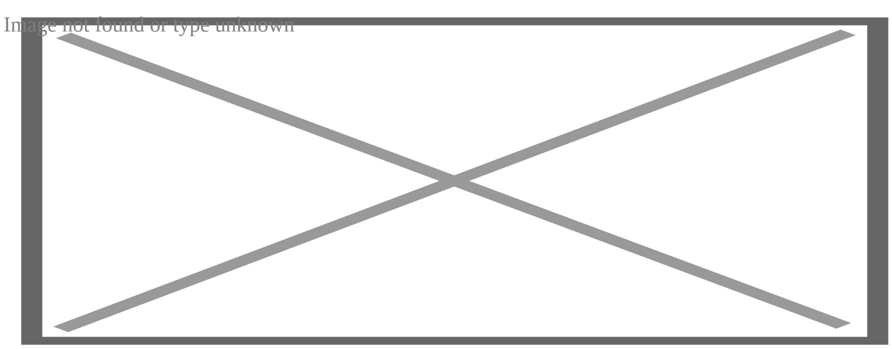


Dust storm approaching Stratford, Texas, in 1935

- Dust from natural sources, usually large areas of land with little or no vegetation.
- Methane, emitted by the digestion of food by animals, for example cattle.
- Radon gas from radioactive decay within the Earth's crust. Radon is a colorless, odorless, naturally occurring, radioactive noble gas that is formed from the decay of radium. It is considered to be a health hazard. Radon gas from natural sources can accumulate in buildings, especially in confined areas such as the basement and it is the second most frequent cause of lung cancer, after cigarette smoking.
- Smoke and carbon monoxide from wildfires. During periods of active wildfires, smoke from uncontrolled biomass combustion can make up almost 75% of all air pollution by concentration.[[83]]
- Vegetation, in some regions, emits environmentally significant amounts of volatile organic compounds (VOCs) on warmer days. These VOCs react with primary anthropogenic pollutants – specifically, NO_x, SO_2, and anthropogenic organic carbon compounds – to produce a seasonal haze of secondary pollutants.[[84]] Black gum, poplar, oak and willow are some examples of vegetation that can produce abundant VOCs. The VOC production from these species result in ozone levels up to eight times higher than the low-impact tree species.[[85]]
- Volcanic activity, which produces sulfur, chlorine, and ash particulates.[[86]]

Emission factors

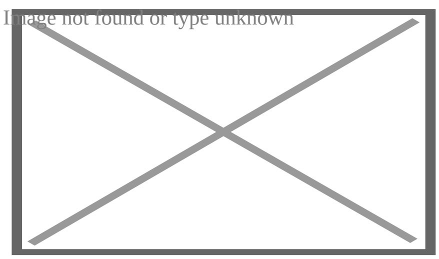
[edit]
Main article: AP 42 Compilation of Air Pollutant Emission Factors



Beijing air in 2005 after rain (left) and a smoggy day (right)

Air pollutant emission factors are reported representative values that aim to link the quantity of a pollutant released into the ambient air to an activity connected with that pollutant's release.[2][87][88][89] The weight of the pollutant divided by a unit weight, volume, distance, or time of the activity generating the pollutant is how these factors are commonly stated (e.g., kilograms of particulate emitted per tonne of coal burned). These criteria make estimating emissions from diverse sources of pollution easier. Most of the time, these components are just averages of all available data of acceptable quality, and they are thought to be typical of long-term averages.

The Stockholm Convention on Persistent Organic Pollutants identified pesticides and other persistent organic pollutants of concern. These include dioxins and furans which are unintentionally created by combustion of organics, like open burning of plastics, and are endocrine disruptors and mutagens.

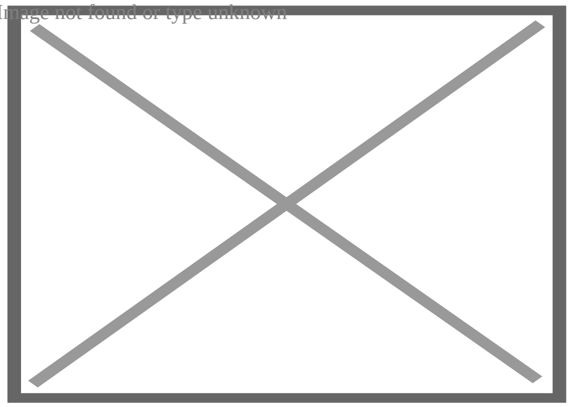


E-waste processing in Agbogbloshie, Ghana, using open-burning of electronics to access valuable metals like copper. Open burning of plastics is common in many parts of the world without the capacity for processing. Especially without proper protections, heavy metals and other contaminates can seep into the soil, and create water pollution and air pollution.

The United States Environmental Protection Agency has published a compilation of air pollutant emission factors for a wide range of industrial sources.[90] The United Kingdom, Australia, Canada, and many other countries have published similar compilations, as well as the European Environment Agency.[91][92][93][94]

Pollutants

[edit]
Main articles: Pollutant and Greenhouse gas emissions



Schematic drawing, causes and effects of air pollution: (1) greenhouse effect, (2) particulate contamination, (3) increased UV radiation, (4) acid rain, (5) increased ground-level ozone concentration, (6) increased levels of nitrogen oxides

An air pollutant is a material in the air that can have many effects on humans and the ecosystem.[95] The substance can be solid particles, liquid droplets, or gases, and often takes the form of an aerosol (solid particles or liquid droplets dispersed and carried by a gas).[96] A pollutant can be of natural origin or man-made. Pollutants are classified as primary or secondary. Primary pollutants are usually produced by processes such as ash from a volcanic eruption.

Other examples include carbon monoxide gas from motor vehicle exhausts or sulfur dioxide released from factories. Secondary pollutants are not emitted directly. Rather, they form in the air when primary pollutants react or interact. Ground level ozone is a prominent example of a secondary pollutant. Some pollutants may be both primary and secondary: they are both emitted directly and formed from other primary pollutants.

Primary pollutants

[edit]

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Pollutants emitted into the atmosphere by human activity include:

- Ammonia: Emitted mainly by agricultural waste. Ammonia is a compound with the formula NH_3. It is normally encountered as a gas with a characteristic pungent odor. Ammonia contributes significantly to the nutritional needs of terrestrial organisms by serving as a precursor to foodstuffs and fertilizers. Ammonia, either directly or indirectly, is also a building block for the synthesis of many pharmaceuticals. Although in wide use, ammonia is both caustic and hazardous.[97

] In the atmosphere, ammonia reacts with oxides of nitrogen and sulfur to form secondary particles.[98]

- Carbon dioxide (CO_2): Carbon dioxide is a natural component of the atmosphere, essential for plant life and given off by the human respiratory system.[99] It is potentially lethal at very high concentrations (typically 100 times "normal" atmospheric levels).[100][101] Although the World Health Organization recognizes CO_2 as a climate pollutant, it does not include the gas in its *Air Quality Guidelines* or set recommended targets for it.[102] Because of its role as a greenhouse gas, CO_2 has been described as "the worst climate pollutant".[103] Statements such as this refer to its long-term atmospheric effects rather than shorter-term effects on such things as human health, food crops, and buildings. This question of terminology has practical consequences, for example, in determining whether the U.S. Clean Air Act (which is designed to improve air quality) is deemed to regulate CO_2 emissions.[104] That issue was resolved in the United States by the Inflation Reduction Act of 2022, which specifically amended the Clean Air Act "to define the carbon dioxide produced by the burning of fossil fuels as an 'air pollutant.'"[105] CO_2 currently forms about 410 parts per million (ppm) of Earth's atmosphere, compared to about 280 ppm in pre-industrial times,[106] and billions of metric tons of CO_2 are emitted annually by burning of fossil fuels.[107] CO_2 increase in Earth's atmosphere has been accelerating.[108] CO_2 is an asphyxiant gas and not classified as toxic or harmful in general.[109] Workplace exposure limits exist in places like UK (5,000 ppm for long-term exposure and 15,000 ppm for short-term exposure).[101] Natural disasters like the limnic eruption at Lake Nyos can result in a sudden release of huge amount of CO_2 as well.[110]
- Carbon monoxide (CO): CO is a colorless, odorless, toxic gas.[111] It is a product of combustion of fuel such as natural gas, coal or wood. Vehicular exhaust contributes to the majority of carbon monoxide let into the atmosphere. It creates a smog type formation in the air that has been linked to many lung diseases and disruptions to the natural environment and animals.
- Chlorofluorocarbons (CFCs): Emitted from goods that are now prohibited from use; harmful to the ozone layer. These are gases emitted by air conditioners, freezers, aerosol sprays, and other similar devices. CFCs reach the stratosphere after being released into the atmosphere.[112] They interact with other gases here, causing harm to the ozone layer. UV rays are able to reach the Earth's surface as a result of this. This can result in skin cancer, eye problems, and even plant damage.[113]
- Nitrogen oxides (NO_x): Nitrogen oxides, particularly nitrogen dioxide, are expelled from high temperature combustion, and are also produced during thunderstorms by electric discharge. They can be seen as a brown haze dome above or a plume downwind of cities. Nitrogen dioxide is a chemical compound with the formula NO_2. It is one of several nitrogen oxides. One of the most prominent air pollutants, this reddish-brown toxic gas has a characteristic sharp, biting odor.
- Odors: Such as from garbage, sewage, and industrial processes.
- Particulate matter/particles (PM), also known as particulates, atmospheric particulate matter (APM), or fine particles, are microscopic solid or liquid particles

suspended in a gas.[114] Aerosol is a mixture of particles and gas. Volcanoes, dust storms, forest and grassland fires, living plants, and sea spray are all sources of particles. Aerosols are produced by human activities such as the combustion of fossil fuels in automobiles, power plants, and numerous industrial processes.[115] Averaged worldwide, anthropogenic aerosols – those made by human activities – currently account for approximately 10% of the atmosphere. Increased levels of fine particles in the air are linked to health hazards such as heart disease,[116] altered lung function and lung cancer. Particulates are related to respiratory infections and can be particularly harmful to those with conditions like asthma.[117]

- Persistent organic pollutants, which can attach to particulates. Persistent organic pollutants are organic compounds that are resistant to environmental degradation due to chemical, biological, or photolytic processes (POPs). As a result, they've been discovered to survive in the environment, be capable of long-range transmission, bioaccumulate in human and animal tissue, biomagnify in food chains, and pose a major threat to human health and the ecosystem.[118]
- Persistent free radicals connected to airborne fine particles are linked to cardiopulmonary disease.[119][120]
- Polycyclic Aromatic Hydrocarbons (PAHs): a group of aromatic compounds formed from the incomplete combustion of organic compounds including coal and oil and tobacco.[121]
- Radioactive pollutants: Produced by nuclear explosions, nuclear events, war explosives, and natural processes such as the radioactive decay of radon.
- Sulfur oxides (SO_x): particularly sulfur dioxide, a chemical compound with the formula SO_2. SO_2 is produced by volcanoes and in various industrial processes. Coal and petroleum often contain sulfur compounds, and their combustion generates sulfur dioxide. Further oxidation of SO_2, usually in the presence of a catalyst such as NO_2, forms H_2SO_4, and thus acid rain is formed. This is one of the causes for concern over the environmental impact of the use of these fuels as power sources.
- Toxic metals, such as lead and mercury, especially their compounds.
- Volatile organic compounds (VOC): VOCs are both indoor and outdoor air pollutants.[122] They are categorized as either methane (CH_4) or non-methane (NMVOCs). Methane is an extremely efficient greenhouse gas which contributes to enhanced global warming. Other hydrocarbon VOCs are also significant greenhouse gases because of their role in creating ozone and prolonging the life of methane in the atmosphere. This effect varies depending on local air quality. The aromatic NMVOCs benzene, toluene and xylene are suspected carcinogens and may lead to leukemia with prolonged exposure. 1,3-butadiene is another dangerous compound often associated with industrial use.

