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University of Baghdad –College of Science
Department of Biology

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أ.د. ايثار كامل عباس

Prof.Dr.Ithar Kamil Abbas

Chemical pollution: is the presence or increase in our environment of chemical pollutants that are not naturally present there or are found in amounts higher than their natural background values. Most of the chemicals that pollute the environment are man-made, resulted from the various activities in which toxic chemicals are used for various purposes.

Chemical compounds: which are the main causes of chemical pollution may organic or inorganic chemicals. The most common chemical pollutants are those compounds used across large areas and which are persistent, meaning they do not easily degrade in nature. Examples are most pesticides, herbicides, insecticides used in agriculture and gardening, as well as chlorinated solvents used in many industrial processes and dry-cleaning activities. Based on their chemical structure, these chemical pollutants can be classified into naturally-occurring and man-made categories.

Chemical intoxication: is caused by exposure to chemical pollutants and can have immediate effects or delayed effects, which may appear after weeks or even months after the exposure occurred. Severe chemical intoxication may cause the death of the person that inhales an increased quantity of such substances.

What is the best criteria for classification?

1-Physical properties 2- Chemical properties 3- Chemical structure 4-Effect on the environment 5- Organic and Inorganic:

Organic Chemicals : Hydrocarbons – Halogenated hydrocarbons – Oxygenated hydrocarbons – Nitrogen compounds – Sulfur compounds – Phosphorus compounds.

Inorganic pollutants : Arsenic – Lead – Copper – Cadmium – Mercury – Chromium – Chlorine – Cyanide – Nitrate – Ammonia

Also, it can classify the chemical pollutants according to their Priority :

a-Amount Produced/Released **b-** Persistence **c-** Bioaccumulation **d-** Toxicity

e- Other Effects.

Amount Produced or Released : Some pollutants are produced in large amounts but only released accidentally (e.g. chlorinated solvents, benzene) Others are released intentionally in large amounts (e.g. pesticides) , Some very toxic pollutants are only produced in very small amounts (e.g. dioxins).

Persistence : Resistance to transformation in the environment either chemical or biological, **Persistent** chemicals can migrate widely, measured as residence time or as

“**half-life**” ,, Chlorinated/halogenated compounds are typically persistent (e.g. DDT, PCBs, CFCs) , **Rate of degradation** depends on environmental conditions.

Bioaccumulation: **Uptake** of pollutant by organisms depends on hydrophobicity (i.e. water hating), **persistence and toxicity** of pollutant, ,, **concentration** may increase more than 100,000 times from water to fish ,, concentration is “biomagnified” going up the food chain .

-Toxicity: Acute toxicity: – concentration which kills 50% of a given population (usually determined in lab) – expressed as Lethal Dose to 50%: LD50, in units of mg chemical/kg body weight – also depends on exposure.

-Chronic toxicity – “Sub-lethal” tests – adverse effects: cease to feed, grow more slowly, unable to reproduce or just abnormal behavior – typically occurs at dosages 10 to 100 times smaller than acute toxicity; more difficult, controversial & expensive to test.

-Toxicology: Solvents as a general class ,Usually have high vapor pressures, so they form vapors: major intake route is through **inhalation** . Toxicity usually expressed as LD50 in terms of air concentration , most solvents depress the central nervous system => anesthetic effect.(CNS depression symptoms: , dizziness, confusion , headaches , loss of coordination , convulsions , coma , death).

-Genotoxicity – Carcinogenic or mutagenic , New tests are constantly developed, but given low dosage and exposure, it is always difficult to determine increased risk ,Short-term, high dosage test vs. long-term, low dosage in real life – Additional environmental factors also genotoxic.

Other Effects: Ability to influence large-scale biogeochemistry (e.g. CFCs, acid rain), Alter availability of nutrients or other needed organic chemicals, odor (e.g. sulfur compounds, MTBE) , Color (e.g. organic dyes) , Foaming (e.g. detergents) , Interfere with visibility (e.g. SO₂ particulates).

As explain above , There are two types of chemical pollutants :

a- Organic pollutants ,includes :

Hydrocarbons: Formed by: - biogenic processes: microbes, vegetation, animals.

- Contamination from oil spills, refineries, leaking USTs (underground storage tanks), fuel transport and use .

- Only slightly soluble in water, very hydrophobic: **Hexane about 10 mg/L = 10 g/m³**

-**Linear hydrocarbons** are easily degraded by microbes; branched are resistant.

Hydrocarbons with double or triple bonds (alkenes, alkynes) are highly reactive, usually be with short lives in the environment ,,

Aromatics: Fairly toxic (e.g. benzene, xylenes, ethylbenzene, toluene), Considerably more soluble in water (**e.g. benzene = 1780 g/m³**), major concern for water supplies.

Fusion of benzene rings produces polycyclic aromatic hydrocarbons (**PAHs**)= polynuclear aromatic hydrocarbons (**PNAs**) . Many are considered potential carcinogens.(benzo, pyrene)

Halogenated Hydrocarbons:

-**Chlorinated aromatics** – biologically active, i.e. they interfere with normal processes, persistent, useful as pesticides and disinfectants. EX:(Pentachlorophenol , Chlorobenzenes, dichlorobenzenes)

- **Polychlorinated biphenyls (PCBs):**., Large family (209) of compounds , Very stable, used as electrical insulator fluids in power transformers until ~ 20 years, fluorescent light until 1970s ,, hydraulic fluids, brake fluids, heat transfer, plasticizers, lubricants, flame retardants and base for pesticides

- **PCBs** persistent and significant bioaccumulation , low acute toxicity, incident in Japan in 1968 brought them attention (1291 individuals affected by contaminated rice

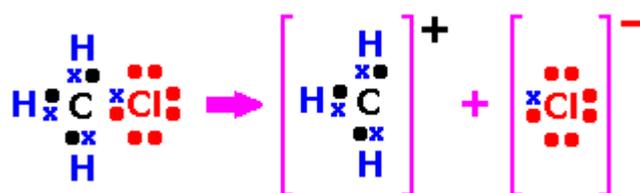
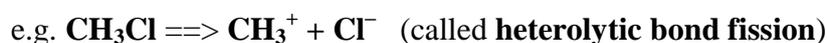
oil) .from 1979 on, total ban on use of PCBs except in completely enclosed systems ,, river sediments are a major reservoir (e.g. Upper Hudson, St. Lawrence).

Fluorinated and chlorofluorinated hydrocarbons are extremely stable , best example is TEFLON, a fluorinated polymer with extreme stability, temperature resistance and hydrophobicity (usually not a pollutant) , CFCs are used as refrigerants due to their stability. Their persistence in the lower atmosphere allows transport to stratosphere where they interact with ozone formation. Half-lives of decades in the atmosphere.

-A **CFC** is a covalently bonded relatively small molecule of carbon, chlorine and fluorine atoms (**chlorofluorocarbon**).

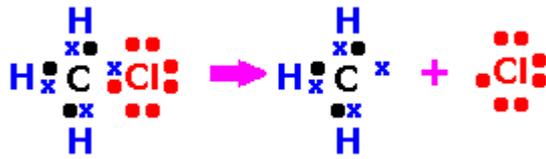
-If enough energy is supplied by heat or by visible/UV electromagnetic radiation, or the is weak enough, a covalent bond can break in two ways. This illustrated with the molecule chloromethane CH_3Cl .

-The bond breaks unevenly where the electron bond pair can stick with one fragment and a positive and negative ion form.



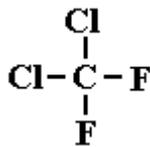
The bond breaks evenly, where the bonding pair of electrons are equally divided between two highly reactive fragments called **free radicals**, which are characterized by having **an unpaired electron** not involved in a chemical bond. The means the 'lone' electron on the free radical, which is not part of a bond anymore, and wants to pair up with another electron to form a stable bond – that's why free radicals are so reactive.

- e.g. $\text{CH}_3\text{Cl} \implies \text{CH}_3\cdot + \cdot\text{Cl}$ (called **homolytic bond fission**)



-Homolytic bond fission can occur by molecules hit by UV photons i.e. ultraviolet electromagnetic radiation of quite high energy – great enough to cause homolytic bond fission.

-The **chemistry of free radicals** is important in the current environmental issue of **ozone layer depletion**.

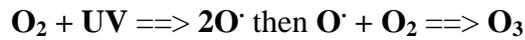


- **Chlorofluorocarbons** (CFC's for shorthand) are organic molecules containing carbon, fluorine and chlorine
- e.g. dichlorodifluoromethane has the formula CCl_2F_2 .
- They are very useful low boiling organic liquids or gases, until recently, extensively used in **refrigerators** and **aerosol sprays** e.g. repellents.
- They are **relatively unreactive, non-toxic and have low flammability**, So in many ways they are 'ideal' for the purpose they were used for.
- However it is their chemical stability in the environment that eventually causes the ozone problem but first we need to look at **how ozone is formed and destroyed** in a '**natural cycle**'. This presumably has been in balance for millions of years and explains the UV ozone protection in the upper atmosphere – the **stratosphere**.

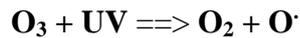
- **Ozone is formed in the stratosphere by free radical reactions.**

- 'ordinary' stable **oxygen O_2 (dioxygen)** is split (dissociates) into two by high energy **ultraviolet electromagnetic radiation** into two oxygen atoms (which

are themselves radicals) and then a 'free' oxygen atom combines with an oxygen molecule (dioxygen) to form ozone (trioxygen).



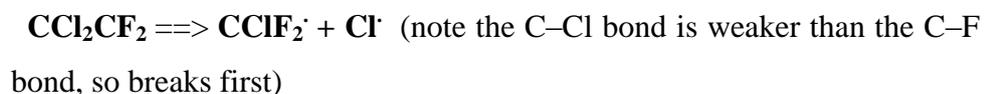
The ozone is a highly reactive and unstable molecule and decomposes into dioxygen when hit by other UV light photons.



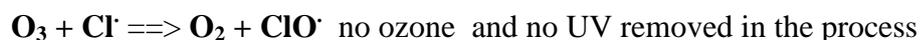
The oxygen atom radical can do several things including ...

- This last reaction is the main **UV screening effect** of the upper atmosphere and the ozone absorbs a lot of the harmful incoming UV radiation from the Sun.
- If the ozone levels are reduced more harmful UV radiation reaches the Earth's surface and can lead to medical problems such as increased risk of sunburn and skin cancer and it also accelerates skin aging processes.
- There is strong evidence to show there are 'holes' in the ozone layer with potentially harmful effects, which is back already to the effect of CFCs :

The **chemically very stable CFCs diffuse up into the stratosphere** and decompose when hit by ultraviolet light (UV) to produce free radicals, including free chlorine atoms, which themselves are highly reactive free radicals.



The **formation of chlorine atom radicals is the root of the problem** because they readily react with ozone and change it back to much more stable ordinary oxygen.



and then: $\mathbf{ClO + O \implies Cl + O_2}$, which means the 'destructive' Cl atom free radical is still around.

-The two reactions above involving chlorine atoms are known as a **catalytic cycle** because the chlorine atoms from CFCs act as a catalyst in the destruction of ozone.- Therefore **many countries are banning the use of CFCs**, but not all despite the fact that scientists predict it will take many years for the depleted ozone layer to return to its 'original' O₃ concentration and alternatives to CFC's are already being marketed.

Oxygenated Compounds:

-**Alcohols (OH group):** very widely used industrially , usually water soluble, highly degradable in the environment , only an issue if spilled in large quantities ,large-chain alcohols (e.g. Octanol) can be solvent for hydrophobic and hydrophilic organics.

-**Phenols** : aromatics with alcohol group , may disrupt biological processes , chlorinated phenols are particularly toxic , so they used in wood preservation (e.g. telephone poles) which has led to widespread contamination of certain sites , they Biodegradable ,so may be used to stimulate bioremediation.

-**Esters, Ethers, Ketones & Aldehydes:** usually only a problem in atmospheric pollution, where they contribute to ozone formation in urban areas , fairly reactive in aquatic systems , may be formed by incomplete combustion , industrial use is relatively small and carcinogenicity of aldehydes.

-**Organic acids:** usually quite reactive, so they are not of major environmental concern.

-**Dioxins and dibenzofurans:** form by oxidation/combustion of chlorinated organics at high temperatures , possibly the most toxic organics

-Nitrogenated organics :

Amines, amino acids, proteins, etc. , most are formed in biological processes , they can be quite toxic, but typically produced only in small quantities , biologically active but degradable , some are formed during incomplete combustion of fossil fuels (e.g. nitro PNAs) , explosives manufacture and use (TNT).

- **Pesticides** :include

-Organochlorines : DDT, Methoxychlor, Aldrin, and Endosulfan.
Organophosphates : Malathion, Parathion, Diazinon, and Chlorpyrifos, Glyphosate (Roundup).

Chemical pollution

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Carbamate Esters : Carbofuran, Aldicarb

Phenoxy Esters : 2,4-D, Silvex, 2,4,5-T

Pesticides, Also grouped by intended function: Insecticides , Herbicides , Fungicides, Rodenticides.

B-Inorganic Pollutants:

A- Metals:

– most are essential for biological activity, divided into two :

- **Macronutrients:** calcium, magnesium, iron, potassium, sodium.

- **Micronutrients:** chromium, cobalt, copper, manganese, nickel, selenium, zinc.

They are be toxic in large doses ,Some of them like mercury and lead form organometallic compounds which disrupt normal biological processes.

The main sources of inorganic pollutants represents with:

Natural: releases via volcanoes

Human sources: mining , fuel combustion, cement production, foundries, refuse incineration, industrial products, processes and waste, pesticides or fertilizers.

B- Nitrate (NO₃)

– good fertilizer, toxic at high concentrations, easily leaches out to rivers, ponds and lakes which led later to cause of lake eutrophication

C- Ammonia (NH₃)

– good fertilizer

– very toxic even at low concentrations

– easily oxidized to nitrate in presence of O₂

– in high concentrations affects pH of soil.

The major chemicals pollutants in Air

Carbon monoxide (CO) is a colorless, odorless gas that is produced by the incomplete burning of carbon-based fuels including petrol, diesel, and wood. It is also produced from the combustion of natural and synthetic products such as cigarettes. Carbon monoxide is present in Earth's atmosphere at very low concentrations. The gas eventually reacts with oxygen (O_2) to form carbon dioxide (CO_2). Natural sources of carbon monoxide in Earth's atmosphere include volcanoes and bush fires. Volcanic gases contain between 0.01 and 2% carbon monoxide.

Exposure to carbon monoxide can be acutely harmful since it readily displaces oxygen in the bloodstream, leading to lower the amount of oxygen which led to asphyxiation at high enough concentrations and exposure times.

Breathing **CO** can cause headache, dizziness, vomiting, and nausea. If **CO** levels are high enough, you may become unconscious or die. Exposure to moderate and high levels of **CO** over long periods of time has also been linked with increased **risk** of heart disease.

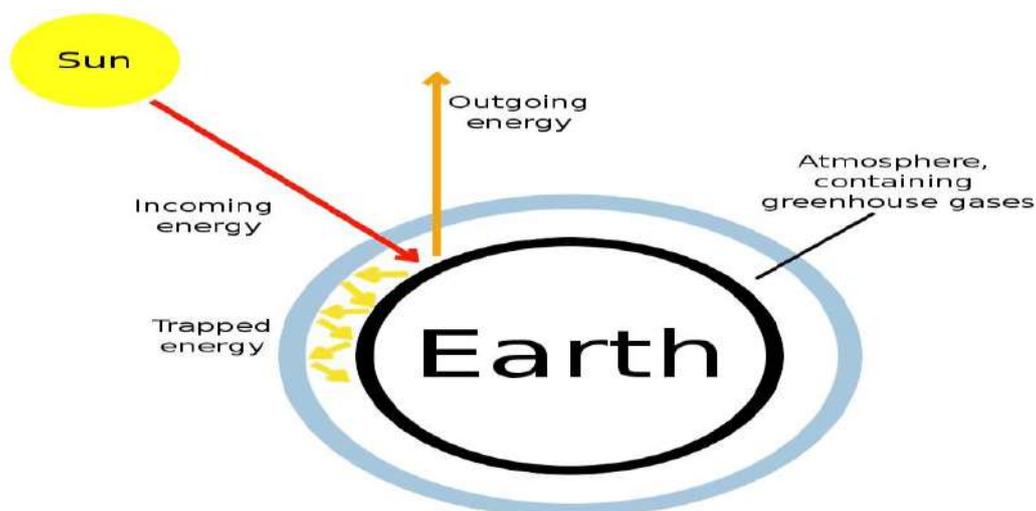
Carbon dioxide (CO_2) is the principle greenhouse gas emitted as a result of human activities such as the burning of coal, oil, and natural gases. The main principles of greenhouse effect represent as follow :

- Solar radiation reaches the Earth's atmosphere - some of this is reflected back into space. The rest of the sun's energy is absorbed by the land and the oceans, heating the Earth. Heat radiates from Earth towards space.

Some of this heat is trapped by greenhouse gases (The most abundant greenhouse gases responsible for the greenhouse effect in the atmosphere are water vapor, carbon dioxide, methane, nitrous oxide, and ozone) in the atmosphere, keeping the Earth warm enough to sustain life. Human activities such as burning fossil fuels, agriculture and land clearing are increasing the amount of greenhouse gases released into the atmosphere. This is trapping extra heat, and causing the Earth's temperature to rise.

With more explanation :

The greenhouse effect works like this: First, the sun's energy enters the top of the atmosphere as shortwave radiation and makes its way down to the ground without reacting with the greenhouse gases. Then the ground, clouds, and other earthly surfaces absorb this energy and release it back towards space as long wave radiation. As the long wave radiation goes up into the atmosphere, it is absorbed by the greenhouse gases. The greenhouse gases then emit their radiation (also long wave), which will often keep being absorbed and emitted by various surfaces, even other greenhouse gases, until it eventually leaves the atmosphere. Since some of the re-emitted radiation goes back towards the surface of the earth, it warms up more than it would if no greenhouse gases were present.



