Air pollution

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Air Pollution: Introduction

علم الارصاد الجوية

Meteorology,

Topographical Influences,

& the Atmosphere

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* الـ CO_2 لا يعتبر ملوث مع انه الـ اهتزاره
لانه موجود بالطبيعة واله اكثر من مصدر

* المناطق المفتوحة تتشتت فيها الملوثات
على عكس المغلقة يتركز فيها

* الملوثات ممكن تنتقل او تخف او تتكسر الخ

Meteorology and the Atmosphere

علم يدرس الغلاف الجوي

- **Meteorology:** is the science of the atmosphere.

- **The atmosphere:** is the media (Fluid) into which all air pollution is emitted. Atmospheric processes such as the movement of air (wind) and the exchange of heat (convection and radiation for example) dictate the fate of pollutants as they go through the stages of transport, dispersion, transformation and removal.

- **Air pollution meteorology** is the study of how these atmospheric processes affect the fate of air pollutants.

بصير ابخات

* لازم يكون عندي اتزان بين حرارة الغلاف من تحته وفوق يلي طالعه بليل غير هيك بصير انقلاب حراري لانه بتخزن عندي حرارة

بجرد شو اخ يصير بالملوث من انتقال او تشتت والخ

علم يدرس كيف التغيرات في الاتموسفير اخ تأثر في الملوثات

* شو اخ يصير مع الملوث
اخ يتفاعل او يتشتت او الخ

Composition of the Atmosphere

Table 1-1. Chemical composition of dry atmospheric air

Substance	Concentration (ppm)[1]
Nitrogen	780,900
Oxygen	209,400
Argon	9,300
Carbon dioxide	315 (375 ppm)
Neon	18
Helium	5.2
Methane	2.3
Krypton	0.5
Hydrogen	0.5
Xenon	0.08
Nitrogen dioxide	0.02
Ozone	0.01-0.04

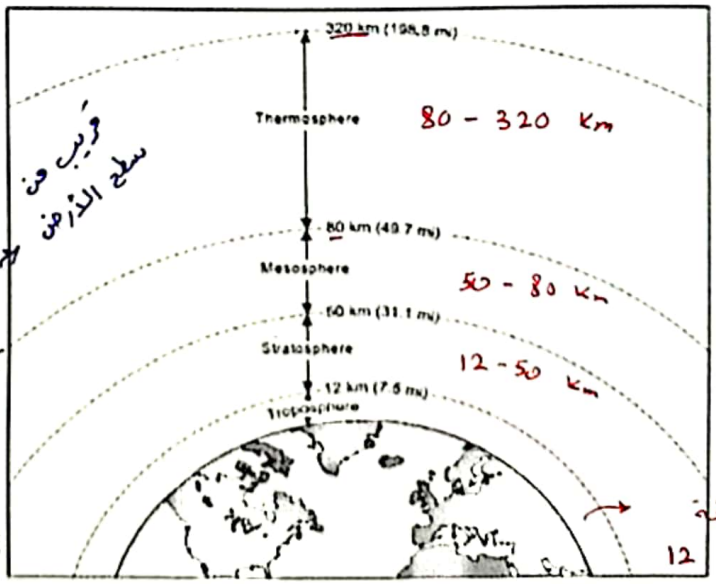
1. ppm is an abbreviation for parts per million. To convert from a concentration expressed as ppm to a concentration expressed as a percent of a total, divide the ppm concentration by 10,000.

Source: *Handbook of Air Pollution* 1968.

Although the **water vapor** content of the air is fairly small, it absorbs six times more radiation than any other atmospheric constituent and is therefore a very important component of the atmosphere.

Layers of the Atmosphere طبقات الغلاف الجوي

- **Troposphere**
  - 75–80% of the earth's air mass
  - contains nearly all of the water associated with the atmosphere (vapor, clouds and precipitation).
  - Close to the earth's surface
  - Chemical composition of air
  - Rising and falling air currents: weather and climate
  - Involved in chemical cycling



- The depth of the troposphere changes constantly due to changes in atmospheric temperature

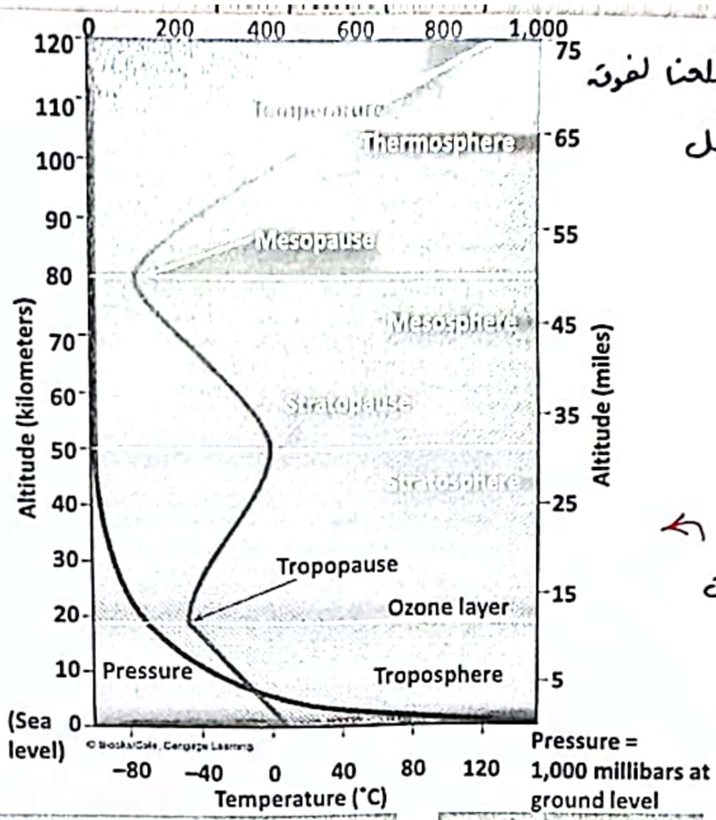
شبه الطبقة يلي قبل بس في استثنائين

❑ Stratosphere

- Similar composition to the troposphere, with 2 exceptions
  - ➢ Much less water
  - ➢ O_3, **ozone layer,** filters UV

← بعمل طفرات ويسبب السرطان

← بسرع تفاعلات



كل ما طلعنا لفوق الضغط بقل

تغيير الحرارة ← في الطبقات

* كل ما زاد سمك طبقة الأوزون بكون أفضل
← ما بتعدا شعة السمانتي

* ثقب الأوزون يعني سماكة قليلة بمر من خلالها ال UV

افتراض،

- Virtually all air pollution is emitted within the troposphere. Air pollution transport is governed by the speed and direction of the winds.

اللي بتحكم في انتقال الملوثات هو سرعة و اتجاه الهواء

← على شو بعتمد التشتت

نوع السطح

- The rate of dispersion is influenced by the thermal structure of the atmosphere as well as by mechanical agitation of the air as it moves over the different surface features of the earth.

بتأثر من ← تعرضه

- Transformation of the emitted air pollutants is impacted by exposure to solar radiation and moisture as well as other constituents in the atmosphere.

- The removal of pollutants depends not only on the pollutants' characteristics but also on weather phenomena such as rain, snow and fog.

إزالة نفايات تعتمد على :-

١- خصائص الملوثات ٢- ظواهر الجوية

لازم يكون عندي غرفة داخلة نفسها يلي طالعة
عين هيدا متل كويس

Heat Balance of the Atmosphere

طول موجة
بلعب دور

- The sun energy is transferred by radiation of heat in the form of electromagnetic waves.
- The radiation from the sun has its peak energy transmission in the visible wavelength range [0.38 to 0.78 micrometers (μm)] of the electromagnetic spectrum.

طول موجة
هربي — بتمتص فيها الأرض وهو طول

الأشعة تحت الحمراء

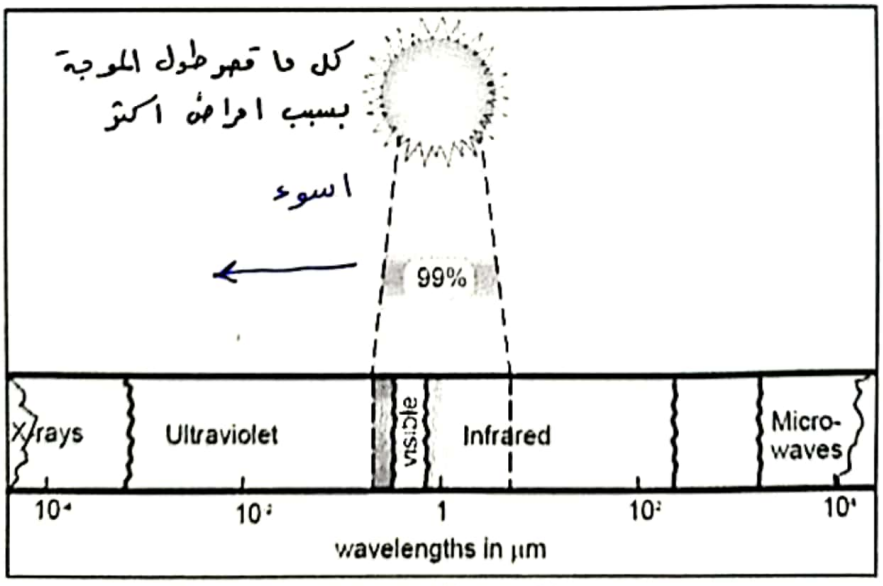
- The sun also releases considerable energy in the ultraviolet and infrared regions.
- Ninety-nine percent of the sun's energy is emitted in wavelengths between 0.15 to 40 μm.

99%

- solar radiation striking the earth generally has a wavelength between 0.29 and 2.5 μm.

دهرب

الاشعة يلي بتوصل الارض طولها الموجي بين
0.29 - 2.5 μm



طول الموجات

Source for data: Moran and Morgan 1994

The amount of incoming solar radiation received at a particular time and location in the earth-atmosphere system is called ***insolation***.

Insolation is governed by four factors:

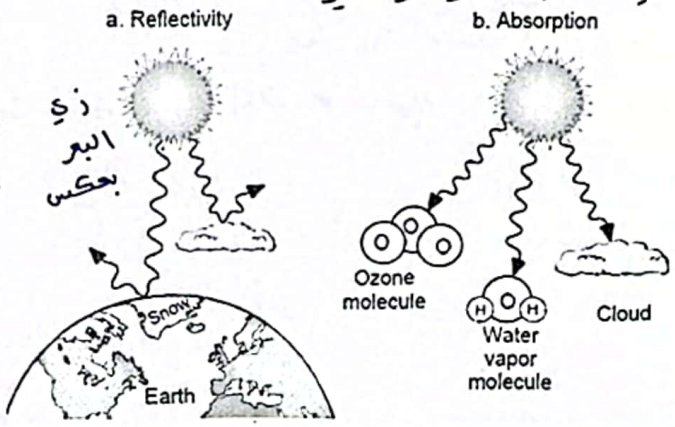
- Solar constant
- Transparency of the atmosphere
- Daily sunlight duration
- Angle at which the sun's rays strike the earth

Values for Solar Constant

Solar constant = 1.94 cal/cm^2 min
1,353 W/m^2
428 Btu/ft^2 hr
4,871 kJ/m^2 hr

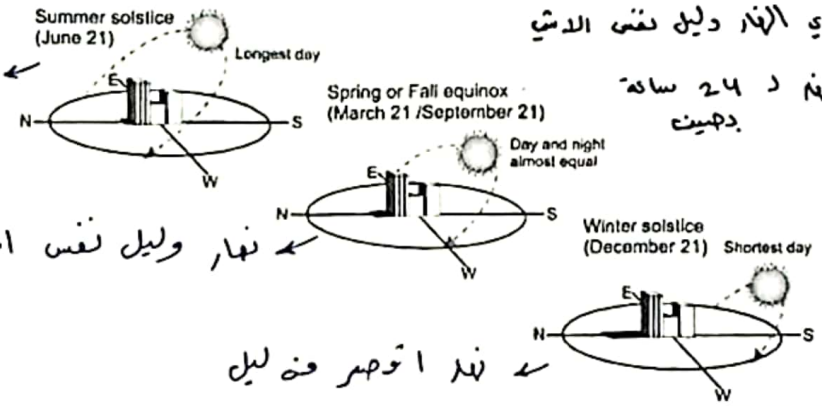
Transparency

- Transparency of the atmosphere refers to how much radiation penetrates the atmosphere and reaches the earth's surface without being depleted.
- The emitted radiation is depleted as its passes through the atmosphere.
  * Different atmospheric constituents absorb or reflect energy in different ways and in varying amounts.
- some of the radiation received by the atmosphere is reflected from the tops of clouds and from the earth's surface and some is absorbed by molecules and clouds.



Daylight Duration

- The duration of daylight also affects the amount of insolation received: the longer the period of sunlight, the greater the total possible insolation.
- Daylight duration varies with latitude and the seasons. At the equator, day and night are always equal. In the polar regions, the daylight period reaches a maximum of twenty-four hours in summer and a minimum of zero hours in winter.



* الزاوية يلي بتسقط فيها اشعة الشمس

Angle of Rays

- A relatively flat surface perpendicular to an incoming vertical sun ray receives the largest amount of insolation.

اذا سقطت الاشعة بشكل عامودي بعطين اكبر كمية insolation

- At solar noon, the intensity of insolation is greatest. In the morning and evening hours, when the sun is at a low angle, the amount of insolation is small.

* الظهريات عندي insolation اعلى شدة

* الصبح والمسا شمس بكون الها زاوية بتاني الـ insolation بتكون شدته اقل

في حالة اي طالع اكبر من اي داخل اكبر

اي خلل بسبب انجماد او احتباس حراري

Heat Balance

عليه سؤال

- The earth absorbs short-wave solar radiation and emits longer wavelength terrestrial radiation.

بليل اذا سماء مغيمة بكون الهواء ادفى من لما تكون صافية

- This phenomenon explains the reason air temperatures are usually warmer on nights with cloud cover than on clear nights.

- Since energy from the sun is always entering the atmosphere, the earth would overheat if all this energy were stored in the earth-atmosphere system. So, energy must eventually be released back into space. On the whole, this is what happens. Incoming radiation eventually goes back out as terrestrial radiation, and a heat balance, called the **radiational balance** results.

لما ترجع كلها عشان يكون عندي balance

- For every 100 units of energy that enters the atmosphere, 51 units are absorbed by the earth, 19 units are absorbed in the atmosphere and 30 units are reflected back to space. The 70 units that are absorbed by the earth-atmosphere system (51 units +19 units) are eventually reradiated to space as long wave radiation.