Secondary pollutants

[edit]

Secondary pollutants include:

- Ground level ozone (O_3): Ozone is created when NOx and VOCs mix. It is a significant part of the troposphere.[123] It's also an important part of the ozone layer, which can be found in different sections of the stratosphere. Photochemical and chemical reactions involving it fuel many of the chemical activities that occur in the atmosphere during the day and night. It is a pollutant and a component of smog that is produced in large quantities as a result of human activities (mostly the combustion of fossil fuels).[124] O_3 is largely produced by chemical reactions involving NO_x gases (nitrogen oxides, especially from combustion) and volatile organic compounds in the presence of sunlight. Due to the influence of temperature and sunlight on this reaction, high ozone levels are most common on hot summer afternoons.[125]
- Peroxyacetyl nitrate ($C_2H_3NO_5$): similarly formed from NO_x and VOCs.
- Photochemical smog: particles are formed from gaseous primary contaminants and chemicals.[126] Smog is a type of pollution that occurs in the atmosphere. Smog is caused by a huge volume of coal being burned in a certain region, resulting in a mixture of smoke and sulfur dioxide.[127] Modern smog is usually caused by automotive and industrial emissions, which are acted on in the atmosphere by UV light from the sun to produce secondary pollutants, which then combine with the primary emissions to generate photochemical smog.

Other pollutants

[edit]

There are many other chemicals classed as hazardous air pollutants. Some of these are regulated in the USA under the Clean Air Act and in Europe under numerous directives (including the Air "Framework" Directive, 96/62/EC, on ambient air quality assessment and management, Directive 98/24/EC, on risks related to chemical agents at work, and Directive 2004/107/EC covering heavy metals and polycyclic aromatic hydrocarbons in ambient air).[128][129]

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Hazardous air pollutants (4 C, 68 P)

Before flue-gas desulfurization was installed, the emissions from this power plant in New M

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Before flue-gas desulfurization was installed, the emissions from this power plant in New Mexico contained excessive amounts of sulfur dioxide.

Thermal oxidisers are air pollution abatement options for hazardous air pollutants (HAPs), v

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Thermal oxidisers are air pollution abatement options for hazardous air pollutants (HAPs), volatile organic compounds (VOCs), and odorous emissions.

- This video provides an overview of a NASA study on the human fingerprint on global air quality.

Exposure

[edit]

The risk of air pollution is determined by the pollutant's hazard and the amount of exposure to that pollutant. Air pollution exposure can be measured for a person, a group, such as a neighborhood or a country's children, or an entire population. For example, one would want to determine a geographic area's exposure to a dangerous air pollution, taking into account the various microenvironments and age groups. This can be calculated[130] as an inhalation exposure. This would account for daily exposure in various settings, e.g. different indoor micro-environments and outdoor locations. The exposure needs to include different ages and other demographic groups, especially infants, children, pregnant women, and other sensitive subpopulations.[130]

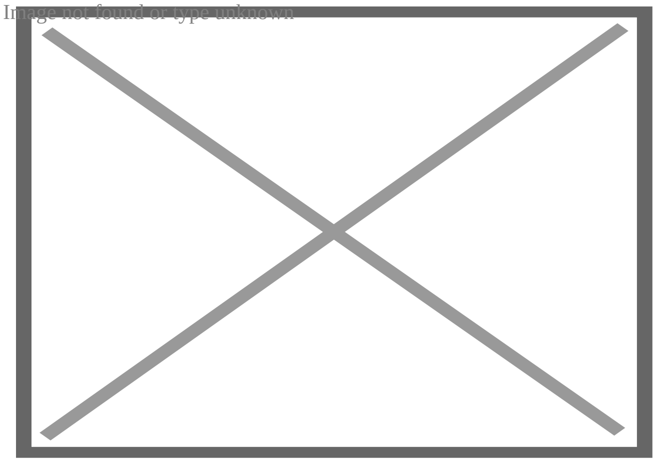
For each specific time that the subgroup is in the setting and engaged in particular activities, the exposure to an air pollutant must integrate the concentrations of the air pollutant with regard to the time spent in each setting and the respective inhalation rates for each subgroup, playing, cooking, reading, working, spending time in traffic, etc. A little child's inhaling rate, for example, will be lower than that of an adult. A young person engaging in strenuous exercise will have a faster rate of breathing than a child engaged in sedentary activity. The daily exposure must therefore include the amount of time spent in each micro-environmental setting as well as the kind of activities performed there. The air pollutant concentration in each microactivity/microenvironmental setting is summed to indicate the exposure.[130]

For some pollutants such as black carbon, traffic related exposures may dominate total exposure despite short exposure times since high concentrations coincide with proximity to major roads or participation in (motorized) traffic.[131] A large portion of total daily exposure occurs as short peaks of high concentrations, but it remains unclear how to define peaks and determine their frequency and health impact.[132]

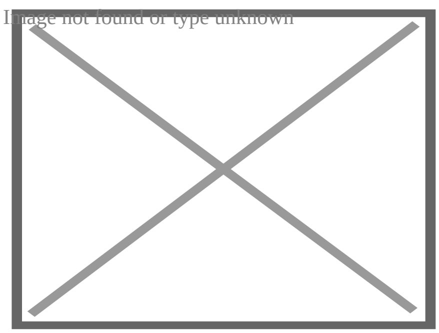
In 2021, the WHO halved its recommended guideline limit for tiny particles from burning fossil fuels. The new limit for nitrogen dioxide (NO_2) is 75% lower.[133] Growing evidence that air pollution—even when experienced at very low levels—hurts human health, led the WHO to revise its guideline (from 10 ?g/m^3 to 5 ?g/m^3) for what it considers a safe level of exposure of particulate pollution, bringing most of the world—97.3 percent of the global population—into the unsafe zone.[134]

Indoor air quality

[edit]
Main articles: Indoor air quality and Indoor air pollution in developing countries



The share of total deaths from indoor air pollution, 2017



Air quality monitoring, New Delhi, India

A lack of ventilation indoors concentrates air pollution where people often spend the majority of their time. Indoor air pollution can pose a significant health risk. According to EPA reports, the concentrations of many air pollutants can be two to five times higher in indoor air than in outdoor air. Indoor air pollutants can be up to 100 times higher in some cases than they are inside. People can spend up to 90% of their time indoors, according to the American Lung Association; the US Consumer Product Safety Commission (CPSC) 2012; and the US Environmental Protection Agency 2012a.[135]

Indoor contaminants that can cause pollution include asbestos, biologic agents, building materials, radon, tobacco smoke, and wood stoves, gas ranges, or other heating systems.[135]

Radon (Rn) gas, a carcinogen, is exuded from the Earth in certain locations and trapped inside houses. Building materials including carpeting and plywood emit formaldehyde (H-CHO) gas. Paint and solvents give off volatile organic compounds (VOCs) as they dry. Lead paint can degenerate into dust and be inhaled.[136][137]

Intentional air pollution is introduced with the use of air fresheners, incense, and other scented items. Controlled wood fires in cook stoves and fireplaces can add significant amounts of harmful smoke particulates into the air, inside and out.[136][137] Indoor pollution fatalities may be caused by using pesticides and other chemical sprays indoors without proper ventilation. Also the kitchen in a modern produce harmful particles and gases, with equipment like toasters being one of the worst sources.[138]

Carbon monoxide poisoning and fatalities are often caused by faulty vents and chimneys, or by the burning of charcoal indoors or in a confined space, such as a tent.[139] Chronic carbon monoxide poisoning can result even from poorly-adjusted pilot lights. Traps are built into all domestic plumbing to keep sewer gas and hydrogen sulfide, out of interiors. Clothing emits tetrachloroethylene, or other dry cleaning fluids, for days after dry cleaning.

Though its use has now been banned in many countries, the extensive use of asbestos in industrial and domestic environments in the past has left a potentially very dangerous material in many localities. Asbestosis is a chronic inflammatory medical condition affecting the tissue of the lungs. It occurs after long-term, heavy exposure to asbestos from asbestos-containing materials in structures. Those with asbestosis have severe dyspnea (shortness of breath) and are at an increased risk regarding several different types of lung cancer. As clear explanations are not always stressed in non-technical literature, care should be taken to distinguish between several forms of relevant diseases. According to the World Health Organization,[140] these may be defined as asbestosis, lung cancer, and peritoneal mesothelioma (generally a very rare form of cancer, when more widespread it is almost always associated with prolonged exposure to asbestos).

Biological sources of air pollution are also found indoors, as gases and airborne particulates. Pets produce dander, people produce dust from minute skin flakes and decomposed hair, dust mites in bedding, carpeting and furniture produce enzymes and micrometre-sized fecal droppings, inhabitants emit methane, mold forms on walls and generates mycotoxins and spores, air conditioning systems can incubate Legionnaires' disease and mold, and houseplants, soil and surrounding gardens can produce pollen, dust, and mold. Indoors, the lack of air circulation allows these airborne pollutants to accumulate more than they would otherwise occur in nature.

Health effects

[edit]

Air pollution has both acute and chronic effects on human health, affecting a number of different systems and organs but principally affect the body's respiratory system and the cardiovascular system. Afflictions include minor to chronic upper respiratory irritation such as difficulty in breathing, wheezing, coughing, asthma[141] and heart disease, lung cancer, stroke, acute respiratory infections in children and chronic bronchitis in adults, aggravating pre-existing heart and lung disease, or asthmatic attacks.

Short and long term exposures have been linked with premature mortality and reduced life expectancy[142] and can result in increased medication use, increased doctor or emergency department visits, more hospital admissions and premature death.[130][*better source* Diseases that develop from persistent exposure to air pollution are environmental health diseases, which develop when a health environment is not maintained.[143]

Even at levels lower than those considered safe by United States regulators, exposure to three components of air pollution, fine particulate matter, nitrogen dioxide and ozone, correlates with cardiac and respiratory illness.[144] Individual reactions to air pollutants depend on the type of pollutant a person is exposed to, the degree of exposure, and the individual's health status and genetics.[130] The most common sources of air pollution include particulates and ozone (often from burning fossil fuels),[145] nitrogen dioxide, and sulfur dioxide. Children aged less than five years who live in developing countries are the most vulnerable population to death attributable to indoor and outdoor air pollution.[146]

Under the Clean Air Act, U.S. EPA sets limits on certain air pollutants, including setting limits on how much can be in the air anywhere in the United States.[147] Mixed exposure to both carbon black and ozone could result in significantly greater health affects.[148]

Mortality

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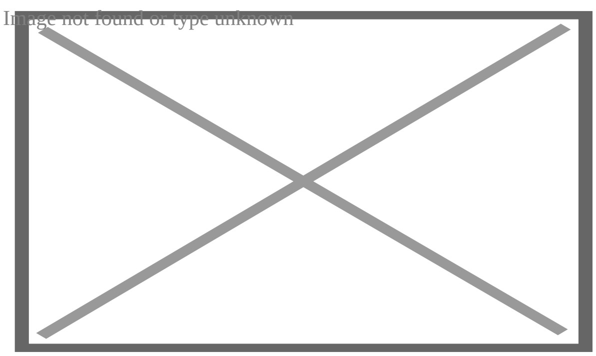
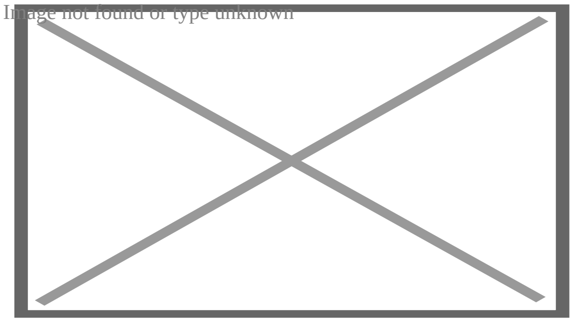
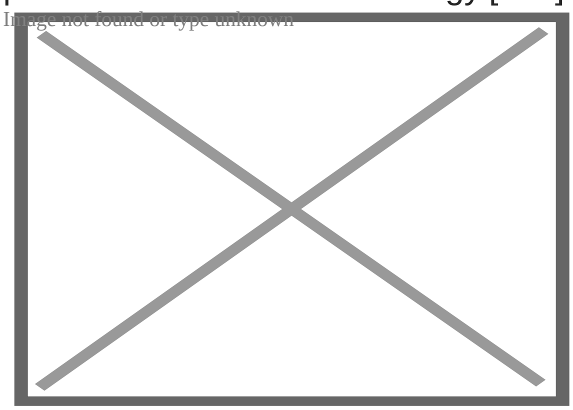


Estimates of the death toll from air pollution vary across publications.



