Unit 1 Air Pollution
空 气 污 染

Acid Rain
酸 雨

Acid rain is a rain or any other forms of ***precipitation*** that is unusually acidic, i.e., elevated levels of ***hydrogen*** ions (low pH). It can have harmful effects on plants, aquatic animals, and infrastructure through the process of wet deposition. Acid rain is caused by emissions of sulfur dioxide and nitrogen oxides which react with the water molecules in the atmosphere to produce acids. Governments have made efforts since the 1970s to reduce the release of sulfur dioxide into the atmosphere with positive results. Nitrogen oxides can also be produced naturally by lightning strikes and sulfur dioxide is produced by ***volcanic eruptions***.

1. Definition

"Acid rain" is a popular term referring to the deposition of wet (rain, snow, sleet, fog, cloud water, and dew) and dry (acidifying particles and gases) acidic components. A more accurate term is "acid deposition". Distilled water, once carbon dioxide is removed, has a neutral pH of 7. Liquids with a pH less than 7 are acidic, and those with a pH greater than 7 are ***alkaline***. "Clean" or unpolluted rain has a slightly acidic pH of over 5.7, because carbon dioxide and water in the air react together to form carbonic acid, but unpolluted rain also contains other chemicals.

$$H_2O\,(l) + CO_2(g) \rightleftharpoons H_2CO_3(aq)$$

Carbonic acid then can ionize in water forming low concentrations of hydronium and hydrogen carbonate ions:

$$H_2O\,(l) + H_2CO_3(aq) \rightleftharpoons HCO_3^-(aq) + H_3O^+(aq)$$

Acid deposition as an environmental issue would include additional acids

to H_2CO_3.

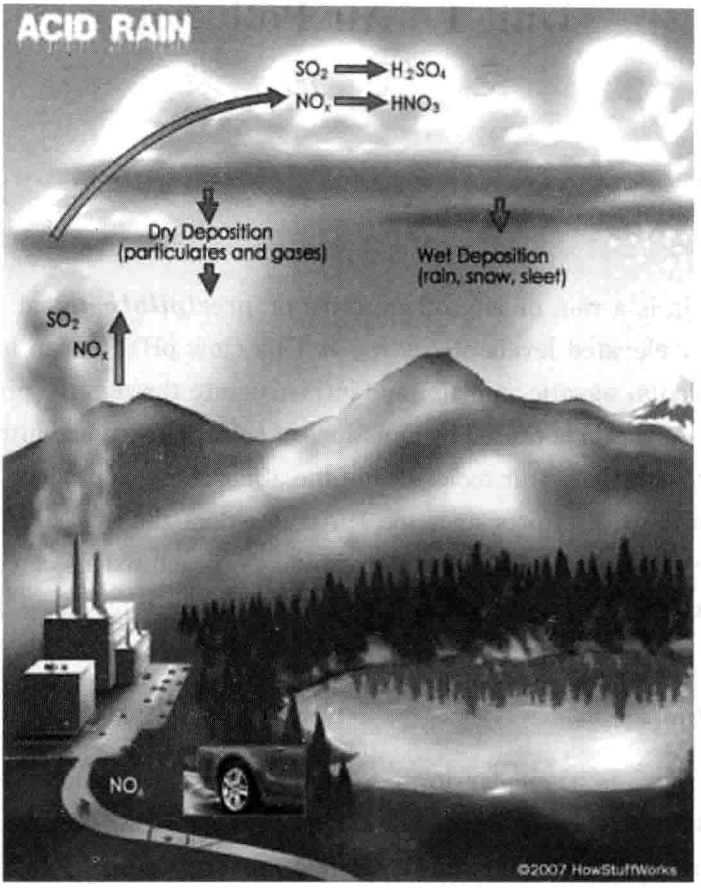

Fig. 1　Emissions of sulfur dioxide and nitrogen oxides react with water vapor in the atmosphere to create sulfuric and nitric acids

(Source: http://science. how stuff works. com/nature/climate-weather/atmospheric/acid-rain. htm)

2. Emissions of chemicals leading to acidification

The most important gas which leads to acidification is sulfur dioxide. Emissions of nitrogen oxides which are oxidized to form nitric acid are of increasing importance due to stricter controls on emissions of sulfur containing compounds. 70 Tg(S) (1 kilogram = 0.000000001 teragram(Tg)) per year in the form of

SO_2 comes from fossil fuel combustion and industry, 2.8 Tg(S) from wildfires and 7—8 Tg(S) per year from volcanoes.