بوصل 51 باليابسة فقط لسطح الارض

لازم يرجعوا على طول موجة اطول الى space بس للاسف ما بصير هيك

لون السماء الازرق هو عبارة عن انعكاس للبحار والمحيطات

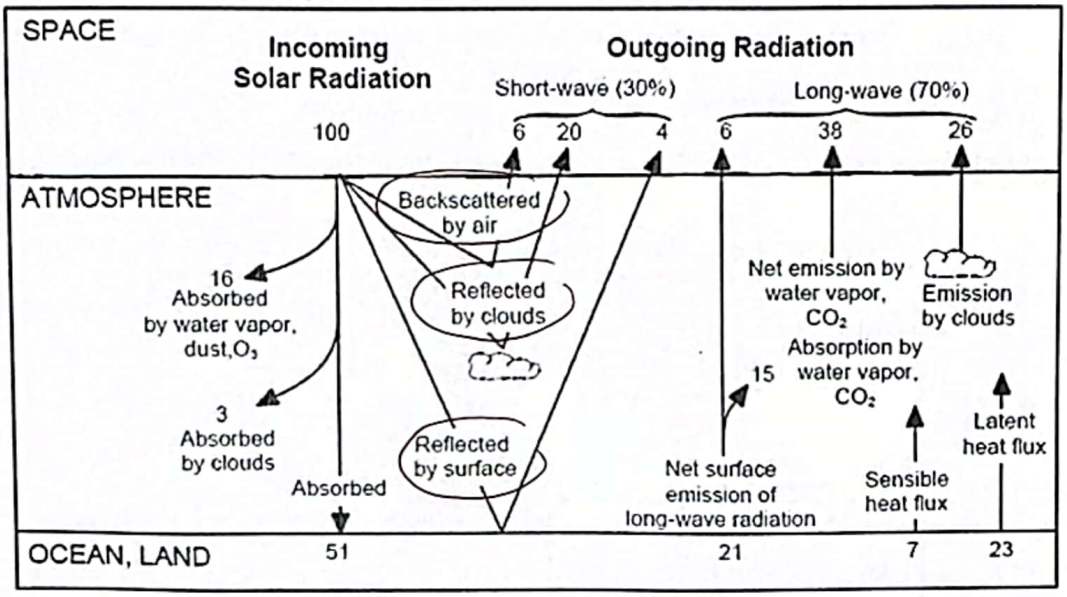
٪19 راح يمتص في الاتموسفير

٪30 راح يرجع للـ space

مهم :-

طول موجة ←

نسب ←



The mean annual radiation and heat balance of the atmosphere relative to 100 units of incoming solar radiation

Source: National Academy of Sciences 1975, p. 18.

$PV = nRT$ حسب جداً ← بتمدد الهواء ليعادل تغير في الضغط

كل اشي موجود في ال يتمدد هاد وهاد مشكلة

- Air moves in an attempt to equalize the air pressure imbalances that develop as a result of variations in insolation and differential heating.
- Differential heating is the main cause of atmospheric motion on the earth
- Air pressure is a function of the number of air molecules in a given volume and the speed at which they are moving.

محصور حتى بدورة مغلقة بنسبة ١٠٠٪

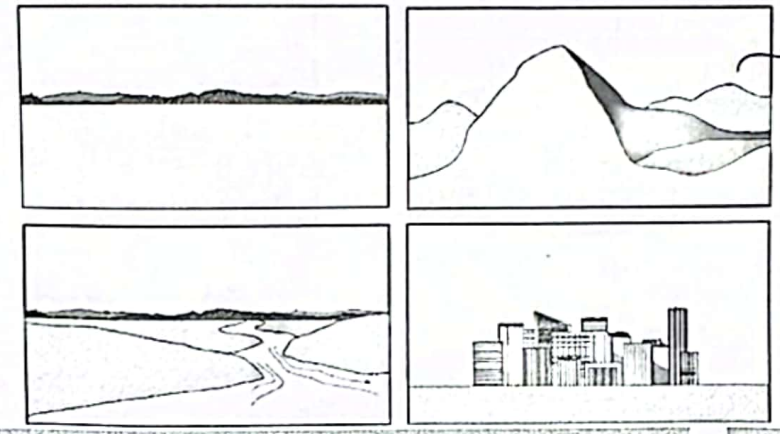
- When air is confined within a certain boundary, heating the air increases its pressure and cooling the air decreases its pressure.

open ← كيف طبيعة المكان
close ← وديان, جبال

Topographical Influences تأثير التضاريس

Terrain features or topography: The physical characteristics of the earth's surface. الخصائص الفيزيائية لسطح الأرض — ميزات التضاريس

- Topographical features not only influence the way the earth and its surrounding air heat up, but they predominantly affect air flow relatively close to the earth's surface. تؤثر على طريقة تسخين الأرض والهواء المحيط بها بالإضافة الى تدفق الهواء القريب نسبياً الى سطح الأرض



* من وين اتجاه الهواء + الديناميك تاع الهواء

تضاريس جبلي الها تأثير على Air pollution

تؤثر على الأتوسفير بطريقتين:

Topographical features affect the atmosphere in two ways:

- Thermally (through heating); and
- geometrically (also known as mechanically).

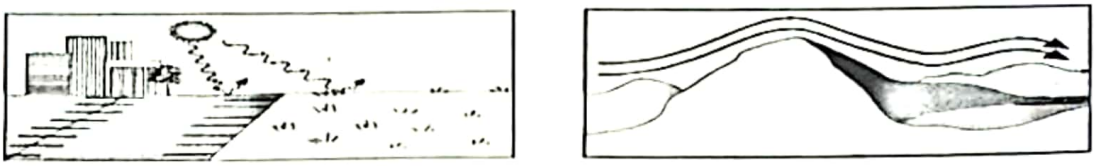
وإما عن طريق تسخين — ديناميك

- The thermal turbulence is caused by **differential heating**. Different objects give off heat at different rates. For example, a grassy area will not absorb and subsequently release as much heat as an asphalt parking lot

تعلقة الأجسام المختلفة واه بمعدلات مختلفة — قال الفرق بين الأماكن العشبة و مواقف سيارات الاسفلت

- Mechanical turbulence is caused by the wind flowing over different sizes and shapes of objects. For example, a building affects the wind flowing around it differently than a corn field would affect it.

اضطرابات ميكانيكية بسبب مرور الهواء على أشكال مختلفة



في نوع ثاني complex

open

Flat Terrain

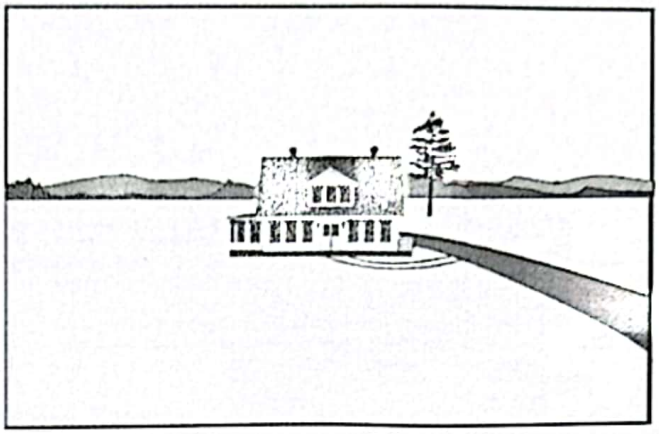
* في فيلان sharp
يكون الفيلان smoth

Although very little of the earth's surface is completely flat, some terrain is called flat for topographical purposes. Included in this category are oceans, even though they have a surface texture; and gently rolling features on land

المحيطات تعتبر مسطحة على الرغم من انه الها تموجات وتضاريس متدرجة

تقتصر الاضطرابات في الرياح فوقه الاراضي المسطحة على مقدار التخشونة طبيعية صنع الانسان

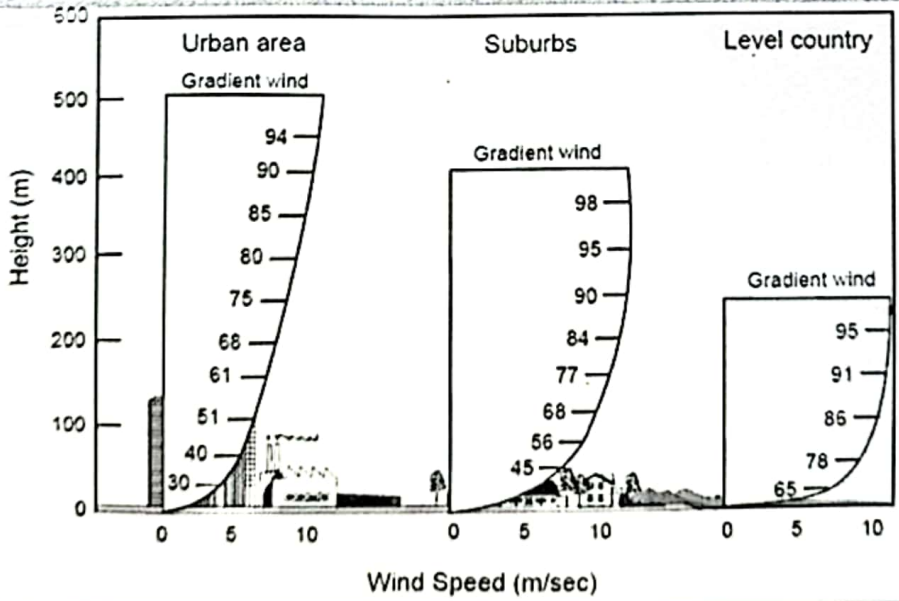
- Turbulence in the wind over flat terrain is limited to the amount of roughness of either natural or manmade features that are on the ground.
- These features induce a frictional effect on the wind speed and result in the well known wind profile with height.



هذيك الشغلة اذ تسبب تغير سرعة الرياح بتالي علاقة بين سرعة الرياح والارتفاع

Complex

* كل ما كان في تضاريس وعباني معقدة بتقل سرعة الهواء



Examples of variation of wind with height over different surface roughness elements (Figures are percentages of gradient wind.) **Source: Turner 1970.**

عشان هيك البحر حيته بالصيف ابرد من جو وبالشتاء الحكس

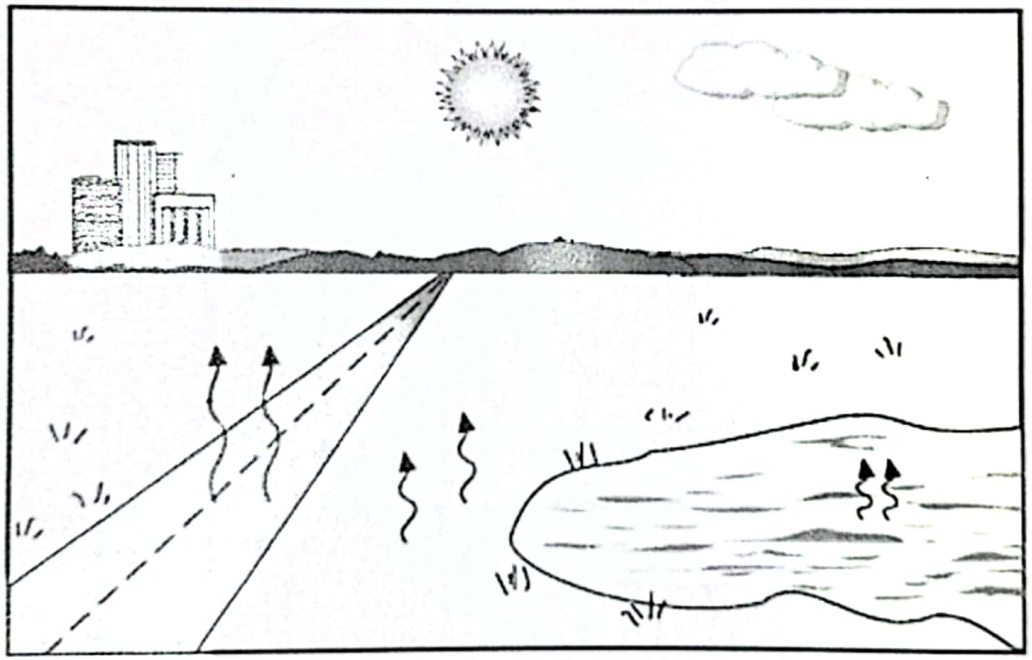
* حرارة المياه بتتأخر عن حرارة باقي الأجسام ٣٠ يوم

قراءة

طبعاً وطلوب

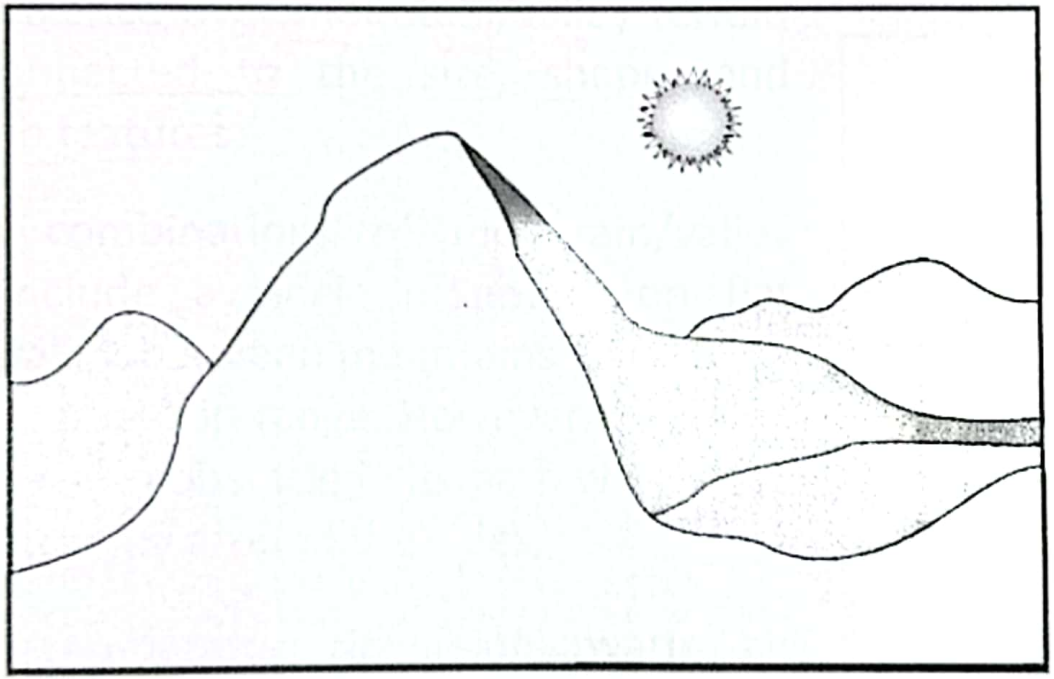
Cases

Thermal turbulence over flat terrain is due to natural or manmade features.



Air rises over heated objects in varying amounts (convection)

Mountain/ Valley: complex terrain.