Deaths caused by accidents and air pollution from fossil fuel use in power plants exceed those caused by production of renewable energy.[149]



Estimated annual number of deaths attributed to air pollution in 2019. This includes three categories of air pollution: indoor household, outdoor particulate matter and ozone.

Estimates of deaths toll due to air pollution vary.[150] In 2014 the World Health Organization estimated that every year air pollution causes the premature death of 7 million people worldwide,[5] 1 in 8 deaths worldwide.[151] A study published in 2019 indicated that in 2015 the number may be closer to 8.8 million, with 5.5 million of these premature deaths due to air pollution from anthropogenic sources.[152][153] A 2022 review concluded that in 2019 air pollution was responsible for approximately 9 million premature deaths. It concluded that since 2015 little real progress against pollution has been made.[14][154] Causes of deaths include strokes, heart disease, COPD, lung cancer, and lung infections.[5] Children are particularly at risk.[155]

In 2021, the WHO reported that outdoor air pollution was estimated to cause 4.2 million premature deaths worldwide in 2019.[156]

The global mean loss of life expectancy (LLE; similar to YPLL) from air pollution in 2015 was 2.9 years, substantially more than, for example, 0.3 years from all forms of direct violence.[16] Communities with persons that live beyond 85 years have low ambient air pollution, suggesting a link between air pollution levels and longevity.[157]

Primary mechanisms

[edit]

The WHO estimates that in 2016, ~58% of outdoor air pollution-related premature deaths were due to ischaemic heart disease and stroke.[156] The mechanisms linking air pollution to increased cardiovascular mortality are uncertain, but probably include pulmonary and systemic inflammation.[158]

By region

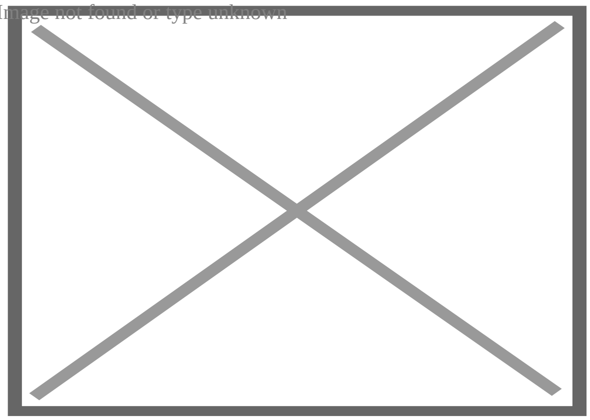
[edit]

India and China have the highest death rate due to air pollution.[159][160] India also has more deaths from asthma than any other nation according to the World Health Organization. In 2019, 1.6 million deaths in India were caused by air pollution.[161] In 2013, air pollution was estimated to kill 500,000 people in China each year.[162] In 2012, 2.48% of China's total air pollution emissions were caused by exports due to US demand, causing an additional 27,963 deaths across 30 provinces.[163]

Annual premature European deaths caused by air pollution are estimated at 430,000[164] to 800,000.[153] An important cause of these deaths is nitrogen dioxide and other nitrogen oxides (NOx) emitted by road vehicles.[164] Across the European Union, air pollution is estimated to reduce life expectancy by almost nine months.[165] In a 2015 consultation document the UK government disclosed that nitrogen dioxide is responsible for 23,500 premature UK deaths per annum.[166] There is a positive correlation between pneumonia-related deaths and air pollution from motor vehicle emissions in England.[167]

Eliminating energy-related fossil fuel emissions in the United States would prevent 46,900–59,400 premature deaths each year and provide $537–$678 billion in benefits from avoided $PM_{2.5}$-related illness and death.[168]

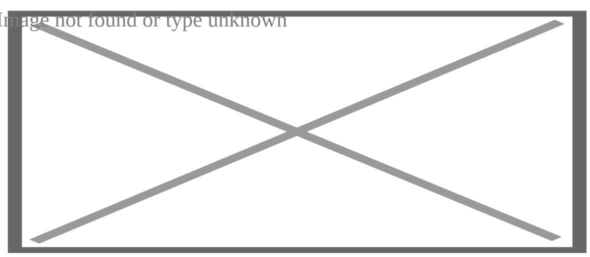
A study published in 2023 in *Science* focused on sulfur dioxide emissions by coal power plants (coal $PM_{2.5}$) and concluded that "exposure to coal $PM_{2.5}$ was associated with 2.1 times greater mortality risk than exposure to $PM_{2.5}$ from all sources."[169] From 1999 to 2020, a total of 460,000 deaths in the US were attributed to coal $PM_{2.5}$.[169]



Air pollution deaths by nation due to fossil fuels

Major causes

[edit]
Further information: § Sources



A comparison of footprint-based and transboundary pollution-based relationships among G20 nations for the number of $PM_{2.5}$-related premature deaths[170]

The largest cause of air pollution is fossil fuel combustion[171] – mostly the production and use of cars, electricity production, and heating.[172] There are estimated 4.5 million annual premature deaths worldwide due to pollutants released by high-emission power stations and vehicle exhausts.[173]

Diesel exhaust (DE) is a major contributor to combustion-derived particulate matter air pollution. In several human experimental studies, using a well-validated exposure chamber setup, DE has been linked to acute vascular dysfunction and increased thrombus formation.[174][175]

A study concluded that $PM_{2.5}$ air pollution induced by the contemporary free trade and consumption by the 19 G20 nations causes two million premature deaths annually, suggesting that the average lifetime consumption of about ~28 people in these countries causes at least one premature death (average age ~67) while developing countries "cannot be expected" to implement or be able to implement countermeasures without external support or internationally coordinated efforts.[176][170]

Guidelines

[edit]
Main article: Air quality guideline

The US EPA has estimated that limiting ground-level ozone concentration to 65 parts per billion (ppb), would avert 1,700 to 5,100 premature deaths nationwide in 2020 compared with the 75 ppb standard. The agency projected the more protective standard would also prevent an additional 26,000 cases of aggravated asthma, and more than a million cases of missed work or school.[177][178] Following this assessment, the EPA acted to protect public health by lowering the National Ambient Air Quality Standards (NAAQS) for ground-level ozone to 70 ppb.[179]

A 2008 economic study of the health impacts and associated costs of air pollution in the Los Angeles Basin and San Joaquin Valley of Southern California shows that more than 3,800 people die prematurely (approximately 14 years earlier than normal) each year because air pollution levels violate federal standards. The number of annual premature deaths is considerably higher than the fatalities related to auto collisions in the same area, which average fewer than 2,000 per year.[180][181][182] A 2021 study found that outdoor air pollution is associated with substantially increased mortality "even at low pollution levels below the current European and North American standards and WHO guideline values" shortly before the WHO adjusted its guidelines.[183][184]

Cardiovascular disease

[edit]

According to the Global Burden of Disease Study, air pollution is responsible for 19% of all cardiovascular deaths.[185][186] There is strong evidence linking both short- and long-term exposure to air pollution with cardiovascular disease mortality and morbidity, stroke, blood pressure, and ischemic heart diseases (IHD).[186]

Air pollution is a leading risk factor for stroke, particularly in developing countries where pollutant levels are highest.[187] A systematic analysis of 17 different risk factors in 188 countries found air pollution is associated with nearly one in three strokes (29%) worldwide (33.7% of strokes in developing countries versus 10.2% in developed countries).[187][188] In women, air pollution is not associated with hemorrhagic but with ischemic stroke.[189] Air pollution was found to be associated with increased incidence and mortality from coronary stroke.[190] Associations are believed to be causal and effects may be mediated by vasoconstriction, low-grade inflammation and atherosclerosis.[191] Other mechanisms such as autonomic nervous system imbalance have also been suggested.[192][193]

Lung disease

[edit]

Research has demonstrated increased risk of developing asthma[194] and chronic obstructive pulmonary disease (COPD)[195] from increased exposure to traffic-related air pollution. Air pollution has been associated with increased hospitalization and mortality from asthma and COPD.[196][197]

COPD comprises a spectrum of clinical disorders that include emphysema, bronchiectasis, and chronic bronchitis.[198] COPD risk factors are both genetic and environmental. Elevated particle pollution contributes to the exacerbation of this disease and likely its pathogenesis.[199]

The risk of lung disease from air pollution is greatest for infants and young children, whose normal breathing is faster than that of older children and adults; the elderly; those who work outside or spend a lot of time outside; and those who have heart or lung disease comorbidities.[200]

A study conducted in 1960–1961 in the wake of the Great Smog of 1952 compared 293 London residents with 477 residents of Gloucester, Peterborough, and Norwich, three towns with low reported death rates from chronic bronchitis. All subjects were male postal truck drivers aged 40 to 59. Compared to the subjects from the outlying towns, the London subjects exhibited more severe respiratory symptoms (including cough, phlegm, and dyspnea), reduced lung function (FEV_1 and peak flow rate), and increased sputum production and purulence. The differences were more pronounced for subjects aged 50 to 59. The study controlled for age and smoking habits, so concluded that air pollution was the most likely cause of the observed differences.[201] More studies have shown that air pollution exposure from traffic reduces lung function development in children[202] and lung function may be compromised by air pollution even at low concentrations.[203]

It is believed that, much like cystic fibrosis, serious health hazards become more apparent when living in a more urban environment. Studies have shown that in urban areas people experience mucus hypersecretion, lower levels of lung function, and more self-diagnosis of chronic bronchitis and emphysema.[204]

Cancer

[edit]

Dark factory clouds obscure the Clark Avenue Bridge in Cleveland, Ohio, July 1973.

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Dark factory-emitted clouds obscuring the Clark Avenue Bridge in Cleveland, Ohio in July 1973

Around 300,000 lung cancer deaths were attributed globally in 2019 to exposure to fine particulate matter, $PM_{2.5}$, suspended in the air.[205] $PM_{2.5}$ exposure, such as from car exhausts, activates dormant mutations in lung cells, causing them to become cancerous.[206][205] Unprotected exposure to $PM_{2.5}$ air pollution can be equivalent to smoking multiple cigarettes per day,[207][*dead link*] potentially increasing the risk of cancer, which is mainly the result of environmental factors.[208]

Long-term exposure to $PM_{2.5}$ (fine particulates) increases the overall risk of non-accidental mortality by 6% per 10 ?g/m^3 increase. Exposure to $PM_{2.5}$ is also associated with an increased risk of mortality from lung cancer (range: 15–21% per 10 ?g/m^3 increase) and total cardiovascular mortality (range: 12–14% per 10 ?g/m^3 increase).[209]

The review further noted that living close to busy traffic appears to be associated with elevated risks of these three outcomes – increase in lung cancer deaths, cardiovascular deaths, and overall non-accidental deaths. The reviewers also found suggestive evidence that exposure to $PM_{2.5}$ is positively associated with mortality from coronary heart diseases and exposure to SO_2 increases mortality from lung cancer, but the data was insufficient to provide solid conclusions.[209] Another investigation showed that higher activity level increases deposition fraction of aerosol particles in human lung and recommended avoiding heavy activities like running in outdoor space at polluted areas.[210]

In 2011, a large Danish epidemiological study found an increased risk of lung cancer for people who lived in areas with high nitrogen oxide concentrations.[211] Another Danish study, likewise noted evidence of possible associations between air pollution and other forms of cancer, including cervical cancer and brain cancer.[212]

Kidney disease

[edit]

A study of 163,197 Taiwanese residents over the period of 2001–2016 estimated that every 5 ?g/m^3 decrease (from an approximate peak of 30?g/m^3) in the ambient concentration of PM$_{2.5}$ was associated with a 25% reduced risk of chronic kidney disease development.[213] According to a cohort study involving 10,997 atherosclerosis patients, higher PM 2.5 exposure is associated with increased albuminuria.[214]

Fertility

[edit]

Nitrogen dioxide (NO_2)

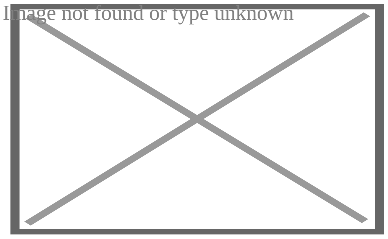
[edit]