Chlorofluorocarbons (CFC) are gases that are released mainly from air-conditioning systems and refrigeration. When released into the air, CFCs rise to the stratosphere, where they come in contact with few other gases, which leads to a reduction of the ozone layer that protects the earth from the harmful ultraviolet rays of the sun.

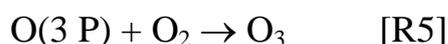
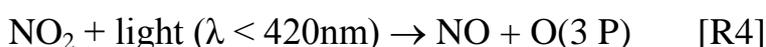
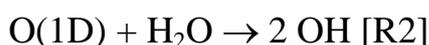
Lead is present in petrol, diesel, lead batteries, paints, hair dye products, etc. Lead affects children in particular. It can cause nervous system damage and digestive problems and, in some cases, cause cancer.

Ozone : is triatomic allotrope of oxygen (a form of oxygen in which the [molecule](#) contains three atoms instead of two as in the common form), occur naturally in the upper layers of the atmosphere. This important gas shields the earth from the harmful ultraviolet rays of the sun. However, at the ground level, it is a pollutant with highly toxic effects. Vehicles and industries are the major source of ground-level ozone emissions. which otherwise could cause severe damage to living organisms on earth's surface. Under certain conditions, photochemical reactions between [nitrogen](#) oxides and hydrocarbons in the lower atmosphere can produce ozone in concentrations high enough to cause irritation of the eyes and [mucous membranes](#) and it lowers our resistance to colds and pneumonia.

Nitrogen oxide (NO_x) : causes smog and acid rain. It is produced from burning fuels including petrol, diesel, and coal. Nitrogen oxides can make children susceptible to respiratory diseases in winters.

NO_x Reactions (Day)

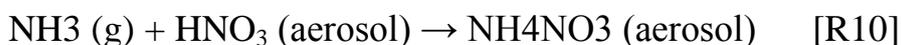
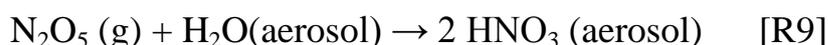
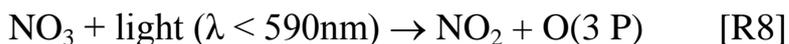
$O_3 + \text{light } (\lambda < 340\text{nm}) \rightarrow O(1D) + O_2$ [R1] , Reaction R1 is a key process in tropospheric chemistry because the O(1D) atom has sufficient excitation energy to react with water vapour to produce hydroxyl radicals:



There is no sunlight at **Night**. Therefore the night-time concentration of OH is (almost) zero. Instead, another oxidant, the nitrate radical, NO₃ , is generated at night by the reaction of NO₂ with ozone. NO₃ radicals further react with NO₂ to establish a chemical equilibrium with N₂O₅ .



Reaction R6 happens during the day too. However, NO₃ is quickly photolysed by daylight, and therefore NO₃ and its equilibrium partner N₂O₅ are both heavily suppressed during the day.

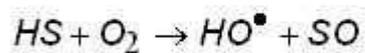




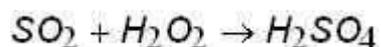
Sulphur dioxide (SO₂) is a gas produced from burning coal, mainly in thermal power plants. Some industrial processes, such as production of paper and smelting of metals, produce sulphur dioxide. It is a major contributor to smog and acid rain. Sulfur dioxide can lead to lung diseases.

Reactions of SO_x in environ.:

Sulfur is released to the atmosphere as either hydrogen sulfide or sulfur dioxide. Both forms are toxic gases that are primary air pollutants. Hydrogen sulfide is oxidized to sulfur dioxide in a three step process



The atmospheric reactions of SO₂ are very complex, and proceed through three different pathways to the sulfate ion (SO₄²⁻). Sulfur dioxide can react with the hydroxyl radical to form an HSO₃ radical, which can react with another hydroxyl radical to form water and SO₃ or H₂SO₄. Sulfur dioxide also dissolves in water droplets where it can react with oxygen gas to form SO₄²⁻. The third pathway to sulfate is when sulfur dioxide reacts with hydrogen peroxide to sulfuric acid.



The ultimate fate of all sulfur in the atmosphere is to be oxidized to the sulfate ion, usually as sulfuric acid (H₂SO₄). The most common base

present in the atmosphere is ammonia (NH_3) which reacts with sulfuric acid to form ammonium bisulfate (NH_4HSO_4) and ammonium sulfate ($(\text{NH}_4)_2\text{SO}_4$). Sulfuric acid, ammonium bisulfate and ammonium sulfate are all hygroscopic substances, readily dissolving in water. They wash out of the atmosphere during precipitation events.

Suspended particulate matter (SPM) consists of solids in the air in the form of smoke, dust, and vapour that can remain suspended for extended periods and is also the main source of haze which reduces visibility. The finer of these particles, when breathed in can lodge in our lungs and cause lung damage and respiratory problems.

Major Chemical Pollutants in Water

Fresh, clean, and drinkable water is a necessary but limited resource on the planet. Industrial, agricultural, and domestic wastes can contribute to the pollution of this valuable resource, and water pollutants can damage human and animal health. Three important classes of water pollutants are **heavy metals**, **inorganic pollutants**, and **organic pollutants**. Heavy metals include **transition metals** such as cadmium, mercury, and lead, all of which can contribute to brain damage. Inorganic pollutants like hydrochloric acid, sodium chloride, and sodium carbonate change the acidity, salinity, or alkalinity of the water, making it undrinkable or unsuitable for the support of animal and plant life. These effects can result in dire consequences for higher mammals such as humans. A list of organic pollutants includes pesticides such as [chlorpyrifos](#) and paraquat (1,1-Dimethyl-4,4-bipyridinium dichloride) ($\text{C}_{12}\text{H}_{14}\text{Cl}_2\text{N}_2$), and their byproducts, such as dioxin. All of these substances are highly lethal to animals, and many can be readily absorbed through the skin.

Other researchers suggest that the main chemical pollutants in water includes:

-Ammonia (NH_3)/Ammonium (NH_4) (Agriculture, aquaculture, industry, urban) Ammonia is highly toxic to fish and can convert into nitrates.

-Nitrate (NO_3)/Nitrite (NO_2) (Agriculture, industry, aquaculture, sewage) These can accelerate aquatic plant growth leading to eutrophication.

-Toxic metals (Mining, urban, industry) These include arsenic (As), mercury (Hg), selenium (Se) and lead (Pb) and can persist in the environment for decades. They can be poisonous to aquatic life and may slow down their development

-Crude oil (Hydrocarbons (HxCx)) (Urban, industry) This mainly enters the marine environment in oil spills and can have detrimental effects on marine animals, plants and birds.

-Phosphorous (P)/Phosphate (PO_4^{3-}) (Agriculture, urban) Similar in effect to nitrates, these can also lead to eutrophication of water bodies.

-Sulphates/sulphide minerals (minerals containing S^{2-}) (Mining) Sulphur dioxide mixes with water particle in the air to form acid. This falls as acid rain leading to acidification of water bodies. Sulphide minerals can be unearthed during the mining process and are a leading cause of acidification of water in mines. When this acidic water is discharged it is known as acid rock drainage. The most common mineral associated with this process is pyrite (FeS_2).

The Major Chemical Pollutants in Soil

The most common chemicals involved are petroleum hydrocarbons, solvents, pesticides, lead, and other heavy metals.

Other researchers suggest that the major pollutants includes: plant nutrients such as nitrate and phosphate, heavy metals such as cadmium, chromium and lead , oxyanions such as arsenite, arsenate and selenite, organic chemicals , inorganic acids; and radionuclides.

The sources of these pollutants include : fertilizers ,pesticides acidic deposition , agricultural and industrial waste materials, and radioactive fallout.

Life Cycle of Chemicals:

Chemicals that enter the environment usually do so as wastes or as by-products, and as such are mixed with other chemicals. They may interact when they are mixed in an additive, synergistic or antagonistic way. They may produce breakdown products, by-products or react to form new substances in the waste stream or in the environment.

Pollution does not recognize national borders. Priority pollutants which tend to persist in the environment for long periods and can therefore be transported long distances, have led to growing international action on priority pollutant control.

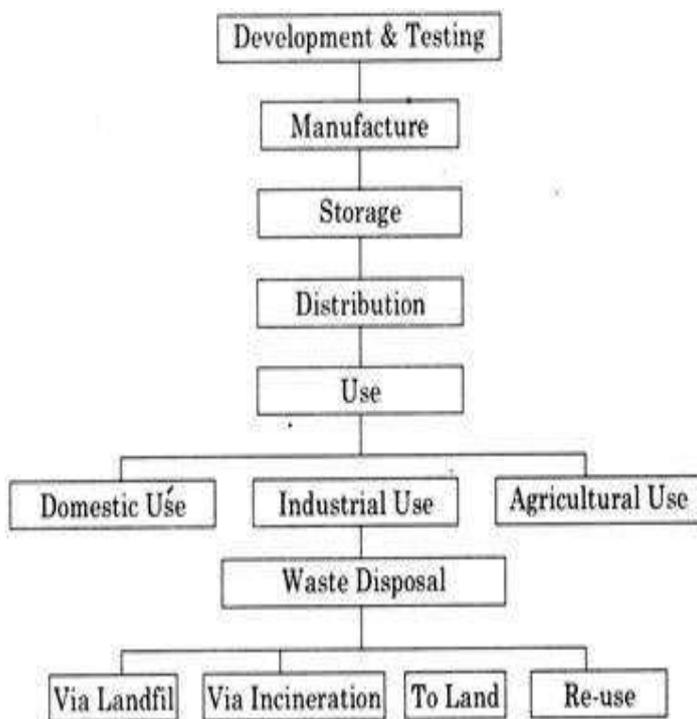


Fig. 1. Life-cycle of chemicals

Prof. Dr .Ithar Kamil Abbas

Pathways of pollutants in environment :

The first stage involves the sources from which chemical compounds **arise**. Compounds may be of natural and anthropogenic origin. sometimes , pollutants arise where otherwise natural processes have been intensified and concentrated by anthropogenic activity (as when municipal wastes are dumped).most of pollutants these processes emit(like methane, hydrogen sulphide or carbon dioxide, plus the hydrocarbons released into the soil/aquatic environment), are also created by processes proceeding as matter is cycled in the unpolluted natural environment. They may nevertheless assume a new , much greater significance under anthropogenic influence , as is the case , for example , at landfill sites for the aforementioned municipal wastes, such a landfill is turned into a kind of bioreactor , with the chemical compounds it releases playing a potentially significant role both **locally**(influencing the soil and aquatic environment), and **globally**(as methane enhance the greenhouse effect) . Allowing , as it will , for more effective strategies , a better understanding of the processes taking place at landfill sites will certainly help to minimize negative effects on the environment , The first element of any mitigation strategy is however, to limit emissions at source.

However , no matter what actions are taken , certain amount of chemical compounds will always be emitted from the source, **penetrating** more widely into geoecosystems. From the standpoint of environment quality criteria, the most important question then becomes; *How do pollutants enter the food chain?*

Two major parts of the environment –water and air- are particularly responsible for the **migration** of chemicals through different compartments of the environment .

Both water and air move over long distances and carry suspended and/or soluble particles in their stream. Water and air bodies can therefore be regarded as the major carries responsible for the migration of natural and man-made chemicals through the environment as whole. furthermore, in the course of their **translocation** through air or water , chemicals may **react with one another** to form new compounds having environmental impacts differing from their precursors.

There are well known natural cycles of some essential species like water and some compounds formed by carbon, sulfur and nitrogen. These have played an essential role in stabilization of the environment , for example, the water cycle is responsible for the continuous restoration of the a quality of surface waters , and it is only thanks to the latter that the existence of biosphere is even possible . Unfortunately , the above situation only applies where water from rainfall reaches the unpolluted surface of the earth. In polluted environment ,clean rainfall is mixed with impurities to extent that the restorative role of the water cycle is wrecked. A similar situation applies to the carbon cycle.

In an environment with limited anthropogenic pressure, an equilibrium is set up between carbon from the atmosphere and from the waste.

The pollution always has a **source and a recipient**. The **pathway** of pollution is that the way the pollutant moves from the source, enters into the environment, and finally how it reaches the human body or other recipient. The pathway between source and recipient can take several different forms depending on the type of pollutant. Primary recipients for pollution are water, air, and soil. Pollutants usually reach humans through

the consumption of contaminated and polluted water and food, and breathing polluted air.

Once released into the environment, the worst effects of many pollutants are reduced by one or more of the following processes:

- Dispersion – smoke disperses into the air and is no longer noticeable away from the source.
- Dilution – soluble pollutants are diluted in the water of a river or lake.
- Deposition – some suspended solids carried in a river settle (are deposited) on the river bed.
- Degradation – some substances break down (degrade) by natural processes into different, simpler substances that are not polluting.

In each case the effect is to reduce the concentration of the pollutant. **Concentration** is a measure of the amount of the substance in a known volume of water or air. The units used for water pollutants are usually milligrams per liter (mg/l, also written as mg l^{-1}), although sometimes write as **ppm** which stands for ‘parts per million’.

These processes do not apply to all pollutants. There are some **persistent pollutants** which remain intact when released into the environment because they do not break down by natural processes.

Fate of chemicals pollutants in Air

Ventilation is the most important word in air pollution. As we know from sitting in a room with no ventilation when people are smoking, the air soon becomes heavy and stagnant; create air movement by opening a door or window, and the air becomes tolerable. If you had suitable

equipment, you could burn everything that would burn, and grind to finest dust everything that wouldn't burn, and spew tons of pollutants into the atmosphere every hour, and nobody would know the difference —IF you were doing it where the **wind** velocity was fast enough to spread the aerial garbage and keep it from accumulating at one time in one place as an air mass. **But**

what ultimately becomes of all this material foreign to the atmosphere?

Fortunately for man, the atmosphere has a built-in self-cleansing operation in which oxygen, sunlight, and rain combine to remove all foreign materials. Sometimes the operation is slow but eventually the pollutant or a product of its reaction with other materials is absorbed or entrained by rain drops or snow flakes and returned to the earth to become a part of the soil.

It has become popular to talk about our living in an aerial sewer. It is fortunate that we do, because many of the waste products of man and his legitimate activities can be disposed of in no other way. But even as a sewer pipe can become overloaded, so can the atmosphere. Further, our atmosphere is fickle. At times it can dispose thousands of tons of pollutants with ease; at other times a few pounds can cause a problem.

Pollutants are normally dispersed in the air **in two ways, laterally by the wind and vertically by the temperature** differential with height.

Dispersion by wind is simple to understand. When the air is calm, an odorous pollutant, for example, will remain in the vicinity of its source for hours. With slight wind movement, two to three mph wind speed the pollutant will spread downwind slowly almost as a single mass and be quite noticeable for several miles. Eventually it will become diluted sufficiently not to be noticeable. At higher wind speeds, the pollutant will dissipate more rapidly, until at some point it isn't a problem even at the point of origin. In a few cases, moderate winds may create a problem. If a

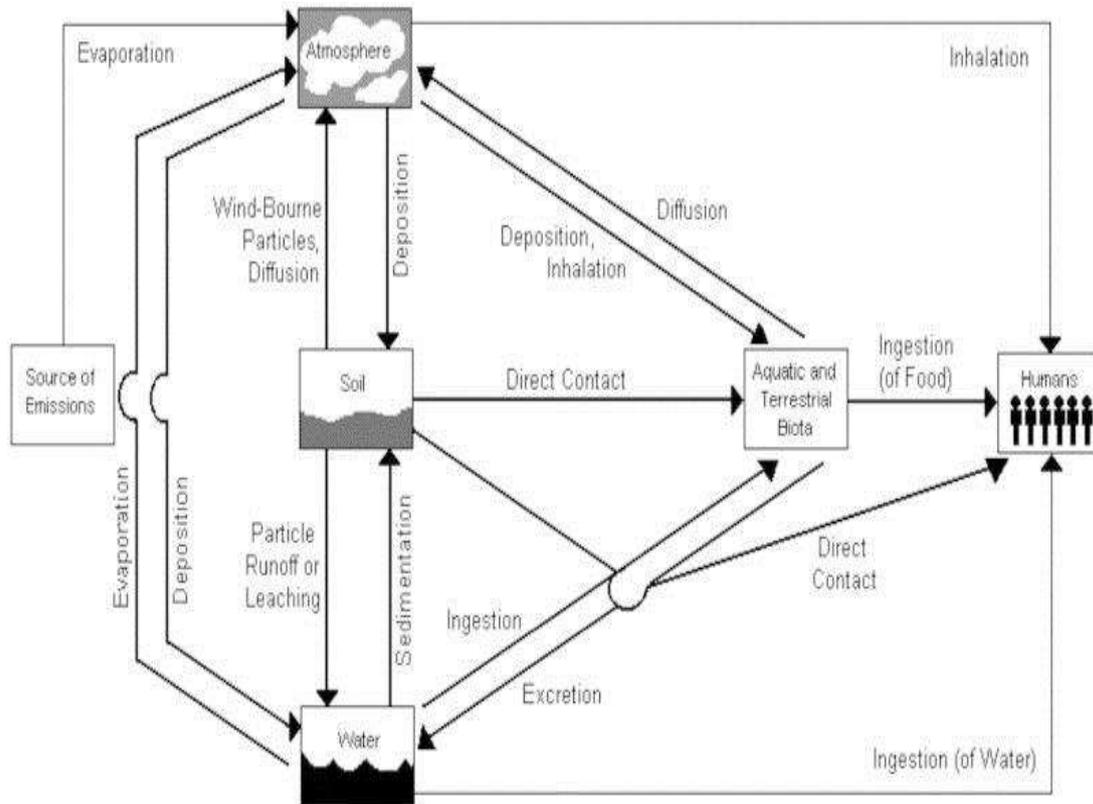
stack is putting out large amounts of dust, the heavier and larger particles may fall out near the stack at low wind speeds but be carried further before dropping out at higher wind speeds. High winds may also produce a problem where there are newly-plowed fields or unpaved roads but we are all familiar with this effect. In addition to lateral dispersion of pollutants by the wind, we may usually also count on vertical dispersion. Normally, as we go up in the air the temperature becomes about four degrees cooler with every 1000 ft. Most chimney effluents are hot, particularly smoke and other combustion effluents. These hot gases and entrained aerosols tend to move to regions of lower temperature. Thus on a normal day we say smoke goes "up" where it finds cooler air. Occasionally we encounter an upside down condition of the atmosphere which we call a **temperature inversion**. On a clear night with little wind, the earth cools rapidly by radiation, and in turn the air close to the earth cools, and eventually we may find that the air actually becomes warmer as we go up until we reach a point where the air becomes normal again and temperature decreases as we ascend. Below this point, which may be a few feet from the ground, or several hundred or a thousand feet we say we have a temperature inversion. All of us have observed this phenomenon when we have watched the formation of fog. It forms first near the ground where the air cools first below the dew point and droplets of moisture are forced out of the air. The type of temperature inversion I have just described is called a "radiation" inversion. If in the presence of such an inversion for a height of 300 ft for instance we discharge smoke or fumes at a height less than 300 ft, the smoke or fumes or pollutant gases will not penetrate the inversion barrier but will collect in the "inverted" atmosphere near the ground.