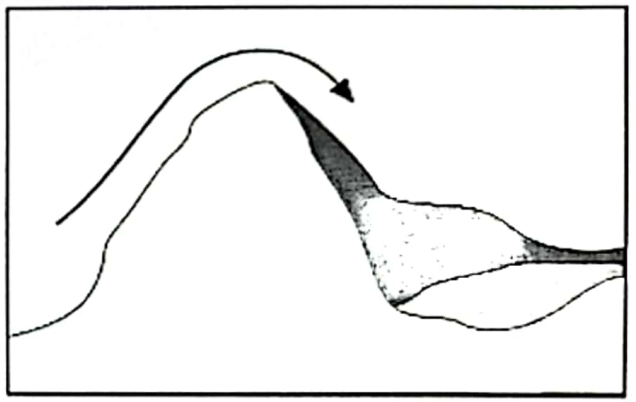


* كل علماء تلوث الهواء بحكوا انه تشتت الهواء في المناطق الـ complex مختلف وعقد اكتر من الـ flat

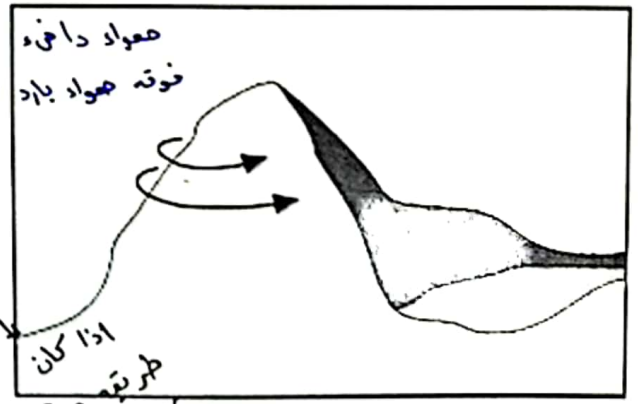
All air pollution investigators agree that atmospheric dispersion in complex terrain areas can be very different from, and much more complicated than, that over flat ground.

على واذا تربطها الإضطرابات الميكانيكية فوق تضاريس جبال و الوديان

Mechanical turbulence over mountain/valley terrain is invariably connected to the size, shape, and orientation of the features.



The numerous combinations of mountain/valley arrangements include a single mountain on flat terrain, a deep valley between mountains, a valley in flat terrain, or a mountain range. However, air tends to flow up and over an obstacle in its path with some air trying to find its way around the sides.



If an elevated temperature inversion (warm air overlying cooler air) caps the higher elevation, then the air must try to find its way around the sides of the mountain. If the air flow is blocked, then trapping or recirculation of the air occurs. At night, hills and mountains induce downslope wind flow because the air is cooler at higher elevations.

نفس يلي قبله بتو بأكد عليه

Thermal turbulence in mountain/valley terrain is also connected to the size, shape, and orientation of the features.

الترابة من متسلدية بسبب حركة الشمس في السماء

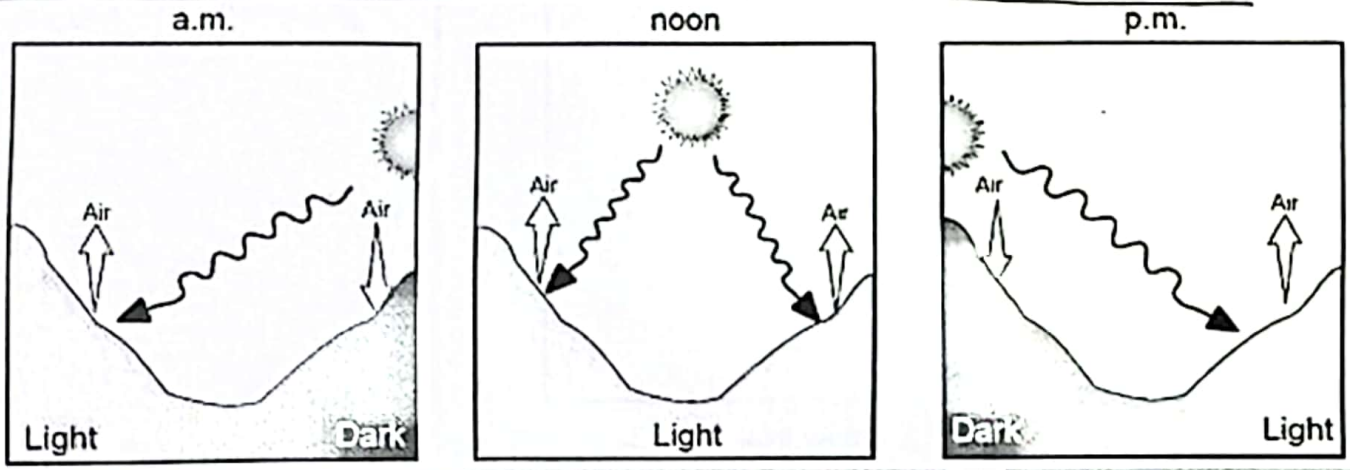
- Mountain/valleys heat unevenly because of the sun's motion across the sky:
  - In the morning, one side of a mountain or valley is lit and heated by the sun. The other side is still dark and cool. Air rises on the lighted side and descends on the dark side.
  - At midday both sides are "seen" by the sun and are heated.
  - The late afternoon situation is similar to the morning. After dark, as the air cools due to radiational cooling, the air drains down into the valley from all higher slopes.

الصبح جهة وحدة هم منه للشمس

noon

نفس الحالة الاولى بس عكس عجهة ثانية

لما بسبب برودة الهواء بنزل الهواء لتحت في الوادي من كل مناطق العالية

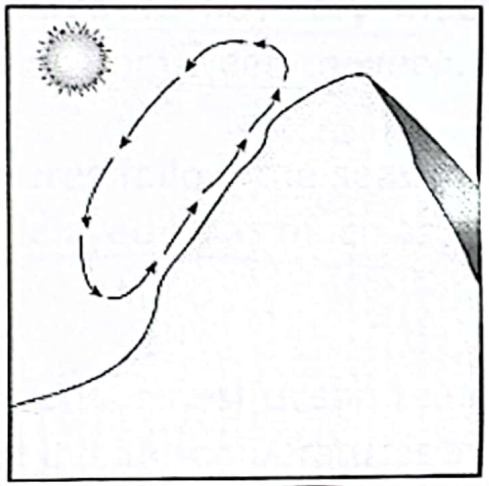


upslope ↑ downslope ↗

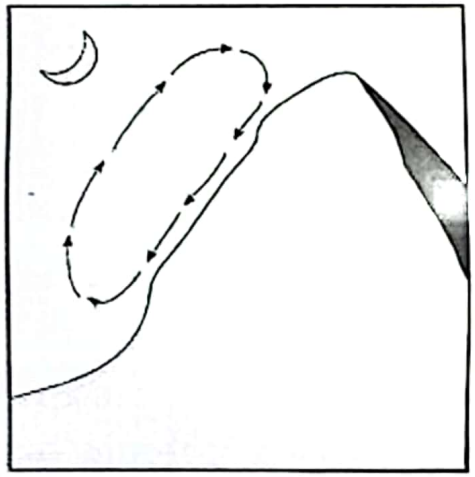
The upslope and downslope winds occur during the day and night respectively. In a true valley situation, downslope winds can occur on opposite slopes of the valley causing cool, dense air to accumulate or pool on the valley floor.

This cooler air can move down the valley resulting in air movement due to cold air drainage. Also, since the cooler air drains to the valley floor the air aloft is warmer.

This results in a temperature inversion which restricts vertical transport of air pollutants



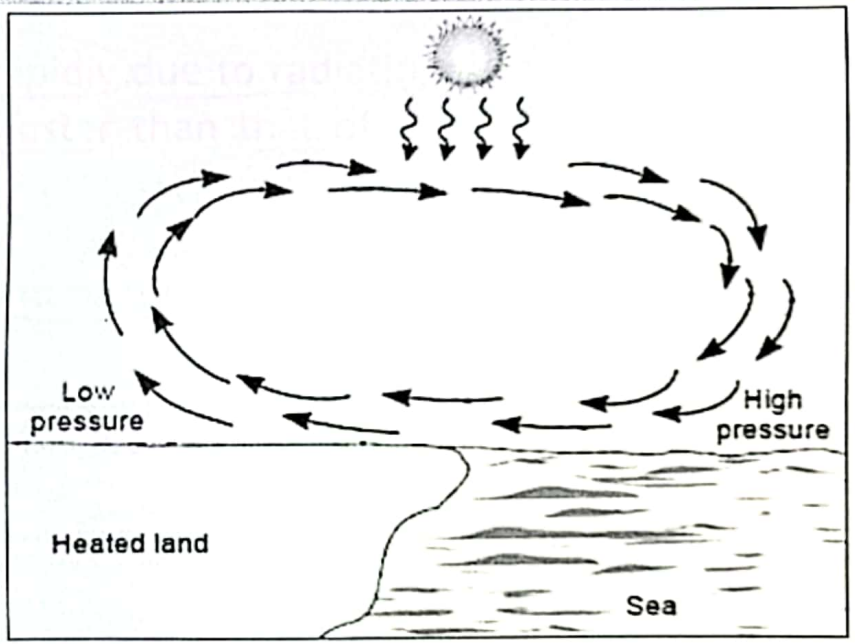
Upslope wind



Downslope wind

Sea breeze due to differential heating

As the sun shines down on the land/water interface, solar radiation will penetrate several feet through the water. On the other hand solar radiation striking land will only heat the first few inches. Also, as the sun shines on the water surface, evaporation and some warming take place.



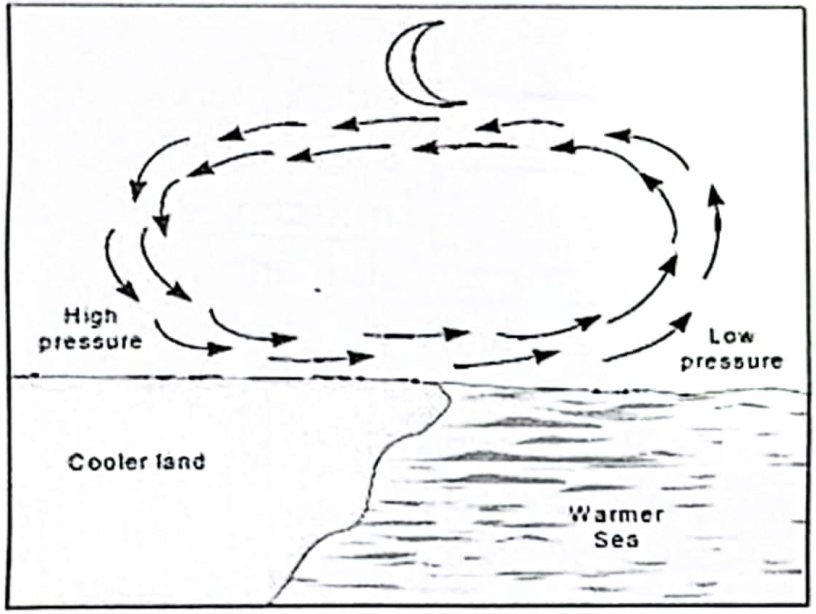
The thin layer of water next to the air cools due to evaporation and mixes downward, overturning with the small surface layer that has warmed. This mixing of the water layer close to the surface keeps the water temperature relatively constant. On the other hand, land surfaces warm quickly, causing the adjacent air to heat up, become less dense, and rise. The cooler air over the water is drawn inland and becomes the well-known **sea breeze**

At night, the air over the land cools rapidly due to radiational cooling, which causes the land temperature to fall faster than that of the adjacent water body.

يبرد الهواء فوقه بسرعة يابسة سطح يليل

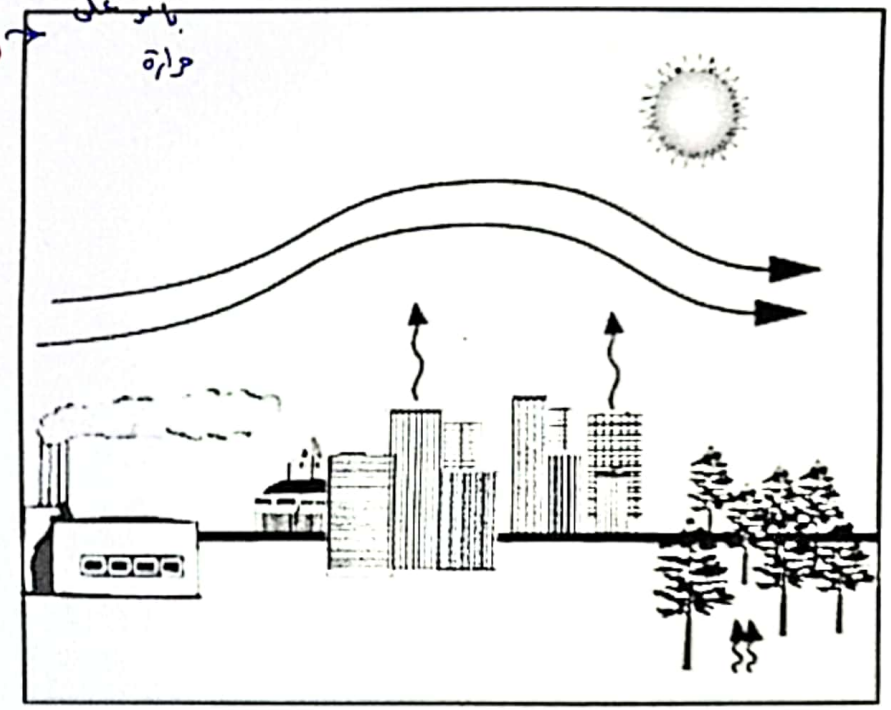
ويكون

This creates a return flow called the **land breeze**



Urban

- Urban areas have added roughness features and different thermal characteristics due to the presence of man-made elements.
- The thermal influence dominates the influence of the frictional components.
- Building materials such as brick and concrete absorb and hold heat more efficiently than soil and vegetation found in rural areas. After the sun sets, the urban area continues to radiate heat from buildings, paved surfaces, etc. Air warmed by this urban complex rises to create a dome over the city. It is called **the heat island effect**.



The city emits heat all night. Just when the urban area begins to cool, the sun rises and begins to heat the urban complex again. Generally, city areas never revert to stable conditions because of the continual heating that occurs.

Air Pollution: Concepts & Factors

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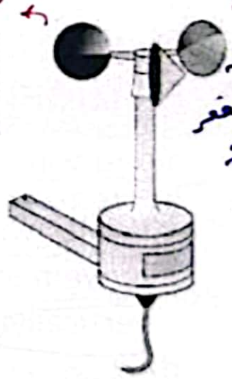
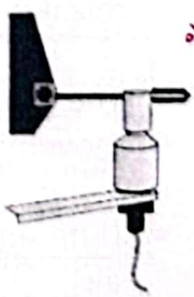
Concepts

- High wind speeds result in lower pollutant concentrations,
- Seasonal wind directions and patterns identify communities that may be vulnerable to pollutant exposure,
- In urban areas, for example, a record of wind direction is used to estimate average concentrations of hydrocarbons, sulfur dioxide, and other pollutants,
- A wind rose is a diagram designed to depict the relative frequency with which the wind blows from the various directions around the compass. Specific information can be recorded for seasonal wind patterns as well as local fluctuations by time of day.