An increase in NO_2 is significantly associated with a lower live birth rate in women undergoing IVF treatment.[215] In the general population, there is a significant increase in miscarriage rate in women exposed to NO_2 compared to those not exposed.[215]

Carbon monoxide (CO)

[edit]

CO exposure is significantly associated with stillbirth in the second and third trimester.[215]



Standard line-angle structure of benzo-a-pyrene (BaP)

Polycyclic aromatic hydrocarbons

[edit]

Polycyclic aromatic hydrocarbons (PAHs) have been associated with reduced fertility. Benzo(a)pyrene (BaP) is a well-known PAH and carcinogen which is often found in exhaust fumes and cigarette smoke.[216] PAHs have been reported to administer their toxic effects through oxidative stress by increasing the production of Reactive Oxygen Species (ROS) which can result in inflammation and cell death. More long-term exposure to PAHs can result in DNA damage and reduced repair.[217]

Exposure to BaP has been reported to reduce sperm motility and increasing the exposure worsens this effect. Research has demonstrated that more BaPs were found in men with reported fertility issues compared to men without.[218]

Studies have shown that BaPs can affect folliculogenesis and ovarian development by reducing the number of ovarian germ cells via triggering cell death pathways and inducing inflammation which can lead to ovarian damage.[219]

Particulate matter

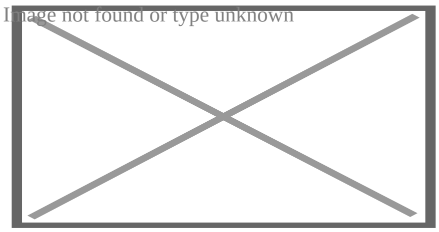
[edit]

Particulate matter (PM) refers to the collection of solids and liquids suspended in the air. These can be harmful to humans, and more research has shown that these effects may be more extensive than first thought; particularly on male fertility. PM can be different sizes, such as $PM_{2.5}$ which are tiny particles of 2.5 microns in width or smaller, compared with PM_{10} which are classified as 10 microns in diameter or less.

A study in California found that increased exposure to $PM_{2.5}$ led to decreased sperm motility and increased abnormal morphology. Similarly, in Poland exposure to $PM_{2.5}$ and PM_{10} led to an increase in the percentage of cells with immature chromatin (DNA that has not fully developed or has developed abnormally).[220]

In Turkey, a study examined the fertility of men who work as toll collectors and are therefore exposed to high levels of traffic pollutants daily. Traffic pollution often has high levels of PM_{10} alongside carbon monoxide and nitrogen oxides.[220] There were significant differences in sperm count and motility in this study group compared to a control group with limited air pollution exposure.

In women, while overall effects on fertility do not appear significant there is an association between increased exposure to PM_{10} and early miscarriage. Exposure to smaller particulate matter, $PM_{2.5}$, appears to have an effect on conception rates in women undergoing IVF but does not affect live birth rates.[215]



Ozone structure showing three oxygen atoms

Ground-level ozone pollution

[edit]

Ground-level ozone (O_3), when in high concentrations, is regarded as an air pollutant and is often found in smog in industrial areas.

There is limited research about the effect that ozone pollution has on fertility.[215] At present, there is no evidence to suggest that ozone exposure poses a deleterious effect on spontaneous fertility in either females or males. However, there have been studies which suggest that high levels of ozone pollution, often a problem in the summer months, exert an effect on in vitro fertilisation (IVF) outcomes. Within an IVF population, NO_x and ozone pollutants were linked with reduced rates of live birth.[215]

While most research on this topic is focused on the direct human exposure of air pollution, other studies have analysed the impact of air pollution on gametes and embryos within IVF laboratories. Multiple studies have reported a marked improvement in embryo quality, implantation and pregnancy rates after IVF laboratories have implemented air filters in a concerted effort to reduce levels of air pollution.[221] Therefore, ozone pollution is considered to have a negative impact on the success of assisted reproductive technologies (ART) when occurring at high levels.

Ozone is thought to act in a biphasic manner where a positive effect on live birth is observed when ozone exposure is limited to before IVF embryo implantation. Conversely, a negative effect is demonstrated upon exposure to ozone after embryo implantation. However, after adjusting for NO2, the association between O3 and IVF live birth rate was no longer significant.[222][223]

In terms of male fertility, ozone is reported to cause a significant decrease in the concentration and count of sperm in semen after exposure.[224] Similarly, sperm vitality, the proportion of live spermatozoa in a sample, was demonstrated to be diminished as a result of exposure to air pollution.[223] However, findings on the effect of ozone exposure on male fertility are somewhat discordant, highlighting the need for further research.[223]

Children

[edit]

Children and infants are among the most vulnerable to air pollution. Polluted air leads to the poisoning of millions of children under the age of 15, resulting in the death of some 600,000 children annually (543,000 under 5 years of age and 52,000 aged 5-15 years).[225] Children in low or middle income countries are exposed to higher levels of fine particulate matter than those in high income countries.[225]

Health effects of air pollution on children include asthma, pneumonia and lower respiratory tract infections and low birth weight.[226] A study in Europe found that exposure to ultrafine particles can increase blood pressure in children.[227]

Prenatal exposure

[edit]

Prenatal exposure to polluted air has been linked to a variety of neurodevelopmental disorders in children. For example, exposure to polycyclic aromatic hydrocarbons (PAH) was associated with reduced IQ scores and symptoms of anxiety and depression.[228] They can also lead to detrimental perinatal health outcomes that are often fatal in developing countries.[8] A 2014 study found that PAHs might play a role in the development of childhood attention deficit hyperactivity disorder (ADHD).[229]

Researchers have found a correlation between air pollution and risk of autism spectrum disorder (ASD) diagnosis, although definitive causality has not yet been established. In Los Angeles, children living in areas with high levels of traffic-related air pollution were more likely to be diagnosed with autism between three–five years of age.[230] A cohort study in Southern California linked in-utero exposure to near-roadway air pollution to an increased risk of ASD diagnosis[231] and a study in Sweden concluded that exposure to

$PM_{2.5}$ during pregnancy was associated with ASD.[232] A Danish study linked exposure to air pollution during infancy, but not during pregnancy, to an increased risk of ASD diagnosis.[233]

The connection between air pollution and neurodevelopmental disorders in children is thought to be related to epigenetic dysregulation of the primordial germ cells, embryo, and fetus during a critical period. Some PAHs are considered endocrine disruptors and are lipid soluble. When they build up in adipose tissue they can be transferred across the placenta can exert a genotoxic effect, cauding DNA damange and mutations.[234] Air pollution has been associated with the prevalence of preterm births.[235]

Infants

[edit]

Ambient levels of air pollution have been associated with preterm birth and low birth weight. A 2014 WHO worldwide survey on maternal and perinatal health found a statistically significant association between low birth weights (LBW) and increased levels of exposure to $PM_{2.5}$. Women in regions with greater than average $PM_{2.5}$ levels had statistically significant higher odds of pregnancy resulting in a low-birth weight infant even when adjusted for country-related variables.[236] The effect is thought to be from stimulating inflammation and increasing oxidative stress.

A study found that in 2010 exposure to $PM_{2.5}$ was strongly associated with 18% of preterm births globally, which was approximately 2.7 million premature births. The countries with the highest air pollution associated preterm births were in South and East Asia, the Middle East, North Africa, and West sub-Saharan Africa.[237] In 2019, ambient particulate matter pollution in Africa resulted in at least 383,000 early deaths, according to new estimates of the cost of air pollution in the continent. This increased from 3.6% in 1990 to around 7.4% of all premature deaths in the area.[238][239][240]

The source of $PM_{2.5}$ differs greatly by region. In South and East Asia, pregnant women are frequently exposed to indoor air pollution because of wood and other biomass fuels being used for cooking, which are responsible for more than 80% of regional pollution. In the Middle East, North Africa and West sub-Saharan Africa, fine PM comes from natural sources, such as dust storms.[237] The United States had an estimated 50,000 preterm births associated with exposure to $PM_{2.5}$ in 2010.[237]

A study between 1988 and 1991 found a correlation between sulfur dioxide (SO_2) and total suspended particulates (TSP) and preterm births and low birth weights in Beijing. A group of 74,671 pregnant women, in four separate regions of Beijing, were monitored from early pregnancy to delivery along with daily air pollution levels of SO_2 and TSP (along with other particulates). The estimated reduction in birth weight was 7.3 g for every 100 ?g/m^3 increase in SO_2 and 6.9 g for each 100 ?g/m^3 increase in TSP. These associations were statistically significant in both summer and winter, although summer was greater. The proportion of low birth weight attributable to air pollution, was 13%. This is the largest attributable risk ever reported for the known risk factors of low birth weight.[241] Coal stoves, which are in 97% of homes, are a major source of air pollution in this area.

Brauer et al. studied the relationship between air pollution and proximity to a highway with pregnancy outcomes in a Vancouver cohort of pregnant women using addresses to estimate exposure during pregnancy. Exposure to NO, NO_2, CO, PM_{10} and $PM_{2.5}$ were associated with infants born small for gestational age (SGA). Women living less than 50 meters away from an expressway or highway were 26% more likely to give birth to a SGA infant.[242]

Central nervous system

[edit]
See also: Brain health and pollution and neuroplastic effects of pollution

Data is accumulating that air pollution exposure also affects the central nervous system.[243]

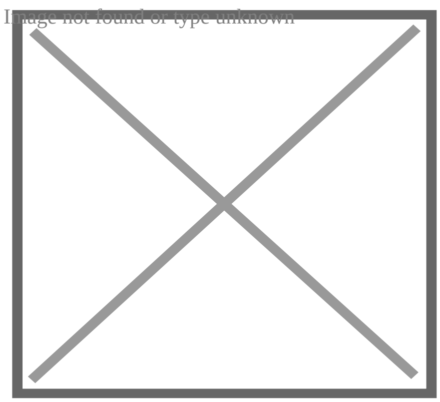
Air pollution increases the risk of dementia in people over 50 years old.[244] Indoor air pollution exposure during childhood may negatively affect cognitive function and neurodevelopment.[245][246] Prenatal exposure may also affect neurodevelopment.[247][248] Studies show that air pollution is associated with a variety of developmental disabilities, oxidative stress, and neuro-inflammation and that it may contribute to Alzheimer's disease and Parkinson's disease.[246]

Researchers found that early exposure to air pollution causes the same changes in the brain as autism and schizophrenia in mice. It also showed that air pollution also affected short-term memory, learning ability, and impulsivity. In this study, air pollution had a larger negative impact on male mice than on females.[249][250] Lead researcher on the study, Deborah Cory-Slechta, said that:[251]

> When we looked closely at the ventricles, we could see that the white matter that normally surrounds them hadn't fully developed. It appears that inflammation had damaged those brain cells and prevented that region of the brain from developing, and the ventricles simply expanded to fill the space. Our findings add to the growing body of evidence that air pollution may play a role in autism, as well as in other neurodevelopmental disorders.

