Disinfection is a process whereby pathogenic organisms, but not necessarily all microorganisms or spores, are destroyed. Disinfection may be accomplished by physical or chemical means.A number of factors influence the activity of disinfectants such as the following:Types of organisms present: Bacterial spores such as Bacillus spp., are the most resistant, followed by mycobacteria (acid-fast bacilli). Younger cells are usually more readily destroyed than mature organisms.Number of organisms present (microbial load): Time necessary for killing microorganisms increases in direct proportion with the number of organisms (microbial load). This is particularly true of instruments contaminated with organic material such as blood, pus, or mucus.Concentration of disinfectant: Generally, higher concentration of chemical disinfectants has higher killing power. Over a short-range, a small increase in concentration leads to an exponential rise in effectiveness but beyond a certain point, an increase in concentration may not raise the killing rate. Sometimes, an agent is more effective at lower concentrations. For example, 70% ethyl alcohol is more effective as a disinfectant than 95% ethyl alcohol.Amount of organics (blood, mucus, pus) present: The organic material should be mechanically removed before chemical sterilization to decrease the microbial load. This is analogous to removing dried food from utensils before placing them in a dishwasher and is important for cold sterilization of instruments such as bronchoscopes.Length of contact time: More is the exposure time to sterilant/disinfectant, the better is the efficacy.Type of water available (hard vs. soft): Hard water may reduce the rate of killing of microorganisms.Temperature and pH of the process: An increase in the temperature at which chemical acts often enhances its activity. A lower concentration of disinfectants can be used at a higher temperature. Heat kills more readily in acidic pH.Nature of surface to be disinfected (e.g., potential for corrosion; porous vs. nonporous surface)The three physical methods of disinfection are:Boiling at 100°C for 15 minutes kills vegetative bacteria.Pasteurizing at 63°C for 30 minutes or 72°C for 15 seconds kills food pathogens.Using nonionizing radiation such as ultraviolet (UV) light. UV rays are long wavelength and low energy. They do not penetrate well and organisms must have direct surface exposure, such as working surfaces of a biological safety cabinet (BSC), for this form of disinfection to work.When chemicals are used to destroy all life forms they are called chemical sterilants or biocides; however, these same chemicals used for shorter periods are disinfectants. Disinfectants are chemicals that kill microorganisms and are used on inanimate objects. Chemicals used on living tissue (skin) are called antiseptics.Chemical disinfectants can be classified into four groups based on their microbicidal activity;Low-level disinfectantsIntermediate-level disinfectantsHigh-level disinfectantsChemical sterilantClassUse Concentration of Active IngredientActivity LevelEthylene oxide (gas)450-500 mg/literHighGlutaraldehyde, aqueous2%High to intermediateFormaldehyde + alcohol8+70%HighStabilized hydrogen peroxide6-30%High to intermediateFormaldehyde, aqueous6-8%High to intermediateIodophors750-5,000 mg/literHigh to intermediateIodophors75-150 mg/literIntermediate to lowIodine + alcohol0.5+70%IntermediateChlorine compounds0.1-0.5%IntermediatePhenolic compounds, aqueous0.5-3%Intermediate to lowIodine, aqueous1%IntermediateAlcohols (ethyl, isopropyl)70%IntermediateQuaternary ammonium compounds0.1-0.2%LowChlorhexidine0.75%-4%LowHexachlorophene1-3%LowMercurial compounds0.1-0.2%LowChemical disinfectants comprise many classes, including the following:Alcohols: They are among the most widely used disinfectants and antiseptics. Ethyl or isopropyl alcohol is non-sporicidal (does not kill spores) and evaporates quickly. Alcohols are best used on the skin as an antiseptic (surgical spirit). Clinical thermometers and small instruments can be disinfected by soaking in isopropyl alcohol for 10-15 minutes.Aldehydes: Formaldehyde, glutaraldehyde, and ortho-phthalaldehyde are commonly used aldehydes. They are sporicidal and can be used as chemical sterilants. Formaldehyde (formalin; i.e. formaldehyde in water) is used to preserve anatomical specimens and for fumigation of closed areas, such as operation theaters. They are generally not used as surface disinfectants because of their irritating fumes.Halogens: Halogens, especially chlorine and iodine, are frequently used as disinfectants as they possess antimicrobial activity. They exist in a free state and form a salt with sodium and most other metals.Chlorine: It is the most commonly available disinfectant. Chlorine is most often used in the form of sodium hypochlorite (NaOCl), the compound known as household bleach. CDC recommends that tabletops be cleaned following blood spills with a 1:10 dilution of bleach. It is also used for municipal water supplies, swimming pools, dairy and food industries, etc.Iodine: Iodine compounds are widely employed antiseptics. Iodine is prepared either as tincture with alcohol or as an iodophor coupled with a neutral polymer, for example, povidone-iodine."70% ethyl alcohol, followed by an iodophor, is the most common compound used for skin disinfection before drawing blood cultures or surgery".Heavy metals: Salts of heavy metals, such as mercury, silver, zinc, and copper were widely used in the past as germicides but their use has been replaced by less toxic chemicals over the period. Eyedrop solution containing 1% silver nitrate is still instilled in the eyes of newborns to prevent ophthalmia neonatorum (an infection with Neisseria gonorrhoeae)."Heavy metals containing mercury are no longer recommended because mercury is toxic to the environment".Quaternary ammonium compounds (Quats): Quaternary ammonium compounds such as benzalkonium chloride, are used to disinfect bench-tops or other