3. Natural phenomena

The principal natural phenomena that contribute acid-producing gases to the atmosphere are emissions from volcanoes. Thus, for example, fumaroles from Laguna Caliente crater of Poás Volcano create extremely high amounts of acid rain and fog with acidity 2 of pH, clearing an area of any vegetation and frequently causing irritation to the eyes and lungs of inhabitants in nearby settlements. Acid-producing gases are created also by biological processes that occur on the land, in wetlands, and in the oceans. The major biological source of sulfur containing compounds is ***dimethyl*** sulfide.

Nitric acid in rainwater is an important source of fixed nitrogen for plant life, and is also produced by electrical activity in the atmosphere such as lightning. Acidic deposits have been detected in glacial ice thousands of years old in remote parts of the globe. Soils of coniferous forests are naturally very acidic due to the shedding of needles and this phenomenon should not be confused with acid rain.

4. Human activity

The principal cause of acid rain is sulfur and nitrogen compounds from human sources, such as electricity generation, factories, and motor vehicles. Coal power plants are one of the most polluting. The gases can be carried hundreds of kilometers in the atmosphere before they are converted to acids and deposited. In the past, factories had short funnels to let out smoke but this caused many problems locally; thus, factories now have taller smoke funnels. However, dispersal from these taller stacks causes pollutants to be carried farther, causing widespread ecological damage. Also, livestock production plays a major role.

5. Chemical processes

Combustion of fuels creates sulfur dioxide and nitric oxides. They are converted into sulfuric acid and nitric acid.

6. Gas phase chemistry

In the gas phase, sulfur dioxide is oxidized by reaction with the hydroxyl radical via an intermolecular reaction:

$$SO_2 + OH\cdot \longrightarrow HOSO_2\cdot$$

which is followed by:

$$HOSO_2\cdot + O_2 \longrightarrow HO_2\cdot + SO_3$$

In the presence of water, sulfur trioxide (SO_3) is converted rapidly to sulfuric acid:

$$SO_3(g) + H_2O(l) \longrightarrow H_2SO_4(l)$$

Nitrogen dioxide reacts with OH· to form nitric acid:

$$NO_2 + OH\cdot \longrightarrow HNO_3$$

7. Chemistry in cloud droplets

When clouds are present, the loss rate of SO_2 is faster than that can be explained by gas phase chemistry alone. This is due to reactions in the liquid water ***droplets***.

(1) Hydrolysis

Sulfur dioxide dissolves in water and then, like carbon dioxide, hydrolyses in a series of ***equilibrium*** reactions:

$$SO_2(g) + H_2O \rightleftharpoons SO_2\cdot H_2O$$

$$SO_2\cdot H_2O \rightleftharpoons H^+ + HSO_3^-$$

$$HSO_3^- \rightleftharpoons H^+ + SO_3^{2-}$$

(2) Oxidation

There are a large number of aqueous reactions that oxidize sulfur from S(Ⅳ) to S(Ⅵ), leading to the formation of sulfuric acid. The most important oxidation reactions are with ozone, hydrogen peroxide and oxygen (reactions with oxygen are catalyzed by iron and manganese in the cloud droplets).

8. Acid deposition

(1) Wet deposition

Wet deposition of acids occurs when any form of precipitation (rain, snow,

etc.) removes acids from the atmosphere and delivers it to the earth's surface. This can result from the deposition of acids produced in the raindrops (see aqueous phase chemistry above) or by the precipitation removing the acids either in clouds or below clouds. Wet removal of both gases and aerosols are both of importance for wet deposition.

(2) Dry deposition

Acid deposition also occurs via dry deposition in the absence of precipitation. This can be responsible for as much as 20% to 60% of total acid deposition. This occurs when particles and gases stick to the ground, plants or other surfaces.

9. Adverse effects

Acid rain has been shown to have adverse impacts on forests, freshwaters and soils, killing insect and aquatic life-forms as well as causing damage to buildings and having impacts on human health.