Exposure to fine particulate matter can increase levels of cytokines - neurotransmitters produced in response to infection and inflammation that are also associated with depression and suicide. Pollution has been associated with inflammation of the brain, which may disrupt mood regulation. Heightened $PM_{2.5}$ levels are linked to more self-reported depressive symptoms, and increases in daily suicide rates.[252][253]

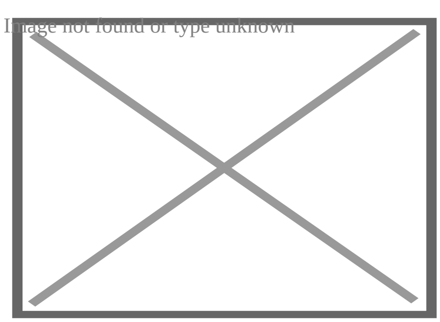
In 2015, experimental studies reported the detection of significant episodic (situational) cognitive impairment from impurities in indoor air breathed by test subjects who were not informed about changes in the air quality. Significant deficits were observed in the performance scores achieved in increasing concentrations of either volatile organic compounds (VOCs) or carbon dioxide, while keeping other factors constant. The highest impurity levels reached are not uncommon in some classroom or office environments.[254][255] Higher $PM_{2.5}$ and CO_2 concentrations were shown to be associated with slower response times and reduced accuracy in tests.[256]



PM2.5 Levels Across the World's 5 Most Populated Nations in 2019

"Clean" areas

[edit]



Share of the population exposed to air pollution levels above WHO guidelines, 2017

Even in areas with relatively low levels of air pollution, public health effects can be significant and costly, since a large number of people breathe in such pollutants. A study found that even in areas of the U.S. where ozone and $PM_{2.5}$ meet federal standards, Medicare recipients who are exposed to more air pollution have higher mortality rates.[257]

Rural populations in India, like those in urban areas, are also exposed to high levels of air pollution.[258] In 2020, scientists found that the boundary layer air over the Southern Ocean around Antarctica is 'unpolluted' by humans.[259]

Agricultural effects

[edit]

Various studies have estimated the impacts of air pollution on agriculture, especially ozone. A 2020 study showed that ozone pollution in California may reduce yields of certain perennial crops such as table grapes by as much as 22% per year, translating into economic damages of more than $1 billion per year.[260] After air pollutants enter the agricultural environment, they not only directly affect agricultural production and quality, but also enter agricultural waters and soil.[261] The COVID-19 induced lockdown served as a natural experiment to expose the close links between air quality and surface greenness. In India, the lockdown induced improvement in air quality, enhanced surface greenness and photosynthetic activity, with the positive response of vegetation to reduce air pollution was dominant in croplands.[262] On the other hand, agriculture in its traditional form is one of the primary contributors to the emission of trace gases like atmospheric ammonia.[263]

Economic effects

[edit]

Air pollution costs the world economy $5 trillion per year as a result of productivity losses and degraded quality of life.[24][25][26] These productivity losses are caused by deaths due to diseases caused by air pollution. One out of ten deaths in 2013 was caused by diseases associated with air pollution and the problem is getting worse.

A small improvement in air quality (1% reduction of ambient $PM_{2.5}$ and ozone concentrations) would produce $29 million in annual savings in the lower Fraser Valley region in 2010.[264] This finding is based on health valuation of lethal (death) and sub-lethal (illness) affects.

The problem is even more acute in the developing world. "Children under age 5 in lower-income countries are more than 60 times as likely to die from exposure to air pollution as children in high-income countries."[24][25] The report states that additional economic losses caused by air pollution, including health costs[265] and the adverse effect on agricultural and other productivity were not calculated in the report, and thus the actual costs to the world economy are far higher than $5 trillion.

A study published in 2022 found "a strong and significant connection between air pollution and construction site accidents" and that "a 10-ppb increase in NO_2 levels increases the likelihood of an accident by as much as 25%".[266]

Other effects

[edit]

Artificial air pollution may be detectable on Earth from distant vantage points such as other planetary systems via atmospheric SETI – including NO_2 pollution levels and with telescopic technology close to today. It may also be possible to detect extraterrestrial civilizations this way.[267][268][269]

Historical disasters

[edit]

The world's worst short-term civilian pollution crisis was the 1984 Bhopal Disaster in India.[270] Leaked industrial vapours from the Union Carbide factory, belonging to Union Carbide, Inc., U.S.A. (later bought by Dow Chemical Company), killed at least 3787 people and injured from 150,000 to 600,000. The United Kingdom suffered its worst air pollution event when the 4 December Great Smog of 1952 formed over London. In six days more than 4,000 died and more recent estimates put the figure at nearer 12,000.[271]

An accidental leak of anthrax spores from a biological warfare laboratory in the former USSR in 1979 near Yekaterinburg (formerly Sverdlovsk) is believed to have caused at least 64 deaths.[272] The worst single incident of air pollution to occur in the US occurred in Donora, Pennsylvania, in late October 1948, when 20 people died and over 7,000 were injured.[273]

Reduction and regulation

[edit]

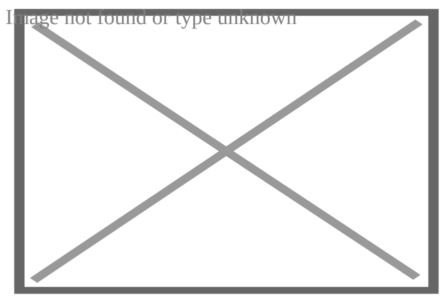
Global depletion of the surrounding air pollution will require valiant leadership, a surplus of combined resources from the international community, and extensive societal changes.[274] Pollution prevention seeks to prevent pollution such as air pollution and could include adjustments to industrial and business activities such as designing sustainable manufacturing processes (and the products' designs)[275] and related legal regulations as well as efforts towards renewable energy transitions.[276][277]

Efforts to reduce particulate matter in the air may result in better health.[278]

The 9-Euro-Ticket scheme in Germany which allowed people to buy a monthly pass allowing use on all local and regional transport (trains, trams and busses) for 9 euro (€) for one month of unlimited travel saved 1.8 million tons of CO_2 emissions during its three-month implementation from June to August 2022.[279]

Pollution control

[edit]



Burning of items polluting Jamestown environment in Accra, Ghana

Various pollution control technologies and strategies are available to reduce air pollution.[280][281] At its most basic level, land-use planning is likely to involve zoning and transport infrastructure planning. In most developed countries, land-use planning is an important part of social policy, ensuring that land is used efficiently for the benefit of the wider economy and population, as well as to protect the environment.[282] Stringent environmental regulations, effective control technologies and shift towards the renewable source of energy also helping countries like China and India to reduce their sulfur dioxide pollution.[283]

Titanium dioxide has been researched for its ability to reduce air pollution. Ultraviolet light will release free electrons from material, thereby creating free radicals, which break up VOCs and

NO*x* gases. One form is superhydrophilic.[284]

Pollution-eating nanoparticles placed near a busy road were shown to absorb toxic emission from around 20 cars each day.[285]

Energy transition

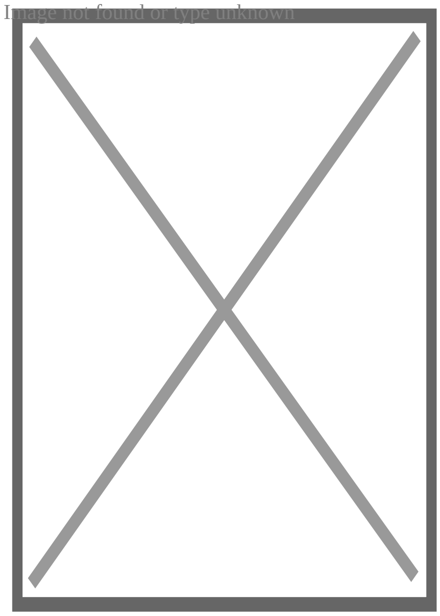
[edit]

Since a large share of air pollution is caused by combustion of fossil fuels such as coal and oil, the reduction of these fuels can reduce air pollution drastically. Most effective is the switch to clean power sources such as wind power, solar power, hydro power which do not cause air pollution.[286] Efforts to reduce pollution from mobile sources includes expanding regulation to new sources (such as cruise and transport ships, farm equipment, and small gas-powered equipment such as string trimmers, chainsaws, and snowmobiles), increased fuel efficiency (such as through the use of hybrid vehicles), conversion to cleaner fuels, and conversion to electric vehicles. For example, buses in New Delhi, India, have run on compressed natural gas since 2000, to help eliminate the city's "pea-soup" smog.[226][287]

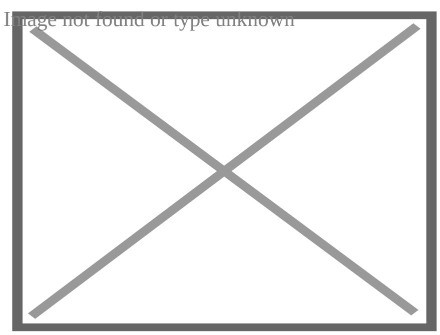
A very effective means to reduce air pollution is the transition to renewable energy. According to a study published in Energy and Environmental Science in 2015 the switch to 100% renewable energy in the United States would eliminate about 62,000 premature mortalities per year and about 42,000 in 2050, if no biomass were used. This would save about $600 billion in health costs a year due to reduced air pollution in 2050, or about 3.6% of the 2014 U.S. gross domestic product.[286] Air quality improvement is a near-term benefit among the many societal benefits from climate change mitigation.

Alternatives to pollution

[edit]



Support for a ban on high-emission vehicles in city centres in Europe, China and the US from respondents to the European Investment Bank Climate Survey



Support, use and infrastructure-expansion of forms of public transport that do not cause air pollution may be a critical key alternative to pollution.

There are now practical alternatives to the principal causes of air pollution:

- Strategic substitution of air pollution sources in transport with lower-emission or, during the lifecycle, emission-free forms of public transport[288][289] and bicycle use and infrastructure (as well as with remote work, reductions of work, relocations, and localizations)
  - Phase-out of fossil fuel vehicles is a critical component of a shift to sustainable transport; however, similar infrastructure and design decisions like electric vehicles may be associated with similar pollution for production as well as mining and resource exploitation for large numbers of needed batteries as well as the energy for their recharging[290][291]
- Areas downwind (over 20 miles) of major airports have more than double *total particulate emissions in air* than other areas, even when factoring in areas with frequent ship calls, and heavy freeway and city traffic like Los Angeles.[292] Aviation biofuel mixed in with jetfuel at a 50/50 ratio can reduce jet derived cruise

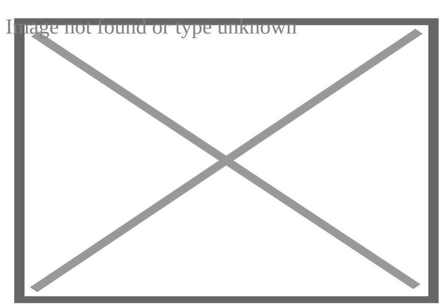
altitude particulate emissions by 50–70%, according to a NASA led 2017 study (however, this should imply ground level benefits to urban air pollution as well).[293]

- Ship propulsion and idling can be switched to much cleaner fuels like natural gas. (Ideally a renewable source but not practical yet)
- Combustion of fossil fuels for space heating can be replaced by using ground source heat pumps and seasonal thermal energy storage.[294]
- Electricity generated from the combustion of fossil fuels can be replaced by nuclear and renewable energy. Heating and home stoves, which contribute significantly to regional air pollution, can be replaced with a much cleaner fossil fuel, such as natural gas, or, preferably, renewables, in poor countries.[295][296]
- Motor vehicles driven by fossil fuels, a key factor in urban air pollution, can be replaced by electric vehicles. Though lithium supply and cost is a limitation, there are alternatives. Herding more people into clean public transit such as electric trains can also help. Nevertheless, even in emission-free electric vehicles, rubber tires produce significant amounts of air pollution themselves, ranking as 13th worst pollutant in Los Angeles.[297]
- Reducing travel in vehicles can curb pollution. After Stockholm reduced vehicle traffic in the central city with a congestion tax, nitrogen dioxide and PM_{10} pollution declined, as did acute pediatric asthma attacks.[298]
- Biodigesters can be utilized in poor nations where slash and burn is prevalent, turning a useless commodity into a source of income. The plants can be gathered and sold to a central authority that will break them down in a large modern biodigester, producing much needed energy to use.[299]
- Induced humidity and ventilation both can greatly dampen air pollution in enclosed spaces, which was found to be relatively high inside subway lines due to braking and friction and relatively less ironically inside transit buses than lower sitting passenger automobiles or subways.[300]

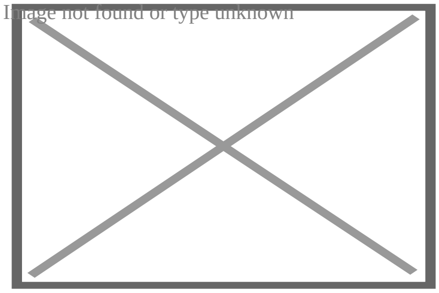
Further information: § Sources

Control devices

[edit]



Tarps and netting are often used to reduce the amount of dust released from construction sites.