The severity of the resulting air pollution problem will depend on **the amount of pollutant discharged, the rate of lateral air movement, and**

the period of time the inversion exists. Sooner or later sunlight will reach the ground and warm it up. The earth will heat the lower layer of air to a temperature greater than the air above it and the inversion will "break." Normal conditions will return, the smoke and gases will disperse and our air pollution problem will vanish. In most cases the radiation inversion forms during the night and breaks several hours after sunrise.

The fate of the emitted pollutants is largely determined by the source release characteristics. After pollutants are released to the atmosphere, their transport, dispersion, and transformation are governed by meteorological principles, terrain characteristics, wet and dry deposition rates, and certain chemical properties of the air pollutant (such as aqueous solubility, vapor pressure, air-water partition coefficient (i.e., Henry's Law constant), molecular diffusivity, phase partition coefficient, melting point, and adsorptivity). For a limited subset of air pollutants, it is important to consider deposition from air to soil, vegetation, or water bodies. For others, such deposition is not important.

Many studies indicate that a limited number of pollutants emitted into the atmosphere (e.g., mercury) are passed to humans or wildlife through non-inhalation pathways. An example would be an air pollutant depositing from the air onto the soil, followed by ingestion of the soil by a human or by biota in an ecosystem. The figure below is an example of the conceptual model diagram for an ecological risk scenario involving multipath way exposure to air pollutants. For a limited subset of air pollutants, greater human and ecological exposures to the pollutant occur through non-inhalation exposures than through inhalation exposures. These air pollutants typically are persistent in the environment, have a strong tendency to bio accumulate, and exhibit moderate to high toxicity.



Source: Adapted from NRC 1991a.

Fate of chemical pollutants in water:

Study of the sources, reactions, transport, effects and fates of chemicals in the water is very important for the water resources protection.

Water has a number of unique properties that are essential to life, many of which are due to water's ability to form hydrogen bonds. The most important properties of water are:

- Excellent solvent making biological processes possible because of the transport of nutrients and pollutants.
- Highest dielectric constant of any common liquid that means high solubility of ionic substances and their ionization.
- Highest surface tension than any other liquid.
- Colorless, allowing light required for photosynthesis to reach considerable depths in water body;

- Higher heat of evaporation determining transfer of heat and water molecules between the atmosphere and water body.
- Maximum density as a liquid at 4°C.
- Higher heat capacity than any other liquid except ammonia that is significant for the stabilization of temperatures of organisms and geographical regions.
- Higher latent heat of fusion (temperature stabilized at the freezing point of water).

Many chemical processes occur in water, Three important types of reactions in water are **precipitation, acid-base, and oxidation-reduction reactions** .

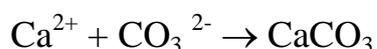
They are influenced by the action of algae and bacteria in water. For example, algal photosynthesis fixes inorganic carbon from HCO_3^- ion in the form of biomass in a process that also produces CO_3^{2-} :



Carbonate undergoes an acid-base reaction:

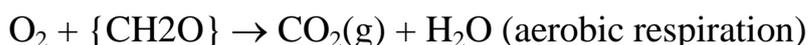


or it reacts with Ca^{2+} to precipitate



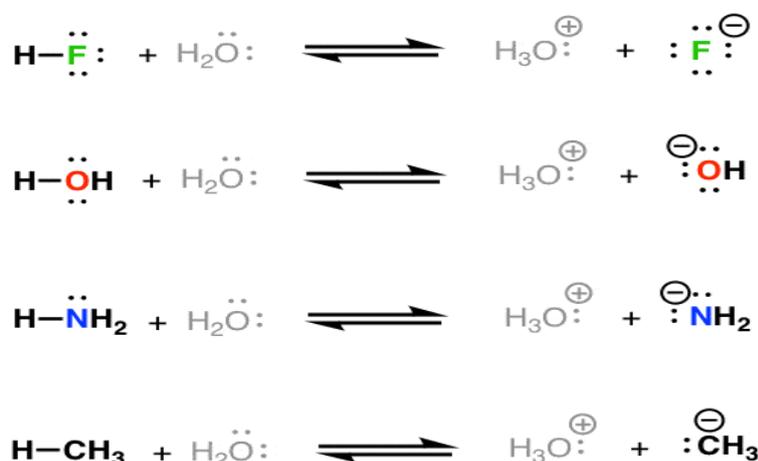
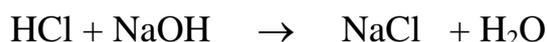
Oxidation-reduction reactions in water involve the transfer of electrons between chemical species. Metal ions in water are always bonded to water molecules in the form of hydrated ions represented by the general formula, $\text{M}(\text{H}_2\text{O})_x^{n+}$ Metals in water may be bound to organic chelating agents. Hardness is due to the presence of calcium ion and to a lesser extent to magnesium ion.

Many oxidation-reduction reactions are catalyzed by bacteria. For example, bacteria convert inorganic nitrogen to ammonium ion, NH_4^+ , in the oxygen-deficient lower layers of water body. Near the surface, where O_2 is available, bacteria convert inorganic nitrogen to nitrate ion, NO_3^- . In water bacteria use oxidation-reduction reactions to obtain the energy that they need for their own growth and reproduction. Some bacteria require oxygen for their metabolic needs and are called aerobic bacteria. Other anaerobic bacteria extract their oxygen from sources such as NO_3^- , SO_4^{2-} and other matter represented as $\{\text{CH}_2\text{O}\}$. The most common bacterially mediated reaction in water is the oxidation of organic matter:



Acid-base reactions in water :

When an acid and a base react, the reaction is called a neutralization reaction. That's because the reaction produces neutral products. Water is always one product, and a salt is also produced.



Fater of chemical pollutants in Soil

Toxic substances including heavy metal, such as arsenic , mercury ,lead, cadmium , chromium(VI) ,Cr(VI)) and organic contaminants, such as polycyclic aromatic hydrocarbons (PAHs) (e.g., benzo[a]pyrene), persistent organic pollutants (POPs) (e.g., polychlorinated biphenyl) or emerging pollutants (e.g., per- and poly-fluoroalkyl substances, polybrominated biphenyls, etc. that present unique issues and challenges to environmental quality) have been detected in soils .The available fractions of such pollutants in soil are often toxic to soil organisms and humans .

Adsorption and desorption of chemical pollutants in soils largely depend on pH, redox conditions, and the available chemical species. Inorganic ions, such as HPO_4^{-2} , NO_3^- , Cl^- , and SO_4^{-2} and organic ligands, such as citrate, oxalate, fulvic, and dissolved organic carbon (DOC) can affect pollutant behavior in soils . Inorganic ions can influence adsorption through their interactions with metal. For example, metal(loid)s complexed with such ions exhibit less sorption affinity to soils than free ions, but free states of some ions (e.g., PO_4^{-3}) in soil increase net negative surface charge and therefore increase the sorption of cationic metal(loid)s . Soil organic constituents, such as soil organic matter (SOM), which is often estimated and expressed as soil organic carbon (SOC) , play an important role in the sorption of soil pollutants . Some SOM, such as humic substances have a high affinity for metal cations. The heavy metal ion-binding ability of humic substances is attributed to the negative surface charge, particle size, and diffusion coefficient of humic acid as well as the content of oxygen-containing functional groups, including -OH, -COOH, -SH, and -C=O .

Another important process in soil is the microbial activity relative to the fate and transformation of pollutants. For example, the microbial degradation of petroleum hydrocarbons is experienced as the natural clean-up process of organic pollutants. Also, heavy metal(loid)s can be remediated using the soil-grown plants (commonly accepted as “phytoremediation”), particularly with the microbial-assisted rhizosphere.

Prof.Dr.Ithar Kamil Abbas

Biodegradable and Non- Biodegradable Pollutants in Environment :

As we become more technologically advanced, we produce materials that can withstand extreme temperatures, are durable and easy to use. Plastic bags, synthetics, plastic bottles, tin cans, and computer hardware- these are some of the things that make life easy for us.

But what we forget is that these advanced products do not break down naturally. When we dispose them in a garbage pile, the air, moisture, climate, or soil cannot break them down naturally to be dissolved with the surrounding land. They are not biodegradable. However natural waste and products made from nature break down easily when they are disposed as waste.

But as more and more biodegradable materials pile up, there is increased threat to the environment.

One of the most common household waste is polythene- mostly used as polythene bags for shopping and carrying light things. Since they are cheap, they are used by almost everyone from the local vegetable seller to the supermarket bread shelf.

Biodegradable matter is generally [organic material](#) that serves as a nutrient for microorganisms. Microorganisms are so numerous and diverse that, a huge range of compounds are biodegraded, including [hydrocarbons](#) (e.g.oil), [polychlorinated biphenyls](#) (PCBs), [polyaromatic hydrocarbons](#) (PAHs), pharmaceutical substances. Decomposition of biodegradable substances may include both biological and [abiotic](#) steps.

Factors affecting biodegradation rate:

In practice, almost all chemical compounds and materials are subject to biodegradation, the key is the relative rates of such processes - minutes, days, years, centuries. A number of factors determine the degradation rate of organic compounds. Salient factors include light, water and oxygen. Temperature is also important because chemical reactions proceed more quickly at higher temperatures. The degradation rate of many organic compounds is limited by their bioavailability. Compounds must be released into solution before organisms can degrade them.

Biodegradability can be measured in a number of ways. [Respirometry](#) tests (is a general term that encompasses a number of techniques for obtaining estimates of the rates of [metabolism](#) of [vertebrates](#), [invertebrates](#), [plants](#), tissues, cells, or [microorganisms](#) via an indirect measure of heat production ([calorimetry](#)), can be

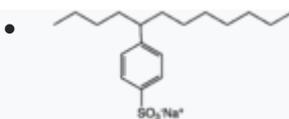
used for [aerobic microbes](#). First one places a solid waste sample in a container with microorganisms and soil, and then aerate the mixture. Over the course of several days, microorganisms digest the sample bit by bit and produce carbon dioxide – the resulting amount of CO₂ serves as an indicator of degradation. Biodegradability can also be measured by anaerobic microbes and the amount of methane or alloy that they are able to produce. In formal scientific literature, the process is termed bio-remediation.

| Approximated time for compounds to biodegrade in a marine environment¹ | |
|--|---------------------------|
| Product | Time to Biodegrade |
| Paper towel | 2–4 weeks |
| Newspaper | 6 weeks |
| Apple core | 2 months |
| Cardboard box | 2 months |
| Wax coated milk carton | 3 months |
| Cotton gloves | 1–5 months |

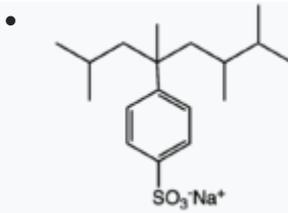
| | |
|------------------------------------|--------------|
| Wool gloves | 1 year |
| Plywood | 1–3 years |
| Painted wooden sticks | 13 years |
| Plastic bags | 10–20 years |
| Tin cans | 50 years |
| Disposable diapers | 50–100 years |
| Plastic bottle | 100 years |
| Aluminum cans | 200 years |
| Glass bottles | Undetermined |

Detergents :

In advanced societies, laundry [detergents](#) are based on *linear* [alkylbenzenesulfonates](#). Branched alkylbenzenesulfonates, used in former times, were abandoned because they biodegrade too slowly.



4-(5-Dodecyl) benzenesulfonate, a linear dodecylbenzenesulfonate

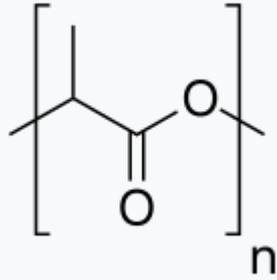


A branched dodecylbenzenesulfonate, which has been phased out in developed countries.

Plastics

Plastic is a material consisting of any of a wide range of [synthetic](#) or semi-synthetic [organic compounds](#) that are [malleable](#) and can be [molded](#) into solid objects. Plastics are typically [organic polymers](#) of high [molecular mass](#), but they often contain other substances. They are usually synthetic, most commonly derived from [petrochemicals](#), but many are made from renewable materials such as polylactic acid from corn or cellulosic from cotton linters. [Plasticity](#) is the general property of all materials that are able to irreversibly deform without breaking, but this occurs to such a degree with this class of moldable [polymers](#) that their name is an emphasis on this ability.

Plastic biodegrade at highly variable rates. [PVC\(poly vinyl chloride\)](#)-based plumbing is specifically selected for handling [sewage](#) because PVC biodegrades very slowly. Some packaging materials on the other hand are being developed that would degrade readily upon exposure to the environment. Illustrative synthetic polymers that are biodegrade quickly include [polycaprolactone](#), others are [polyesters](#) and aromatic-aliphatic esters, due to their ester bonds being susceptible to attack by water. A prominent example is [poly-3-hydroxybutyrate](#), the renewably derived [polylactic acid](#), and the synthetic polycaprolactone. Others are the cellulose-based cellulose acetate and celluloid (cellulose nitrate).



[Polylactic acid](#) is an example of a plastic that biodegrades quickly.

Under [low oxygen](#) conditions biodegradable plastics break down slower and with the production of [methane](#), like other organic materials do. The breakdown process is accelerated in a dedicated [compost heap](#). Starch-based plastics will degrade within two to four months in a home compost bin, while polylactic acid is largely undecomposed, requiring higher temperatures. Polycaprolactone and polycaprolactone-starch composites decompose slower, but the starch content accelerates decomposition by leaving behind a porous, high surface area polycaprolactone. Nevertheless, it takes many months. In 2016, a bacterium named [Ideonella sakaiensis](#) was found to biodegrade [PET\(Polyethylene terephthalate\)](#)—it is a kind of thermo plastic polymer-.

Many [plastic producers](#) have gone so far even to say that their plastics are compostable, typically listing [corn starch](#) as an ingredient. However, these claims are questionable because the [plastics industry](#) operates under its own definition of compostable:

That which is capable of undergoing biological decomposition in a compost site such that the material is not visually distinguishable and breaks down into carbon dioxide, water, inorganic compounds and biomass at a rate consistent with known compostable materials.

The term "**composting**" is often used informally to describe the biodegradation of packaging materials. Legal definitions exist for

compostability , the process that leads to compost. Four criteria are offered by the European Union:

- Biodegradability, the conversion of >90% material into CO₂ and water by the action of micro-organisms within 6 months.
- Disintegrability, the fragmentation of 90% of the original mass to particles that then pass through a 2 mm sieve.
- Absence of toxic substances and other substances that impede composting.

Nondegradable pollutant: A pollutant that is not broken down by natural processes. Some non-degradable pollutants, like the heavy metals , create problems because they are toxic and persistent in the environment . Others, like synthetic plastics , are a problem because of their sheer volume. Non-biodegradable materials do not decompose. Instead, they remain intact in landfills and cause potential harm to the environment once they have outlived their usefulness. Such materials include items like metals, plastic and glass. Some manufacturers now strive to make their goods biodegradable, and environmentalists urge consumers to stay away from non-biodegradable products as much as possible.

Some references mention that this kinds of pollutants called **Notable pollutants** include the following groups:

- [Persistent organic pollutants](#) POP
- [Environmental Persistent Pharmaceutical Pollutants](#) EPPP
- [Polycyclic Aromatic Hydrocarbons](#) PAH
- [Volatile Organic Compounds](#) VOC

Unlike biodegradable waste, such as food and other organic waste, non-biodegradable waste remains stable indefinitely. It includes items like rubber tires, Styrofoam, plastic, fiberglass and metals. Because non-

biodegradable waste cannot be broken down, recycling is the best option for managing it. Many businesses and municipalities have special bins designated specifically for the disposal of non-biodegradable waste.