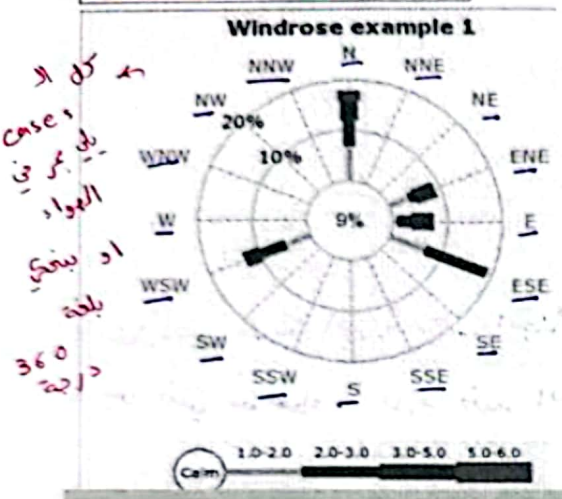
Rotating Cup Anemometer

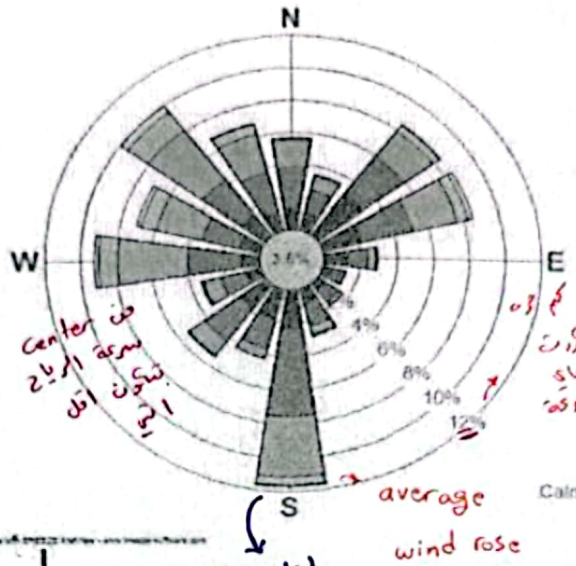


Wind Direction Vane

Wind rose

A wind rose is a chart which gives a view of how wind speed and wind direction are distributed at a particular location over a specific period of time.





average wind rose

Atmospheric Stability

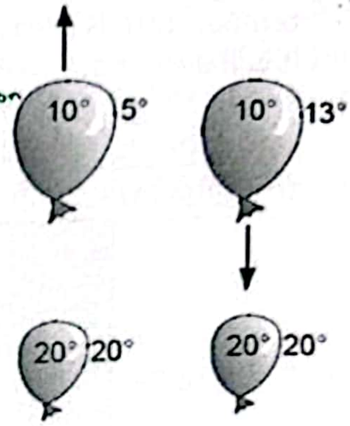
الاستقرار الجوي

- While wind speed and direction generally relate to the horizontal movement of air, atmospheric stability relates to the forces that move air vertically.
- The vertical movement of air, or atmospheric stability, is most directly affected by high and low-pressure systems that lift air over terrain and mix it with the upper atmosphere.
- The mechanisms that are specifically responsible for the vertical movement of air are atmospheric temperature and pressure.
- Differential heating: Conduction & Convection (the vertical mixing of the air)

Principles Related to Vertical Motion

Parcel

- A *parcel* of air is theoretically infinitesimal parcel is a relatively well-defined body of air (a constant number of molecules) that acts as a whole.
- Self-contained, it does not readily mix with the surrounding air.
- The exchange of heat between the parcel and its surroundings is minimal, and the temperature within the parcel is generally uniform.
- The air inside a balloon is an analogy for an air parcel.



Buoyancy Factors

- Atmospheric temperature and pressure influence the buoyancy of air parcels. Holding other conditions constant, the temperature of air (a fluid) increases as atmospheric pressure increases, and conversely decreases as pressure decreases.
- With respect to the atmosphere, where air pressure decreases with rising altitude, the normal temperature profile of the troposphere is one where temperature decreases with height.
- An air parcel that becomes warmer than the surrounding air (for example, by heat radiating from the earth's surface), begins to expand and cool. As long as the parcel's temperature is greater that the surrounding air, the parcel is less dense than the cooler surrounding air. Therefore, it rises, or is buoyant. As the parcel rises, it expands thereby decreasing its pressure and, therefore, its temperature decreases as well. The initial cooling of an air parcel has the opposite effect.

الهواء البارد بنزل لتقت عكسها
الهواء السخن بترتفع وبيرد
وبيرد

In short, warm air rises and cools, *while* cool air descends and warms

اعلى اشي

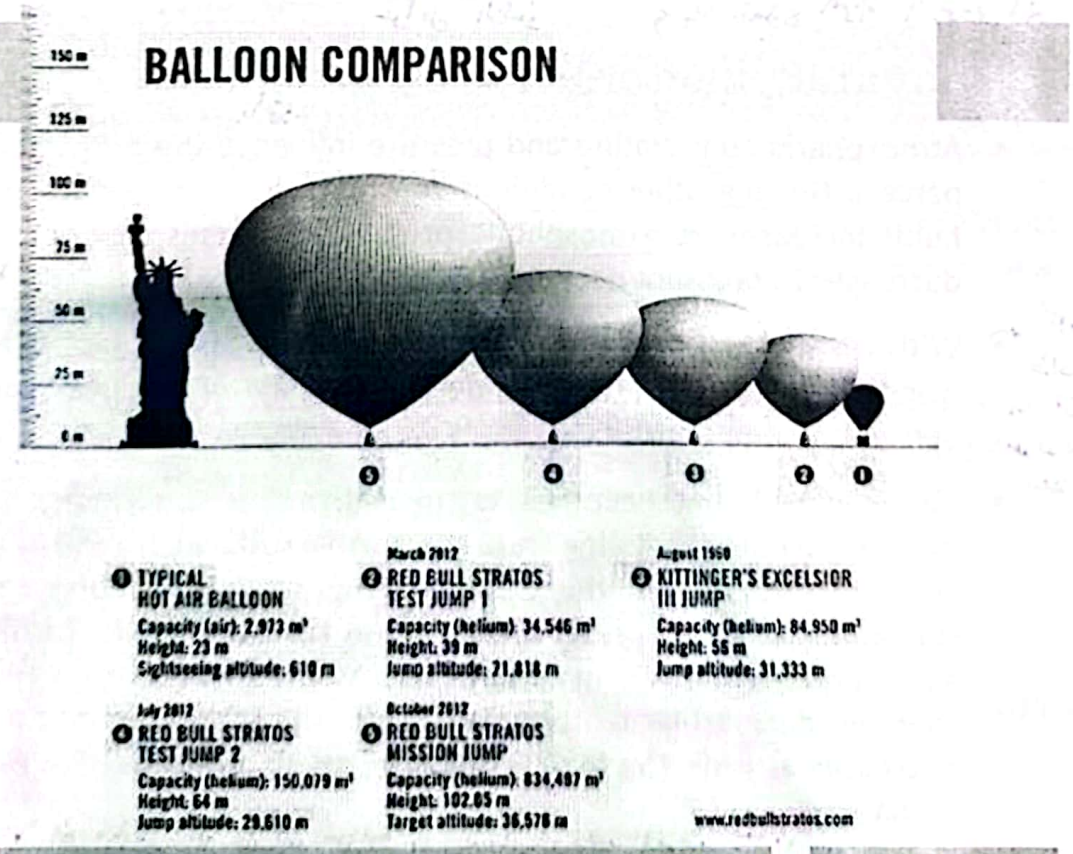
The extent to which an air parcel rises or falls depends on the relationship of its temperature to that of the surrounding air. As long as the parcel's temperature is greater, it will rise; as long as the parcel's temperature is cooler, it will descend.

When the temperatures of the parcel and the surrounding air are the same, the parcel will neither rise nor descend unless influenced by wind flow.

برصله ال
لحد
او اقل اشي
بنزل اله

ح
بضل يطلع
او ينزل لبين
ما يصيروا نفس حرارة

بس يصيروا بنفس
الحرارة اح تضل
محافظ الا اذا
اثر فيها الهواء
(الرياح)

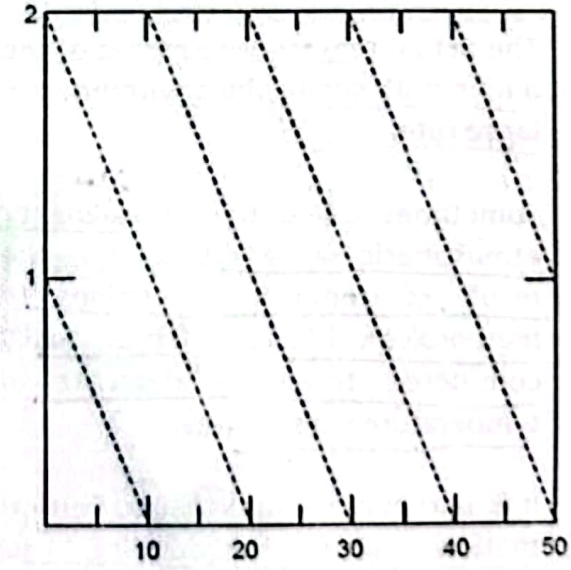


Lapse Rates

- The lapse rate is defined as the rate at which air temperature changes with height.
- The actual lapse rate in the atmosphere is approximately −6 to −7°C per km (in the troposphere) but it varies widely depending on location and time of day.
- We define a temperature *decrease* with height as a negative lapse rate and a temperature *increase* with height as a positive lapse rate.

Dry Adiabatic lapse rate

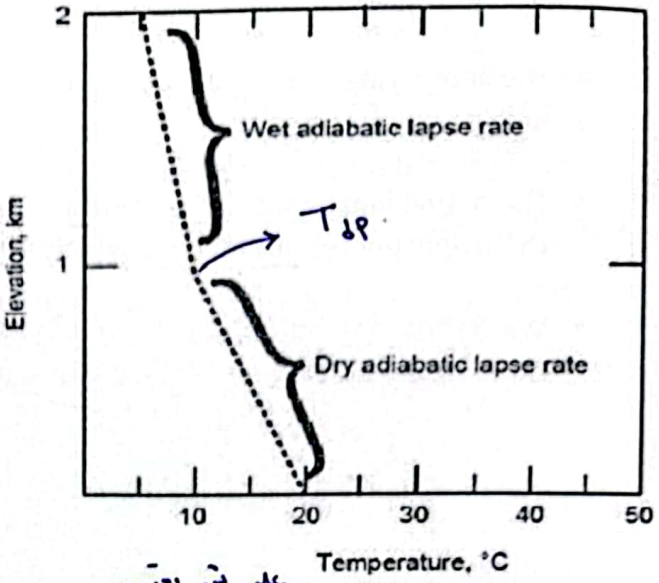
- The dry adiabatic lapse rate is a fixed rate, entirely independent of ambient air temperature.
- An air parcel that is warmer than the surrounding air does not transfer heat to the atmosphere.
- A dry air parcel rising in the atmosphere cools at the dry adiabatic rate of 9.8°C/1000m and has a lapse rate of −9.8°C/1000m. Likewise, a dry air parcel sinking in the atmosphere heats up at the dry adiabatic rate of 9.8°C/1000m and has a lapse rate of 9.8°C/1000m. Air is considered dry, in this context, as long as any water in it remains in a gaseous state.



In an adiabatic process, compression results in heating and expansion results in cooling.

Wet Adiabatic lapse rate

- A rising parcel of dry air containing water vapor will continue to cool at the dry adiabatic lapse rate until it reaches its condensation temperature, or dew point. At this point the pressure of the water vapor equals the saturation vapor pressure of the air, and some of the water vapor begins to condense.
- Condensation releases latent heat in the parcel, and thus the cooling rate of the parcel slows.



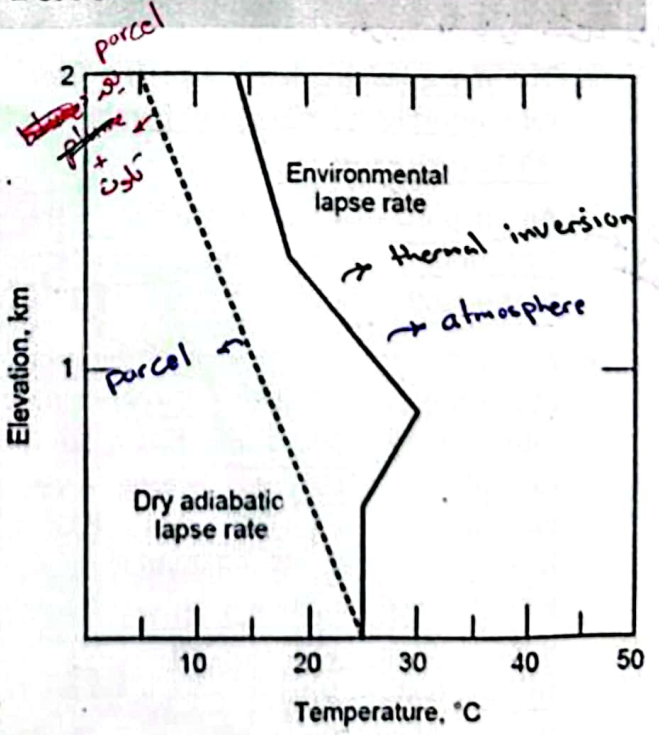
Unlike the **dry adiabatic lapse rate**, the **wet adiabatic lapse rate** is not constant but depends on temperature and pressure. In the middle troposphere, however, it is assumed to be approximately −6 to −7°C/1000 m.

Environmental lapse rate

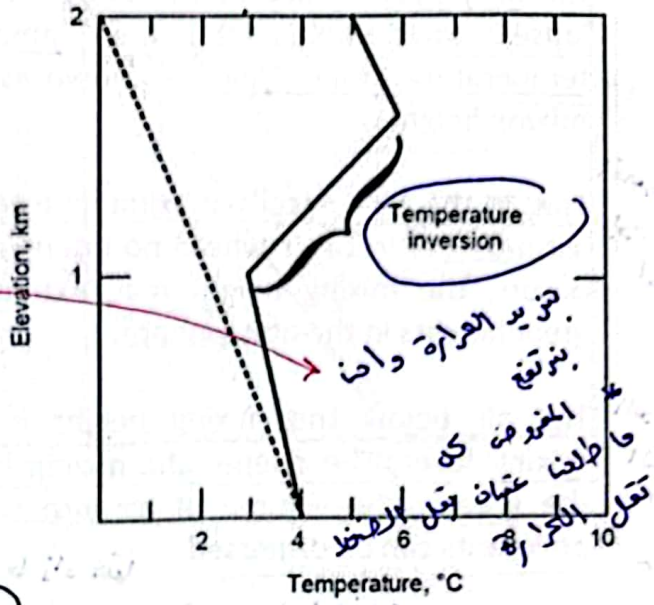
The actual temperature profile of the ambient air shows the **environmental lapse rate.**

Sometimes called the **prevailing or atmospheric lapse rate,** it is the result of complex interactions of meteorological factors, and is usually considered to be a decrease in temperature with height.