Air pollution from a car

The following items are commonly used as pollution control devices in industry and transportation. They can either destroy contaminants or remove them from an exhaust stream before it is emitted into the atmosphere.

- **Particulate control**
  - Mechanical collectors (dust cyclones, multicyclones)
  - Electrostatic precipitators: An electrostatic precipitator (ESP), or electrostatic air cleaner, is a particulate collection device that removes particles from a flowing gas (such as air), using the force of an induced electrostatic charge. Electrostatic precipitators are highly efficient filtration devices that minimally impede the flow of gases through the device, and can easily remove fine particulates such as dust and smoke from the air stream.
  - Baghouses: Designed to handle heavy dust loads, a dust collector consists of a blower, dust filter, a filter-cleaning system, and a dust receptacle or dust removal system (distinguished from air cleaners which utilize disposable filters to remove the dust).
  - Particulate scrubbers: A wet scrubber is a form of pollution control technology. The term describes a variety of devices that use pollutants from a furnace flue gas or from other gas streams. In a wet scrubber, the polluted gas stream is brought into contact with the scrubbing liquid, by spraying it with the liquid, by forcing it through a pool of liquid, or by some other contact method, so as to remove the pollutants.
- **Scrubbers**
  - Baffle spray scrubber
  - Cyclonic spray scrubber
  - Ejector venturi scrubber
  - Mechanically aided scrubber
  - Spray tower
  - Wet scrubber
- **NO*x* control**
  - LO-NOx burners
  - Selective catalytic reduction (SCR)
  - Selective non-catalytic reduction (SNCR)

    - NOx scrubbers
    - Exhaust gas recirculation
    - Catalytic converter (also for VOC control)
  - **VOC abatement**
    - Adsorption systems, using activated carbon, such as Fluidized Bed Concentrator
    - Flares
    - Thermal oxidizers
    - Catalytic converters
    - Biofilters
    - Absorption (scrubbing)
    - Cryogenic condensers
    - Vapor recovery systems
  - **Acid gas/SO_2 control**
    - Wet scrubbers
    - Dry scrubbers
    - Flue-gas desulfurization
  - **Mercury control**
    - Sorbent injection technology
    - Electro-catalytic oxidation (ECO)
    - K-Fuel
  - **Dioxin and furan control**
  - **Miscellaneous associated equipment**
    - Source capturing systems
    - Continuous emissions monitoring systems (CEMS)

Monitoring

[edit]
See also: Smart city
Further information: Air pollution measurement and Environmental monitoring

Spatiotemporal monitoring of air quality may be necessary for improving air quality, and thereby the health and safety of the public, and assessing impacts of interventions.[301] Such monitoring is done to different extents with different regulatory requirements with discrepant regional coverage by a variety of organizations and governance entities such as using a variety of technologies for use of the data and sensing such mobile IoT sensors,[302][303] satellites,[304][305][306] and monitoring stations.[307][308] Some websites attempt to map air pollution levels using available data.[309][310][311]

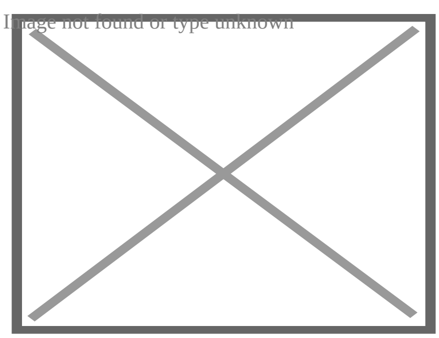
Air quality modeling

[edit]
Main article: Air quality modeling

Numerical models either on a global scale using tools such as GCMs (general circulation models coupled with a pollution module) or CTMs (Chemical transport model) can be used to simulate the levels of different pollutants in the atmosphere. These tools can have several types (Atmospheric model) and different uses. These models can be used in forecast mode which can help policy makers to decide on appropriate actions when an air pollution episode is detected. They can also be used for climate modeling including evolution of air quality in the future, for example the IPCC (Intergovernmental Panel on Climate Change) provides climate simulations including air quality assessments in their reports (latest report accessible through their site).

Regulations

[edit]
Main article: Air quality law



Smog in Cairo

In general, there are two types of air quality standards. The first class of standards (such as the U.S. National Ambient Air Quality Standards and E.U. Air Quality Directive[312]) set maximum atmospheric concentrations for specific pollutants. Environmental agencies enact regulations which are intended to result in attainment of these target levels. The second class (such as the North American air quality index) take the form of a scale with various thresholds, which is used to communicate to the public the relative risk of outdoor activity. The scale may or may not distinguish between different pollutants.

Canada

[edit]

In Canada, air pollution and associated health risks are measured with the Air Quality Health Index (AQHI).[313] It is a health protection tool used to make decisions to reduce short-term exposure to air pollution by adjusting activity levels during increased levels of air pollution.

The AQHI is a federal program jointly coordinated by Health Canada and Environment Canada. However, the AQHI program would not be possible without the commitment and support of the provinces, municipalities and NGOs. From air quality monitoring to health risk communication and community engagement, local partners are responsible for the vast majority of work related to AQHI implementation. The AQHI provides a number from 1 to 10+ to indicate the level of health risk associated with local air quality. Occasionally, when the amount of air pollution is abnormally high, the number may exceed 10. The AQHI provides a local air quality current value as well as a local air quality maximums forecast for today, tonight and tomorrow and provides associated health advice.

1	2	3	4	5	6	7	8	9	10	+

Risk: Low **(1–3)** Moderate **(4–6)** High **(7–10)** Very high **(above 10)**

As it is now known that even low levels of air pollution can trigger discomfort for the sensitive population, the index has been developed as a continuum: The higher the number, the greater the health risk and need to take precautions. The index describes the level of health risk associated with this number as 'low', 'moderate', 'high' or 'very high', and suggests steps that can be taken to reduce exposure.[314]

Health risk	Air Quality Health Index	Health messages[315]	
		At risk population	General population
Low	1–3	**Enjoy** your usual outdoor activities.	**Ideal** air quality for outdoor activities
Moderate	4–6	**Consider reducing** or rescheduling strenuous activities outdoors if you are experiencing symptoms.	**No need to modify** your usual outdoor activities unless you experience symptoms such as coughing and throat irritation.

High	**7–10**	**Reduce** or reschedule strenuous activities outdoors. Children and the elderly should also take it easy.	**Consider reducing** or rescheduling strenuous activities outdoors if you experience symptoms such as coughing and throat irritation.
Very high	**Above 10**	**Avoid** strenuous activities outdoors. Children and the elderly should also avoid outdoor physical exertion and should stay indoors.	**Reduce** or reschedule strenuous activities outdoors, especially if you experience symptoms such as coughing and throat irritation.

The measurement is based on the observed relationship of nitrogen dioxide (NO_2), ground-level ozone (O_3) and particulates ($PM_{2.5}$) with mortality, from an analysis of several Canadian cities. Significantly, all three of these pollutants can pose health risks, even at low levels of exposure, especially among those with pre-existing health problems.

When developing the AQHI, Health Canada's original analysis of health effects included five major air pollutants: particulates, ozone, and nitrogen dioxide (NO_2), as well as sulfur dioxide (SO_2), and carbon monoxide (CO). The latter two pollutants provided little information in predicting health effects and were removed from the AQHI formulation.

The AQHI does not measure the effects of odour, pollen, dust, heat or humidity.

Germany

[edit]

TA Luft is the German air quality regulation.[316]

Governing urban air pollution

[edit]
Further information: Phase-out of fossil fuel vehicles § Cities and territories

In Europe, Council Directive 96/62/EC on ambient air quality assessment and management provides a common strategy against which member states can "set objectives for ambient air quality in order to avoid, prevent or reduce harmful effects on human health and the environment ... and improve air quality where it is unsatisfactory".[317]

In July 2008, in the case *Dieter Janecek v. Freistaat Bayern*, the European Court of Justice ruled that under this directive[317] citizens have the right to require national authorities to implement a short term action plan that aims to maintain or achieve compliance to air quality limit values.[318][319]

This important case law appears to confirm the role of the EC as centralised regulator to European nation-states as regards air pollution control. It places a supranational legal obligation on the UK to protect its citizens from dangerous levels of air pollution, furthermore superseding national interests with those of the citizen.

In 2010, the European Commission (EC) threatened the UK with legal action against the successive breaching of PM_{10} limit values.[320] The UK government has identified that if fines are imposed, they could cost the nation upwards of £300 million per year.[321]

In March 2011, the Greater London Built-up Area remained the only UK region in breach of the EC's limit values, and was given three months to implement an emergency action plan aimed at meeting the EU Air Quality Directive.[322] The City of London has dangerous levels of PM_{10} concentrations, estimated to cause 3000 deaths per year within the city.[323] As well as the threat of EU fines, in 2010 it was threatened with legal action for scrapping the western congestion charge zone, which is claimed to have led to an increase in air pollution levels.[324]

In response to these charges, mayor of London Boris Johnson has criticised the current need for European cities to communicate with Europe through their nation state's central government, arguing that in future "A great city like London" should be permitted to bypass its government and deal directly with the European Commission regarding its air quality action plan.[322]

This can be interpreted as recognition that cities can transcend the traditional national government organisational hierarchy and develop solutions to air pollution using global governance networks, for example through transnational relations. Transnational relations include but are not exclusive to national governments and intergovernmental organisations,[325] allowing sub-national actors including cities and regions to partake in air pollution control as independent actors.

Global city partnerships can be built into networks, for example the C40 Cities Climate Leadership Group, of which London is a member. The C40 is a public 'non-state' network of the world's leading cities that aims to curb their greenhouse emissions.[326] The C40 has been identified as 'governance from the middle' and is an alternative to intergovernmental policy.[327] It has the potential to improve urban air quality as participating cities "exchange information, learn from best practices and consequently mitigate carbon dioxide emissions independently from national government decisions".[326] A criticism of the C40 network is that its exclusive nature limits influence to participating cities and risks drawing resources away from less powerful city and regional actors.

Indigenous people

[edit]

Because Indigenous people[328] frequently experience a disproportionate share of the effects of environmental degradation and climate change, even while they have made very little contribution to the processes causing these changes, environmental justice is especially important to them. Indigenous peoples have been marginalized and their lands and resources have been exploited as a result of historical and continuing colonization, institutional injustices, and inequality.

Indigenous groups frequently lack the political and financial clout to influence policy decisions that impact their lands and means of subsistence or to lessen the effects of climate change. This makes the already-existing inequalities in these communities' social, economic, and health conditions worse. Furthermore, traditional ecological knowledge and Indigenous knowledge systems provide insightful information about sustainable resource management and climate change adaptation techniques. To promote persistence and environmental justice, Indigenous viewpoints must be acknowledged and integrated into efforts to mitigate the effects of climate change and adapt to them.

Combating climate change necessitates an all-encompassing strategy that recognizes the interdependence of social, economic, and environmental elements. This entails defending treaty rights, advancing Indigenous sovereignty and self-determination, and aiding Indigenous-led projects for sustainable development and environmental preservation.