-Persistent organic pollutants POP

POPs typically are halogenated organic compounds and as such exhibit high lipid solubility. For this reason, they bioaccumulate in fatty tissues. Halogenated compounds also exhibit great stability reflecting the non-reactivity of C-Cl bonds toward hydrolysis and photolytic degradation. The stability and lipophilicity of organic compounds often correlates with their halogen content, thus polyhalogenated organic compounds are of particular concern. They exert their negative effects on the environment through two processes, long range transport, which allows them to travel far from their source, and bioaccumulation, which reconcentrates these chemical compounds to potentially dangerous levels. Compounds that make up POPs are also classed as PBTs (**P**ersistent, **B**ioaccumulative and **T**oxic) or **TOMPs** (**T**oxic **O**rganic **M**icro **P**ollutants).

POPs enter the gas phase under certain environmental temperatures and volatize from soils, vegetation, and bodies of water into the atmosphere, resisting breakdown reactions in the air, to travel long distances before being re-deposited. This results in accumulation of POPs in areas far from where they were used or emitted, specifically environments where POPs have never been introduced such as Antarctica, and the Arctic circle. POPs can be present as vapors in the atmosphere or bound to the surface of solid particles. POPs have low solubility in water but are easily captured by solid particles, and are soluble in organic fluids (oils, fats, and liquid fuels). POPs are not easily

degraded in the environment due to their stability and low [decomposition](#) rates. Due to this capacity for long-range transport, POP environmental contamination is extensive, even in areas where POPs have never been used, and will remain in these environments years after restrictions implemented due to their resistance to degradation.

[Bioaccumulation](#) of **POPs** is typically associated with the compounds high lipid solubility and ability to accumulate in the [fatty tissues](#) of living organisms for long periods of time. Persistent chemicals tend to have higher concentrations and are eliminated more slowly. Dietary accumulation or [bioaccumulation](#) is another hallmark characteristic of POPs, as POPs move up the food chain, they increase in concentration as they are processed and metabolized in certain tissues of organisms. The natural capacity for animals [gastrointestinal tract](#) concentrate ingested chemicals, along with poorly [metabolized](#) and [hydrophobic](#) nature of POPs makes such compounds highly susceptible to [bioaccumulation](#). Thus POPs not only persist in the environment, but also as they are taken in by animals they bioaccumulate, increasing their concentration and toxicity in the environment.

-Environmental persistent pharmaceutical pollutants :

The term **Environmental persistent pharmaceutical pollutants** (EPPP) was first suggested in the nomination in 2010 of [pharmaceuticals](#) and [environment](#) as an emerging issue in a Strategic Approach to International Chemicals Management ([SAICM](#)) by the [International Society of Doctors for the Environment](#) (ISDE). The occurring problems from EPPPs are in parallel explained under [environmental impact of pharmaceuticals and personal care products](#) (PPCP). The [European Union](#) summarizes pharmaceutical

residues with the potential of contamination of water and soil together with other micropollutants under “priority substances” .

Pharmaceuticals comprise one of the few groups of chemicals that are specifically designed to act on living cells, which presents a special risk when they enter, persist and disseminate in the environment.

With exception for downstream [sewage treatment plants](#), the concentration of pharmaceuticals in water is probably extremely low. However, the effect that the chronic exposure to environmental pharmaceuticals chemicals adds to the effects of other chemicals in the cocktail is still not studied. The different chemicals might be potentiating synergistic effects (1+1=3). An extremely sensitive group in this respect are foetuses.

EPPPs are already found in water all over the world. The diffuse exposure might contribute to

- extinction of species and imbalance of sensible [ecosystems](#), as many EPPPs affect the reproductive systems of for example frogs, fish and mussels
- genetic, developmental, immune and hormonal health effects to humans and other species, in the same way as e.g. oestrogen-like chemicals
- development of microbes resistant to antibiotics, as is found in India.

Concentrations of Pharmaceuticals in surface waters, [groundwater](#) and partially treated water are typically less than 0.1 µg/l (or 100 ng/l), and concentrations in treated water are generally below 0.05 µg/l (or 50 ng/l).(ng 8 WHO), However, all water on the earth is part of the same stable pool, and as larger amounts of pharmaceuticals are

consumed, there is a risk that the concentration of pharmaceuticals in drinking water will increase.

Pharmaceuticals reach the environment mainly in three ways:

- They are excreted from humans and animals, intact or metabolized, mainly into the urine, passing on to the environment directly or via [sewage treatment plants](#).
- Unused pharmaceuticals reach the environment either via household wastewater or via urban solid garbage handling.
- Manufacturing plants producing the active substances might unintentionally release pharmaceuticals into the environment.

Due to improved measurement methods pharmaceuticals may be detected today in concentrations that probably have been present already for decades but could not be measured before. Many pharmaceuticals are (after consumption) excreted or washed off: investigations have shown excretion rates between 30% and 70% of orally taken substances, and even higher rates considering externally applied ointments or gel. Some pharmaceuticals are degraded to various extents in sewage treatment plants, but others leave the plant in active forms. Active residues of pharmaceuticals have been detected in surface water, and they may persist in the environment for long periods of time. Large amounts of antibiotics and other pharmaceuticals have been found downstream from sewage treatment plants in sub catchments where the discharge of hospital waste water plays a major role, or in catchments with pharmaceutical industries. **EPPPs** from [treated sewage sludge](#) used as fertilizer are absorbed by soya, and antibiotics have been found in the leaves.

Some of these environmental pharmaceuticals chemicals are well known to have serious genotoxic effects in humans, Half-life in nature varies depending on the environment (air, water, soil, sludge), but is more than one year for several compounds.

Concentrations of EPPPs can vary from 1 ng to 1 mg per liter . Serious effects of EPPPs on water-living organisms, especially on reproductive systems, have been already shown, as well as on microbial communities. This would be of much less concern if the population were to keep their excrement out of the [wastewater](#) via the use of the [urine-diverting dry toilet](#) or systems that recycle treated [blackwater](#) to flush toilets again indefinitely.

Pharmaceuticals are special kinds of chemicals. They are manufactured to be biologically active in living organisms.

The levels of pharmaceuticals in surface or drinking water are generally below 1 mg per liter, often measured in ng per liter . This low concentration might appear to guarantee that they hardly pose any problem to public health. Assuming a concentration of 100 ng/l of a pharmaceutical that in humans has DDD (defined daily dose) of 10 mg implies that a volume of 100,000 litres would be required to make up one single DDD. Such calculation does not take into account the vulnerable population exposure for example during the period of development.

Prof.Dr.Ithar Kamil Abbas

Photodissociation, photolysis, or photodecomposition:

Photodissociation, photolysis, or photodecomposition is a [chemical reaction](#) in which a [chemical compound](#) is broken down by [photons](#). It is defined as the interaction of one or more photons with one target molecule. Photodissociation is not limited to [visible light](#). Any photon with sufficient [energy](#) can affect the chemical bonds of a chemical compound. Since a photon's energy is inversely proportional to its wavelength, [electromagnetic waves](#) with the energy of visible light or higher, such as [ultraviolet light](#), [x-rays](#) and [gamma rays](#) are usually involved in such reactions.

Photolysis occurs in the atmosphere as part of a series of reactions by which primary [pollutants](#) such as [hydrocarbons](#) and [nitrogen oxides](#) react to form secondary pollutants such as [peroxyacyl nitrates](#).

The two most important photodissociation reactions in the [troposphere](#) are firstly:

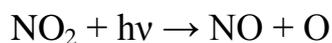


which generates an excited oxygen atom which can react with water to give the [hydroxyl radical](#):



The hydroxyl radical is central to [atmospheric chemistry](#) as it initiates the [oxidation](#) of hydrocarbons in the atmosphere and so acts as a [detergent](#).

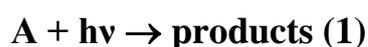
Secondly the reaction:



is a key reaction in the formation of [tropospheric ozone](#).

The formation of the [ozone layer](#) is also caused by photodissociation. Ozone in the Earth's [stratosphere](#) is created by ultraviolet light striking oxygen molecules containing two oxygen [atoms](#) (O_2), splitting them into individual oxygen atoms (atomic oxygen). The atomic oxygen then combines with unbroken O_2 to create [ozone](#), O_3 . In addition, photolysis is the process by which [CFCs](#) are broken down in the upper atmosphere to form ozone-destroying chlorine [free radicals](#).

Chemicals and pollutants in the atmosphere, water and even snowpack may be directly photolysed by solar radiation. It is useful to know how fast this process may be or to calculate a photolysis lifetime (time to decay to $1/e$ of an initial concentration). Consider a pollutant chemical, A, released to the environment that is photolabile. The pollutant, A, may absorb a photon of solar radiation, $h\nu$



The rate of loss of concentration of chemical A, [A] is

$$d[\text{A}]/dt = -J[\text{A}] \quad (2)$$

The coefficient, J is dependent on the intensity of solar radiation and the photo-physical properties of chemical A and may be calculated as

$$J = \int \Phi(\lambda, T) \sigma(\lambda, T) F(\theta, \lambda) d\lambda \quad (3)$$

where Φ is the quantum yield for photolysis of chemical A and σ is the absorption cross-section, both as a function of wavelength, λ and

temperature, T . The solar spherical or point irradiance is $F(\theta, \lambda)$. The quantity $F(\theta, \lambda)$ is often termed as the “actinic flux” but this term is often wrong and misleading (1), θ is the solar zenith angle. The calculation or measurement of spherical or point irradiance can be tricky. The quantity, J , is a first-order reaction decay constant, thus the reciprocal of J is a characteristic lifetime (i.e. time τ for the concentration of A, $[A]$ to decay to $1/J$ or $\sim 37\%$ of its initial concentration).

$$\tau = 1/J \quad (4)$$

Hydrolysis :

Hydrolysis literally means reaction with water. It is a chemical process in which a [molecule](#) is cleaved into two parts by the addition of a molecule of water. One fragment of the parent molecule gains a hydrogen ion (H^+) from the additional water molecule. The other group collects the remaining hydroxyl group (OH^-). To illustrate this process, some examples from real life and actual living systems are discussed here.

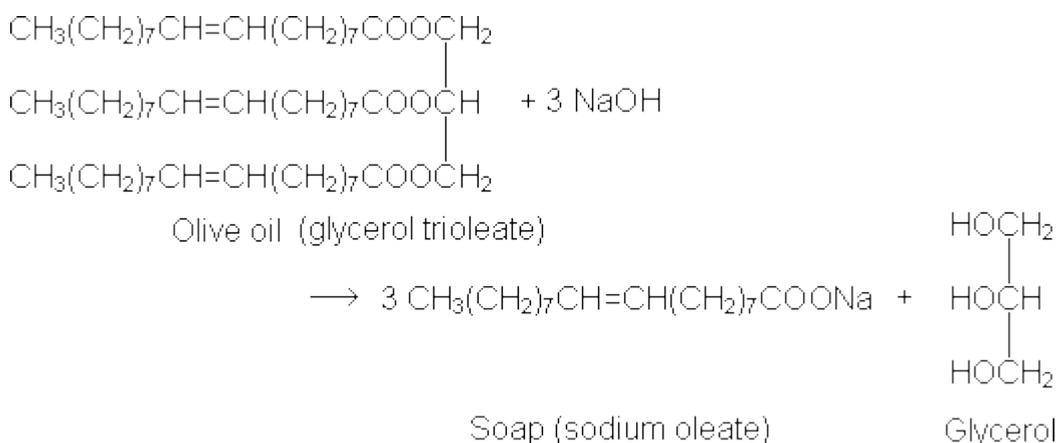
The most common hydrolysis occurs when a salt of a weak acid or weak base (or both) is dissolved in water. Water autoionizes into negative hydroxyl ions and [hydrogen ions](#). The salt breaks down into positive and negative ions. For example, sodium acetate dissociates in water into sodium and acetate ions. Sodium ions react very little with hydroxyl ions whereas acetate ions combine with hydrogen ions to produce neutral acetic acid, and the net result is a relative excess of hydroxyl ions, causing a basic solution.

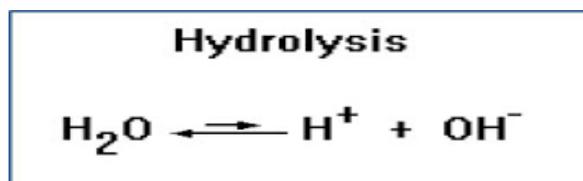
However, under normal conditions, only a few reactions between water and organic compounds occur. Generally, strong acids or bases must be added in order to achieve hydrolysis where water has no effect. The acid

or base is considered a **catalyst** . They are meant to speed up the reaction, but are recovered at the end of it.

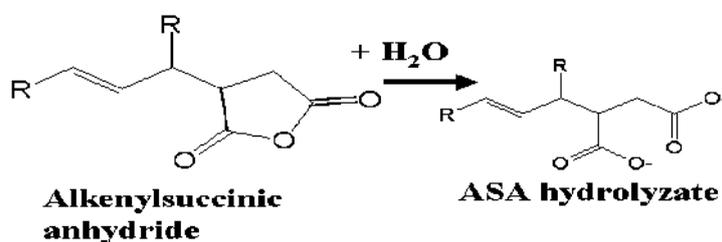
Acid–base-catalyzed hydrolyses are very common; one example is the hydrolysis of amides or **esters** . Their hydrolysis occurs when the nucleophile (a nucleus-seeking agent, e.g., water or hydroxyl ion) attacks the carbon of the carbonyl group of the [ester](#) or [amide](#). In an aqueous base, hydroxyl ions are better nucleophiles (molecular or ion or atom that donates a pair of electrons to form a new covalent bond, nucleus loving) than dipoles such as water. In acid, the carbonyl group becomes protonated, and this leads to a much easier nucleophilic attack. The products for both hydrolyses are compounds with **carboxylic acid** groups.

Perhaps the oldest example of ester hydrolysis is the process called **Saponification**. It is the hydrolysis of a [triglyceride](#) (fat) with an aqueous base such as sodium hydroxide (NaOH). During the process, glycerol, also commercially named glycerin, is formed, and the fatty acids react with the base, converting them to salts. These salts are called soaps, commonly used in households.



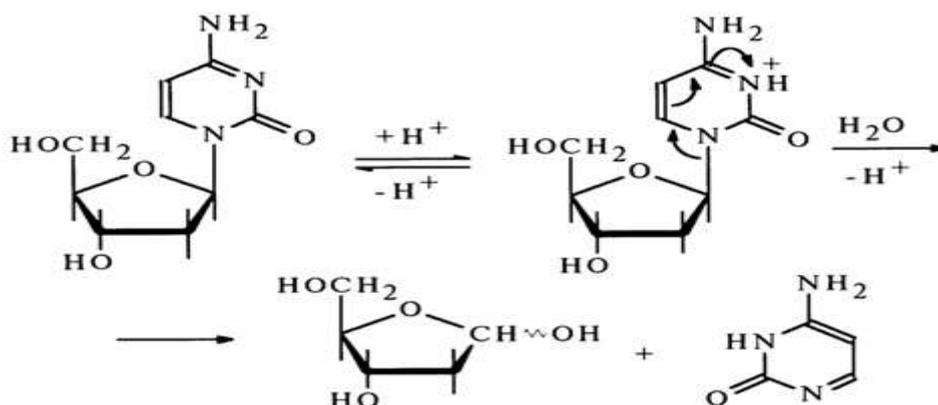


Hydrolysis of ASA



M. Hubbe

ASA=Acetyl Salicylic Acid (Aspirin)



Advanced Oxidation processes :

Advanced oxidation processes (AOPs), defined as those technologies that utilize the hydroxyl radical ($\cdot\text{OH}$) for oxidation, have received

increasing attention in the research and development of wastewater treatment technologies in the last decades. These processes have been applied successfully for the removal or degradation of toxic pollutants or used as pretreatment to convert recalcitrant pollutants into biodegradable compounds that can then be treated by conventional biological methods. The efficacy of AOPs depends on the generation of reactive free radicals, the most important of which is the hydroxyl radical ($\cdot\text{OH}$). The authors summarize the formation reactions of $\cdot\text{OH}$ and the mechanisms of pollutants degradation. They cover six types of advanced oxidation processes, including radiation, photolysis and photocatalysis, sonolysis, electrochemical oxidation technologies, Fenton-based reactions, and ozone-based processes. Controversial issues in pollutants degradation mechanism were discussed. They review the application of these processes for removal of different kinds of toxic pollutants from wastewater, including aromatic compounds, dyes, pharmaceutical compounds, and pesticides, with emphasis on the parameters assessed, removal effectiveness, and the degradation mechanisms of pollutants. The authors discuss issues associated with practical wastewater treatment and offer suggestions for the direction for future researches.

Advanced Oxidation processes, are a set of chemical treatment procedures designed to remove organic (and sometimes inorganic) materials in [water](#) and [waste water](#) by [oxidation](#) through reactions with [hydroxyl radicals](#) ($\cdot\text{OH}$). In real-world applications of [wastewater treatment](#), however, this term usually refers more specifically to a subset of such chemical processes that employ [ozone](#) (O_3), [hydrogen peroxide](#) (H_2O_2) and/or UV light. One such type of process is called [in situ chemical oxidation](#).

Chemistry in AOPs could be essentially divided into three parts:

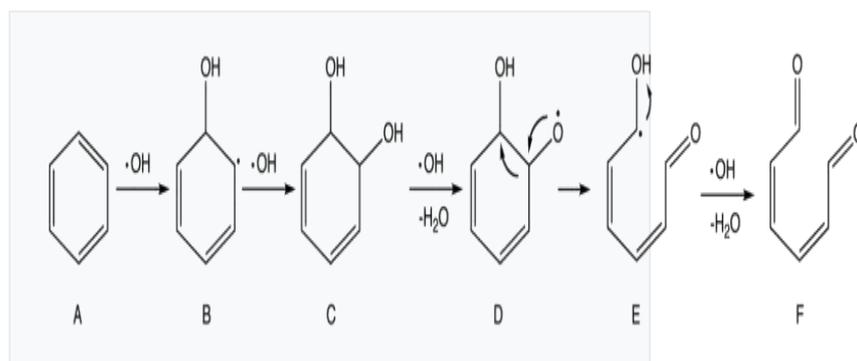
Formation of $\cdot\text{OH}$;

1. Initial attacks on target molecules by $\cdot\text{OH}$ and their breakdown to fragments;
2. Subsequent attacks by $\cdot\text{OH}$ until ultimate [mineralization](#).