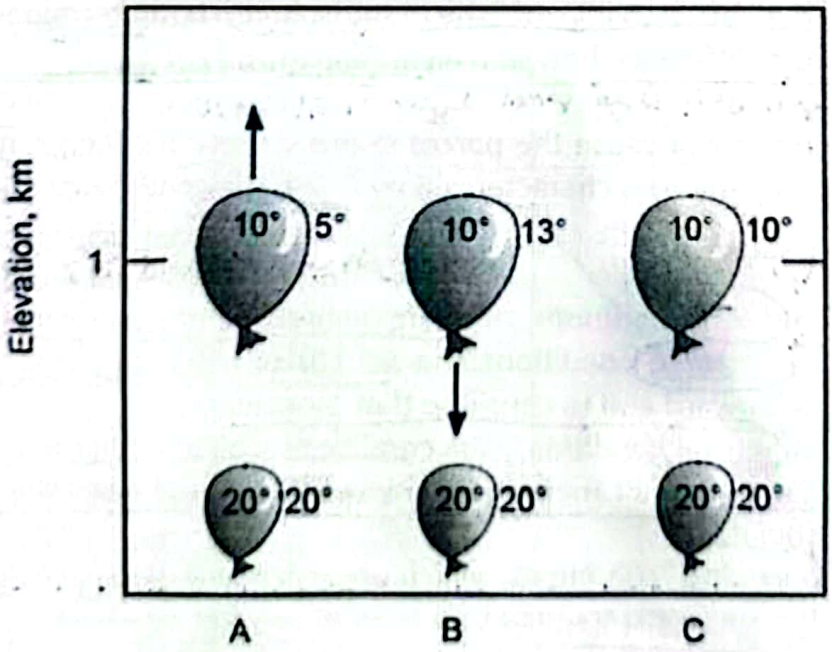
It is particularly important to vertical motion since surrounding air temperature determines the extent to which a parcel of air rises or falls.



- The temperature profile can vary considerably with altitude, sometimes changing at a rate greater than the dry adiabatic lapse rate and some times changing less.
- The condition when temperature actually increases with altitude is referred to as a **temperature inversion.**
- The temperature inversion occurs at elevations of from 200 to 350 m. This situation is particularly important in air pollution, because it limits vertical air motion.



Relationship of adiabatic lapse rate to air temperature

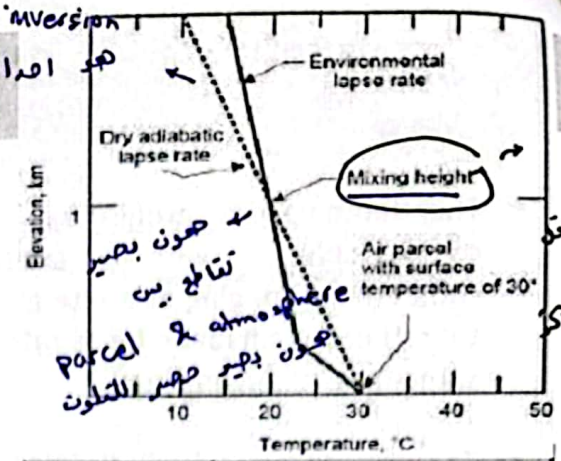


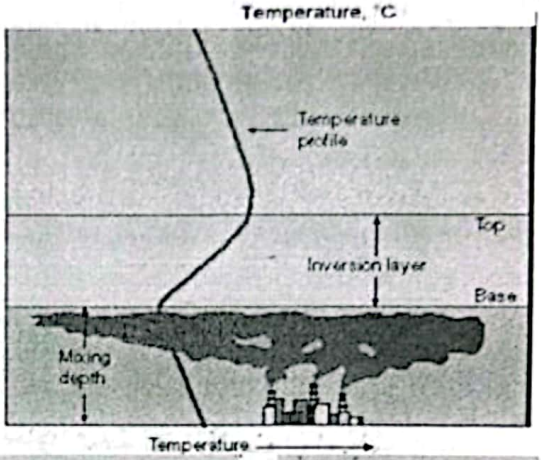
Mixing Height

In an adiabatic diagram, the point at which the air parcel cooling at the dry adiabatic lapse rate intersects the ambient temperature profile "line" is known as the **mixing height.**

This is the air parcel's maximum level of ascendance. In cases where no intersection occurs, the mixing height may extend to great heights in the atmosphere.

The air below the mixing height is the **mixing layer.** The deeper the mixing layer, the greater the volume of air into which pollutants can be dispersed.





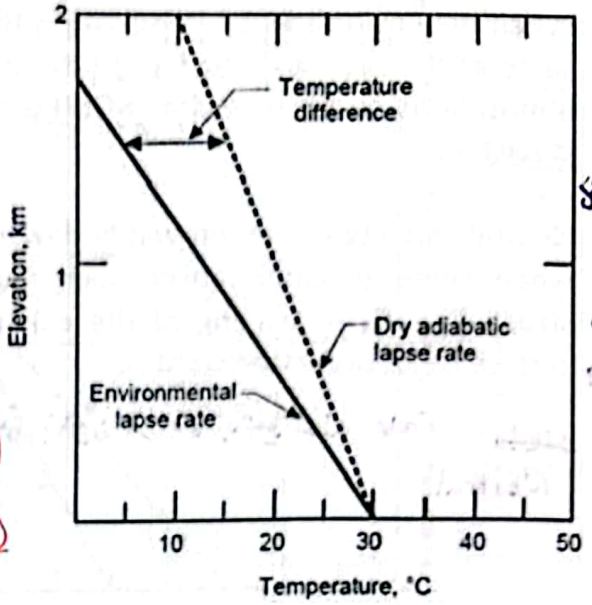
Atmospheric Stability

- The degree of stability of the atmosphere is determined by the temperature difference between an air parcel and the air surrounding it.
- This difference can cause the parcel to move vertically (i.e., it may rise or fall). This movement is characterized by four basic conditions:

- In stable conditions, this vertical movement is discouraged,
- In unstable conditions the air parcel tends to move upward or downward and to continue that movement,
- In neutral conditions, the conditions which neither encourage nor discourage air movement beyond the rate of adiabatic heating or cooling.
- Inversion conditions, which are extremely stable, cooler air near the surface is trapped by a layer of warmer air above it.

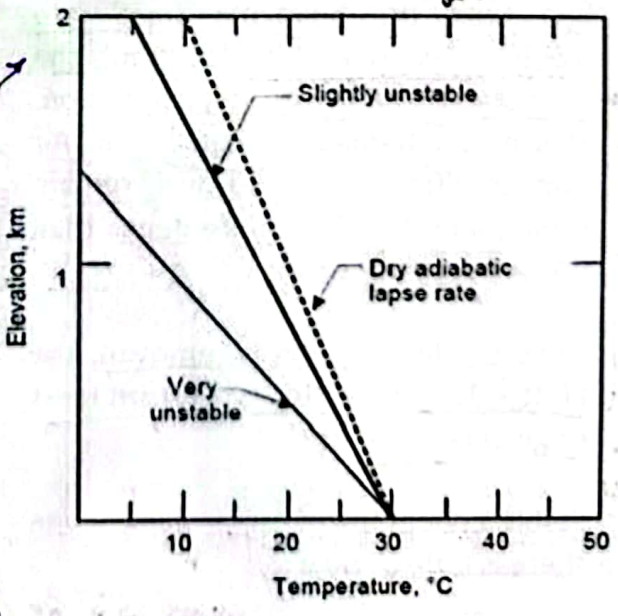
Unstable Conditions

- This assumes that the surrounding atmosphere has a lapse rate greater than the adiabatic lapse rate (cooling at more than 9.8°C/1000 m), so that the rising parcel will continue to be warmer than the surrounding air. This is a **superadiabatic lapse rate**.
- the temperature difference between the actual environmental lapse rate and the dry adiabatic lapse rate actually increases with height, and buoyancy is enhanced.



As the air rises, cooler air moves underneath. It, in turn, may be heated by the earth's surface and begin to rise. Under such conditions, vertical motion in both directions is enhanced, and considerable vertical mixing occurs. The degree of instability depends on the degree of difference between the environmental and dry adiabatic lapse rates.

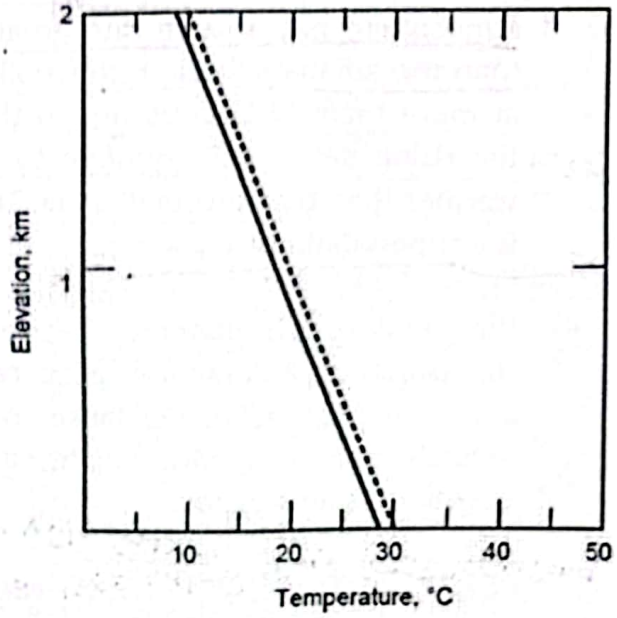
Unstable conditions most commonly develop on sunny days with low wind speeds where strong insolation is present.



Neutral Conditions

When the environmental lapse rate is the same as the dry adiabatic lapse rate, the atmosphere is in a state of neutral stability.

Neutral stability occurs on windy days or when there is cloud cover such that strong heating or cooling of the earth's surface is not occurring.

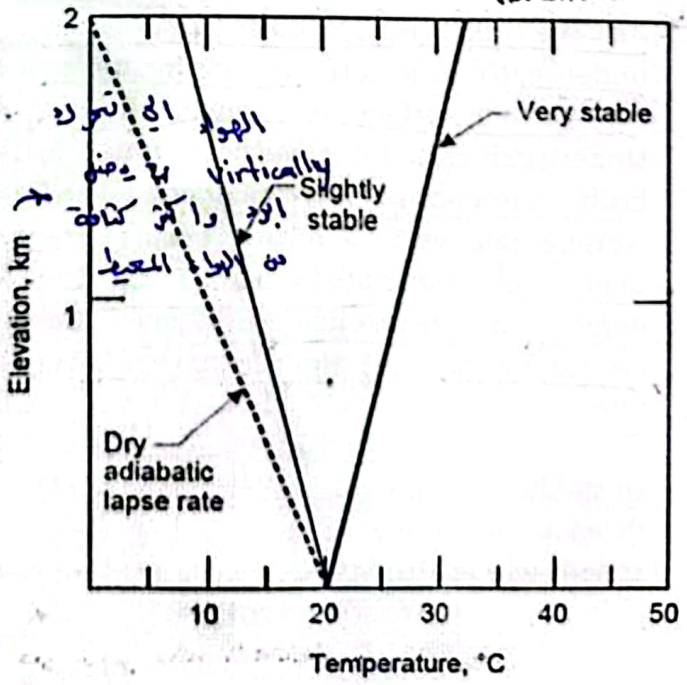


Stable Conditions

When the environmental lapse rate is less than the adiabatic lapse rate (cools at less than 9.8°C/1000 m), the air is stable and resists vertical motion. This is a subadiabatic lapse rate. Air that is lifted vertically will remain cooler, and therefore more dense than the surrounding air.

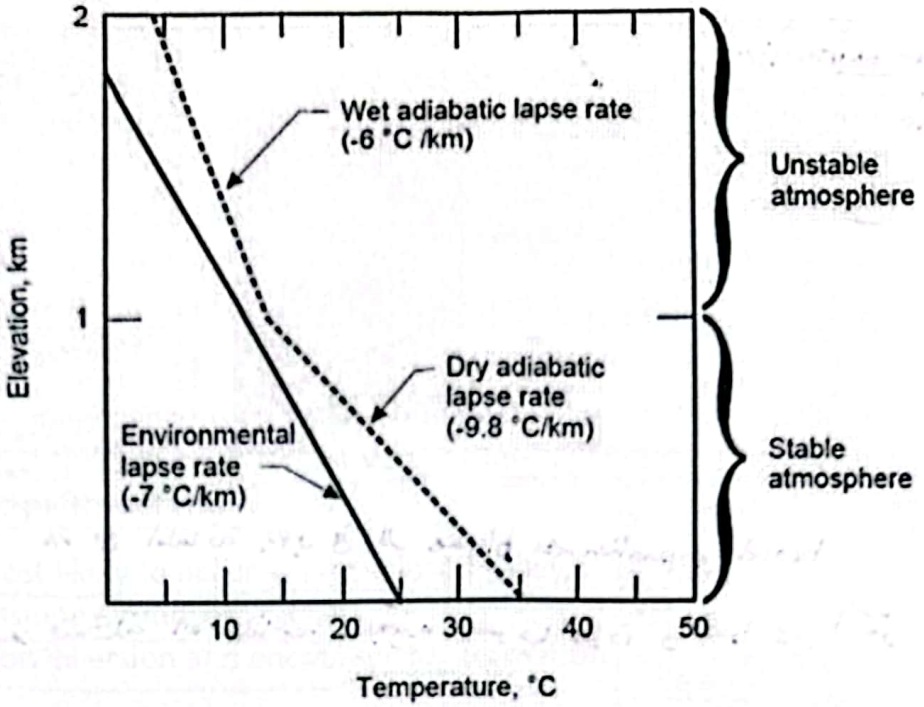
Once the lifting force is removed, the air that has been lifted will return to its original position.

Stable conditions occur at night when there is little or no wind.