Hotspots

[edit]
Main article: Toxic hotspot
See also: Cancer alley and Superfund

Air pollution hotspots are areas where air pollution emissions expose individuals to increased negative health effects.[329] They are particularly common in highly populated, urban areas, where there may be a combination of stationary sources (e.g. industrial facilities) and mobile sources (e.g. cars and trucks) of pollution. Emissions from these sources can cause respiratory disease, childhood asthma,[141] cancer, and other health problems. Fine particulate matter such as diesel soot, which contributes to more than 3.2 million premature deaths around the world each year, is a significant problem. It is very small and can lodge itself within the lungs and enter the bloodstream. Diesel soot is concentrated in densely populated areas, and one in six people in the U.S. live near a diesel pollution hot spot.[330]

External videos

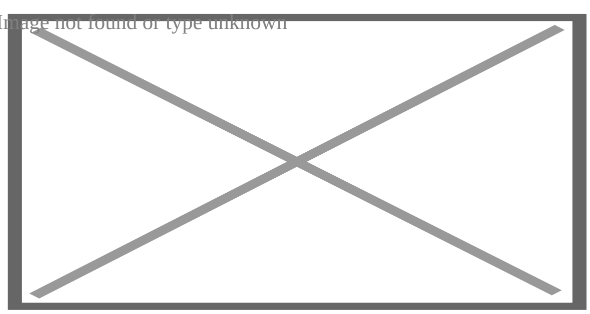
video *AirVisual Earth* – realtime map of global wind and air pollution[331]

While air pollution hotspots affect a variety of populations, some groups are more likely to be located in hotspots. Previous studies have shown disparities in exposure to pollution by race and/or income. Hazardous land uses (toxic storage and disposal facilities, manufacturing facilities, major roadways) tend to be located where property values and income levels are low. Low socioeconomic status can be a proxy for other kinds of social vulnerability, including race, a lack of ability to influence regulation and a lack of ability to move to neighborhoods with less environmental pollution. These communities bear a disproportionate burden of environmental pollution and are more likely to face health risks such as cancer or asthma.[332]

Studies show that patterns in race and income disparities not only indicate a higher exposure to pollution but also higher risk of adverse health outcomes.[333] Communities characterized by low socioeconomic status and racial minorities can be more vulnerable to cumulative adverse health impacts resulting from elevated exposure to pollutants than more privileged communities.[333] Blacks and Latinos generally face more pollution than Whites and Asians, and low-income communities bear a higher burden of risk than affluent ones.[332] Racial discrepancies are particularly distinct in suburban areas of the Southern United States and metropolitan areas of the Midwestern and Western United States.[334] Residents in public housing, who are generally low-income and cannot move to healthier neighborhoods, are highly affected by nearby refineries and chemical plants.[335]

Cities

[edit]
See also: List of most polluted cities in the world by particulate matter concentration
Further information: List of least polluted cities by particulate matter concentration



Nitrogen dioxide concentrations as measured from satellite 2002–2004

Air pollution is usually concentrated in densely populated metropolitan areas, especially in developing countries where cities are experiencing rapid growth and environmental regulations are relatively lax or nonexistent. Urbanization leads to a rapid rise in premature mortality due to anthropogenic air pollution in fast-growing tropical cities.[336] However, even populated areas in developed countries attain unhealthy levels of pollution, with Los Angeles and Rome being two examples.[337] Between 2002 and 2011 the incidence of lung cancer in Beijing near doubled. While smoking remains the leading cause of lung cancer in China, the number of smokers is falling while lung cancer rates are rising .[338]

[339]

World's Most Polluted Cities 2020	2020 Average	2019 Average
Hotan, China	110.2	110.1
Ghaziabad, India	106.6	110.2
Bulandshahr, India	98.4	89.4
Bisrakh Jalalpur, India	96.0	-
Bhiwadi, India	95.5	83.4

Tehran was declared the most polluted city in the world on May 24, 2022.[340]

Projections

[edit]

In a 2019 projection, by 2030 half of the world's pollution emissions could be generated by Africa.[341] Potential contributors to such an outcome include increased burning activities (such as the burning of open waste), traffic, agri-food and chemical industries, sand dust from the Sahara, and overall population growth.

In a 2012 study, by 2050 outdoor air pollution (particulate matter and ground-level ozone) is projected to become the top cause of environmentally related deaths worldwide.[342]

See also

[edit]

- icon Image not found or type unknown Global warming portal
- icon Image not found or type unknown Plants portal
- icon Image not found or type unknown Trees portal

Source

- Beehive burner
- Bottom ash
- Concrete#Concrete – health and safety
- Diwali-related air pollution
- Flue-gas emissions from fossil-fuel combustion
- Health impacts of sawdust
- Joss paper
- Metal working
- Mining
- Non-exhaust emissions
- Power tool
- Rubber pollution
- Slag
- Smelting
- Tire fire
- Welding
- Wood ash

Measurement

- Air pollutant concentrations
- Air pollution measurement
- Organic molecular tracers
- Intake fraction
- Particulate matter sampler

Others

- Air stagnation
- ASEAN Agreement on Transboundary Haze Pollution
- Asian brown cloud
- Atmospheric chemistry
- BenMAP
- Best Available Control Technology
- Critical load
- Emission standard
- Emissions & Generation Resource Integrated Database
- Environmental agreement
- Environmental racism
- Exposome
- Global Atmosphere Watch
- Global dimming
- Great Smog of London
- Haze
- Health Effects Institute (HEI)

- Indicator value
- International Agency for Research on Cancer
- International Day of Clean Air for Blue Skies
- Kyoto Protocol
- Light water reactor sustainability
- List of smogs by death toll
- Lowest Achievable Emissions Rate
- NASA Clean Air Study
- NIEHS
- Phytoremediation
- Polluter pays principle
- Regulation of greenhouse gases under the Clean Air Act
- Silicosis#Prevention

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[edit]

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Further reading

[edit]
Library resources about
Air pollution

- Resources in your library
- Resources in other libraries
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they cross into the bloodstream and spread throughout the body. They can travel through the nose, up the olfactory nerve, and lodge ... in the brain. They can form deposits on the lining of arteries, constricting blood vessels and raising the likelihood of ... strokes and heart attacks. [T]hey exacerbate respiratory illnesses like asthma and chronic obstructive pulmonary disease ... There's ... evidence linking air pollution exposure to an increased risk of Alzheimer's and other forms of dementia." (p. 64.)

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External links

[edit]

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Wikivoyage has travel information for ***Air pollution***.

- WHO fact sheet on outdoor air pollution
- Air Pollution: Everything You Need to Know Guide by the Natural Resources Defense Council (NRDC)
- Global real-time air quality index map
- Air Quality Index (AQI) Basics
- AQI Calculator AQI to Concentration and Concentration to AQI for five pollutants
- UNEP Urban environmental planning
- European Commission > Environment > Air > Air Quality
- Database: outdoor air pollution in cities from the World Health Organization
- The Mortality Effects of Long-Term Exposure to Particulate Air Pollution in the United Kingdom, UK Committee on the Medical Effects of Air Pollution, 2010.
- Hazardous air pollutants | What are hazardous pollutants at EPA.gov

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Pollution

History

Air	◦ Acid rain
	◦ Air quality index
	◦ Atmospheric dispersion modeling
	◦ Chlorofluorocarbon
	◦ Combustion
	    ◦ Biofuel
	    ◦ Biomass
	    ◦ Joss paper
	    ◦ Open burning of waste
	◦ Construction
	    ◦ Renovation
	◦ Demolition
	◦ Exhaust gas
	    ◦ Diesel exhaust
	◦ Haze
	    ◦ Smoke
	◦ Indoor air quality
	◦ Internal combustion engine
	◦ Global dimming
	◦ Global distillation
	◦ Mining
	◦ Ozone depletion
	◦ Particulates
	    ◦ Asbestos
	    ◦ Metal working
	    ◦ Oil refining
	    ◦ Wood dust
	    ◦ Welding
	◦ Persistent organic pollutant
	◦ Smelting
	◦ Smog
	◦ Soot
	    ◦ Black carbon
	◦ Volatile organic compound
	◦ Waste

Biological	◦ Biological hazard ◦ Genetic pollution ◦ Introduced species ◦ Invasive species
Digital	◦ Information pollution

Electromagnetic	◦ Light
	    ◦ Ecological light pollution
	    ◦ Overillumination
	◦ Radio spectrum pollution

Natural	◦ Ozone ◦ Radium and radon in the environment ◦ Volcanic ash ◦ Wildfire

Noise	◦ Transportation
	    ◦ Land
	    ◦ Water
	    ◦ Air
	    ◦ Rail
	    ◦ Sustainable transport
	◦ Urban
	◦ Sonar
	    ◦ Marine mammals and sonar
	◦ Industrial
	◦ Military
	◦ Abstract
	◦ Noise control

Radiation	◦ Actinides ◦ Bioremediation ◦ Nuclear fission ◦ Nuclear fallout ◦ Plutonium ◦ Poisoning ◦ Radioactivity ◦ Uranium ◦ Electromagnetic radiation and health ◦ Radioactive waste

Soil	◦ Agricultural pollution
	    ◦ Herbicides
	    ◦ Manure waste
	    ◦ Pesticides
	◦ Land degradation
	◦ Bioremediation
	◦ Open defecation
	◦ Electrical resistance heating
	◦ Soil guideline values
	◦ Phytoremediation

<table>
<tr><td>Solid waste</td><td>

Advertising mail
Biodegradable waste
Brown waste
Electronic waste
Battery recycling
Foam food container
Food waste
Green waste
Hazardous waste
Biomedical waste
Chemical waste
Construction waste
Lead poisoning
Mercury poisoning
Toxic waste
Industrial waste
Lead smelting
Litter
Mining
Coal mining
Gold mining
Surface mining
Deep sea mining
Mining waste
Uranium mining
Municipal solid waste
Garbage
Nanomaterials
Plastic pollution
Microplastics
Packaging waste
Post-consumer waste
Waste management
Landfill
Thermal treatment

</td></tr>
<tr><td>Space</td><td>Satellite</td></tr>
<tr><td>Visual</td><td>Air travel
Clutter (advertising)
Traffic signs
Overhead power lines
Vandalism</td></tr>
</table>

War	○ Chemical warfare ○ Herbicidal warfare (Agent Orange) ○ Nuclear holocaust (Nuclear fallout - nuclear famine - nuclear winter) ○ Scorched earth ○ Unexploded ordnance ○ War and environmental law

Water	○ Agricultural wastewater
	○ Biological pollution
	○ Diseases
	○ Eutrophication
	○ Firewater
	○ Freshwater
	○ Groundwater
	○ Hypoxia
	○ Industrial wastewater
	○ Marine
	    ○ debris
	○ Monitoring
	○ Nonpoint source pollution
	○ Nutrient pollution
	○ Ocean acidification
	○ Oil exploitation
	○ Oil exploration
	○ Oil spill
	○ Pharmaceuticals
	○ Sewage
	    ○ Septic tanks
	    ○ Pit latrine
	○ Shipping
	○ Stagnation
	○ Sulfur water
	○ Surface runoff
	○ Thermal
	○ Turbidity
	○ Urban runoff
	○ Water quality

Topics	○ Pollutants
	    ○ Heavy metals
	    ○ Paint
	○ Brain health and pollution

Misc	◦ Area source ◦ Debris ◦ Dust ◦ Garbology ◦ Legacy pollution ◦ Midden ◦ Point source ◦ Waste
Responses	◦ Cleaner production ◦ Industrial ecology ◦ Pollution haven hypothesis ◦ Pollutant release and transfer register ◦ Polluter pays principle ◦ Pollution control ◦ Waste minimisation ◦ Zero waste
Lists	◦ Diseases ◦ Law by country ◦ Most polluted cities ◦ Least polluted cities by $PM_{2.5}$ ◦ Most polluted countries ◦ Most polluted rivers ◦ Treaties

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Asia pollution topics

Air pollution

- **Notable incidents**
  - **Dust storm**
    - 2010 China dust storms
  - **Forest fires and haze**
    - 1997 SEA haze
    - 1997 Indonesian forest fires
    - 2005 Malaysian haze
    - 2006 SEA haze
    - 2009 SEA haze
    - 2010 SEA haze
    - 2013 SEA haze
    - 2015 SEA haze
    - 2016 Malaysian haze
    - 2016 SEA haze
    - 2017 SEA haze
    - 2019 SEA haze
    - 2019 Vietnam forest fires
    - 2024 Indo-Pakistani smog
  - **Air radioactive contamination**
    - 1982 Bukit Merah radioactive pollution
- **By countries**
  - China
  - Hong Kong
  - India
  - Macau
  - Malaysia
  - Taiwan
- **Recurrent issues**
  - Asian brown cloud
  - Asian Dust
  - Shamal
  - Southeast Asian haze
- **Counter-measures**
  - ASEAN Agreement on Transboundary Haze Pollution
    - Operation Haze
    - Pollutant Standards Index
  - Great Green Wall (China)

Water pollution	**Notable incidents**	**Water radioactive contamination**: 2011 Fukushima Daiichi nuclear disaster
		Marine pollution: 2016 Vietnam marine life disaster; 2019 Kim Kim River toxic pollution; Pollution of the Pasig River
	By countries	China (Water crisis); India; Japan; Philippines; Vietnam