surfaces in the laboratory. However, organic materials, such as blood, may inactivate heavy metals or quaternary ammonium compounds, thus limiting their utility.Phenolics: Phenolics, such as the common laboratory disinfectant amphyl, are derivatives of carbolic acid (phenol). The addition of detergent results in a product that cleans and disinfects at the same time, and at a concentration between 2%-5% these products are widely used for cleaning benchtops.References and further readingsMadigan Michael T, Bender, Kelly S, Buckley, Daniel H, Sattley, W. Matthew, & Stahl, David A. (2018). Brock Biology of Microorganisms (15th Edition). Pearson.Procop, G. W., & Koneman, E. W. (2016). Koneman's Color Atlas and Textbook of Diagnostic Microbiology (Seventh, International edition). Lippincott Williams and Wilkins.Tille, P. (2017). Bailey & Scott's Diagnostic Microbiology (14 edition). Mosby.Willey, Joanne M, Sherwood, Linda M, & Woolverton, Christopher J. (2016). Prescott's Microbiology (10 edition). McGraw-Hill Education.link to Martin Lewis Agar: Principle, Composition, and Useslink to Hematopoiesis: Stages, Sites, and Its Regulation Antimicrobial agent that inactivates or destroys microbes "Sanitizers" redirects here. For the software, see AddressSanitizer. This article is about antimicrobial agents. For the Macintosh anti-virus software, see Disinfectant (software). Disinfection of a floor using disinfectant liquid applied using a mop. Levels of resistance of microbes to disinfectants. A disinfectant is a chemical substance or compound used to inactivate or destroy microorganisms on inert surfaces.[1] Disinfection does not necessarily kill all microorganisms, especially resistant bacterial spores; it is less effective than sterilization, which is an extreme physical or chemical process that kills all types of life.[1] Disinfectants are generally distinguished from other antimicrobial agents such as antibiotics, which destroy microorganisms within the body, and antiseptics, which destroy microorganisms on living tissue. Disinfectants are also different from biocides—the latter are intended to destroy all forms of life, not just microorganisms. Disinfectants work by destroying the cell wall of microbes or interfering with their metabolism. It is also a form of decontamination, and can be defined as the process whereby physical or chemical methods are used to reduce the amount of pathogenic microorganisms on a surface.[2][3] Disinfectants can also be used to destroy microorganisms on the skin and mucous membrane, as in the medical dictionary historically the word simply meant that it destroys microbes.[4][5][6] Sanitizers are substances that simultaneously clean and disinfect.[7] Disinfectants kill more germs than sanitizers.[8] Disinfectants are frequently used in hospitals, dental surgeries, kitchens, and bathrooms to kill infectious organisms. Sanitizers are mild compared to disinfectants and are used primarily to clean things that are in human contact, whereas disinfectants are concentrated and are used to clean surfaces like floors and building premises.[citation needed][9] Bacterial endospores are most resistant to disinfectants, but some fungi, viruses and bacteria also possess some resistance.[10] Disinfectants are used to rapidly kill bacteria. They kill off the bacteria by causing the proteins to become damaged and the outer layers of the bacteria cell to rupture. The DNA material subsequently leaks out.[citation needed] In wastewater treatment, a disinfection step with chlorine, ultra-violet (UV) radiation or ozonation can be included as tertiary treatment to remove pathogens from wastewater, for example if it is to be discharged to a river or the sea where there body contact immersion recreations is practiced (Europe) or reused to irrigate golf courses (US). An alternative term used in the sanitation sector for disinfection of waste streams, sewage sludge or fecal sludge is sanitisation or sanitization.[citation needed] The Australian Therapeutic Goods Order No. 54 defines several grades of disinfectant as will be used below.[11] Sterilant means a chemical agent which is used to sterilize critical medical devices or medical instruments. A sterilant kills all micro-organisms with the result that the sterility assurance level of a microbial survivor is less than 10^{-6}. Sterilant gases are not within this scope.[citation needed] Low level disinfectant means a disinfectant that rapidly kills most vegetative bacteria as well as medium-sized lipid containing viruses, when used according to labelling. It cannot be relied upon to destroy, within a practical period, bacterial endospores, mycobacteria, fungi, or all small nonlipid viruses.[citation needed] Intermediate level disinfectant means a disinfectant that kills all microbial pathogens except bacterial endospores, when used as recommended by the manufacturer. It is bactericidal, tuberculocidal, fungicidal (against asexual spores but not necessarily dried chlamydospores or sexual spores), and virucidal.[citation needed] High level disinfectant means a disinfectant that kills all microbial pathogens, except large numbers of bacterial endospores when used as recommended by its manufacturer.