(1) Surface waters and aquatic animals

Both the lower pH and higher aluminium concentrations in surface water that occur as a result of acid rain can cause damage to fish and other aquatic animals. At pH lower than 5, most fish eggs will not hatch and lower pH can kill adult fish. As lakes and rivers become more acidic, ***biodiversity*** is reduced. Acid rain has eliminated insect life and some fish species, including the brook trout in some lakes, streams, and creeks in geographically sensitive areas, such as the Adirondack Mountains of the United States. However, the extent to which acid rain contributes directly or indirectly via runoff from the catchment to lake and river acidity (i.e., depending on characteristics of the surrounding watershed) is variable. The United States Environmental Protection Agency's (EPA) website states: "Of the lakes and streams surveyed, acid rain caused acidity in 75% of the acidic lakes and about 50% of the acidic streams".

(2) Soils

Soil biology and chemistry can be seriously damaged by acid rain. Some microbes are unable to tolerate changes to low pH and are killed. The enzymes of

these microbes are denatured (changed in shape so they no longer function) by the acid. The hydronium ions of acid rain also mobilize toxins such as aluminium, and leach away essential nutrients and minerals such as magnesium.

$$2\ H^+(aq) + Mg^{2+}(clay) \rightleftharpoons 2\ H^+(clay) + Mg^{2+}(aq)$$

Soil chemistry can be ***dramatically*** changed when base cations, such as calcium and magnesium, are leached by acid rain thereby affecting sensitive species, such as sugar maple (acer saccharum).

(3) Forests and other vegetation

Adverse effects may be indirectly related to acid rain, like the acid's effects on soil (see above) or high concentration of gaseous precursors to acid rain. High altitude forests are especially vulnerable as they are often surrounded by clouds and fog which are more acidic than rain.

Other plants can also be damaged by acid rain, but the effect on food crops is minimized by the application of lime and fertilizers to replace lost nutrients. In cultivated areas, limestone may also be added to increase the ability of the soil to keep the pH stable, but this tactic is largely unusable in the case of wilderness lands. When calcium is leached from the needles of red ***spruce***, these trees become less cold tolerant and exhibit winter injury and even death.

(4) Human health effects

Acid rain does not directly affect human health. The acid in the rainwater is too dilute to have direct adverse effects. However, the particulates responsible for acid rain (sulfur dioxide and nitrogen oxides) do have an adverse effect. Increased amounts of fine particulate matter in the air do contribute to heart and lung problems including ***asthma*** and ***bronchitis***.

(5) Other adverse effects

Acid rain can also damage buildings and historic monuments, especially those made of rocks such as limestone and marble containing large amounts of calcium carbonate. Acids in the rain react with the calcium compounds in the stones to create gypsum, which then flakes off.

$$CaCO_3(s) + H_2SO_4(aq) \rightleftharpoons CaSO_4(aq) + CO_2(g) + H_2O(l)$$

The effects of this are commonly seen on old gravestones, where acid rain

can cause the inscriptions to become completely illegible. Acid rain also increases the oxidation rate of metals, in particular copper and bronze.

(6) Affected areas

Places with significant impact by acid rain around the globe include most of Eastern Europe from Poland northward into Scandinavia, the third of the eastern United States, and southeastern Canada. Other affected areas include the southeastern coast of Mainland China and Taiwan district.

10. Prevention methods

(1) Technical solutions

Many coal-firing power plants use flue gas desulfurization (FGD) to remove sulfur-containing gases from their stack gases. For a typical coal-fired power station, FGD will remove 95% or more of the SO_2 in the flue gases. An example of FGD is the wet scrubber which is commonly used. A wet scrubber is basically a reaction tower equipped with a fan that extracts hot smoke stack gases from a power plant into the tower. Lime or limestone in slurry form is also injected into the tower to mix with the stack gases and combine with the sulfur dioxide present. The calcium carbonate of the limestone produces pH-neutral calcium sulfate that is physically removed from the scrubber. That is, the scrubber turns sulfur pollution into industrial sulfates.

In some areas the sulfates are sold to chemical companies as gypsum when the purity of calcium sulfate is high. In others, they are placed in landfill. However, the effects of acid rain can last for generations, as the effects of pH level change can stimulate the continued leaching of undesirable chemicals into otherwise pristine water sources, killing off vulnerable insect and fish species and blocking efforts to restore native life.

Vehicle emissions control reduces emissions of nitrogen oxides from motor vehicles.