Conditional Stability and Instability

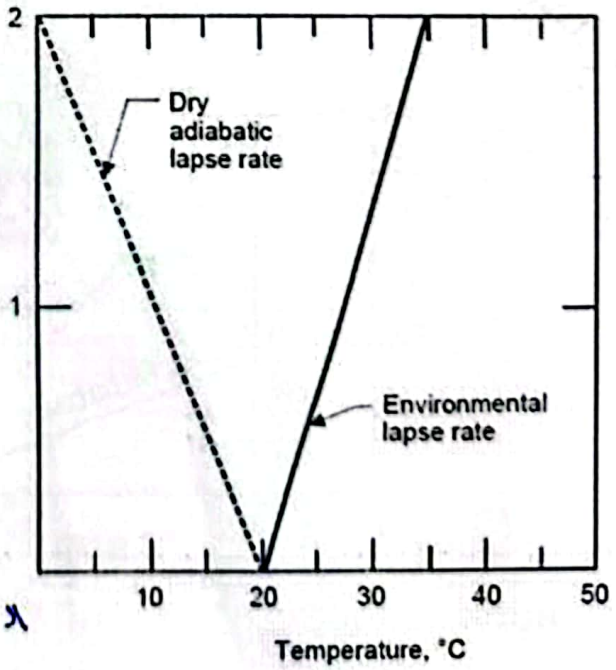
- ✓ Conditional instability occurs when the environmental lapse rate is greater than the wet adiabatic lapse rate but less than the dry rate.
- ✓ Stable conditions occur up to the condensation level and unstable conditions occur above it.



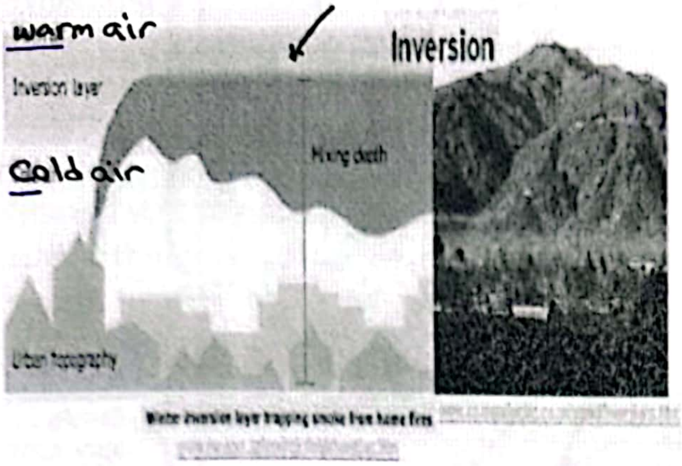
Inversions

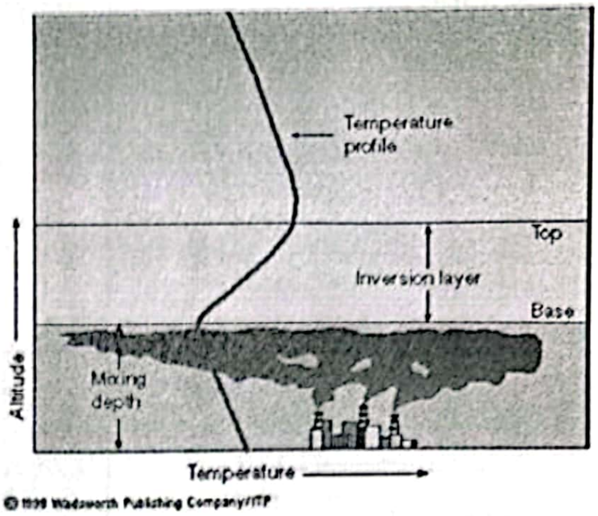
An inversion occurs when air temperature increases with altitude. This situation occurs frequently but is generally confined to a relatively shallow layer.

Plumes emitted into air layers that are experiencing an inversion (inverted layer) do not disperse very much as they are transported with the wind. Plumes that are emitted above or below an inverted layer do not penetrate that layer, rather these plumes are trapped either above or below that inverted layer.



صور الـ plume
اخذت شكل الـ layer



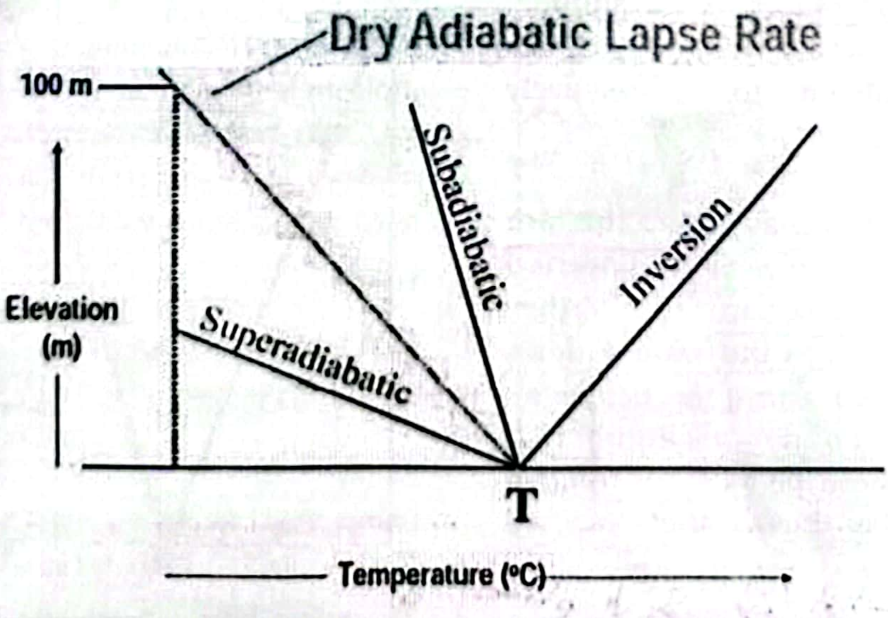


* مع المسافة بصير في الـ plume ⇐ broad expantion

* مشكلة ان المناطق البعيده بصير فيها تلوث و بحسوا في اكثر

Summary

حفظ
يحكي يطلبه ترسمها



Radiation

حالات فيها الـ topography تلعب دور

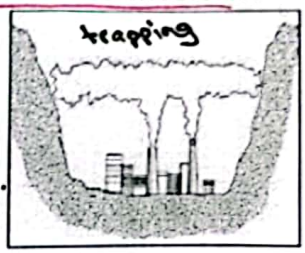
- The **radiation inversion** is the most common form of surface inversion and occurs when the earth's surface cools rapidly. As the earth cools, so does the layer of air close to the surface. If this air cools to a temperature below that of the air above, it becomes very stable, and the layer of warmer air impedes any vertical motion. يصير مستقر

يفتح عندما تبرد حرارة سطح الأرض وبرد بدوره سطح الأرض رح يبرد الهواء الي حواليه فإذا برد لدرجة صار ابرد من الهواء يلي فوقه رح يصير مستقر

- Radiation inversions usually occur in the late evening through the early morning under clear skies with calm winds, when the cooling effect is greatest.

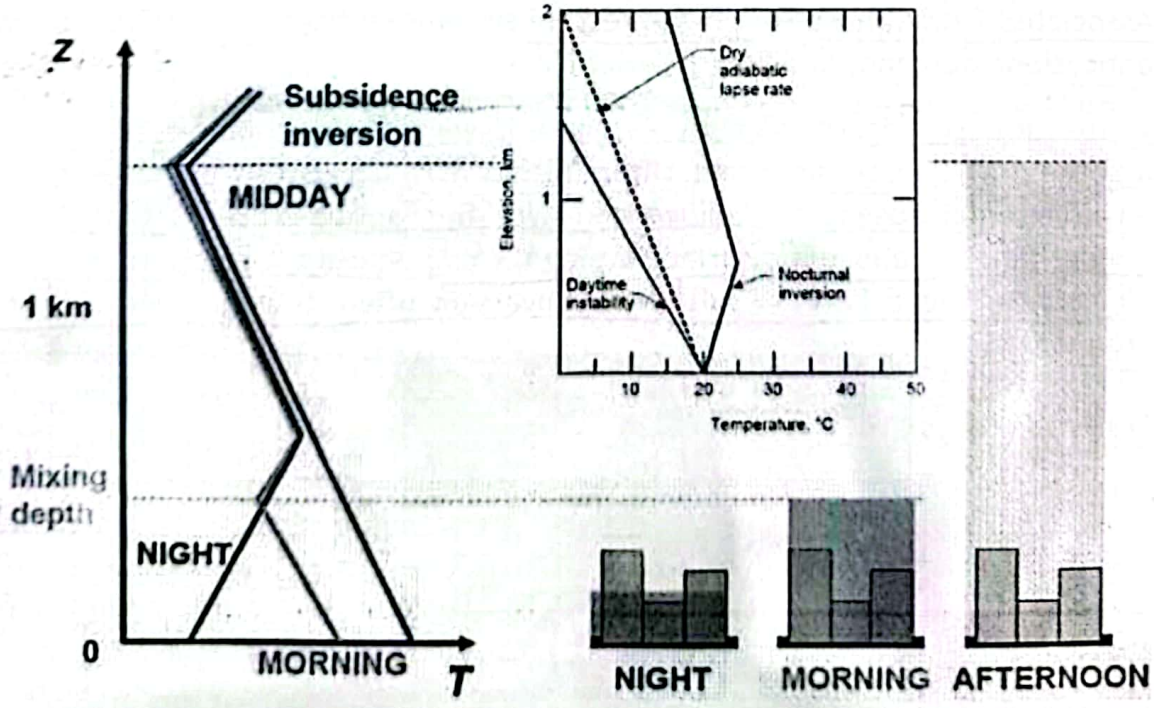
- The effects of radiation inversions are often short-lived. Pollutants trapped by the inversions are dispersed by vigorous vertical mixing after the inversion breaks down shortly after sunrise.

- This situation is most likely to occur in an enclosed valley, where cool, downslope air movement can reinforce a radiation inversion and encourage fog formation.



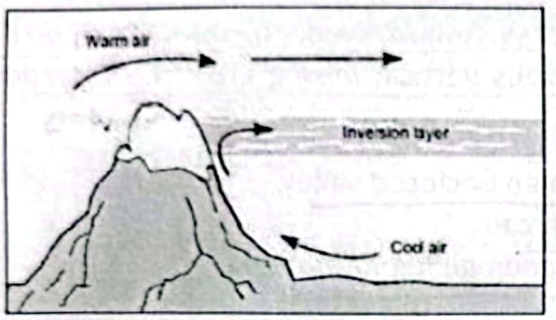
مع اختلاف الوقت كيف بختلف انتشار تلوث (بليل ا كتر)

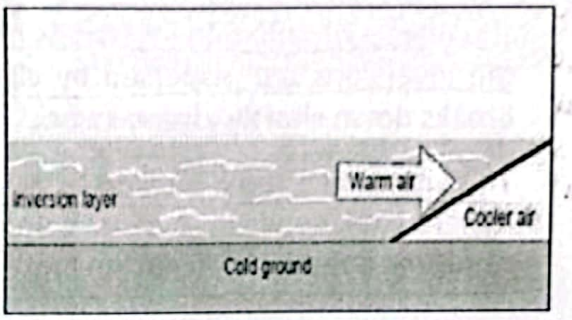
Diurnal Cycle of Surface Heating /Cooling



Advection

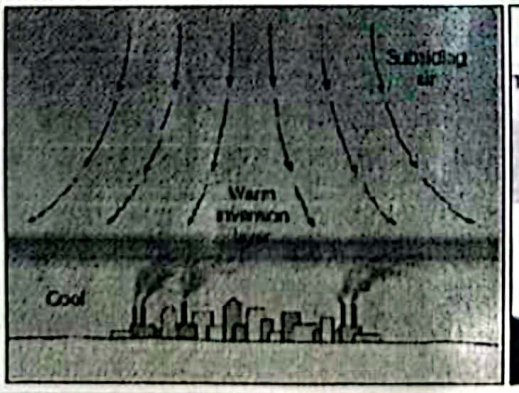
- Advection inversions are associated with the horizontal flow of warm air. When warm air moves over a cold surface, conduction and convection cools the air closest to the surface, causing a surface-based inversion .
- This inversion is most likely to occur in winter when warm air passes over snow cover or extremely cold land.

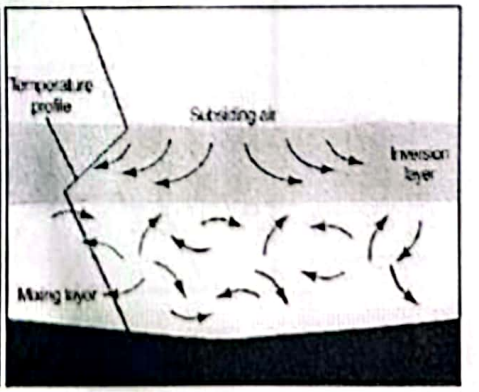




Subsidence Inversion

- Associated with atmospheric high-pressure systems (anticyclones). Where air in an anticyclone descends and flows outward in a clockwise rotation
- As the air descends, the higher pressure at lower altitudes compresses and warms it at the dry adiabatic lapse rate. Often this warming occurs at a rate faster than the environmental lapse rate. The inversion layer thus formed is often elevated several hundred meters above the surface during the day. At night, because of the surface air cooling, the base of a subsidence inversion often descends perhaps to the ground.
- Persists for days





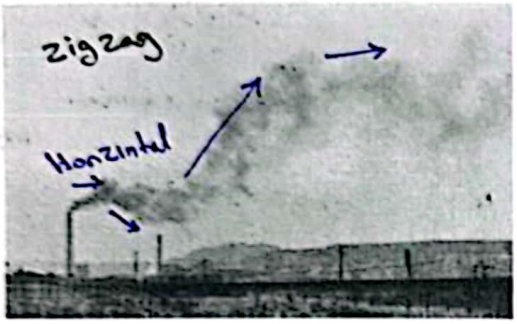
Stability and Plume Behavior

- The degree of atmospheric stability and the resulting mixing height have a large effect on pollutant concentrations in the ambient air. Although the discussion of vertical mixing did not include a discussion of horizontal air movement, or wind, you should be aware that horizontal motion does occur under inversion conditions. Pollutants that cannot be dispersed upward may be dispersed horizontally by surface winds.

حركة الهواء الأفقية و الرأسية بتأثر في سلوك الـ plumes اللي بتطلع من المدخنة

- The combination of vertical air movement and horizontal air flow influences the behavior of plumes from point sources (stacks).