The mechanism of $\cdot\text{OH}$ production (Part 1) highly depends on the sort of AOP technique that is used. For example, ozonation, UV/ H_2O_2 and photocatalytic oxidation rely on different mechanisms of $\cdot\text{OH}$ generation:

- UV/ H_2O_2 :
 $\text{H}_2\text{O}_2 + \text{UV} \rightarrow 2\cdot\text{OH}$ (*homolytic bond cleavage of the O-O bond of H_2O_2 leads to formation of $2\cdot\text{OH}$ radicals*)
- Ozone based AOP:
 - $\text{O}_3 + \text{HO}^- \rightarrow \text{HO}_2^- + \text{O}_2$ (*reaction between O_3 and a hydroxyl ion leads to the formation of H_2O_2 (in charged form)*)
 - $\text{O}_3 + \text{HO}_2^- \rightarrow \text{HO}_2\cdot + \text{O}_3^- \cdot$ (*a second O_3 molecule reacts with the HO_2^- to produce the ozonide radical*)
 - $\text{O}_3^- \cdot + \text{H}^+ \rightarrow \text{HO}_3\cdot$ (*this radical gives to $\cdot\text{OH}$ upon protonation*)
 - $\text{HO}_3\cdot \rightarrow \cdot\text{OH} + \text{O}_2$
- Photocatalytic oxidation with TiO_2 :
 $\text{TiO}_2 + \text{UV} \rightarrow e^- + h^+$ (*irradiation of the photocatalytic surface leads to an excited [electron](#) (e^-) and electron gap (h^+)*)
 $\text{Ti(IV)} + \text{H}_2\text{O} \rightleftharpoons \text{Ti(IV)-H}_2\text{O}$ (*water adsorbs onto the catalyst surface*)
 $\text{Ti(IV)-H}_2\text{O} + h^+ \rightleftharpoons \text{Ti(IV)-}\cdot\text{OH} + \text{H}^+$ (*the highly reactive electron gap will react with water*)

Currently there is no consensus on the detailed mechanisms in Part 3, but researchers have cast light on the processes of initial attacks in Part 2. In essence, $\cdot\text{OH}$ is a radical species and should behave like a highly reactive electrophile. Thus two type of initial attacks are supposed to be [Hydrogen Abstraction](#) and [Addition](#). The following scheme, describes a possible mechanism of the oxidation of [benzene](#) by $\cdot\text{OH}$.

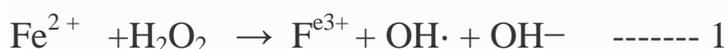


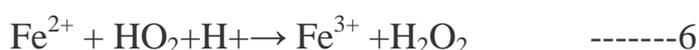
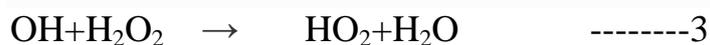
Proposed mechanism of the oxidation of benzene by hydroxyl radicals

The first and second steps are electrophilic addition that breaks the aromatic ring in benzene (A) and forms two hydroxyl groups (–OH) in intermediate C. Later an ·OH grabs a hydrogen atom in one of the hydroxyl groups, producing a radical species (D) that is prone to undergo rearrangement to form a more stable radical (E). E, on the other hand, is readily attacked by ·OH and eventually forms 2,4-hexadiene-1,6-dione (F). As long as there are sufficient ·OH radicals, subsequent attacks on compound F will continue until the fragments are all converted into small and stable molecules like H₂O and CO₂ in the end, but such processes may still be subject to a myriad of possible and partially unknown mechanisms.

Fenton-Related AOPs :

Among these metals that are able to activate H₂O₂ and produce hydroxyl radicals in water, iron is the most frequently used. In the so-called Fenton process, H₂O₂ reacts with Fe²⁺ to generate strong reactive species. The reactive species produced are traditionally recognized as hydroxyl radicals, though other substances such as ferryl ions are proposed. The classical Fenton radical mechanisms primarily involve the following reactions:





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Ph.D. Students

OH· is generated from Eq. [1](#) through electron transfer. However, OH· produced can be scavenged by either of Fenton reagents as shown in Eqs. [2](#) and [3](#). Therefore, the optimal molar ratio of iron ion to hydrogen peroxide needs to be experimentally determined for minimization of the unwanted scavenging. Although Eq. [2](#) indicates that the produced Fe³⁺ from Eq. [1](#) can be reduced to Fe²⁺, the iron cannot be a catalyst in the Fenton system because the rate constant in Eq. [2](#) is several orders of magnitude less than that in Eq. [1](#). Consequently, Fe³⁺ forms iron sludge at typical water and wastewater treatment conditions. The sludge needs to be separately disposed of, thus increasing the treatment complexity and operational costs. Of note, the generation of hydroxyl radicals during the Fenton reaction is the most effective only at an acidic pH condition. As a result, the application of Fenton reaction for wastewater treatment is restricted in practice.

Prof.Dr.Ithar Kamil Abbas

Radiation in the Environment

Many forms of "radiation" are encountered in the natural environment and are produced by modern technology. Most of them have the potential for both beneficial and harmful effects. Even sunlight, the most essential radiation of all, can be harmful in excessive amounts. Most public attention is given to the category of radiation known as "ionizing radiation." This radiation can disrupt atoms, creating positive ions and negative electrons, and cause biological harm. Ionizing radiation includes [x-rays](#), gamma rays, alpha particles, beta particles, neutrons, and the varieties of cosmic rays.

The radioactive nuclei, or [radionuclides](#), found naturally on Earth can be grouped into three series—headed by uranium-238, uranium-235, and thorium-232—plus several isolated beta-particle emitting nuclei, most prominently potassium-40 and rubidium-87.

Units of Radioactivity and Dose

The original unit for measuring the amount of radioactivity was the [curie \(Ci\)](#)—first defined to correspond to one gram of radium-226 and more recently defined as:

$$1 \text{ curie} = 3.7 \times 10^{10} \text{ radioactive decays per second [exactly].}$$

In the International System of Units (SI) the curie has been replaced by the [becquerel \(Bq\)](#), where

$$1 \text{ becquerel} = 1 \text{ radioactive decay per second} = 2.703 \times 10^{11} \text{ Ci.}$$

The magnitude of radiation exposures is specified in terms of the [radiation dose](#). There are two important categories of dose:

1. The *absorbed dose*, sometimes also known as the *physical dose*, defined by the amount of energy deposited in a unit mass in human tissue or other media. The original unit is the *rad* [100 erg/g]; it is now being widely replaced by the SI unit, the [gray](#) (Gy) [1 J/kg], where 1 gray = 100 rad.

The biological dose, sometimes also known as the *dose equivalent*, expressed in units of [rem](#) or, in the SI system, sievert (Sv). This dose reflects the fact that the biological damage caused by a particle depends not only on the total energy deposited but also on the rate of energy loss per unit distance traversed by the particle (or "linear energy transfer"). For example, alpha particles do much more damage per unit energy deposited than do electrons. This effect can be represented, in rough overall terms, by a *quality factor*, Q . Over a wide range of incident energies, Q is taken to be 1.0 for electrons (and for x-rays and gamma rays, both of which produce electrons) and 20 for alpha particles. For neutrons, the adopted quality factor varies from 5 to 20, depending on neutron energy.

The biological impact is specified by the *dose equivalent* H , which is the product of the absorbed dose D and the quality factor Q : $H = Q D$.

The unit for the dose equivalent is the rem if the absorbed dose is in rads and the [sievert](#) (Sv) if the absorbed dose is in grays. Thus, 1 Sv = 100 rem. As discussed below, 1 rem is roughly the average dose received

in 3 years of exposure to natural radiation. 1 Sv is at the bottom of the range of doses that, if received over a short period of time, are likely to cause noticeable symptoms of radiation sickness.

The dose equivalent is still not the whole story. If only part of the body is irradiated, the dose must be discounted with an appropriate weighting factor if it is to reflect overall risk. The discounted dose is termed the *effective dose equivalent* or just the *effective dose*, expressed in rems or sieverts.

Typical Radiation Doses

The chief sources of radiation exposure in the United States, as tabulated by the NCRP, are indicated in table 1. The largest single source of exposure is from radon, which is produced in the decay of radium-226 in the soil and enters a house through openings at the base. The "radon" dose arises mostly from the inhalation of the progeny of radon-222, and varies widely from house-to-house depending upon the radium content of the underlying soil, its porosity, and the house construction. The average effective dose of 2.0 mSv/yr (200 mrem/yr) corresponds to the average radon concentration, but there are more than one million homes with radon levels that are more than five times as great.

Table 1. Half-lives and average abundances of natural radionuclides.

| | ⁴⁰ K | ⁸⁷ Rb | ²³² Th | ²³⁸ U |
|---------------------------|-----------------|------------------|-------------------|------------------|
| Half-life (billion years) | 1.277 | 47.5 | 14.05 | 4.468 |

Upper continental crust

| | | | | |
|---------------------------------|-------|-----|------|-----|
| Elemental abundance (ppm) | 28000 | 112 | 10.7 | 2.8 |
| Activity (Bq/kg) | 870 | 102 | 43 | 35 |
| Activity (nCi/kg) | 23 | 2.7 | 1.2 | 0.9 |
| Activity (kCi/km ³) | 66 | 8 | 3.3 | 2.6 |

Oceans

| | | | | |
|------------------------------------|------|-------|--------------------|--------|
| Elemental concentration (mg/liter) | 399 | 0.12 | 1x10 ⁻⁷ | 0.0032 |
| Activity (Bq/liter) | 12 | 0.11 | 4x10 ⁻⁷ | 0.040 |
| Activity (nCi/liter) | 0.33 | 0.003 | 1x10 ⁻⁸ | 0.0011 |

Ocean sediments

| | | | | |
|---------------------------|-------|--|-----|-----|
| Elemental abundance (ppm) | 17000 | | 5.0 | 1.0 |
| Activity (Bq/kg) | 500 | | 20 | 12 |
| Activity (nCi/kg) | 14 | | 0.5 | 0.3 |

Human body

| | | | | |
|----------------------|------|-----|-------|------|
| Total activity (Bq) | 4000 | 600 | 0.08 | 0.4* |
| Total activity (nCi) | 100 | 16 | 0.002 | 0.01 |

* In the human body the activity of ²¹⁰Pb and ²¹⁰Po, both progeny of ²³⁸U, is much greater than that of ²³⁸U itself.

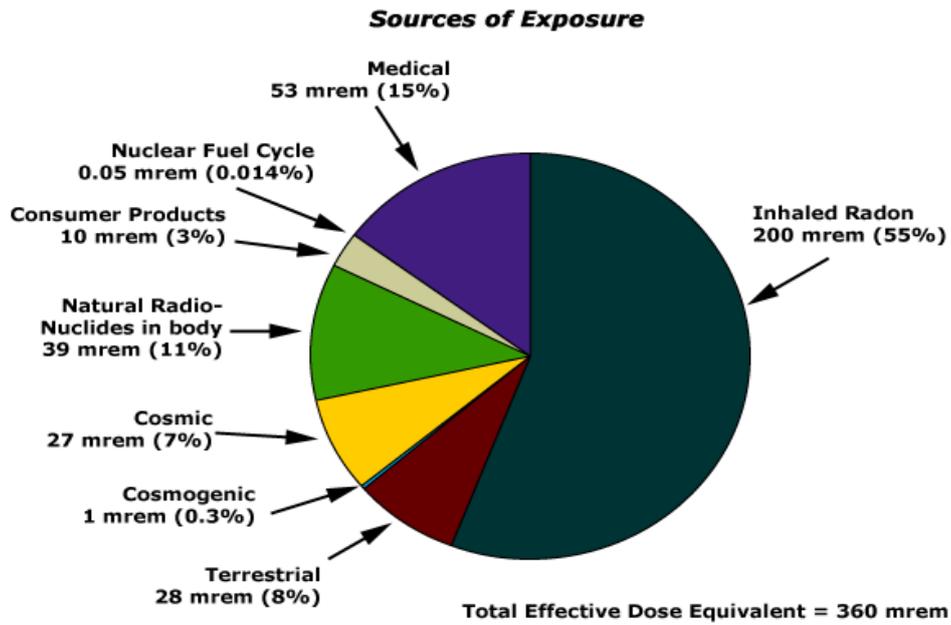


Table -2. Average radiation doses in the United States, 1980-1982 (effective dose per year).*

| Radiation source | Comments | <u>Effective dose</u> | |
|-----------------------|--|-----------------------|-----------|
| | | mSv/yr | mrem/yr |
| Natural sources | | | |
| indoor radon | due to seepage of ²²² Rn from ground | 2.0 | 200 |
| radionuclides in body | primarily ⁴⁰ K and ²³⁸ U progeny | 0.39 | 39 |
| terrestrial radiation | due to gamma-ray emitters in ground | 0.28 | 28 |
| cosmic rays | roughly doubles for 2000 m gain in elevation | 0.27 | 27 |
| cosmogenic | especially ¹⁴ C | <u>0.01</u> | <u>1</u> |
| total (rounded) | | 3.0 | 300 |
| Medical sources | | | |
| Diagnostic x-rays | excludes dental examinations | 0.39 | 39 |
| Medical treatments | radionuclides used in diagnosis (only) | <u>0.14</u> | <u>14</u> |
| total | | 0.53 | 53 |

| | | | |
|--------------------|--|--------|------|
| Other | | | |
| consumer products | primarily drinking water, building materials | 0.1 | 10 |
| occupational | averaged over entire US population | 0.01 | 1 |
| nuclear fuel cycle | does not include potential reactor accidents | 0.0005 | 0.05 |
| TOTAL (rounded) | | 3.6 | 360 |

*From *Ionizing Radiation Exposure of the Population of the United States*, NCRP Report No. 93 (National Council on Radiation Protection and Measurements, Washington DC, 1987).

Effect of small Doses

Most of the radiation doses that are received by members of the public and by radiation workers—both routinely and in accidents—are what are commonly referred to as "low doses." There is no precise definition of "low" but it would include doses below, for example, 10 mSv per year. As seen from Previous table 1, the average radiation doses received by people in the U.S. are in the "low dose" region. It is obviously important to determine the effects of low radiation doses—or, more precisely, the effects of small additions to the unavoidable natural background dose.

However, despite much study, these effects are not known, being too small to see unambiguously. The most prominent assumption, accepted by most official bodies, is the so-called *linearity hypothesis*, according to which the cancer risk is directly proportional to the magnitude of the dose, down to zero dose. In applying this assumption a consensus estimate is that the risk to a "typical" individual of an eventual fatal cancer is 0.00005 per mSv (or 0.05 per Sv). Thus, if 100,000 people each receive an added dose of 1 mSv, then 5 additional cancer deaths are to be

expected. At the same time, while adopting the linearity hypothesis as a prudent working assumption, many of the leading studies have also indicated the possibility that small increases in radiation dose do not create any additional cancer risk. This reflects the considerable disagreement that exists within the scientific community as to the validity of the linearity hypothesis.

Effects of Large Doses

Radiation doses above 3 Gy (300 rad) can be fatal and doses above 6 Gy (600 rad) are almost certain to be fatal, with death occurring within several months (in shorter times at higher doses). [Note: Very high doses are commonly expressed in grays, because the standard quality factor is not appropriate. For gamma rays and electrons, 1 Gy corresponds to 1 Sv.] Above 1 Gy, radiation causes a complex of symptoms, including nausea and blood changes, known as radiation sickness. For doses below 1 Sv (100 rem), there is little likelihood of radiation sickness, and the main danger is an increased cancer risk. The most important data base and analyses are from the RERF studies (Radiation Effect Research Foundation) of the Hiroshima and Nagasaki survivors. In these studies, the exposure and medical histories are analyzed for an exposed group (50,113 people) and an unexposed, or minimally exposed, group (36,459 people). Through 1990, there have been 4,741 cancer fatalities in the exposed group, of which 454 are attributed to radiation exposure. There is a statistically significant excess for both solid cancer tumors and leukemia for doses above 0.2 Sv (20 rem). These data, in a succession of updated versions, have provided much of the information used in comprehensive studies of radiation effects.

Biological effect of Radiation

Whether the source of radiation is natural or man-made, whether it is a small dose of radiation or a large dose, there will be some biological effects.

The effect of radiation on living cells, in actuality, ionizing radiation, by definition, interacts only with atoms by a process called ionization. Thus, all biological damage effects begin with the consequence of radiation interactions with the atoms forming the cells. As a result, radiation effects on humans proceed from the lowest to the highest levels.

Even though all subsequent biological effects can be traced back to the interaction of radiation with atoms, there are two mechanisms by which radiation ultimately affects cells. These two mechanisms are commonly called **direct and indirect effects**.

Direct Effects :

If radiation interacts with the atoms of the DNA molecule, or some other cellular component critical to the survival of the cell, it is referred to as a direct effect. Such an interaction may affect the ability of the cell to reproduce and, thus, survive. If enough atoms are affected such that the chromosomes do not replicate properly, or if there is significant alteration in the information carried by the DNA molecule, then the cell may be destroyed by “direct” interference with its life-sustaining system.