(2) International treaties

A number of international treaties on the long range transport of atmospheric pollutants have been agreed, e. g. , Sulphur Emissions Reduction Protocol

under the Convention on Long-range Trans-boundary Air Pollution. Most European countries and Canada have signed the treaties.

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Vocabulary

precipitation *n*. 沉淀;(雨等)降落;某地区降雨等的量
hydrogen *n*. 〈化〉氢
volcanic *adj*. 火山的;猛烈的;暴烈的 *n*. 火山岩
eruptions *n*. 喷发, 爆发
alkaline *adj*. 碱性的 *n*. 碱度,碱性
dimethyl *adj*. 〈化〉二甲基的
droplet *n*. 小滴,微滴;小水珠
equilibrium *n*. 平衡
biodiversity *n*. 生物多类状态,生物多样性
dramatically *adv*. 戏剧性地,引人注目地
spruce *n*. 针枞;云杉;云杉木
asthma *n*. 〈医〉气喘, 哮喘
bronchitis *n*. 支气管炎

Dust Pollution
粉 尘 污 染

Dust pollution is one of the sources of atmospheric pollution. Industry dust from ***demolition*** projects, blasting operations, roads and dirt roads, and uncovered materials in ***stockpiles*** or being transported can pose a serious health hazard. The coal industry creates many health threats, including risks from coal dust and coal ash, some of which can be addressed through meaningful ***fugitive*** dust regulations. Dust consists of particles in the atmosphere that comes from

various sources such as soil dust lifted by weather (an Aeolian process), volcanic eruptions, and pollution. Dust in homes, offices, and other human environments contains small amounts of plant pollen, human and animal hairs, textile fibers, paper fibers, minerals from outdoor soil, human skin cells, burnt meteorite particles and many other materials which may be found in the local environment.

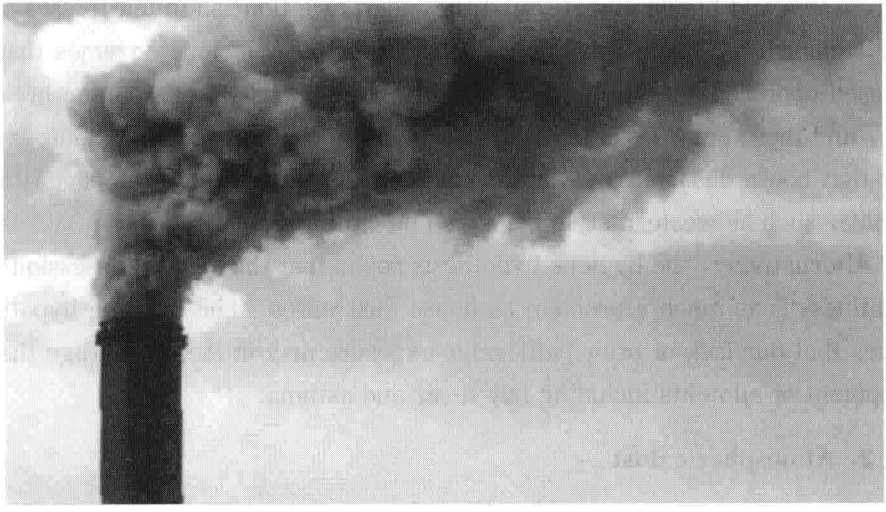

Fig. 2 Air pollution caused due to dust

(Source: http://www.raxa.com/sites/default/files/imagecache/640×480_image/photos/air_pollution3.jpg)

1. Domestic dust and humans

Dust may worsen hay fever. Circulating outdoor air through a house by keeping doors and windows open, or at least slightly ajar, may reduce the risk of hay fever-causing dust. In colder climates, occupants seal even the smallest air gaps, and eliminate outside fresh air circulating inside the house. So it is essential to manage dust and airflow.

House dust mites are ubiquitous everywhere humans live indoors. Positive tests for dust mite allergies are extremely common among people with asthma. Dust mites are microscopic arachnids whose primary food is dead human skin

cells. They do not actually live on people, though. They and their feces and other allergens they produce are major constituents of house dust, but because they are so heavy they are not long suspended in the air. They generally are on the floor and other surfaces, until disturbed (by walking, for example). Sources suggest it could take somewhere between 20 minutes and 2 hours for them to settle back down out of the air. Dust mites are a nesting species that prefer a dark, warm and humid climate, and they therefore flourish in mattresses, bedding, upholstered furniture, and carpets. Their feces include enzymes that are released upon contact with a moist surface, as happens when a person breathes it in, and these enzymes actually kill cells within the human body. Sources suggest that house dust mites did not become a problem until humans began to use textiles, such as western style blankets and clothing.