مدخنة ولازم ارتفاعها يكون معين



هذا احسن من بسة الثانية

plume rise

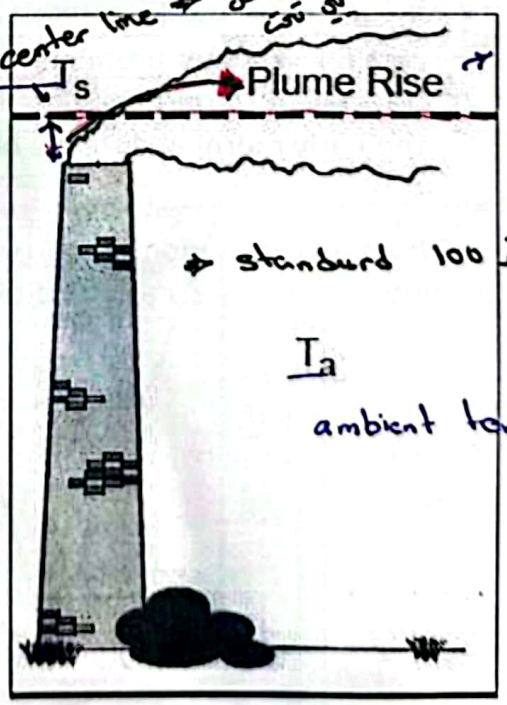
* حرارة وضغط الـ plume بيلعبوا دور في

surounding

plume = عبارة عن سحابة من chemical طالع

Plume Rise

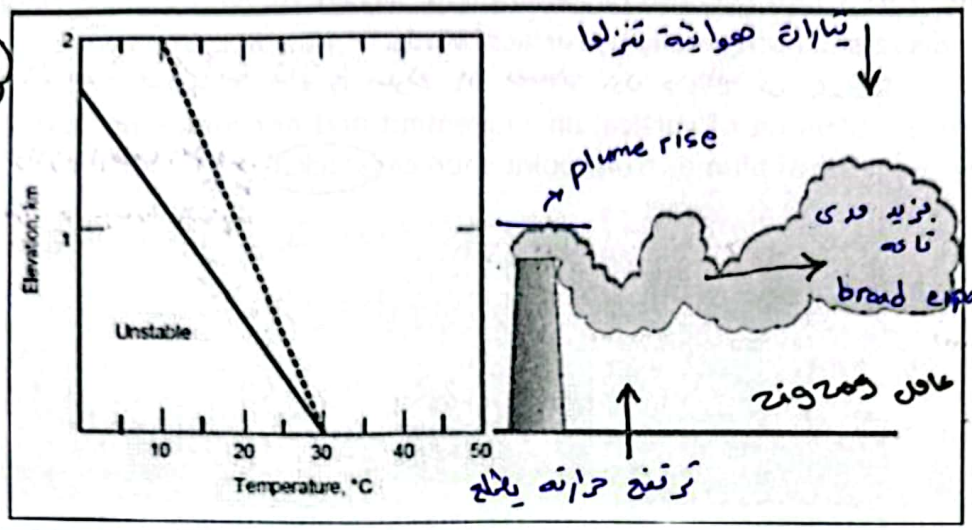
- The distance that the plume rises above the stack is called *plume rise.*
- It is actually calculated as the distance to the imaginary centerline of the plume rather than to the upper or lower edge of the plume.
- The Plume rise, Δh, depends on the stack's physical characteristics. For example, the effluent characteristic of stack temperature in relation to the surrounding air temperature is more important than the stack characteristic of height. The difference in temperature between the stack gas (T_s) and the ambient air (T_a) determine plume density and that density affects plume rise.



stack height + plume rise = effective stack height

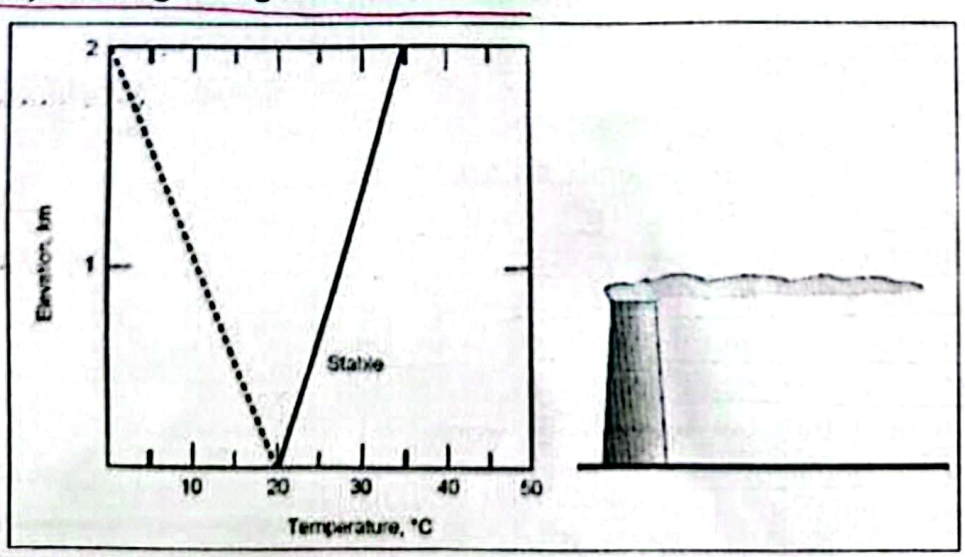
The looping plume

- It occurs in highly unstable conditions and results from turbulence caused by the rapid overturning of air. While unstable conditions are generally favorable for pollutant dispersion, momentarily high ground-level concentrations can occur if the plume loops downward to the surface.



The fanning plume

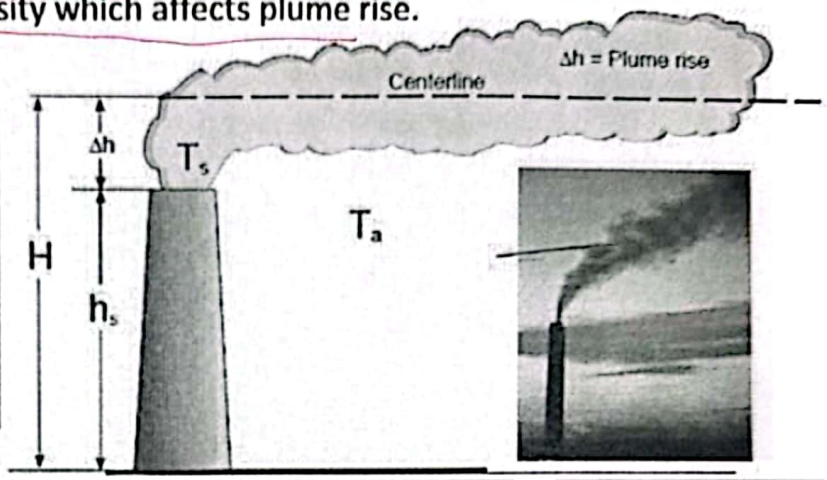
- It occurs in stable conditions. The inversion lapse rate discourages vertical motion without prohibiting horizontal motion, and the plume may extend downwind from the source for a long distance. Fanning plumes often occur in the early morning during a radiation inversion



Plume Rise: Momentum and Buoyancy

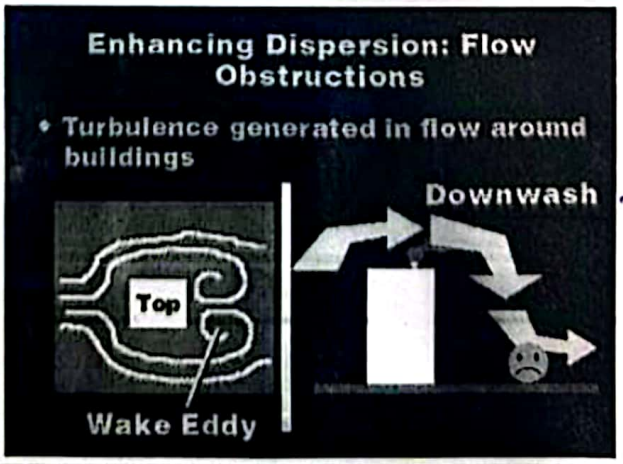
- The final height of the plume, referred to as the effective stack height (H), is the sum of the physical stack height (h_s) and the plume rise (Δh).
- Plume rise is actually calculated as the distance to the imaginary centerline of the plume rather than to the upper or lower edge of the plume
- The difference in temperature between the stack gas (Ts) and ambient air (Ta) determines the plume density which affects plume rise.

✓ The velocity of the stack gases which is a function of the stack diameter and the volumetric flow rate of the exhaust gases determines the plume's momentum



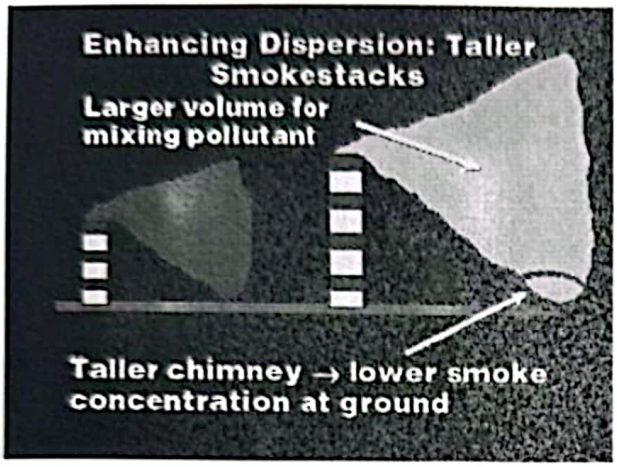
Enhancing Dispersion: Flow Obstructions

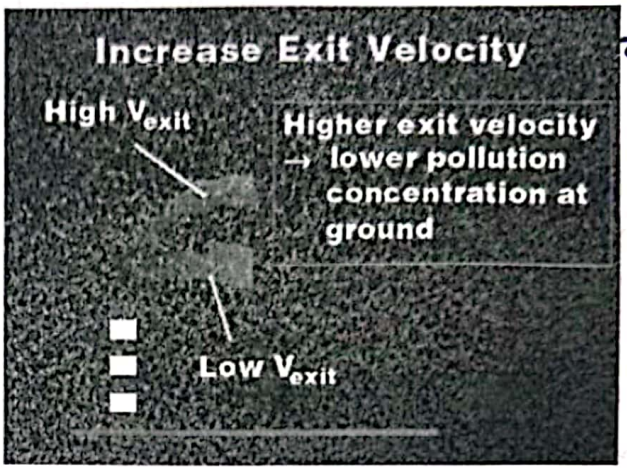
- The turbulent wake behind a building helps mix pollutants to the ground that might not have been there normally, in a stable atmosphere.
- Downwash is especially bad when there are pollution sources on the top of the building.
- It is important to get the pollution emitted high enough above the building so that it does not get caught in the downwash and get carried down to the ground



Enhancing Dispersion with Smokestacks

- Pollution emitted from a taller stack has to travel a longer distance to get to the ground, so it will become more dilute.
- The faster the smoke gushes out, the more momentum it has, and the higher it will fly before it levels out and disperses toward the ground.





* اذا زادت سرعة رفع وبباخه مسافة اكبر

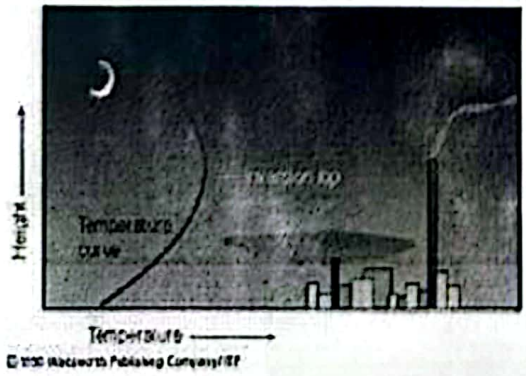
* كل ما رفعت الـ stack بتزيد مسافة ليوصل height

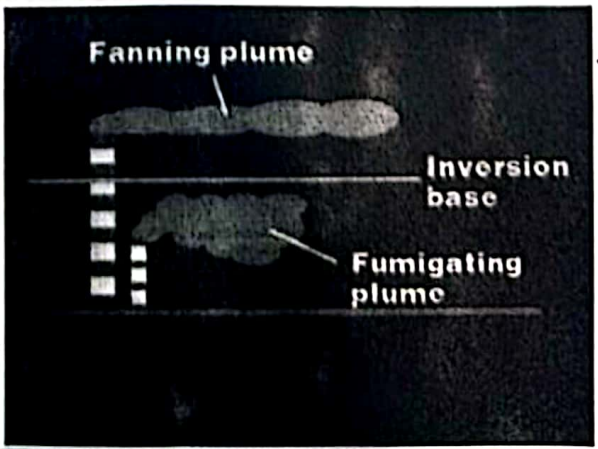
ground لـ ثلوث

Tall and Short Smoke Stacks

tall → fanning
short → fumigate

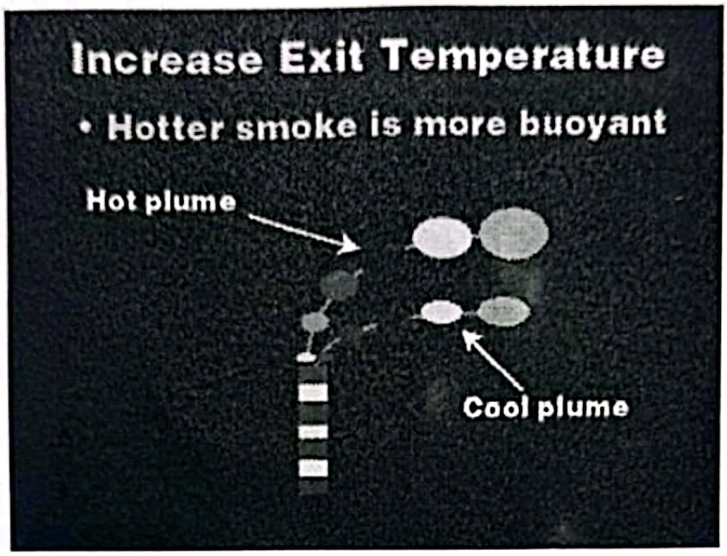
- With a tall enough smokestack, pollution is emitted within the inversion aloft, forming a fanning plume that does not pollute the area near the smokestack. If it's not tall enough, it will fumigate the countryside.
- Switching the layers so that the inversion is at the ground, we need the smokestack tall enough to be above the ground inversion, so that a lofting plume is formed. Architects will need to know the average depth of the nocturnal radiation inversion in order to know how tall to build the smokestack.