Indirect Effects :

If a cell is exposed to radiation, the probability of the radiation interacting with the DNA molecule is very small since these critical components make up such a small part of the cell. However, each cell,

just as is the case for the human body, is mostly water. Therefore, there is a much higher probability of radiation interacting with the water that makes up most of the cell's volume. When radiation interacts with water, it may break the bonds that hold the water molecule together, producing fragments such as hydrogen (H) and hydroxyls (OH). These fragments may recombine or may interact with other fragments or ions to form compounds, such as water, which would not harm the cell. However, they could combine to form toxic substances, such as hydrogen peroxide (H₂O₂), which can contribute to the destruction of the cell.

Not all living cells are equally sensitive to radiation. Those cells which are actively reproducing are more sensitive than those which are not. This is because dividing cells require correct DNA information in order for the cell's offspring to survive. A direct interaction of radiation with an active cell could result in the death or mutation of the cell, whereas a direct interaction with the DNA of a dormant cell would have less of an effect.

As a result, living cells can be classified according to their rate of reproduction, which also indicates their relative sensitivity to radiation. This means that different cell systems have different sensitivities. Lymphocytes (white blood cells) and cells which produce blood are constantly regenerating, and are, therefore, the most sensitive. Reproductive and gastrointestinal cells are not regenerating as quickly and are less sensitive. The nerve and muscle cells are the slowest to regenerate and are the least sensitive cells.

Cells, like the human body, have a tremendous ability to repair damage. As a result, not all radiation effects are irreversible. In many instances, the cells are able to completely repair any damage and function normally.

If the damage is severe enough, the affected cell dies. In some instances, the cell is damaged but is still able to reproduce. The daughter cells, however, may be lacking in some critical life-sustaining component, and they die. The other possible result of radiation exposure is that the cell is affected in such a way that it does not die but is simply mutated. The mutated cell reproduces and thus perpetuates the mutation. This could be the beginning of a malignant tumor.

The sensitivity of the various organs of the human body correlate with the relative sensitivity of the cells from which they are composed. For example, since the blood forming cells were one of the most sensitive cells due to their rapid regeneration rate, the blood forming organs are one of the most sensitive organs to radiation. Muscle and nerve cells were relatively insensitive to radiation, and therefore, so are the muscles and the brain.

The rate of reproduction of the cells forming an organ system is not the only criterion determining overall sensitivity. The relative importance of the organ system to the well-being of the body is also important.

One example of a very sensitive cell system is a malignant tumor. The outer layer of cells reproduces rapidly, and also has a good supply of blood and oxygen. Cells are most sensitive when they are reproducing, and the presence of oxygen increases sensitivity to radiation. Anoxic cells (cells with insufficient oxygen) tend to be inactive, such as the cells located in the interior of a tumor.

As the tumor is exposed to radiation, the outer layer of rapidly dividing cells is destroyed, causing it to “shrink” in size. If the tumor is given a massive dose to destroy it completely, the patient might die as well. Instead, the tumor is given a small dose each day, which gives the healthy

tissue a chance to recover from any damage while gradually shrinking the highly sensitive tumor. Another cell system that is composed of rapidly dividing cells with a good blood supply and lots of oxygen is the developing embryo. Therefore, the sensitivity of the developing embryo to radiation exposure is similar to that of the tumor, however, the consequences are dramatically different.

Whole body sensitivity depends upon the most sensitive organs which, in turn, depend upon the most sensitive cells. As noted previously, the most sensitive organs are the blood forming organs and the gastrointestinal system. The biological effects on the whole body from exposure to radiation will depend upon several factors. Some of these are listed above. For example, a person, already susceptible to infection, who receives a large dose of radiation may be affected by the radiation more than a healthy person.

Diseases caused by chemical Air pollution

Air Pollution is one of the most widespread pollutions and is one of the inevitable ones. Being an ever pervading medium and carrier, air can transfer the pollutants very fast in no time; making it almost impossible for any person breathing in the polluted air, to avoid the infection. Though the pollutant level, reaction to the pollutants and infestation of the pollutant based diseases in every person is different; the fact that air pollution can have injurious effects on the human body can just not be ignored.

Below, focusing on ten of such diseases caused by the air pollution and what pollutants cause them.

1-Asthma:

This is one of the most common diseases that can affect the humans breathing in the polluted air. It is a chronic disease in which inflammation is caused in the air passages of the human body and the person finds it difficult to breathe. Heavy breathing while doing normal routine activities and strenuous ones are some of the basic symptoms of the disease. Asthma is caused by the particulate matter, oxides of sulfur and nitrogen and ground level ozone. Tobacco smoke can also be a cause of the same and the parents, friends, family members and other people in close contact with the patient should refrain from smoking in his or her presence.

2-Lung Cancer: Owing to the presence of various carcinogens in the air, the lungs can get infested with them which in turn can lead to lung or pulmonary cancer. The disease involves uncontrolled growth of the cells in one or both of the lungs causing a

Chemical Pollution Ph.D. Students
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reduction in the oxygen-carrying capacity and malfunctioning in the complete working of the respiratory system. Though the lung cancer cures depend on the type of cancer and the level of infection in the lungs.

3-COPD (Chronic Obstructive Pulmonary Disease) :

COPD is caused by the air pollution in which the air passages and air sacs or the alveoli change their shape and become distended. Thus, the patient finds it difficult to breathe even while sitting or doing nothing. Emphysema and Chronic Bronchitis are two types of COPD which are common and can lead to cancer and premature deaths as well. The most affected people are the people working in the mines, quarries and docks... etc, that are in constant contact with the dust, fine dust and diesel fumes etc.

4-Leukemia: It is a disease (type of cancer) caused by exposure to the benzene vapors and is fatal as well. The WBCs or the White Blood Cells get increased in the amount owing to persistent infection caused by the infection and the respiratory tract is infected heavily.

5-Pneumonia: Polluted air also carries bacteria that get inhaled into the respiratory tract which in turn causes pneumonia. The disease might get

worse with continued breathing of the polluted air and the disease might get worse with some other disease caused by the pollution.

6-Birth defects and immune system defects: There are a number of defects that can occur in the newborn as well as unborn babies owing to exposure to the polluted air and breathing of polluted air by the pregnant mother respectively. The babies born in

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the areas with air pollution will have lower immunity against the infections, cough and cold and might also exhibit some inborn allergies as well.

7-Autism: Recent studies have revealed that air pollution can also cause Autism, a disease in which the patient has a tendency to live alone.

8-Weakening of Lung Function: If the level of the air pollution is not high, there might be a general or gradual weakening of the lung function in the people breathing in the polluted air. This can be exhibited in a number of forms such as allergies, panting while doing heavy or normal daily routine activities and very low immunity to a cough and cold etc.

9-Cardiovascular Diseases: Owing to the presence of a number of poisonous substances in the polluted air, poisonous gases and particulate matter, the people living in the polluted environment exhibit a lot of cardiovascular diseases of various kinds. The extent of exposure to the pollutants can determine the degree of the disease and infection.

10-Premature Deaths: It has been found that pollutants in the air can lead to premature deaths owing to different reasons such as asphyxiation and extreme reactions caused by the body to the pollutant matter. Every year a huge number of premature deaths are registered all across the world owing to the pollution.

Chemical Soil pollution Disease

Soil pollution occurs when there is a build-up of persistent toxic compounds, salts, radioactive materials, chemicals or disease-causing agents in the soil which affect human, animal and plant health. Soil pollution is mainly a result of human activity, such as the application of pesticides like Atrazine, which is a popular weed killer, and the generation of unwanted industrial waste like arsenic. Soil pollution changes the composition of the soil and creates a pathogenic soil environment, leading to the spread of diseases.

Land or **soil pollution diseases** are those diseases caused by pollutants from the land/dirt/soil. The pollutants may enter the soil/land via:

- waste disposal (e.g. landfills);
- air deposition, either dry (e.g. from mining and smelting activities, foundries etc.) or wet (e.g. acid rain);
- contact with contaminated surface or ground waters.

While [exposure to soil pollutants](#) is generally less problematic than exposure to air and water pollution, it might still have serious effects on children who usually play on the soil. Being in closer proximity to potential pollution, children could accidentally swallow soil particles while playing on the ground.

Soil pollutants, including chemicals and pathogens, have interchangeable liquid, solid or gaseous forms that mix until an equilibrium is reached between the three. The **solid** forms are absorbed or mixed with soil particles, **liquids** fill the voids made of pores between soil particles, and the **gaseous** forms surround the air between soil particles. This means that we can be exposed to gaseous, liquid and solid forms of soil pollution separately or together at the same time. Soil pollution may enter our bodies **directly** - through the inhalation of soil dust or soil particles, or through skin contact, or **indirectly** - through the consumption of food, especially vegetables grown in contaminated soil, or by inhaling the toxic vapors of volatile chemicals polluting the soil.

The exposure to environmental pollution caused by soil contaminants may result in an increased risk for developing a series of conditions.

Short Term Diseases and Symptoms:

The exposure to [environmental pollution caused by soil contaminants](#) may result in an increased risk for developing a series of conditions. One of the most frequently encountered effects of toxic contamination is a series of symptoms that appear immediately after the exposure.

The most common symptoms that appear after direct exposure to soil contaminants are the following: headache ,nausea and vomiting, chest pain ,coughing and lung problems ,fatigue ,skin rash and eye irritations

Along with the symptoms listed above, other conditions may appear after direct or indirect contact with soil contaminants.

Long Term Diseases

The inhalation of soil particulate matter and the ingestion of contaminated food can potentially result in serious conditions, of which the most common include:

Cancer including leukemia : Pesticides, benzene, chromium and herbicides are carcinogens which have been established to lead to all kinds of cancer. Long-term benzene exposure is responsible for irregular menstrual cycles in women, leukemia and anemia. A high level of exposure to benzene is fatal. Benzene is a liquid chemical found in crude oil, gasoline and cigarette smoke. It is used in chemical synthesis and interferes with cellular function by decreasing the production of red blood cells, white blood cells and antibodies, thereby compromising the body's immunity.

Kidney and Liver Disease:

People develop kidney damage when they are exposed to soil which has been contaminated with lead. Soil pollutants like mercury and cyclodienes also greatly increase the possibility of developing irreversible kidney damage. Cyclodienes and

Chemical Pollution **Ph.D. Students**

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PCBs cause toxicity in the liver, as well. This situation is worse for impoverished people who are forced by strained circumstances to live near dump sites, industrial factories and landfills, where they are exposed to soil pollution on a daily basis. They develop impaired immune systems, kidney damage and liver damage, in addition to neurological damage and lung problems.

Brain and Nerve Damage

Children can be exposed to the harmful effects of soil pollution in places like playgrounds and parks, where lead-contaminated soil has been proven to cause brain and neuromuscular development problems.

Chemical water pollution diseases

Water pollution is a huge problem around the world. You've probably heard this, but you might not have ever realized just how significant it really is. Fresh water is being polluted around the world, not just at the surface, but also as deep as groundwater too. Runoff from factories, pollution from dumping, and even the regular use of chemicals in agriculture and around the home contribute to the increase in water contamination around the world.

Unfortunately, this leads to several illnesses caused by water pollution. It's estimated that over 80% of the diseases spread worldwide come from water pollution and that nearly 2 billion deaths every year occur because of this major problem. With so many diseases caused by water contamination, it's a good idea to familiarize yourself with the symptoms in order to recognize any potential problems before they get too bad.

Below are such diseases as well as their causes, risk factors, and more.

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Ulcers : Cause by any type of irritation to the lining of the stomach or intestines, like Chemical pollutants in water, which can damage the

lining of the stomach severely , also Bacteria that may be present in water.

Respiratory Infection

Exposure to chemicals in polluted water ,bacteria that may be ingested through contaminated water and exposure to viruses in water that has been polluted with fecal matter.

Fluorosis :

Over-exposure to water that has been treated with fluoride ,Using fluoride treated toothpaste along with water that already contains too much fluoride and Sometimes referred to as “fluoride poisoning” .

There are some factors which Increase risk includes:

Swallowing toothpaste instead of spitting it out ,Using city water that has been over-treated and drinking other liquids treated with fluoride, such as mouthwash.

Cancer :

There are many causes of cancer, may occur as result of exposure to water that has been contaminated with runoff from nuclear power plants has been known to cause cancer in some individuals. Some factors that Increase Risk include:

Living near a nuclear power facility ,Living near other types of industrial facilities and Drinking or swimming in water near these locations.

Liver Damage

Which caused as result of : Bacteria in water supplies ,Fecal matter in water supplies and Chemicals in water supplies, and weakened immune system ,Very

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young or very old age , frequent use of drugs, tobacco, and alcohol are the factors that increase it risk.

Endocrine Damage

Cause by: Lesions caused by exposure to certain chemicals, Hormone imbalance caused by chemical exposure and Infection from bacteria.

Existing diabetes , Exposure to chemicals and hormones in polluted water and

too much or too little iodine are the factors which increase the risk of this disease.

Lead Poisoning

Was Cause by :Too much lead present in drinking water or Lead present in other sources, such as paint

Some Factors which Increase its risk like:

- Living in an area where lead paint was previously used in homes
- Frequent exposure to lead at work and
- Very young age.

Arsenicosis

Cause by Drinking contaminated groundwater, Drinking surface water that has been contaminated with chemicals and using rainwater without treatment. The factors that Increase Risk includes :

- Frequent exposure to contaminants at the workplace
- Drink water from a well that is made of stone
- Eating undercooked poultry

Heavy metals as more danger chemical pollutants**Dr.Ithar Kamil Abbas**

Metals are substances with high electrical conductivity, malleability, and luster, which voluntarily lose their electrons to form cations. Metals are found naturally in the earth's crust and their compositions vary among different localities, resulting in spatial variations of surrounding concentrations. The metal distribution in the atmosphere is monitored by the properties of the given metal and by various environmental factors .

Heavy metals such as cadmium (Cd), mercury (Hg), lead (Pb), chromium (Cr) and platinum (Pt) are a major environmental and occupational hazard. Unfortunately, these non-essential elements are toxic at very low doses and non-biodegradable with a very long biological half-life. Thus, exposure to heavy metals is potentially harmful. Because of its ability to reabsorb and accumulate divalent metals.

Heavy metal toxicity has proven to be a major threat and there are several health risks associated with it. The toxic effects of these metals, even though they do not have any biological role, remain present in some or the other form harmful for the human body and its proper functioning. They sometimes act as a pseudo element of the body while at certain times they may even interfere with metabolic processes. Few metals, such as aluminium, can be removed through elimination activities, while some metals get accumulated in the body and food chain, exhibiting a chronic nature. Various public health measures have been undertaken to control, prevent and treat metal toxicity occurring at various levels, such as

occupational exposure, accidents and environmental factors. Metal toxicity depends upon the absorbed dose, the route of exposure and duration of exposure, i.e. acute or chronic. This can lead to various disorders and can also result in excessive damage due to oxidative stress induced by free radical formation.

Free radicals : are formed when oxidation occurs, A typical example of oxidation is the browning of a peeled apple when exposed to air. The apple peel contains many antioxidants which prevent oxidation. When removed the apple begins to brown or age. During oxidation, oxygen combines with other molecules in its vicinity. This a normal process , But heavy metals accelerate this process, creating excessive free radical formation and destruction.

Some antioxidant such as vitamin C and E inhibit this process.

Heavy metals are generally referred to as those metals which possess a specific density of more than 5 g/cm^3 and adversely affect the environment and living organisms . These metals are quintessential to maintain various biochemical and physiological functions in living organisms when in very low concentrations, however they become noxious when they exceed certain threshold concentrations. Although it is acknowledged that heavy metals have many adverse health effects and last for a long period of time, heavy metal exposure continues and is increasing in many parts of the world. Heavy metals are significant environmental pollutants and their toxicity is a problem of increasing significance for ecological, evolutionary, nutritional and environmental reasons.

Heavy metals and their toxicity mechanism:

Lead

Lead is a highly toxic metal whose widespread use has caused extensive environmental contamination and health problems in many parts of the world. It is a bright silvery metal, slightly bluish in a dry atmosphere. It begins to tarnish on contact with air, thereby forming a complex mixture of compounds depending on the given conditions. . The sources of lead exposure include mainly industrial processes, food and smoking, drinking water and domestic sources. The sources of lead were gasoline and house paint, which has been extended to lead bullets, plumbing pipes, pewter pitchers, storage batteries, toys and faucets. In the US, more than 100 to 200,000 tons of lead per year is being released from vehicle exhausts. Some is taken up by plants, fixation to soil and flow into water bodies, hence human exposure of lead in the general population is either due to food or drinking water. Lead is an extremely toxic heavy metal that disturbs various plant physiological processes and unlike other metals, such as zinc, copper and manganese, it does not play any biological functions. A plant with high lead concentration fastens the production of reactive oxygen species (ROS), causing lipid membrane damage that ultimately leads to damage of chlorophyll and photosynthetic processes and suppresses the overall growth of the plant , Some research revealed that lead is capable of inhibiting the growth of tea plant by reducing biomass and debases the tea quality by changing the quality of its components . Even at low concentrations, lead treatment was found to cause huge instability in ion uptake by plants, which in turn leads to significant metabolic changes in photosynthetic capacity and ultimately in a strong inhibition of plant growth .

Lead metal causes toxicity in living cells by following ionic mechanism and that of oxidative stress. Many researchers have shown that oxidative stress in living cells is caused by the imbalance between the production of free radicals and the generation of antioxidants to detoxify the reactive intermediates or to repair the resulting damage.

The ionic mechanism of lead toxicity occurs mainly due to the ability of lead metal ions to replace other bivalent cations like Ca^{2+} , Mg^{2+} , Fe^{2+} and monovalent cations like Na^{+} , which ultimately disturbs the biological metabolism of the cell. The ionic mechanism of lead toxicity causes significant changes in various biological processes such as cell adhesion, intra- and inter-cellular signaling, protein folding, maturation, apoptosis, ionic transportation, enzyme regulation, and release of neurotransmitters. Lead can substitute calcium even in picomolar concentration affecting protein kinase C, which regulates neural excitation and memory storage.