[citation needed] Instrument grade disinfectant means: a disinfectant which is used to reprocess reusable therapeutic devices; and when associated with the words "low", "intermediate" or "high" means "low", "intermediate" or "high" level disinfectant respectively. Hospital grade means a disinfectant that is suitable for general purpose disinfection of building and fitting surfaces, and purposes not involving instruments or surfaces likely to come into contact with broken skin:[citation needed] in premises used for: the investigation or treatment of a disease, ailment or injury; or procedures that are carried out involving the penetration of the human skin; or, in connection with: the business of beauty therapy or hairdressing; or the practice of podiatry; but does not include : Instrument grade disinfectants; or sterilant; or an antibacterial clothes preparation; or a sanitary fluid; or a sanitary powder; or a sanitiser. Household/commercial grade disinfectant means a disinfectant that is suitable for general purpose disinfection of building or fitting surfaces, and for other purposes, in premises or involving procedures other than those specified for a hospital-grade disinfectant, but is not:[citation needed] an antibacterial clothes preparation; or a sanitary fluid; or a sanitary powder; or a sanitiser One way to compare disinfectants is to compare how well they do against a known disinfectant and rate them accordingly. Phenol is the standard, and the corresponding rating system is called the "Phenol coefficient". The disinfectant to be tested is compared with phenol on a standard microbe (usually Salmonella typhi or Staphylococcus aureus). Disinfectants that are more effective than phenol have a coefficient > 1. Those that are less effective have a coefficient < 1.[citation needed] The standard European approach for disinfectant validation consists of a basic suspension test, a quantitative suspension test (with low and high levels of organic material added to act as 'interfering substances') and a two part simulated-use surface test.[12] A less specific measurement of effectiveness is the United States Environmental Protection Agency (EPA) classification into either high, intermediate or low levels of disinfection. "High-level disinfection kills all organisms, except high levels of bacterial spores" and is done with a chemical germicide marketed as a sterilant by the U.S. Food and Drug Administration (FDA). "Intermediate-level disinfection kills mycobacteria, most viruses, and bacteria with a chemical germicide registered as a 'tuberculocide' by the Environmental Protection Agency. Low-level disinfection kills some viruses and bacteria with a chemical germicide registered as a hospital disinfectant by the EPA."[13] An alternative assessment is to measure the Minimum inhibitory concentrations (MICs) of disinfectants against selected (and representative) microbial species, such as through the use of microbroth dilution testing.[14] However, those methods are obtained at standard inoculum levels without considering the inoculum effect. More informative methods are nowadays in demand to determine the minimum disinfectant dose as a function of the density of the target microbial species.[15] A perfect disinfectant would also offer complete and full microbiological sterilisation, without harming humans and useful form of life, be inexpensive, and noncorrosive. However, most disinfectants are also, by nature, potentially harmful (even toxic) to humans or animals. Most modern household disinfectants contain denatonium, an exceptionally bitter substance added to discourage ingestion, as a safety measure. Those that are used indoors should never be mixed with other cleaning products as chemical reactions can occur.[16] The choice of disinfectant to be used depends on the particular situation. Some disinfectants have a wide spectrum (kill many different types of microorganisms), while others kill a smaller range of disease-causing organisms but are preferred for other properties (they may be non-corrosive, non-toxic, or inexpensive).[17] There are arguments for creating or maintaining conditions that are not conducive to bacterial survival and multiplication, rather than attempting to kill them with chemicals. Bacteria can increase in number very quickly, which enables them to evolve rapidly. Should some bacteria survive a chemical attack, they give rise to new generations composed completely of bacteria that have resistance to the particular chemical used. Under a sustained chemical attack, the surviving bacteria in successive generations are increasingly resistant to the chemical used, and ultimately the chemical is rendered ineffective. For this reason, some question the wisdom of impregnating cloths, cutting boards and worktops in the home with bactericidal chemicals.[citation needed] See also: Air sanitizer Air disinfectants are typically chemical substances capable of disinfecting microorganisms suspended in the air. Disinfectants are generally assumed to be limited to use on surfaces, but that is not the case. In 1928, a study found that airborne microorganisms could be killed using mists of dilute bleach.[18] An air disinfectant must be dispersed either as an aerosol or vapour at a sufficient concentration in the air to cause the number of viable infectious microorganisms to be significantly reduced.[citation needed] In the 1940s and early 1950s, further studies showed inactivation of diverse bacteria, influenza virus, and Penicillium chrysogenum (previously P. notatum) mold fungus using various glycols, principally propylene glycol and triethylene glycol.[19] In principle, these chemical substances are ideal air disinfectants because they have both high lethality to microorganisms and low mammalian toxicity.[20][21] Although glycols are effective air disinfectants in controlled laboratory environments, it is more difficult to use them effectively in real-world environments because the disinfection of air is sensitive to continuous action. Continuous action in real-world environments with outside air exchanges at door, HVAC, and window interfaces, and in the presence of materials that absorb and remove glycols from the air, poses engineering challenges that are not critical for surface disinfection. The engineering challenge associated with creating a sufficient concentration of the glycol vapours in the air have not to date been sufficiently addressed.[22][23] See also: Hand sanitizer Alcohol hand sanitizer dispenser in an office in Poland Alcohol and alcohol plus Quaternary ammonium cation based compounds comprise a class of proven surface sanitizers and disinfectants approved by the EPA and the Centers for Disease Control for use as a hospital grade disinfectant.