Alternatively, the hygiene hypothesis posits that the modern obsession with cleanliness is as much a problem as house dust mites. The hygiene hypothesis argues that our lack of prior pathogenic exposure may in fact encourage the development of ailments including hay fever and asthma.

2. Atmospheric dust

Dust comes from arid and dry regions where high velocity winds are able to remove mostly silt-sized material, deflating susceptible surfaces. This includes areas where grazing, ploughing, vehicle use and other human activities have further destabilized the land, though not all source areas have been largely affected by ***anthropogenic*** impacts. One-third of the global land area is covered by dust-producing surfaces, made up of hyper-arid regions like the Sahara that covers 0.9 billion hectares, and drylands, which occupy 5.2 billion hectares.

Dust in the atmosphere is produced by saltation and sandblasting of sand-sized grains, and it is transported through the troposphere. This airborne dust is considered an aerosol and once in the atmosphere, it can produce strong local radiative forcing. Saharan dust in particular can be transported and deposited as far as the Caribbean and Amazonia, and may affect air temperatures, cause ocean cooling, and alter rainfall amounts.

Coal dust is responsible for the lung disease known as pneumoconiosis, in-

cluding black lung disease, which occurs among coal miners. The danger of coal dust resulted in environmental legislation regulating work place air quality in some jurisdictions. In addition, if enough coal dust is dispersed within the air in a given area, it can create an explosion hazard under certain circumstances.

3. Road dust

Dust kicked up by vehicles traveling on roads may make up 33% of air pollution. Road dust consists of deposition of vehicle exhausts and industrial exhausts, tire and brake wear, paved roads or potholes, and construction sites. Road dust represents a significant source contributing to the generation and release of particulate matter into the atmosphere. Control of road dust is a significant challenge in urban areas, and also in other spheres with high levels of vehicular traffic upon unsealed roads such as mines and garbage dumps. Road dust may be suppressed by mechanical methods like sweeping vehicles, with vegetable oils, or with water sprayers. Improvements in automotive engineering have reduced the amount of PM10 produced by road traffic, and the proportion representing resuspension of existing particulates has, as a result, increased.

4. Dust control

(1) Control of atmospheric dust

The US EPA mandates facilities that generate dust minimize or mitigate the production of dust in their operation. The most frequent dust control violations occur at new residential housing developments in urban areas. US federal law requires that construction sites obtain permits to conduct earth moving, and include plans to control dust emissions. Control measures include such simple practices as spraying construction and demolition sites with water, and preventing the tracking of dust onto adjacent roads. US federal law requires dust control on sources such as vacant lots, unpaved parking lots, and unpaved roads. Dust in such places may be suppressed by mechanical methods, including paving or laying down gravel, or stabilizing the surface with water, vegetable oils or other dust suppressants, or by using water misters to suppress dust that is already airborne.

(6) Control of domestic dust

Dust control is the suppression of solid particles with diameters less than 500 micrometers. Dust in the airstream poses a serious health threat to children, older people, and those with ***respiratory*** illnesses.

House dust can become airborne easily. Care should be exercised when removing dust to avoid causing the dust to become airborne. A feather duster tends to agitate the dust so it lands elsewhere. Products like Pledge and Swiffer are specifically made for dusting. Some dust removing devices trap some dust. One way to repel dust is with an electric charge. Certified HEPA (tested to MIL STD 282) can effectively trap 99.97% of dust at 0.3 micrometres. Not all HEPA (type/media) filters can effectively stop dust, while vacuum cleaners with HEPA (type/media) filters, water, or cyclones may filter more effectively than without, they may still exhaust millions of particles per cubic foot of air circulated. Laser particle counters are an effective way to measure filter effectiveness, medical grade can test for particles as small as 0.3 micrometres. In order to test for dust in the air, there are several options available. Preweighted filter and matched weight filters made from polyvinyl chloride or mixed cellulose ester are suitable for respirable dust (less than 10 micrometres in diameter).