Mercury

The metallic mercury is a naturally occurring metal which is a shiny silver-white, odorless liquid and becomes colorless and odorless gas when heated. Mercury is very toxic and exceedingly bioaccumulative. Its presence adversely affects the marine environment and hence many studies are directed towards the distribution of mercury in water environment. Major sources of mercury pollution include anthropogenic activities such as agriculture, municipal wastewater discharges, mining, incineration, and discharges of industrial wastewater .

Mercury exists mainly in three forms: metallic elements, inorganic salts and organic compounds, each of which possesses different toxicity and bioavailability. These forms of mercury are present widely in water resources such as lakes, rivers and oceans where they are taken up by the

microorganisms and get transformed into methyl mercury within the microorganism, eventually undergoing biomagnification causing significant disturbance to aquatic lives. Consumption of this contaminated aquatic animal is the major route of human exposure to methyl mercury . Mercury is extensively used in thermometers, barometers, pyrometers, hydrometers, mercury arc lamps, fluorescent lamps and as a catalyst. It is also being used in pulp and paper industries, as a component of batteries and in dental preparations such as amalgams.

Mercury is well known as a hazardous metal and its toxicity is a common cause of acute heavy metal poisoning with cases of 3,596 in 1997 by the American Association of Poison Control Centers. Methylmercury is a neurotoxic compound which is responsible for microtubule destruction, mitochondrial damage, lipid peroxidation and accumulation of neurotoxic molecules such as serotonin, aspartate, and glutamate

The total amount of mercury emission into the environment has been assessed at 2,200 metric tons annually . It is estimated that 8 to 10% of American women have mercury levels that would induce neurological disorders in any child they gave birth to, according to both the Environmental Protection Agency and National Academy of Science . Animals which are exposed to toxic mercury have shown adverse neurological and behavioral changes. Rabbits when exposed to 28.8 mg/m³ mercury vapor for 1 to 13 weeks have shown vague pathological changes, marked cellular degeneration and brain necrosis .

The brain remains the target organ for mercury, yet it can impair any organ and lead to malfunctioning of nerves, kidneys and muscles. It can cause disruption to the membrane potential and interrupt with

intracellular calcium homeostasis. Mercury binds to freely available thiols as the stability constants are high . Mercury vapors can cause bronchitis, asthma and temporary respiratory problems. Mercury plays a key role in damaging the tertiary and quaternary protein structure and alters the cellular function by attaching to the selenohydryl and sulfhydryl groups which undergo reaction with methyl mercury and hamper the cellular structure. It also intervenes with the process of transcription and translation resulting in the disappearance of ribosomes and eradication of endoplasmic reticulum and the activity of natural killer cells. The cellular integrity is also affected causing free radical formation. The basis for heavy metal chelation is that even though the mercury sulfhydryl bond is stable and divided to surrounding sulfhydryl consisting ligands, it also contributes free sulfhydryl groups to promote metal mobility within the ligands .

Cadmium

Cadmium is the seventh most toxic heavy metal as per ATSDR ranking. It is a by-product of zinc production which humans or animals may get exposed to at work or in the environment. Once this metal gets absorbed by humans, it will accumulate inside the body throughout life. This metal was first used in World War I as a substitute for tin and in paint industries as a pigment. In today's scenario, it is also being used in rechargeable batteries, for special alloys production and also present in tobacco smoke. About three-fourths of cadmium is used in alkaline batteries as an electrode component, the remaining part is used in coatings, pigments and plating and as a plastic stabilizer. Humans may get exposed to this metal primarily by inhalation and ingestion and can suffer from acute and chronic intoxications.

Cadmium distributed in the environment will remain in soils and sediments for several decades. Plants gradually take up these metals which get accumulated in them and concentrate along the food chain, reaching ultimately the human body. In the US, more than 500,000 workers get exposed to toxic cadmium each year as per The Agency for Toxic Substances and Disease Registry .Researches have shown that in China the total area polluted by cadmium is more than 11,000 hectares and its annual amount of industrial waste of cadmium discharged into the environment is assessed to be more than 680 tons. In Japan and China, environmental cadmium exposure is comparatively higher than in any other country .Cadmium is predominantly found in fruits and vegetables due to its high rate of soil-to-plant transfer . Cadmium is a highly toxic nonessential heavy metal that is well recognized for its adverse influence on the enzymatic systems of cells, oxidative stress and for inducing nutritional deficiency in plants .

The mechanism of cadmium toxicity is not understood clearly but its effects on cells are known . Cadmium concentration increases 3,000 fold when it binds to cystein-rich protein such as metallothionein. In the liver, the cystein-metallothionein complex causes hepatotoxicity and then it circulates to the kidney and gets accumulated in the renal tissue causing nephrotoxicity. Cadmium has the capability to bind with cystein, glutamate, histidine and aspartate ligands and can lead to the deficiency of iron . Cadmium and zinc have the same oxidation states and hence cadmium can replace zinc present in metallothionein, thereby inhibiting it from acting as a free radical scavenger within the cell.

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Chemical Pollution-8 **Ph.D. Students**

Chemical Pollution-8 **Ph.D. Students**

Prof.Dr.Ithar Kamil Abbas

Chromium : Chromium is the seventh most abundant element on earth . Chromium occurs in several oxidation states in the environment ranging from Cr^{2+} to Cr^{6+} .The most commonly occurring forms of Cr are trivalent- Cr^{+3} and hexavalent- Cr^{+6} , with both states being toxic to animals, humans and plants .

Chromium occurs naturally by the burning of oil and coal, petroleum from ferrocromate refractory material, pigment oxidants, catalyst, chromium steel, fertilizers, oil well drilling and metal plating tanneries. Anthropogenically, chromium is released into the environment through sewage and fertilizers . Cr(III) is immobile in its reduced form and is insoluble in water whereas Cr(VI) in its oxidized state is highly soluble in water and thus mobile .

In order to determine the activities of the metal ions in the environment, metal speciation is very important where in case of chromium the oxidative form of Cr(III) is not an essential contaminant of the ground water but Cr(VI) has been found to be toxic for humans . Cr(III) resides in the organic matter of soil and aquatic environment in the form of oxides, hydroxides and sulphates . Chromium is extensively used in industries such as metallurgy, electroplating, production of paints and pigments, tanning, wood preservation, chemical production and pulp and paper production. These industries play a major role in chromium pollution with an adverse effect on biological and ecological species .

The mechanism of ultrastructural organization, biochemical changes and metabolic regulations has not been clarified since the process of phytotoxicity in the aquatic environment by chromium has not been concentrated on in detail). The discharge of industrial wastes and ground water contamination has drastically increased the concentration of chromium in soil. During manufacturing of chromate, the deposit of the Cr residues and waste water irrigation posed a serious Cr pollution to farmland.

With the implementation of modern agriculture there is continuous release of Cr into the environment by means of Cr residues, Cr dust and Cr waste water irrigation, resulting in soil pollution affecting the soil-vegetable system and also disturbing the vegetable yield and its quality to humans. The presence of excess of chromium beyond the permissible limit is destructive to plants since it severely affects the biological factors of the plant and enters the food chain on consumption of these plant materials. Common features due to Cr phytotoxicity are reduction in root growth, leaf chlorosis, inhibition of seed germination and depressed biomass. Chromium toxicity greatly affects the biological processes in various plants such as maize, wheat, barley, cauliflower, citrullus and in vegetables.

Enzymes like catalase, peroxidase and cytochrome oxidase with iron as their component are affected by chromium toxicity. The catalase activity stimulated with excess supply of chromium inducing toxicity has been studied with respect to photosynthesis, nitrate reductase activity, protein content in algae and photosynthetic pigments. Chromium (III) requires a simple diffusion process to enter into the cell and does not depend on any

specific membrane carrier. In contrast to Cr(III), Cr(IV) can easily pass through the cell membrane .

In the environment, trivalent chromium Cr(III) is generally harmless due to its weak membrane permeability. Hexavalent chromium Cr(VI), on the other hand, is more active in penetrating the cell membrane through passages for isoelectric and isostructural anions such as SO_4^{2-} and HPO_4^{2-} channels and these chromates are taken up through phagocytosis. Cr(VI) is a strong oxidizing agent and can be reduced to give ephemeral species of pentavalent and tetravalent chromium that are different from that of Cr(III). Stabilization of the pentavalent form is carried out by glutathione and hence intracellular reduction of Cr(VI) is considered a detoxification mechanism when reduction occurs away from the target region. However if intracellular reduction of Cr(VI) occurs near the target site, it may serve to activate Cr. The reactions between Cr(VI) and biological reductants like thiols and ascorbate result in the production of reactive oxygen species such as superoxide ion, hydrogen peroxide, and hydroxyl radical, ultimately leading to oxidative stress in the cell causing damage to DNA and proteins. According to literature surveys, Cr(VI) has been found to be much more dangerous than Cr(III), since Cr(VI) enters the cells more readily than does Cr(III) and is eventually reduced to Cr(III). Because of its mutagenic properties, Cr(VI) is categorized as a group 1 human carcinogen by the International Agency for the Research on Cancer.

Aluminum

Aluminum is the third most abundant element found in the earth's crust. Aluminum occurs naturally in the air, water and soil. Mining and

processing of aluminum elevates its level in the environment . Recent investigations on environmental toxicology revealed that aluminum may present a major threat for humans, animals and plants in causing many diseases).

Many factors, including pH of water and organic matter content, greatly influence the toxicity of aluminum. With decreasing pH its toxicity increases. The mobilization of toxic aluminum ions, resulting from changes in the pH of soil and water caused by acid rains and increasing acidification of the surrounding atmosphere, has an adverse effect on the environment. This is manifested by the drying of forests, plant poisoning, crop decline or failure, death of aquatic animals, and also by various imbalances in the function of human and animal systems. A pH of surface layer of soil below 5 (pH<5) can lead to soil acidity which is a major concern around the world that affects crop production. Due to aluminium toxicity, the crop production was constrained to 67% of the total acid soil area in the world. Aluminum is one of the most commonly found elements in the earth crust. Due to acid soils (pH<5), silicon gets leached leaving behind aluminum in solid form known as aluminum oxyhydroxides, such as gibbsite and boehmite. These unstable forms of aluminum discharge phytotoxic Al^{3+} well-known as $Al(OH)^{3+}$ in soil .

The interaction of Al^{3+} with apoplastic, plasma membrane, and symplastic targets leads to toxicity and distracts the physical and cellular processes in plants. The common manifestations are root growth inhibition, cellular modification in leaves, small and dark green leaves, yellowing and death of leaves, chlorosis, purpling and foliar necrosis. Aluminum in high concentrations is very toxic for aquatic animals, especially for gill breathing organisms such as fish, causing osmoregulatory failure by destructing the plasma and hemolymph ions.

The activity of gill enzyme, essential for the uptake of ions, is inhibited by the monomeric form of aluminum in fish. Living organisms in water, such as seaweeds and crawfish, is also affected by Al toxicity .

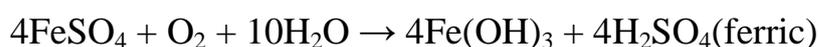
Aluminum has no biological role and is a toxic nonessential metal to microorganisms . Enzymes such as hexokinase, phosphodiesterase, alkalic phosphatase and phosphoxidase are inhibited by aluminum since it has a greater affinity to DNA and RNA. Metabolic pathways in the living organism involving calcium, phosphorous, fluorine and iron metabolism are affected by aluminum. Aluminum has been found to be very harmful to nervous, osseous and hemopoietic cells .

Aluminum interferes with most physical and cellular processes. The exact mechanism of absorption of aluminum by the gastrointestinal tract is not understood completely. Based on literature surveys, it is difficult to give a proper time period for aluminum toxicity since some symptoms of aluminum toxicity can be detected in seconds and others in minutes after exposure to aluminum . Aluminum toxicity probably results from the interaction between aluminum and plasma membrane, apoplasmic and symplasmic targets . In humans Mg^{2+} and Fe^{3+} are replaced by Al^{3+} , which causes many disturbances associated with intercellular communication, cellular growth and secretory functions. The changes that are evoked in neurons by aluminum are similar to the degenerative lesions observed in Alzheimer patients.

Iron

Iron is the second most abundant metal on the earth's crust . Iron occupies the 26th elemental position in the periodic table. Iron is a most crucial element for growth and survival of almost all living organisms . It is one of the vital components of organisms like algae and of enzymes

such as cytochromes and catalase, as well as of oxygen transporting proteins, such as hemoglobin and myoglobin . Iron is an attractive transition metal for various biological redox processes due to its inter-conversion between ferrous (Fe^{2+}) and ferric (Fe^{3+}) ions . The source of iron in surface water is anthropogenic and is related to mining activities. The production of sulphuric acid and the discharge of ferrous (Fe^{2+}) takes place due oxidation of iron pyrites (FeS_2) that are common in coal seams . The following equations represent the simplified oxidation reaction for ferrous and ferric iron :



The concentration of dissolved iron in the deep ocean is normally 0.6 nM or 33.5×10^{-9} mg/L. In freshwater the concentration is very low with a detection level of 5 $\mu\text{g/L}$ – ICP, whereas in groundwater the concentration of dissolved iron is very high with 20 mg/L . In countries like Lithuania, many people have been exposed to elevated levels of iron through drinking water, as the collected groundwater exceeded the permissible limit set by the European Union Directive 98/83/EC on the quality of drinking water . The abundance of species such as periphyton, benthic invertebrates and a fish diversity are greatly affected by the direct and indirect effects of iron contamination . The iron precipitate will cause considerable damage by means of clogging action and hinder the respiration of fishes .

A study of iron toxicity on aquatic plants, particularly rice, reported that the growth of species of aquatic reed was found to be inhibited by concentration of 1 mg/L total iron . Acid soils restrict rice production and together with Zn deficiency cause a macronutrient disorder in wetland

rice. The production of lowland rice was greatly affected by high concentrations of reduced iron (Fe^{2+}) in the flooded soils. The features of iron toxicity in rice include high uptake of Fe^{2+} by roots, acropetal translocation into leaves, bronzing of rice leaves and yield loss .

A wide range of harmful free radicals are formed when the absorbed iron fails to bind to the protein, which in turn severely affects the concentration of iron in mammalian cells and biological fluids. This circulating unbound iron results in corrosive effect of the gastrointestinal tract and biological fluids. An extremely higher level of iron enters into the body crossing the rate-limiting absorption step and becomes saturated. These free irons penetrate into cells of the heart, liver and brain.

Due to the disruption of oxidative phosphorylation by free iron, the ferrous iron is converted to ferric iron that releases hydrogen ions, thus increasing metabolic acidity.

The free iron can also lead to lipid peroxidation, which results in severe damage to mitochondria, microsomes and other cellular organelles .

The toxicity of iron on cells has led to iron mediated tissue damage involving cellular oxidizing and reducing mechanisms and their toxicity towards intracellular organelles such as mitochondria and lysosomes. A wide range of free radicals that are believed to cause potential cellular damage are produced by excess intake of iron. The iron produced hydrogen free radicals attack DNA, resulting in cellular damage, mutation and malignant transformations which in turn cause an array of diseases .

How heavy metals effects Human Health

Dr.Ithar Kamil Abbas

The biological terrain of the body is all about the vital balance of biochemistry and biophysics that establishes the internal environment in which the cells function; that in turn determines health. A well-balanced mineral count is one of the essential parameters for a healthy biological terrain; this is determined by diet, digestion, emotional/mechanical stressors, and environmental pollution (specifically heavy metal burden or intoxication). In 1974, the World Health Organization had suggested that at least 80% of all chronic disease conditions can be attributed to environmental pollution one way or another; and that of all the pollutants, heavy metals pose the biggest threat to our health. They can either directly or indirectly cause, contribute, or worsen nearly every disease or illness we know. They have a devastating influence on our physical, mental, and emotional well-being.

The major cause for all degenerative diseases is the overproduction of free radicals; pollution elevates the production of free radicals that cause oxidation and hence the stage is set for bacteria, viruses, and degenerative diseases to develop. Of the many producers of oxidants, heavy metals are among the most dangerous, because they are not metabolized or broken down, instead, are accumulated and stored in the tissues and organs. It is difficult to avoid heavy metals since they're present in our air, water, food, cosmetics, vaccines, medical drugs, paints, hobbies, and even in our mouths if we have silver-mercury amalgam fillings. They enter the body through inhalation, intestinal absorption, as well as absorption through the skin. In most cases of body burdens, it is the metabolic disturbance

that leads to the increased retention of heavy metals, although the reverse is true as well in that heavy metal accumulation leads to metabolic disturbance; either one can happen first. Deviation from normal digestion and proper protein metabolism, as well as diet, nutritional status, stress, and illness will allow heavy metals to accumulate in the body; this allows them to contribute with their adverse effects on the very conditions that invited them in at the first place. Once absorbed into the body, heavy metals have a wide distribution in various organs, glands, and the central nervous system. Some metals seek bones and therefore settle into the skeletal system and the teeth. Organo-metallic forms of heavy metals can readily pass through membranes and even cross the blood-brain barrier. They can poison enzyme systems, effectively increase free radical production, and displace or compete with essential elements that make up metallo-enzyme complexes, thus interfering with the absorption of nutritional minerals.