[24] Alcohols are most effective when combined with distilled water to facilitate diffusion through the cell membrane; 100% alcohol typically denatures only external membrane proteins.[25] A mixture of 70% ethanol or isopropanol diluted in water is effective against a wide spectrum of bacteria, though higher concentrations are often needed to disinfect wet surfaces.[26] Additionally, high-concentration mixtures (such as 80% ethanol + 5% isopropanol) are required to effectively inactivate lipid-enveloped viruses (such as HIV, hepatitis B, and hepatitis C).[25][26][27][28] The efficacy of alcohol is enhanced when in solution with the wetting agent dodecanoic acid (coconut soap). The synergistic effect of 29.4% ethanol with dodecanoic acid is effective against a broad spectrum of bacteria, fungi, and viruses. Further testing is being performed against Clostridioides difficile (C.Diff) spores with higher concentrations of ethanol and dodecanoic acid, which proved effective with a contact time of ten minutes.[29] Aldehydes, such as formaldehyde and glutaraldehyde, have a wide microbicidal activity and are sporicidal and fungicidal. They are partly inactivated by organic matter and have slight residual activity.[citation needed] Some bacteria have developed resistance to glutaraldehyde, and it has been found that glutaraldehyde can cause asthma and other health hazards, hence ortho-phthalaldehyde is replacing glutaraldehyde.[citation needed] Oxidizing agents act by oxidizing the cell membrane of microorganisms, which results in a loss of structure and leads to cell lysis and death. A large number of disinfectants operate in this way. Chlorine and oxygen are strong oxidizers, so their compounds figure heavily here. Electrolyzed water or "Anolyte" is an oxidizing, acidic hypochlorite solution made by electrolysis of sodium chloride into sodium hypochlorite and hypochlorous acid. Anolyte has an oxidation-reduction potential of +600 to +1200 mV and a typical pH range of 3.5––8.5, but the most potent solution is produced at a controlled pH 5.0–6.3 where the predominant oxychlorine species is hypochlorous acid. Hydrogen peroxide is used in hospitals to disinfect surfaces and it is used in solution alone or in combination with other chemicals as a high level disinfectant. Hydrogen peroxide is sometimes mixed with colloidal silver. It is often preferred because it causes far fewer allergic reactions than alternative disinfectants. Also used in the food packaging industry to disinfect foil containers. A 3% solution is also used as an antiseptic. Hydrogen peroxide vapor is used as a medical sterilant and as room disinfectant. Hydrogen peroxide has the advantage that it decomposes to form oxygen and water thus leaving no long term residues, but hydrogen peroxide as with most other strong oxidants is hazardous, and solutions are a primary irritant. The vapor is hazardous to the respiratory system and eyes and consequently the OSHA permissible exposure limit is 1 ppm (29 CFR 1910.1000 Table Z-1) calculated as an eight-hour time weighted average and the NIOSH immediately dangerous to life and health limit is 75 ppm.[30] Therefore, engineering controls, personal protective equipment, gas monitoring etc. should be employed where high concentrations of hydrogen peroxide are used in the workplace. Vaporized hydrogen peroxide is one of the chemicals approved for decontamination of anthrax spores from contaminated buildings, such as occurred during the 2001 anthrax attacks in the U.S. It has also been shown to be effective in removing exotic animal viruses, such as avian influenza and Newcastle disease from equipment and surfaces. The antimicrobial action of hydrogen peroxide can be enhanced by surfactants and organic acids. The resulting chemistry is known as Accelerated hydrogen peroxide. A 2% solution, stabilized for extended use, achieves high-level disinfection in 5 minutes, and is suitable for disinfecting medical equipment made from hard plastic, such as in endoscopes.[31] The evidence available suggests that products based on Accelerated Hydrogen Peroxide, apart from being good germicides, are safer for humans and benign to the environment.[32] Ozone is a gas used for disinfecting water, laundry, foods, air, and surfaces. It is chemically aggressive and destroys many organic compounds, resulting in rapid decolorization and deodorization in addition to disinfection. Ozone decomposes relatively quickly. However, due to this characteristic of ozone, tap water chlorination cannot be entirely replaced by ozonation, as the ozone would decompose already in the water piping. Instead, it is used to remove the bulk of oxidizable matter from the water, which would produce small amounts of organochlorides if treated with chlorine only. Regardless, ozone has a very wide range of applications from municipal to industrial water treatment due to its powerful reactivity. Potassium permanganate ($KMnO_4$) is a purplish-black crystalline powder that colours everything it touches, through a strong oxidising action. This includes staining "stainless" steel, which somewhat limits its use and makes it necessary to use plastic or glass containers. It is used to disinfect aquariums and is used in some community swimming pools as a foot disinfectant before entering the pool. Typically, a large shallow basin of $KMnO_4$ / water solution is kept near the pool ladder. Participants are required to step in the basin and then go into the pool. Additionally, it is widely used to disinfect community water ponds and wells in tropical countries, as well as to disinfect the mouth before pulling out teeth. It can be applied to wounds in dilute solution. Peroxycarboxylic acids and inorganic peroxo acids are strong oxidants and extremely effective disinfectants.