(7) Control of dust resistance on surfaces

A dust resistant surface is a state of prevention against dust contamination or damage, by a design or treatment of materials and items in manufacturing or through a repair process. A reduced tacticity of a synthetic layer or covering can protect surfaces and release small molecules that could have remained attached. A panel, container or enclosure with seams may feature types of strengthened rigidity or sealant to vulnerable edges and joins.

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Vocabulary

demolition *n*. 毁坏,破坏,拆毁;(pl.)炸药

stockpile *n*.(原料,食品等的)储备,准备急用的备用原料或物资,贮存;资源,富源,矿藏量

fugitive *adj*. 逃亡的;难以捉摸的;短暂的

anthropogenic *adj*. 源于人类活动的;人为的

respiratory *adj*. 呼吸的

Global Warming
全 球 变 暖

Global warming is the observed and projected increases in the average temperature of earth's atmosphere and oceans, especially a sustained increase sufficient to cause climatic change.

According to the National Academy of Sciences of the United States, the earth's surface temperature has risen by about 1 degree ***Fahrenheit*** in the past century, with accelerated warming during the past two decades. There is new and stronger evidence that most of the warming over the last 50 years is attributable to human activities. Human activities have altered the chemical composition of the atmosphere through the buildup of greenhouse gases. According to different assumption about the future behaviour of mankind, a projection of current trends as represented by a number of different scenarios gives temperature increases of about 3—5℃ (5— 9°F) by the year 2100 or soon afterwards. A 3°C

or 5°F rise would likely raise sea levels by about 25 meters (about 82 feet).

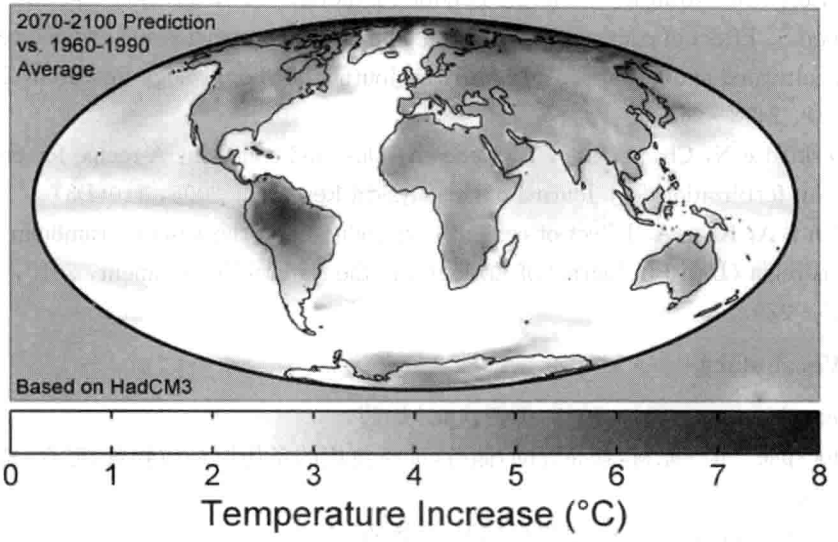

Fig. 3 Temperature increase of global warming

(Source: http://www.phys.ncku.edu.tw/~astrolab/mirrors/apod_e/image/0904/warming_gwa.jpg)

1. Main causes of global warming

The greenhouse effect has been in place for millions of years. When the sun's rays strike the earth, a layer of gas prevents the radiant energy from escaping, which keeps earth's temperature suitable for life. Although this is a natural phenomenon, recently, concentrations of greenhouse gases have increased rapidly and considerably, and have contributed to what is known as global warming. While there are many factors involved in global warming, pollution that humans create is believed by many scientists to be responsible for much of it.

(1) Carbondioxide

The primary source of carbon dioxide is combustion of fossil fuels, and it is the largest contributor to greenhouse gases. Approximately one-third of the carbon dioxide in the atmosphere was placed there by combustion engines. Coal-burning power plants are also a big source of carbon dioxide. Trees remove carbon dioxide from the air, and widespread ***deforestation*** removes trees (usually

by burning, which increases carbon dioxide even more); as such, it is a contributor to global warming.

(2) Methane

Methane is less common but traps heat more than 20 times as efficiently as carbon dioxide does and, therefore, is considered as an important greenhouse gas. Primary sources of methane include flooded rice paddies, melting permafrost (which is, ironically, due to global warming), coal mining, natural gas and ***bovine flatulence***.