Heavy metals are a major source of free radicals that cause cell-damage by oxidation (loss of electrons); this causes the blood to pass protons into the urine which now becomes more acidic as a result of higher proton concentration in it. The body's elimination system is able to get rid of these excess protons; however, a small accumulation of them occurs into the connective tissue and absorption into the cell follows. Once the proton gets inside the cell, intra-cellular potassium will be excreted and washed out with the urine to maintain electrical balance. This leads to an overall body tissue acidification and hence slowing down of all metabolic and digestive processes, diminished kidney function, and a decreased enzyme activity. Degenerative diseases are the outcome of this kind of situation; these result in chronic pain and inflammation which are a major source of free radical production that in turn will cause

further oxidation, thus completing a vicious cycle. Heavy metals like cadmium, lead, mercury and more are so pervasive in our society today that it is no longer a question of whether or not we are toxic, but rather what our toxicity level is.

They disturb the biological terrain of the human body, thereby creating an environment conducive to the development of pathogens that thrive in that specific condition. Usually pathogens and disease occurred only when the biological terrain was destabilized or when an imbalance was present.

Additionally, heavy metals harm the body by tying up binding sites on cells, preventing essential minerals from getting in. In the human system, bivalent metals are engaged in a continuous fight for the site against one another; the result is displacement of the element of lesser atomic mass by another of a heavier atomic mass. Heavy metals grab the biological spaces that would've been filled with necessary minerals that are lighter in mass. As an example, mercury and cadmium that are toxic heavy metals are under the same group in the periodic table of elements as zinc which is a beneficial mineral; mercury and cadmium, being heavier than zinc, can prevent it from being utilized and thus resulting in zinc deficiency. Zinc will be displaced from its biological site in the presence of either one of these two heavy metals. PMS, fatigue, thyroid issues, loss of smell and taste, macular degeneration, prostate enlargement, rheumatoid arthritis, low libido, sterility, immune suppression are only some of the symptoms of zinc deficiency. If ratio of protective nutritional metal to toxic heavy metal falls below an ideal level, then the heavy metal could be interfering with the function of the protective metal, even if heavy metal is not in a toxic reference range.

The success of a medical treatment for a health condition, related to chronic metal poisoning, is dependent upon heavy metal elimination from the body in a safe manner. Heavy metal detoxification programs improve overall immune response and get rid of allergies, headaches, depression, fatigue, pain, digestive issues, weight issues, irritability, brain fog and many more conditions that may have resulted from those toxic loads. Lowering heavy metal loads has turned around heart disease and diabetes, has improved memory, mood, and IQ.

The following is a list of some conditions and/or symptoms that could be attributed to heavy metal load in the body: Parkinson's, Alzheimer's, Autism, ALS, Lupus, Multiple Sclerosis, Asthma, Fibromyalgia, PMS, Hypoglycemia, Crohn's Disease, Arthritis, Type 2 Diabetes, impotence, low libido, liver disorder, kidney disease, skin issues, anger, irritability, mood swings, headaches, inability to concentrate, light sensitivity, loss of smell and taste, metallic taste, muscle twitches or tremors, ulcers, constipation, gas and bloating, rashes, poor lower body circulation, muscle cramps, cold or numb hands and feet, thyroid issues, yeast infections, fatigue, low body temperature, allergies, and overburdened immune system. Heavy metals, particularly mercury, kill the friendly bacteria in the gut that are beneficial for the internal mucosa that's there to protect the gut from toxins or allergens. A compromised gut overburdens the immune system and results in allergies. Furthermore, heavy metals bind to proteins in the body; recognized as foreign, they are attacked by the immune system leading to auto-immune disorders. A rise in cholesterol accompanies the inflammatory response in order to protect the nerves and brain against exposure to fat-soluble toxins and heavy metals; this can cause cardiovascular disease. As for cancer, heavy metals contribute to an acidified tissue in which cancer cells thrive, they exhaust

the immune system by constant inflammatory response, and they bind to oxygen in the blood causing lack of energy and a low oxygen environment that is favorable for cancer cells. Heavy metals combine with bile resulting in a favorable environment for parasites and bacteria to flourish; these will plug up the hepatic or bile duct and hence causing digestive issues. The blocked gallbladder will not be able to process good oils, which will result in low levels of good oils, which in turn affects hormone production. All heavy metals destroy the nervous tissue by the huge number of free radicals they produce. They also inhibit the effects of certain neurotransmitters, causing depression. Adrenal glands can weaken and burn out as they try to self-regulate the compromising effects of heavy metals, leading to fatigue, since the adrenal glands put out the energy hormone Adrenaline.

In light of the above, heavy metal testing followed by treatment for its elimination are obviously key factors in paving the way to homeostasis. Traditional methods of testing, like hair or blood analysis, in some instances may not differentiate between organically bound metal atoms and unbound metal ions that are active electromagnetically; this is because the organic sample is destroyed in the course of analysis. Additionally, external contaminants of heavy metals on the hair samples could result in false positives. On the other hand, heavy metal ions are successfully detected by means of a dithizone process, in bodily liquids like urine and saliva. As a reagent, dithizone is able to accurately indicate the presence of heavy metal ions, both in qualitative and quantitative terms. The latter testing method is a non-invasive, fast, easy, affordable, and reliable way to assess heavy metal load, in comparison to other methods.

Common Diseases occur as result of exposure to heavy metals.

Alzheimer Disease

Alzheimer's is so common today that it has become a 'normal' part of aging. Even more disturbing is that rates of early onset Alzheimer's are soaring, with people as young as 40 or 50 experiencing its effects.-

Obviously, prevention is easier than healing, because most neurological diseases do not become apparent until 75% of brain cells in the affected area have died.

There are many factors that can bring on Alzheimer's including physical and emotional stress and free radical formation. Toxic elements such as mercury, aluminum, copper, fluoride, lead, and cadmium can cause an acceleration of free radical formation.

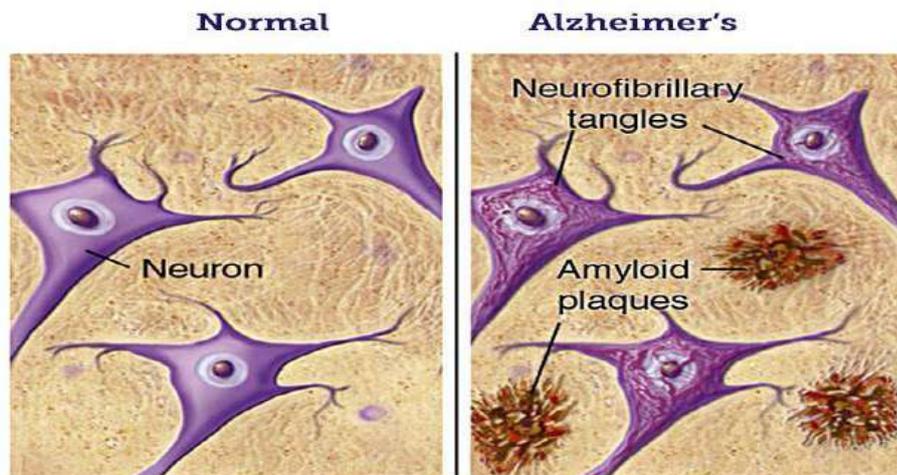
Epidemiological studies have shown an association between heavy metals such as lead (Pb), cadmium (Cd), and mercury (Hg) and AD, because of their involvement in cell toxicity and epigenetic mechanisms . One of the major effects of the heavy metals at both poisoning levels and long term exposure to low levels is insufficient supply of oxygen to the brain and results in anoxia/hypoxia in the brain (no oxygen or little oxygen), leading to serious brain injuries . On the other hand, changes in the levels of biologically important metal ions, regarded as essential for human health in trace amounts including iron (Fe), zinc (Zn), copper (Cu), manganese (Mn), chromium (Cr), and molybdenum (Mo) because they form an integral part of one or more enzymes, could affect their normal function and consequently, the metabolic or biochemical processes in which they are involved. In particular, metals such as iron, zinc, and copper appear to be deregulated in AD.

In many studies, aluminum has been shown to be neurotoxic. In one study, patients with Alzheimer's had the highest levels of aluminum ever recorded. Aluminum can be found in aluminum cookware (coffee pots, teflon), aluminum foil, silver amalgams, antacids, buffered aspirin, and vaccines. Over time, these toxic heavy metals accumulate in our bodies, especially in the fat cells. With age the blood brain barrier begins to fail, allowing toxic elements in the blood to enter the cells in the brain. Since the brain is 60% fat, the fat in the brain cells capture and lock in these damaging toxins. Part of the reason these toxic heavy metals cause so much damage is because they accelerate free radical production in the body.

What is Alzheimer's disease:

Alzheimer's disease (AD) is the most common cause of dementia and the main pathological feature is massive neuronal loss in areas of the brain responsible for memory and learning. In the brain, the major neuropathological hallmarks associated with this disease are the presence of amyloid- β ($A\beta$) plaques and neurofibrillary tangles (NFTs) of hyperphosphorylated microtubule-associated tau, as well as synaptic loss.

Normal vs. Alzheimer's Diseased Brain



Amyloid plaques and Neurofibrillary tangles in Normal and Alzheimer's Disease brain

The formation of amyloid plaques and neurofibrillary tangles are thought to contribute to the degradation of the neurons (nerve cells) in the brain and the subsequent symptoms of Alzheimer's disease.

Amyloid Plaques : One of the hallmarks of Alzheimer's disease is the accumulation of amyloid plaques between nerve cells (neurons) in the brain. Amyloid is a general term for protein fragments that the body produces normally. Beta amyloid is a protein fragment snipped from an amyloid precursor protein (APP). In a healthy brain, these protein fragments are broken down and eliminated. In Alzheimer's disease, the fragments accumulate to form hard, insoluble plaques.

Neurofibrillary Tangles : Neurofibrillary tangles are insoluble twisted fibers found inside the brain's cells. These tangles consist primarily of a protein called tau, which forms part of a structure called a microtubule. The microtubule helps transport nutrients and other important substances from one part of the nerve cell to another. In Alzheimer's disease,

however, the tau protein is abnormal and the microtubule structures collapse.

A multi-institutional team of researchers has defined for the first time how metal ions bind to amyloid fibrils in the brain in a way that appears toxic to neurons. Amyloid fibrils are linked to the development of neurodegenerative diseases such as Alzheimer's, Parkinson's and Creutzfeldt-Jakob. Although metal ions, most notably copper, can bind to amyloid in several specific ways, the researchers found that only one way appears toxic. Amyloids are typically hard, waxy deposits consisting primarily of protein found in body tissue.

Copper ions, atoms that have acquired an electric charge by gaining or losing one or more electrons, are found naturally in the brain, as are other ions such as zinc and iron. Increasing evidence now links these naturally occurring ions to amyloid assembly and to Alzheimer's disease.

There is evidence to support that alteration of metal ion homeostasis leads to neuronal death. Redox metal ions are instrumental in enhancing the production of reactive oxygen species (ROS), affecting cellular redox homeostasis (e.g., the depletion of glutathione), and/or the disruption of mitochondrial function (e.g., dissipation of mitochondrial inner membrane potential). Ion metal dysregulation can also induce intracellular free calcium $[Ca^{2+}]$, which is part of a signaling pathway leading to cell death.

While little is known about the exact mechanisms governing the formation of amyloid fibrils, the study's results suggest that the exact way amyloid binds to copper ions affects the fibers' architecture, rate of propagation and their effect, if any, on surrounding neurons.

"Not all amyloid fibrils are toxic," according for some researches , also "Amyloid is made of proteins, and proteins normally fold into beautiful structures. However, for whatever reason, some misfold and the resulting misfolded structures are also beautiful, but sticky. They stick to themselves and then propagate to form fibrils, but only some of the fibrils turn out to be toxic."

Those who suffer from Alzheimer's disease, for example, have an unusual amount of sticky amyloid fibrils in their brains. Over time, the fibrils accumulate instead of decomposing and increasingly interfere with the brain's structure and function. In contrast, normally folded proteins are cleared from the brain shortly after they are produced.

The scientists, collaborating throughout the United States and across Emory, focused on the smallest individual unit of amino acids that make up amyloid fibrils. By determining only an individual unit's physical and chemical properties when binding with metal, the researchers were able to determine the activity governing the assembly and toxicity of whole fibrils with respect to their effect on brain cells.

They found "that the activity of this minimal unit actually replicates the activity of the whole fibril on the neuronal cell. And it does so by binding the metal in a specific way" .

Forty years ago, scientists began exploring a possible link between overexposure to metals and Alzheimer's disease. Because some people with the disease had aluminum deposits in their brains, it was thought that there was a direct connection between aluminum exposure and Alzheimer's. However, after many years of study, no conclusive evidence links aluminum to neurodegenerative disease, which leaves researchers to focus on zinc, iron and copper.

The researchers also found that several distinct types of structures could be assembled from individual units of amino acids. "they found that we could build lots of different types of structures with an individual unit: fettuccine-shaped structures, tubes, vesicles, and so on, not just fibers.

"The scientist mention to ask what other types of structures these individual units can make, what exactly happens when the units bind to one another, and whether these individual units are important to neurodegenerative diseases or whether the entire fibril must be involved,">. "Like many scientific findings, we know about amyloid because of the diseases it's associated with rather than because of its benefits. "However, researchers are also finding situations in which amyloid is beneficial, such as in long-term memory and synapse maintenance in the marine snail."

Aluminum and Alzheimer's disease

Aluminum was the first metal that was proposed as a possible cause for Alzheimer's disease, leading to panic about the aluminum found in soda cans, cook wear, and many processed foods. In 1965, researchers showed that rabbits injected with aluminum developed toxic tau fibrils in their brains . Multiple studies have since verified this finding in mice, rats, cats, and monkeys .

More than sixty years after the initial experiments, we still have not come to a consensus on whether aluminum exposure can lead to Alzheimer's. Studies have demonstrated that only levels of aluminum far exceeding those found in the body are capable of promoting amyloid-beta aggregation . In addition, multiple studies have failed to find an association between exposure to aluminum (within normal safety guidelines) and risk of Alzheimer's. On the other hand, experiments in

which rats are chronically exposed to aluminum show accumulation of aluminum in their brains, particularly in the hippocampus (the brain's memory center). These rats experienced memory impairments as a result of their aluminum exposure. Overall, it's possible that aluminum contributes in some form to the pathology of Alzheimer's, but there is not enough evidence to conclude a causative relationship.

Zinc, Copper, and Iron

The biometals zinc, copper, and iron play a variety of important roles in the brain, including cell signaling and neuroplasticity. However, too much of these metals may be harmful for our health. In cell cultures, physiological concentrations of zinc and iron (possibly copper as well, but this is less clear) can promote the formation of amyloid-beta plaques. In addition, all three of these biometals can accelerate the aggregation of tau, another toxic protein found in Alzheimer's disease. Copper and iron are also believed to contribute to oxidative stress, **Oxidative stress** is a chemical process involving free oxygen radicals that gradually leads to cell damage and aging; the reason antioxidants are good for us is because they get rid of these free oxygen radicals.

Despite these results, there's more to the biometals than meets the eye, particularly for zinc. The so-called "zinc paradox" arises from seemingly-contradictory evidence suggesting that zinc can also be neuroprotective in Alzheimer's disease. When zinc binds to amyloid-beta, it changes the protein's shape such that its toxicity is reduced. Thus it seems that zinc can stimulate amyloid-beta aggregation but also reduces the toxicity of these aggregates. More research is needed to conclusively determine whether zinc is helpful or harmful in the long-run. As a rule, most researchers agree that these biometals are likely involved in some

way in the pathogenesis of Alzheimer's disease, but there's debate on whether they play a directly causative role. It's also unclear whether risk can be modulated by dietary or environmental exposure to these metals. For example, certain neurological events (such as a stroke or traumatic brain injury) can increase the levels of metal ions in the brain, so it's possible that internal rather than external sources are to blame .

Other Metals

Though the four metals described above have been the main focus of Alzheimer's metallobiology research, it's possible that others could be involved as well. A small number of studies have drawn connections between Alzheimer's and lead, cobalt, cadmium, and manganese, among others. Though there is not nearly enough evidence to make any definitive claims regarding the involvement of these metals in Alzheimer's, they raise the possibility that the onset of Alzheimer's could be exacerbated by chronic exposure to multiple metals simultaneously.

Metal Chelators as Alzheimer's Drugs

If metals are indeed involved in the development of Alzheimer's, it follows that metal chelators could be useful in the treatment of Alzheimer's disease. Chelators are compounds that bind to metal ions and help to expel them from the body. Several types of chelators have been tested in animal and human trials for Alzheimer's. Many of these drugs showed promise, but none have been approved for patient use, most often due to severe side effects. Current studies is working to improve these early drug and make them safer for widespread use .

Reducing Exposure to Metals

At present, there simply isn't enough evidence to conclusively say that exposure to common metals can lead to Alzheimer's disease. The most likely possibility is that metal exposure alone is not sufficient to cause Alzheimer's, but it may contribute to disease pathology in combination with other factors including genetics, diet, exercise, and mental stimulation.

However, this does not necessarily mean that we shouldn't take steps to reduce our exposure to metals. Just because there's not enough evidence now, doesn't mean more won't arise in the future. Reducing daily exposure to metals is simple enough that no harm is done even if they turn out to be innocuous in the end. Here are a few easy tips you can consider .

- Unless instructed by a doctor, avoid vitamins or supplements contain very high levels of zinc, copper, or iron. Most people who consume a balanced diet have no need for biometal supplements. Shellfish, meats, and nuts are the best dietary sources of biometals. If you do choose to take supplements, do not exceed 100% of the daily recommended value.
- If your drinking water comes from copper pipes or faucets, run the water for 15-30 seconds each morning before drinking.
- Reduce your intake of red meat and highly processed foods.
- The levels of aluminum or copper in cookwear are generally considered safe, but may increase when they are used to cook highly acidic foods (such as spicy foods or tomato sauce). Consider switching to glass or stainless steel.

- Limit your use of antacids and aspirins that contain aluminum.
- When baking, use parchment paper instead of foil.