[citation needed] Peroxyformic acid Peracetic acid Peroxypropionic acid Monoperoxyglutaric acid Monoperoxysuccinic acid Peroxybenzoic acid Peroxyanisic acid Chloroperbenzoic acid Monoperoxyphthalic acid Peroxymonosulfuric acid Phenolics are active ingredients in some household disinfectants. They are also found in some mouthwashes and in disinfectant soap and handwashes. Phenols are toxic to cats[33] and newborn humans[34] Phenol is probably the oldest known disinfectant as it was first used by Lister, when it was called carbolic acid. It is rather corrosive to the skin and sometimes toxic to sensitive people. Impure preparations of phenol were originally made from coal tar, and these contained low concentrations of other aromatic hydrocarbons including benzene, which is an IARC Group 1 carcinogen. o-Phenylphenol is often used instead of phenol, since it is somewhat less corrosive. Chloroxylenol is the principal ingredient in Dettol, a household disinfectant and antiseptic. Hexachlorophene is a phenolic that was once used as a germicidal additive to some household products but was banned due to suspected harmful effects. Thymol, derived from the herb thyme, is the active ingredient in some "broad spectrum" disinfectants that often bear ecological claims. It is used as a stabilizer in pharmaceutic preparations. It has been used for its antiseptic, antibacterial, and antifungal actions, and was formerly used as a vermifuge.[35] Amylmetacresol is found in Strepsils, a throat disinfectant. Although not a phenol, 2,4-dichlorobenzyl alcohol has similar effects as phenols, but it cannot inactivate viruses. Quaternary ammonium compounds ("quats"), such as benzalkonium chloride, are a large group of related compounds. Some concentrated formulations have been shown to be effective low-level disinfectants. Quaternary ammonia at or above 200ppm plus alcohol solutions exhibit efficacy against difficult to kill non-enveloped viruses such as norovirus, rotavirus, or polio virus.[24] Newer synergous, low-alcohol formulations are highly effective broad-spectrum disinfectants with quick contact times (3–5 minutes) against bacteria, enveloped viruses, pathogenic fungi, and mycobacteria. Quats are biocides that also kill algae and are used as an additive in large-scale industrial water systems to minimize undesired biological growth.[citation needed] This group comprises aqueous solution of chlorine, hypochlorite, or hypochlorous acid. Occasionally, chlorine-releasing compounds and their salts are included in this group. Frequently, a concentration of < 1 ppm of available chlorine is sufficient to kill bacteria and viruses, spores and mycobacteria requiring higher concentrations. Chlorine has been used for applications, such as the deactivation of pathogens in drinking water, swimming pool water and wastewater, for the disinfection of household areas and for textile bleaching[36] Sodium hypochlorite Calcium hypochlorite Monochloramine Chloramine-T Trichloroisocyanuric acid Chlorine dioxide Hypochlorous acid Iodine Iodophors Sodium hydroxide Potassium hydroxide Calcium hydroxide Magnesium hydroxide Sulfurous acid Sulfur dioxide phosphoric acid[37] dodecylbenzenesulfonic acid[37] Main article: Oligodynamic effectMost metals, especially those with high atomic weights can inhibit the growth of pathogens by disrupting their metabolism.[citation needed] Thymol Pine oil The biguanide polymer polyaminopropyl biguanide is specifically bactericidal at very low concentrations (10 mg/L). It has a unique method of action: The polymer strands are incorporated into the bacterial cell wall, which disrupts the membrane and reduces its permeability, which has a lethal effect to bacteria. It is also known to bind to bacterial DNA, alter its transcription, and cause lethal DNA damage.[38] It has very low toxicity to higher organisms such as human cells, which have more complex and protective membranes. Common sodium bicarbonate ($NaHCO_3$) has antifungal properties,[39] and some antiviral and antibacterial properties,[40] though those are too weak to be effective at a home environment.[41] Ultraviolet germicidal irradiation is the use of high-intensity shortwave ultraviolet light for disinfecting smooth surfaces such as dental tools, but not porous materials that are opaque to the light such as wood or foam. Ultraviolet light is also used for municipal water treatment. Ultraviolet light fixtures are often present in microbiology labs, and are activated only when there are no occupants in a room (e.g., at night).[citation needed] Heat treatment can be used for disinfection and sterilization.[42] The phrase "sunlight is the best disinfectant" was popularized in 1913 by United States Supreme Court Justice Louis Brandeis[43] and later advocates of government transparency. While sunlight's ultraviolet rays can act as a disinfectant, the Earth's ozone layer blocks the rays' most effective wavelengths. Ultraviolet light-emitting machines, such as those used to disinfect some hospital rooms, make for better disinfectants than sunlight.[44] Since the mid-1990s cold plasma has been shown to be an efficient sterilization/disinfection agent.[45][46] Cold plasma is an ionized gas that remains at room temperature. It generates reactive oxygen and reactive nitrogen species that interact with bacterial wall and membrane and cause oxidation of the lipids and proteins and can also lyse the cells. Cold plasma can inactivate bacteria, viruses, and fungi. There has been a rise in the use of electrostatic disinfectants in recent years.[47] Electrostatic disinfection is a process achieved by use of electrostatic sprayers notable examples of which include the Vycel - Vycel 4 or the Techtronics Ryobi. Electrostatic Sprayers are a new technology for disinfecting surfaces. Unlike conventional spraying bottles or devices electrostatic sprayers apply a positive ionic charge to liquid disinfectants as they pass through the nozzle of the device. The positively charged disinfectant distributed through the nozzle of an electrostatic sprayer is attracted to negatively charged surfaces, which allows for efficient coating of disinfectant solutions on to hard nonporous surfaces.