(3) Ozone

Ozone can occur at two levels in the earth's atmosphere—in the ***troposphere*** (low in the atmosphere) and in the ***stratosphere*** (higher up). Ozone in the troposphere is created when oxygen is struck by ultraviolet radiation, which turns the regular oxygen molecule into an ozone molecule and occurs with the combustion of engines. Tropospheric ozone is considered to be the third most powerful greenhouse gas, following only carbon dioxide and methane.

(4) Other pollutants

There are many other gases that are of slightly less importance but are, nonetheless, important greenhouse gases. Nitrous oxide is also a greenhouse gas that is generated during the use of fertilizers and the combustion of fossil fuels. ***Chloro fluoro carbons*** (CFCs) can also be considered to be greenhouse gases but are not as great a threat as some of the others mentioned. The problems that CFCs cause are twofold. They break down the ozone layer, which allows more radiant heat to enter the earth's atmosphere, and they are extremely efficient at holding this heat in. High global warming potential (GWP) gases have a high capacity to hold in radiant heat. These gases (perfluorocarbons, sulfa hexafluoride and hydrofluorocarbons) are found in relatively low concentrations within the atmosphere but are dangerous because of their long persistence times.

2. Effects of global warming

Increasing global temperatures are the primary effects of global warming.

However they are causing a broad range of additional, secondary effects.

Sea levels are rising due to thermal expansion of the ocean, in addition to melting of land ice.

Amounts and patterns of precipitation are changing. The total annual power of hurricanes has already increased markedly since 1975, because their average intensity and average duration have increased (in addition, there has been a high correlation of hurricane power with tropical sea-surface temperature).

Changes in temperature and precipitation patterns have also global effects on extreme weather events: They increase the frequency, duration, and intensity of floods, droughts, heat waves, and tornadoes. Other effects of global warming include higher or lower agricultural yields, further glacial retreat, reduced summer stream flows, species extinctions. As further effects of global warming, diseases like ***malaria*** are returning into areas where they have been extinguished earlier.

Even if the global warming effects would convince mankind to stop emitting greenhouse gases, the global warming is expected to continue past 2100 because carbon dioxide (CO_2) has an estimated atmospheric lifetime of 50—200 years. See also the summary of the predictions for the future increase in temperature up to 2100.

3. The effects of global warming on sea level

(1) Warmer seas and melting ice

When the earth warms, the oceans will warm and expand, causing an increase in the level of the sea. This process is thought to be responsible for about a quarter of the sea level rise recorded during the 20th century. The melting of ice sheets in Greenland and Antarctica could be another major cause, although it is not known what contribution this makes.

According to many studies, sea levels have been rising by 1—2 millimeters (mm) each year for the past 100 years. Current predictions suggest that the sea level may rise by half a meter in the next 100 years.

(2) Flooding

Higher sea levels will threaten the low-lying coastal areas of the world such

as the Netherlands and Bangladesh. Many important fisheries would become threatened and coastal ecosystems damaged.

4. The effects of global warming on agriculture

The changes in the weather will affect the type of crops grown. Some crops such as wheat and rice grow better in higher temperatures, but other plants such as maize and sugarcane do not. Changes in the amount of rainfall will also affect the growth of many plants.

(1) Low-lying land

Low-lying agricultural land is at risk from rising sea levels. South East Asia would be badly affected as most farming takes place on low-lying deltas. If salt water entered the land it would need treating. This would increase costs for farmers, meaning higher food prices for the public.

(2) Carbon dioxide

Plants grow as a result of ***photosynthesis***. This involves plants taking in carbon dioxide and giving off oxygen. Climate change is associated with an increase in the levels of carbon dioxide in the atmosphere and hence plant growth rates could increase.

(3) Uncertainty

It is not certain what the effects of climate change on agriculture will be, but it is thought that crop production will be reduced in some parts of the world, whilst it will increase in others.

5. The effects of global warming on health

The health of human populations depends on the continued use of the earth's natural systems. Climate change is likely to have a negative effect on health, with significant loss of life through a variety of illnesses.

(1) Effects of warmer temperatures

Warmer temperatures can increase local air pollution, which in turn can lead to an increase in breathing problems and respiratory diseases.