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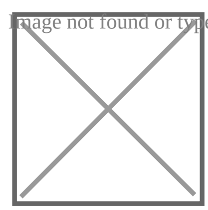
Environmental science

Main fields

- Atmospheric science
- Biogeochemistry
- Ecology
- Environmental chemistry
- Geosciences
- Hydrology
- Limnology
- Oceanography
- Soil science



Related fields	○ Biology
	○ Chemistry
	    ○ green
	○ Ecological economics
	○ Environmental design
	○ Environmental economics
	○ Environmental engineering
	○ Environmental health
	    ○ epidemiology
	○ Environmental studies
	○ Environmental humanities
	○ Environmental statistics
	○ Environmental toxicology
	○ Geodesy
	○ Physics
	○ Radioecology
	○ Sustainability science
	○ Systems ecology
	○ Urban ecology

Applications	○ Energy conservation ○ Environmental technology ○ Natural resource management ○ Pollution control ○ Public transport encouragement ○ Recycling ○ Remediation ○ Renewable energy ○ Road ecology ○ Sewage treatment ○ Urban metabolism ○ Water purification ○ Waste management
Lists	○ Degrees ○ Journals ○ Research institutes ○ Glossary ○ Environment by year
See also	○ Human impact on the environment ○ Sustainability ○ Technogaiansim

- Image not found or type unknown **Category**
  - scientists
- Image not found or type unknown **Commons**
- Image not found or type unknown **Environment portal**
- Image not found or type unknown **WikiProject**

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Public health

General

- Auxology
- Biological hazard
- Chief Medical Officer
- Cultural competence
- Deviance
- Environmental health
- Eugenics
  - History of
  - Liberal
- Euthenics
- Genomics
- Globalization and disease
- Harm reduction
- Health economics
- Health literacy
- Health policy
  - Health system
  - Health care reform
- Housing First
- Human right to water and sanitation
- Management of depression
  - Public health law
  - National public health institute
- Health politics
- Labor rights
- Maternal health
- Medical anthropology
- Medical sociology
- Mental health (Ministers)
- Occupational safety and health
- Pharmaceutical policy
- Pollution
  - Air
  - Water
  - Soil
  - Radiation
  - Light
- Prisoners' rights
- Public health intervention
- Public health laboratory
- Right to food
- Right to health
- Right to housing
- Right to rest and leisure
- Right to sit
- Security of person
- Sexual and reproductive health
- Social psychology
- Sociology of health and illness

Preventive healthcare	○ Behavior change
	  ○ Theories
	○ Family planning
	○ Health promotion
	○ Human nutrition
	  ○ Healthy diet
	  ○ Preventive nutrition
	○ Hygiene
	  ○ Food safety
	  ○ Hand washing
	  ○ Infection control
	  ○ Oral hygiene
	○ Occupational safety and health
	  ○ Human factors and ergonomics
	  ○ Hygiene
	  ○ Controlled Drugs
	  ○ Injury prevention
	  ○ Medicine
	  ○ Nursing
	○ Patient safety
	  ○ Organization
	○ Pharmacovigilance
	○ Safe sex
	○ Sanitation
	  ○ Emergency
	  ○ Fecal–oral transmission
	  ○ Open defecation
	  ○ Sanitary sewer
	  ○ Waterborne diseases
	  ○ Worker
	○ School hygiene
	○ Smoking cessation
	○ Vaccination
	○ Vector control

Population health	○ Biostatistics
	○ Child mortality
	○ Community health
	○ Epidemiology
	○ Global health
	○ Health impact assessment
	○ Health system
	○ Infant mortality
	○ Open-source healthcare software
	○ Multimorbidity
	○ Public health informatics
	○ Social determinants of health
	    ○ Commercial determinants of health
	    ○ Health equity
	    ○ Race and health
	○ Social medicine

Biological and epidemiological statistics	○ Case–control study
	○ Randomized controlled trial
	○ Relative risk
	○ Statistical hypothesis testing
	    ○ Analysis of variance (ANOVA)
	    ○ Regression analysis
	    ○ ROC curve
	    ○ Student's *t*-test
	    ○ *Z*-test
	○ Statistical software

Infectious and epidemic disease prevention	○ Asymptomatic carrier
	○ Epidemics
	    ○ List
	○ Notifiable diseases
	    ○ List
	○ Public health surveillance
	    ○ Disease surveillance
	○ Quarantine
	○ Sexually transmitted infection
	○ Social distancing
	○ Tropical disease
	○ Vaccine trial
	○ WASH

Food hygiene and safety management	○ Food
	    ○ Additive
	    ○ Chemistry
	    ○ Engineering
	    ○ Microbiology
	    ○ Processing
	    ○ Safety
	    ○ Safety scandals
	○ Good agricultural practice
	○ Good manufacturing practice
	    ○ HACCP
	    ○ ISO 22000

Health behavioral sciences	○ Diffusion of innovations ○ Health belief model ○ Health communication ○ Health psychology ○ Positive deviance ○ PRECEDE–PROCEED model ○ Social cognitive theory ○ Social norms approach ○ Theory of planned behavior ○ Transtheoretical model

Organizations, education and history	Organizations	○ Caribbean
		  ○ Caribbean Public Health Agency
		○ China
		  ○ Center for Disease Control and Prevention
		○ Europe
		  ○ Centre for Disease Prevention and Control
		  ○ Committee on the Environment, Public Health and Food Safety
		○ India
		  ○ Ministry of Health and Family Welfare
		○ Canada
		  ○ Health Canada
		  ○ Public Health Agency
		○ U.S.
		  ○ Centers for Disease Control and Prevention
		  ○ Health departments in the United States
		  ○ Council on Education for Public Health
		  ○ Public Health Service
		○ World Health Organization
		○ World Toilet Organization
		○ (Full list)

	Education	○ Health education
		○ Higher education
		  ○ Bachelor of Science in Public Health
		  ○ Doctor of Public Health
		  ○ Professional degrees of public health
		  ○ Schools of public health

	History	○ Sara Josephine Baker ○ Samuel Jay Crumbine ○ Carl Rogers Darnall ○ Joseph Lister ○ Margaret Sanger ○ John Snow ○ Typhoid Mary ○ Radium Girls ○ Germ theory of disease ○ Social hygiene movement

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Natural resources

Air	Pollution / quality	- Ambient standards (US) - Index - Indoor - Law - Clean Air Act (US) - Ozone depletion
	Emissions	- Airshed - Trading - Deforestation (REDD)

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

Land

- 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
  - resilience
- Use
  - planning
  - reserve

Life

- 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
- Wildlife
  - conservation
  - management

- **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
  - Aspects
    - Desalination
    - Floods
    - Law
    - Leaching
    - Sanitation
      - improved
    - Scarcity
    - Security
    - Supply
    - Efficiency
    - Conflict
    - Conservation
    - Peak water
    - Pollution
    - Privatization
    - Quality
    - Right
    - Resources
      - improved
      - policy

Related

- Commons
  - enclosure
  - global
  - land
  - tragedy of
- Economics
  - ecological
  - land
- Ecosystem services
- Exploitation
  - overexploitation
  - Earth Overshoot Day
- Management
  - adaptive
- Natural capital
  - accounting
  - good
- Natural heritage
- Nature reserve
  - remnant natural area
- Systems ecology
- Urban ecology
- Wilderness

Resource
- Common-pool
- Conflict (perpetuation)
- Curse
- Depletion
- Extraction
- Nationalism
- Renewable / Non-renewable

Politics
- Oil war
- Petrostate
- Resource war

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National	◦ Germany ◦ United States ◦ France ◦ BnF data ◦ Japan ◦ Czech Republic ◦ 2 ◦ Spain ◦ Israel
Other	◦ NARA

About Royal Supply Inc

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Things To Do in Jefferson County

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Jefferson County Convention & Visitors Bureau

4.4 (30)

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Jefferson Barracks Park

4.8 (2321)

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Gardens of Jefferson County

0 (0)

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Visit Jefferson County Tennessee

5 (3)

Photo

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Jefferson Landing State Historic Site

4.5 (95)

Photo

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Cliff Cave County Park

4.7 (1989)

Driving Directions in Jefferson County

Driving Directions From Tower Music to Royal Supply Inc

Driving Directions From Lowe's Home Improvement to Royal Supply Inc

Driving Directions From Rent-A-Center to Royal Supply Inc

Driving Directions From JCPenney to Royal Supply Inc

Driving Directions From Barnes & Noble to Royal Supply Inc

Driving Directions From AT&T Store to Royal Supply Inc

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Driving Directions From Jefferson County Area Tourism Council to Royal Supply Inc

Driving Directions From Visit Jefferson County PA to Royal Supply Inc

Driving Directions From Cliff Cave County Park to Royal Supply Inc

Driving Directions From Jefferson Barracks Park to Royal Supply Inc

Driving Directions From Jefferson Historical Museum to Royal Supply Inc

Driving Directions From Jefferson Barracks Park to Royal Supply Inc

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Reviews for Royal Supply Inc

Royal Supply Inc

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Ae Webb

(5)

Royal installed a new furnace and air conditioner just before we got our used mobile home. Recently, the furnace stopped lighting. Jared (sp?) made THREE trips to get it back to good. He was so gracious and kind. Fortunately for us it was still under warranty. BTW, those three trips were from Fenton, Missouri to Belleville, Illinois! Thanks again, Jared!

Royal Supply Inc

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Gidget McCarthy

(5)

Very knowledgeable, friendly, helpful and don't make you feel like you're inconveniencing them. They seem willing to take all the time you need. As if you're the only thing they have to do that day. The store is clean, organized and not cluttered, symmetrical at that. Cuz I'm even and symmetricals biggest fan. It was a pleasure doing business with them and their prices are definitely reasonable. So, I'll be doing business with them in the future no doubt.

Royal Supply Inc

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Terry Self

(1)

Horrible workmanship, horrible customer service, don't show up when they say they are. Ghosted. Was supposed to come back on Monday, no call no show. Called Tuesday and Wednesday, left messages both days. Nothing. Kinked my line, crooked to the pad and house, didn't put disconnect back on, left the trash.....

Royal Supply Inc

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Toney Dunaway

(5)

This is another amazing place where we will do much more business. They are not tyrannical about the totally useless face diapers, they have a great selection of stock, they have very knowledgeable staff, very friendly staff. We got the plumbing items we really needed and will be getting more plumbing items. They also have central units, thermostats, caulking, sealants, doors, seems everything you need for a mobile home. We've found a local treasure and will be bringing much more business. Their store is clean and tidy as well!

Royal Supply Inc

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bill slayton

(1)

Went to get a deadbolt what they had was one I was told I'd have take it apart to lengthen and I said I wasn't buying something new and have to work on it. Thing of it is I didn't know if it was so that it could be lengthened said I didn't wanna buy something new I had to work on just to fit my door. He got all mad and slung the whole box with part across the room. A real business man. I guess the owner approves of his employees doing as such.

Estimating Labor Expenses for Repair Services**View GBP**

Check our other pages :

- **Identifying Hidden Expenses in Older Units**
- **Preparing Official Documents for System Upgrades**
- **Exploring Payment Arrangements for Major Overhauls**

Frequently Asked Questions

What factors should be considered when estimating labor expenses for repairing a mobile home HVAC system?

When estimating labor expenses for repairing a mobile home HVAC system, consider the complexity of the repair, the experience level of the technician, local labor rates, and the expected duration of the job. Additionally, factor in any travel time or special equipment required.

How can I determine the average hourly rate for HVAC technicians in my area?

To determine the average hourly rate for HVAC technicians in your area, research local job postings, check industry reports or wage surveys specific to your region, and consult with other mobile home owners or property managers who have had similar work done recently.

Are there ways to reduce labor costs when repairing a mobile homes HVAC system?

Yes, you can reduce labor costs by obtaining multiple quotes from different contractors to ensure competitive pricing. Consider scheduling repairs during off-peak times or bundling them with other maintenance tasks. Additionally, performing routine maintenance yourself can prevent costly repairs down the line.

Royal Supply Inc

Phone : +16362969959

City : Fenton

State : MO

Zip : 63026

Address : Unknown Address

Google Business Profile

Company Website : **https://royal-durhamsupply.com/locations/lenexa-kansas/**