[48] There are a number of specific disinfectants designed for use with electrostatic sprayers and these are often dissolved in solution or diluted with water. Notable disinfectant sprays that are designed for use with electrostatic sprayers include Citrox Disinfectant Solution and Vital Oxide Disinfectant Solution.[citation needed] Individuals who work manufacturing disinfectants have higher exposure to the raw and harsh chemicals used in the production of disinfectants compared to the general population.[49] This is due to the use of manual labor and automated machinery.[50] However, the use of automated machinery does not dismiss any direct contact with the chemicals within the production of disinfectants.[50][51] Chemicals used in disinfectants vary in forms, such as gel, liquid, and powder.[52][53] Minimal information remains about the health and safety of workers in other sectors of the production and manufacturing process of disinfectants. Inspection is a process of disinfectant manufacturing that only requires human intervention.[50] Many workers in the inspection phase of mass production of disinfectants have reported accidental inhalation of fumes, direct dermal contact, eye irritation, and accidental ingestion of disinfectant substances.[49][53] Studies have shown reports of workers with short-term neurological impairments,[54] dermal hypersensitivity,[5] skin irritation,[5][49] chemical burns,[5][49] dermatitis,[5][49] occupational asthma and work-related asthma,[55][56][57] mucus membrane (nasal)[58] and lung irritation,[49] and some types of cancer after direct and consistent contact with disinfectants.[59][30] The chemicals, quaternary ammonium compounds (QACs)[49][53], phenolic compounds,[53] iodophors,[53] glutaraldehyde,[53] alcohols,[53] and chlorine,[53] were most associated with the previous health effects.[52][53][56][30][58][49][5] This evidence of dermal exposure was associated with the misuse or lack of Personal Protective Equipment (PPE).[59][60][61] Cancer has been shown to only develop in consistent exposure, along with the lack of use of Personal Protective Equipment (PPE).[59] Among these numerous health effects, evidence showed that dermal exposure was more hazardous than inhalation.[52][62] These health effects can be minimized with the implementation of guidelines from the CDC, NPIC, OSHA, and NIOSH.[52][63][61][62][60][51] There is evidence that exposure to cleaning and disinfectant products can cause acute health effects on healthcare workers.[64] Observed effects include eye irritation and watery eyes,[65][66] headaches,[65] dizziness,[65] throat irritation and wheezing,[65][64][66] skin irritation,[65] and work-related asthma.[67][65][64] Most of these have a low severity.[65] Some chemicals in cleaning and disinfectants that have been associated with health impacts include chlorine,[64] ammonia,[2][64] ethanolamine,[64] 2-butoxyethanol,[64] quaternary ammonium compounds (QACs),[65][64] and bleach.[67][65][64] The adverse health impacts of disinfectants are still not well studied, which makes it difficult to develop guidelines for use in healthcare settings that take mind of potential effects.[64] There is also little information about how effective and safe alternative cleaning technology, so-called "green cleaning," is.[64] New guidelines would need to maintain high hygiene standards and prevent healthcare-associated infections.[64] Professional and Industrial cleaners, despite being essential in maintaining hygiene and safety are one of the understudied occupational groups. Continuous exposure to cleaning agents containing ethanolamine,[55] chloramine-T,[55] and Quaternary Ammonium Compounds (QACs)[49] was found to cause Occupational Asthma (OA) in cleaners.[55] QAC was also found to be involved in developing antimicrobial resistance. Symptoms reported were dyspnea, cough, and wheezing. Females had more risk of acquiring OA due to higher exposures both at home and work.[49][68] Exposures happen through dermal contact, hand-to-mouth, and inhalation of aerosolized quats. Researchers suggest continuous use of Personal Protective Equipment (PPE), periodic medical examinations, and guidelines on how to handle chemicals.[68] Dermal, respiratory, immune, reproductive, and developmental effects of exposure are investigated but there is a currently limited scope of this study. Other concerns found were its impact on wastewater management, soil, and food especially in dissolved concentrations.[68] In the United States, the Environmental Protection Agency (EPA), and Food and Drug Administration (FDA) regulate QACs depending on their intended purposes. Stricter regulations and policies are warranted for safer use and search for alternatives to limit exposures.[68] Drug resistance Diethylene glycol - a raw material for air sanitation Hand sanitizer Hygiene List of cleaning products Sanitation Standard Operating Procedures Virucide ^ a b "Division of Oral Health - Infection Control Glossary". U.S. Centers for Disease Control and Prevention. Archived from the original on 13 April 2016. Retrieved 19 April 2016. ^ Loveday HP, Wilson JA, Pratt RJ, Golsorkhi M, Tingle A, Bak A, et al. (January 2014). "epic3: national evidence-based guidelines for preventing healthcare-associated infections in NHS hospitals in England". 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Sandle, T., ed. (2012). The CDC Handbook: A Guide to Cleaning and Disinfecting Cleanrooms (1st ed.). Grosvenor House Publishing Limited. ISBN 978-1781487686. Ohio State University lecture on Sterilization and Disinfection What Germs Are We Killing? Testing and Classifying Disinfectants Disinfectant Selection Guide Disinfectant and Non-Chlorine Bleach Archived 1 June 2010 at the Wayback Machine—Office of DOE Science Education The Viennese Database for Disinfectants (WIDES Database) Cleaning and Custodial Services and Your Safety, by the National Institute for Occupational Safety and Health Retrieved from " Both live and dead microorganisms can be removed from liquids by positive- or negative-pressure filtration. Membrane filters, usually composed of cellulose esters (eg, cellulose acetate), are available commercially with pore sizes of 0.005 to 1μm. For removal of bacteria, a pore size of 0.2μm is effective because filters act not only mechanically but by electrostatic adsorption of particles to their surface. Filtration is used for disinfection of large volumes of fluid, especially those containing heat-labile components such as serum. For microorganisms larger than the pore size filtration "sterilizes" these liquids. It is not considered effective for removing viruses.PasteurizationPasteurization involves exposure of liquids to temperatures in the range 55 to 75°C to re-move all vegetative bacteria of significance in human disease. Spores are unaffected by the pasteurization process. Pasteurization is used commercially to render milk safe and extend its storage quality. With the outbreaks of infection due to contamination with en-terohemorrhagic E. coli , this has been extended (reluctantly) to fruit drinks. To the dismay of some of his compatriots, Pasteur proposed application of the process to winemaking to prevent microbial spoilage and vinegarization. Pasteurization in water at 70°C for 30 minutes has been effective and inexpensive when used to render in-halation therapy equipment free of organisms that may otherwise multiply in mucus and humidifying water.MicrowavesThe use of microwaves in the form of microwave ovens or specially designed units is an-other method for disinfection. These systems are not under pressure, but they but can achieve temperatures near boiling if moisture is present. In some situations, they are being used as a practical alternative to incineration for disinfection of hospital waste. These pro-cedures cannot be considered sterilization only because the most heat-resistant spores may survive the process.Chemical MethodsGiven access and sufficient time, chemical disinfectants cause the death of pathogenic vegetative bacteria. Most of these substances are general protoplasmic poisons and are not currently used in the treatment of infections other than very superficial lesions, having been replaced by antimicrobics . Some disinfectants such as the quater-nary ammonium compounds, alcohol, and the iodophors reduce the superficial flora and can eliminate contaminating pathogenic bacteria from the skin surface. Other agents such as the phenolics are valuable only for treating inanimate surfaces or for rendering conta-minated materials safe. All are bound and inactivated to varying degrees by protein and dirt, and they lose considerable activity when applied to other than clean surfaces. Their activity increases exponentially with increases in temperature, but the relationship be-tween increases in concentration and killing effectiveness is complex and varies for each compound. Optimal in-use concentrations have been established for all available disinfec-tants. The major groups of compounds currently used are briefly discussed next. Chemical disinfectants are classified on the basis of their ability to sterilize. High-level disinfectants kill all agents except the most resistant of bacterial spores. Intermediate-level disinfectants kill all agents but not spores. Low-level disinfectants are active against most vegetative bacteria and lipid-enveloped viruses.AlcoholThe alcohols are protein denaturants that rapidly kill vegetative bacteria when applied as aqueous solutions in the range 70 to 95% alcohol. They are inactive against bacterial spores and many viruses. Solutions of 100% alcohol dehydrate organisms rapidly but fail to kill, because the lethal process requires water molecules. Ethanol (70 – 90%) and iso- propyl alcohol (90 – 95%) are widely used as skin decontaminants before simple invasive procedures such as venipuncture. Their effect is not instantaneous, and the traditional al- cohol wipe, particularly when followed by a vein-probing finger, is more symbolic than effective, because insufficient time is given for significant killing. Isopropyl alcohol has largely replaced ethanol in hospital use because it is somewhat more active and is not subject to diversion to housestaff parties.HalogensIodine is an effective disinfectant that acts by iodinating or oxidizing essential components of the microbial cell. Its original use was as a tincture of 2% iodine in 50% alcohol, which kills more rapidly and effectively than alcohol alone. This preparation has the disadvantage of sometimes causing hypersensitivity reactions and of staining materials with which it comes into contact. Tincture of iodine has now been largely replaced by preparations in which iodine is combined with carriers (povidone) or nonionic detergents. These agents, termed iodophors, gradually release small amounts of iodine. They cause less skin staining and dehydration than tinctures and are widely used in preparation of skin before surgery. Although iodophors are less allergenic than inorganic iodine preparations, they should not be used on patients with a history of iodine sensitivity.Chlorine is a highly effective oxidizing agent, which accounts for its lethality to microbes.It exists as hypochlorous acid in aqueous solutions that dissociate to yield free chlorine over a wide pH range, particularly under slightly acidic conditions. In concentrations of less than one part per million, chlorine is lethal within seconds to most vegetative bacteria, and it inactivates most viruses; this efficacy accounts for its use in rendering supplies of drinking water safe and in chlorination of water in swimming pools. Chlorine reacts rapidly with protein and many other organic compounds, and its activity is lost quickly in the presence of organic material. This property, combined with its toxicity, renders it ineffective on body surfaces; however, it is the agent of choice for decontaminating surfaces and glassware that have been contaminated with viruses or spores of pathogenic bacteria. For these purposes it is usually applied as a 5% solution called hypochlorite.The use of chlorination to disinfect water supplies has proved insufficient in some hospitals because of the relative resistance of Legionella pneumophila to the usual concentrations of chlorine. Some institutions have been forced to augment chlorination with systems that add copper and silver ions to the water. Hydrogen PeroxideHydrogen peroxide is a powerful oxidizing agent that attacks membrane lipids and other cell components. Although it acts rapidly against many bacteria and viruses, it kills bacte- ria that produce catalase and spores less rapidly. Hydrogen peroxide has been useful in disinfecting items such as contact lenses that are not susceptible to its corrosive effect.Surface-Active CompoundsSurfactants are compounds with hydrophobic and hydrophilic groups that attach to andsolubilize various compounds or alter their properties. Anionic detergents such as soaps are highly effective cleansers but have little direct antibacterial effect, probably because their charge is similar to that of most microorganisms. Cationic detergents, particularly thequaternary ammonium compounds ("quats") such as benzalkonium chloride, are highly bactericidal in the absence of contaminating organic matter. Their hydrophobic and lipophilic groups react with the lipid of the cell membrane of the bacteria, alter the membrane's surface properties and its permeability, and lead to loss of essential cell com-ponents and death. These compounds have little toxicity to skin and mucous membranes and, thus, have been used widely for their antibacterial effects in a concentration of 0.1%. They are inactive against spores and most viruses. "Quats" in much higher concentrations than those used in medicine (eg, 5 – 10%) can be used for sanitizing surfaces.The greatest care is needed in the use of quats because they adsorb to most surfaces with which they come into contact, such as cotton, cork, and even dust. As a result, their concentration may be lowered to a point at which certain bacteria, particularly Pseudomonas aeruginosa, can grow in the quat solutions and then cause serious infec-tions. Many instances have been recorded of severe infections resulting from contamina-tion of ophthalmic preparations or of solutions used for treating skin before transcutaneous procedures. It should also be remembered that cationic detergents are totally neutralized by anionic compounds. Thus, the antibacterial effect of quaternary ammonium compounds is inactivated by soap. Because of these problems, quats have been replaced by other antisep-tics and disinfectants for most purposes.PhenolicsPhenol, one of the first effective disinfectants, was the primary agent employed by Listerin his antiseptic surgical procedure, which preceded the development of aseptic surgery. It is a potent protein denaturant and bactericidal agent. Substitutions in the ring structure of phenol have substantially improved activity and have provided a range of phenols and cresols that are the most effective environmental decontaminants available for use in hos-pital hygiene. Concern about their release into the environment in hospital waste and sewage has created some pressure to limit their use. This is another of the classic environ-mental dilemmas of our society: a compound that reduces the risk of disease for one group may raise it for another. Phenolics are less “quenched” by protein than are most other disinfectants, have a detergent-like effect on the cell membrane, and are often for-mulated with soaps to increase their cleansing property. They are too toxic to skin and tissues to be used as antiseptics, although brief exposures can be tolerated. They are the active ingredient in many mouthwash and sore throat preparations.Two diphenyl compounds, hexachlorophene and chlorhexidine, have been extensively used as skin disinfectants. Hexachlorophene is primarily bacteriostatic. Incorporated into a soap, it builds up on the surface of skin epithelial cells over 1 to 2 days of use to pro-duce a steady inhibitory effect on skin flora and Gram-positive contaminants, as long as its use is continued. It was a major factor in controlling outbreaks of severe staphylococ-cal infections in nurseries during the 1950s and 1960s, but cutaneous absorption was found to produce neurotoxic effects in some premature infants. When it was applied in excessive concentrations, similar problems occurred in older children. It is now a pre-scription drug.Chlorhexidine has replaced hexachlorophene as a routine hand and skin disinfectantand for other topical applications. It has greater bactericidal activity than hexa-chlorophene without its toxicity but shares with hexachlorophene the ability to bind to the skin and produce a persistent antibacterial effect. It acts by altering membrane permeabil-ity of both Gram-positive and -negative bacteria. It is cationic and, thus, its action is neu-tralized by soaps and anionic detergents.Glutaraldehyde and FormaldehydeGlutaraldehyde and formaldehyde are alkylating agents highly lethal to essentially all mi-croorganisms. Formaldehyde gas is irritative, allergenic, and unpleasant, properties that limit its use as a solution or gas. Glutaraldehyde is an effective high-level disinfecting agent for apparatus that cannot be heat treated, such as some lensed instruments and equipment for respiratory therapy. Formaldehyde vapor, an effective environmental de-contaminant under conditions of high humidity, is sometimes used to decontaminate labo-ratory rooms that have been accidentally and extensively contaminated with pathogenic bacteria, including those such as the anthrax bacillus that form resistant spores. Such rooms are sealed for processing and thoroughly aired before reoccupancy.Some risk of infection exists in all health care settings. Hospitalized patients are par-ticularly vulnerable and the hospital environment is complex. The proper matching of the principles and procedures described here to general and specialized situations together with aseptic practices can markedly reduce the risks.