Exit Temperature

- The higher the temperature, the greater the positive buoyancy in smoke streaming out of the smokestack.
- The smoke has to rise higher before it has adiabatically cooled to a neutral buoyancy temperature



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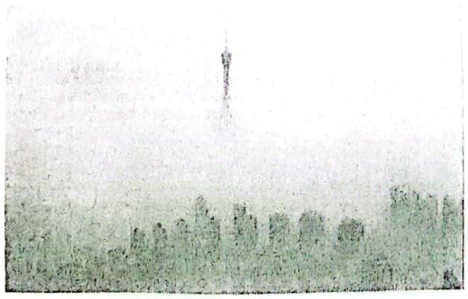
Air Pollution:

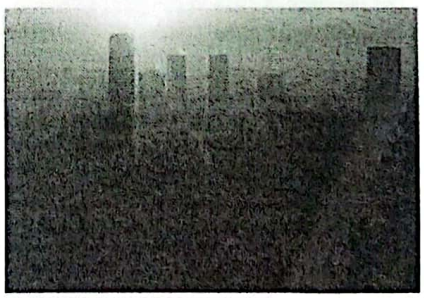
Air Pollutants & Human Health Effects

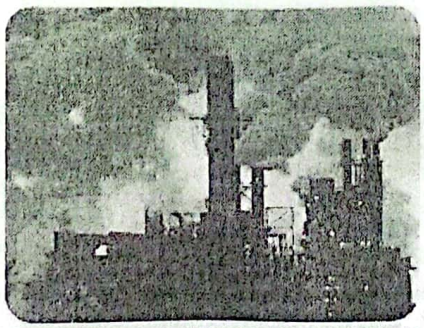
Dr. Motasem Saidan

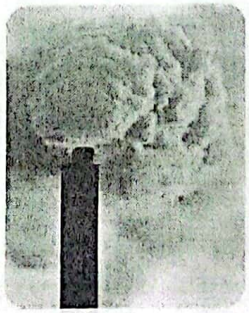
m.saidan@gmail.com

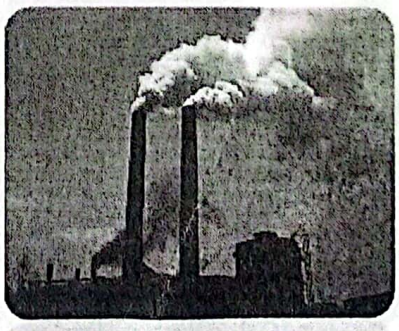
Air Pollution











Air Pollution Definitions

تعريفات التلوث

- Transfer of harmful and/or of Natural/Synthetic materials into the atmosphere as a direct/indirect consequences of human activity (OECD).

- The introduction of chemicals, particulate matter, or biological materials that cause harm or discomfort to humans or other living organisms, or damages the natural environment into the atmosphere

- The overwhelming scientific consensus is that the earth's atmosphere is warming rapidly, mostly because of human activities, and that this will lead to significant climate change during this century

Air Pollutants

- Pollutants mix in the air to form industrial smog, mostly the result of burning coal, and photochemical smog, caused by motor vehicle, industrial, and power plant emissions
- An air pollutant can be a gas or a particulate.
- Sources:
  - Natural sources
    - ✓ Dust blown by wind
    - ✓ Pollutants from wildfires and volcanoes
    - ✓ Volatile organics released by plants
  - Human sources: mostly in industrialized and/or urban areas
    - ✓ Stationary sources → مكان ثابت
    - ✓ Mobile sources ذي المحرك

Air Pollutants Classification

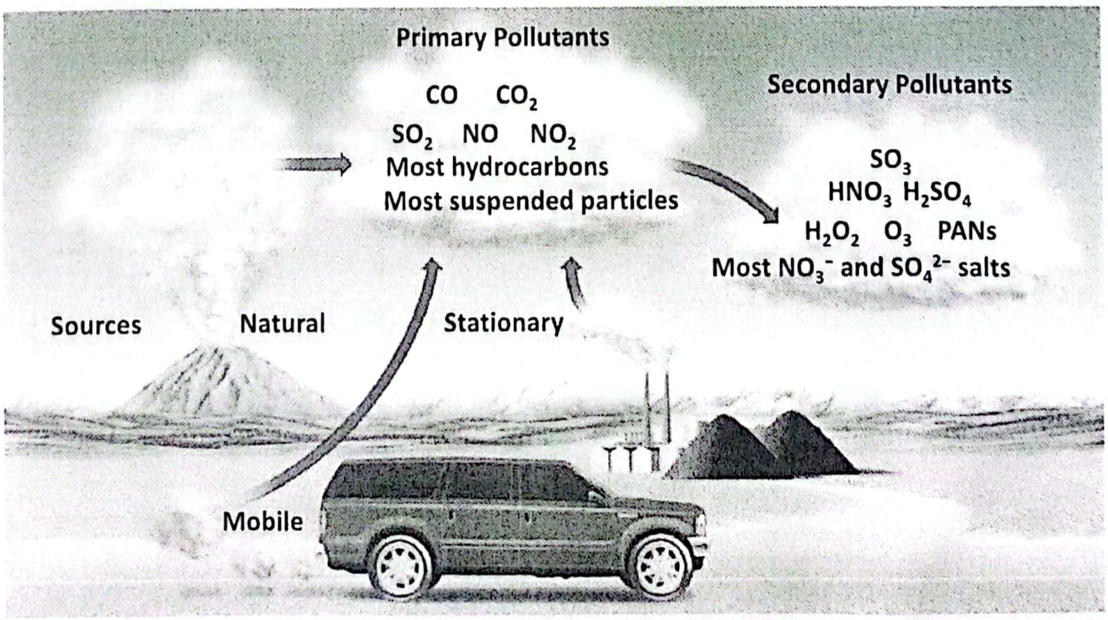
Classified as:

طلعت CO_2 "فلا" بدخل CO_2 (مثل stable زي ما انبعث مثل)

1. **Primary pollutants:** foreign matter injected into the atmosphere by human activities.

2. **Secondary pollutants:** resulting from (chemical transformations), typically with primary pollutants and (often) sunlight.

بجسيو تفاعل بجلطي ـه او الجوية
شعله- ثانية اعطل تبعكون



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Major Air Pollutants

(PM) ستعارف عليها الان بـ

Suspended particulate matter (SPM):

- Consists of a variety of solid particles and liquid droplets (small and light enough) to remain suspended in the air.
- The most harmful forms of SPM are fine particles (PM-10, with an average diameter < 10 micrometers) and ultrafine particles (PM-2.5). ← particle size less than 2.5 micro meters
- According to the EPA, SPM is responsible for about 60,000 premature deaths a year in the U.S.

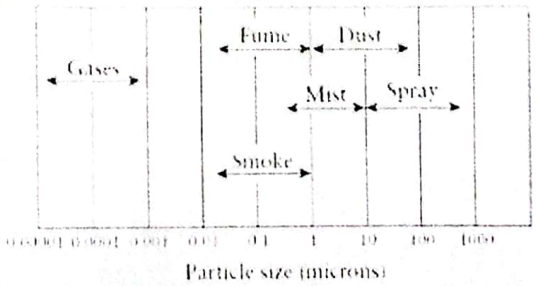
حتى موجودة بسلايدات الدكتور

Major Air Pollutants ⇒ particle size حسب الـ

- Particulate matter or pollutants can be further classified as dusts, fumes, mists, smoke, or spray.

عبارة عن solid

تقسيم المواد حسب الـ particle size



fume ⇒ ابخرة صادرة من المعادن وهي من اسود انواع الأبخرة

Terminology	Abbreviation	Diameter Range (μm)
Ultrafine	–	<0.1
Fine	$PM_{2.5}$	<2.5
Coarse	PM_{10}	2.5–10

Mist تقريباً نفس الـ spray بس الها particle size اقل وكثافة اكبو

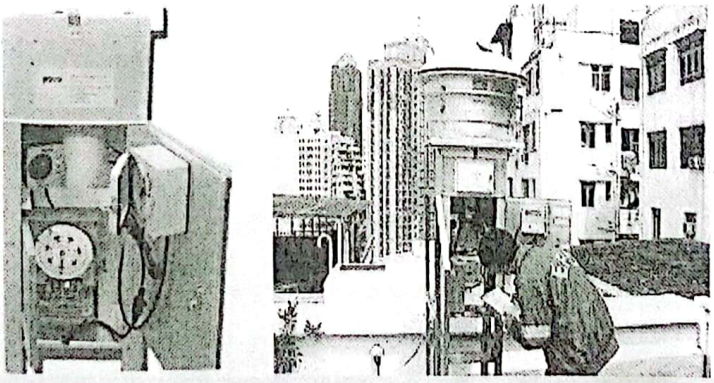
Particulate Matters

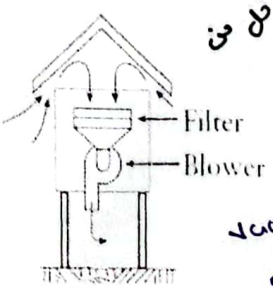
- Dust is defined as solid particles.
- A fume is also a solid particle, frequently a metallic oxide, formed by the condensation of vapors by sublimation, distillation, calcination, or chemical reaction processes. The particles in fumes are quite small, with diameters from 0.03 to 0.3 μ.
- A mist is an entrained liquid particle formed by the condensation of a vapor and perhaps by chemical reaction. Mists typically range from 0.5 to 3.0 μ in diameter.
- Smoke is made up of entrained solid particles formed as a result of incomplete combustion of carbonaceous materials. Smoke particles have diameters from 0.05 to approximately 1 μ.
- a spray is a liquid particle formed by the atomization of a parent liquid. Sprays settle under gravity

How we do the

Measurement of Particulates

- The measurement of PM10 has been historically done by using the *high-volume sampler* (or hi-vol).
- The high-volume sampler operates much like a vacuum cleaner, forcing up to 86,000 ft3 of air through a filter in 24 hr. The analysis is gravimetric; the filter is weighed before and after, and the difference is the particulates collected.





Gaseous Pollutants

- Gaseous pollutants include substances that are gases at normal temperature and pressure as well as vapors of substances that are liquid or solid at normal temperature and pressure.

Name	Formula	Properties of Importance	Significance as Air Pollutant
Sulfur dioxide	SO_2	Colorless gas; intense choking odor; highly soluble in water – forming sulfurous acid H_2SO_3	Damage to property, health, and vegetation
Sulfur trioxide	SO_3	Soluble in water – forming sulfuric acid H_2SO_4	Highly corrosive
Hydrogen sulfide	H_2S	Rotten-egg odor at low concentrations; odorless at high concentrations	Highly poisonous
Nitrous oxide	N_2O	Colorless gas; used as carrier gas in aerosol bottles	Relatively inert; not produced in combustion
Nitric oxide	NO	Colorless gas	Produced during high-temperature (high-pressure) combustion; oxidizes to NO_2
Nitrogen dioxide	NO_2	Brown to orange gas	Major component in the formation of photochemical smog
Carbon monoxide	CO	Colorless and odorless	Product of incomplete combustion; poisonous
Carbon dioxide	CO_2	Colorless and odorless	Formed during complete combustion; greenhouse gas
Ozone	O_3	Highly reactive	Damage to vegetation and property; produced mainly during the formation of photochemical smog
Hydrocarbons	C_xH_y or HC	Many	Emitted from automobiles and industries; formed in the atmosphere
Methane	CH_4	Combustible; odorless	Greenhouse gas
Chlorofluorocarbons	CFC	Nonreactive; excellent thermal properties	Deplete ozone in upper atmosphere

NOx

fume ← gases يتبخر

لانه من أكاسيد الهالدن

M.saidan

Air Pollution Effects

- **Effects on Human Health** → تأثيرات تلوث الهواء على صحة الإنسان يجب التنويه منها

  - Respiratory problems → مشاكل الجهاز التنفسي
  - Allergies → الحساسية
  - Risk for cancer → خطر الإصابة بالسرطان

- **Effects on the environment** → تأثير على البيئة

  - Acid rain (Regional) ← أمطار حامضية
  - Ozone depletion (Stratospheric) → استنزاف طبقة الأوزون
  - Greenhouse Effect (Global warming) ← غازات الدفيئة

Human Health Effects

التعرض لتلوث الهواء يسبب امراض كثيرة

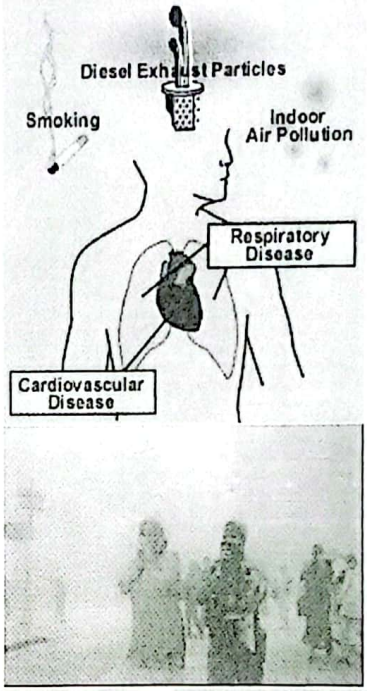
- Exposure to air pollution is associated with numerous effects on human health, including pulmonary, cardiac, vascular, and neurological impairments.

تأثير تلوث الهواء يختلف من شخص لآخر

- The health effects vary greatly from person to person. High-risk groups such as the elderly, infants, pregnant women, and sufferers from chronic heart and lung diseases are more susceptible to air pollution.

- Children are at greater risk because they are generally more exposed to outdoor environment and their lungs are still developing stage.

الصغار اكثر عرضة للخطر لانهم يلعبون بالتواب والرئتين عندهم في مرحلة النمو



كل ملوث و الوصف تاعه * مش حفظ الك جاي

Pollutant	Description	Sources	Health Effects	Welfare Effects
Carbon Monoxide (CO)	Colorless, odorless gas	Motor vehicle exhaust, indoor sources include kerosene or wood burning stoves.	Headaches, reduced mental alertness, heart attack, cardiovascular diseases, impaired fetal development, death.	Contribute to the formation of smog.
Sulfur Dioxide (SO_2)	Colorless gas that dissolves in water vapor to form acid, and interact with other gases and particles in the air.	Coal-fired power plants, petroleum refineries, manufacture of sulfuric acid and smelting of ores containing sulfur.	Eye irritation, wheezing, chest lightness, shortness of breath, lung damage.	Contribute to the formation of acid rain, visibility impairment, plant and water damage, aesthetic damage.
Nitrogen Dioxide (NO_2)	Reddish brown, highly reactive gas.	Motor vehicles, electric utilities, and other industrial, commercial, and residential sources that burn fuels.	Susceptibility to respiratory infections, irritation of the lung and respiratory symptoms (e.g., cough, chest pain, difficulty breathing).	Contribute to the formation of smog, acid rain, water quality deterioration, global warming, and visibility impairment.
Ozone (O_3)	Gaseous pollutant when it is formed in the troposphere.	Vehicle exhaust and certain other fumes. Formed from other air pollutants in the presence of sunlight.	Eye and throat irritation, coughing, respiratory tract problems, asthma, lung damage.	Plant and ecosystem damage.
Lead (Pb)	Metallic element	Metal refineries, lead smelters, battery manufacturers, iron and steel producers.	Anemia, high blood pressure, brain and kidney damage, neurological disorders, cancer, lowered IQ.	Affects animals and plants, affects aquatic ecosystems.
Particulate Matter (PM)	Very small particles of soot, dust, or other matter, including tiny droplets of liquids.	Diesel engines, power plants, industries, windblown dust, wood stoves.	Eye irritation, asthma, bronchitis, lung damage, cancer, heavy metal poisoning, cardiovascular effects.	Visibility impairment, atmospheric deposition, aesthetic damage.

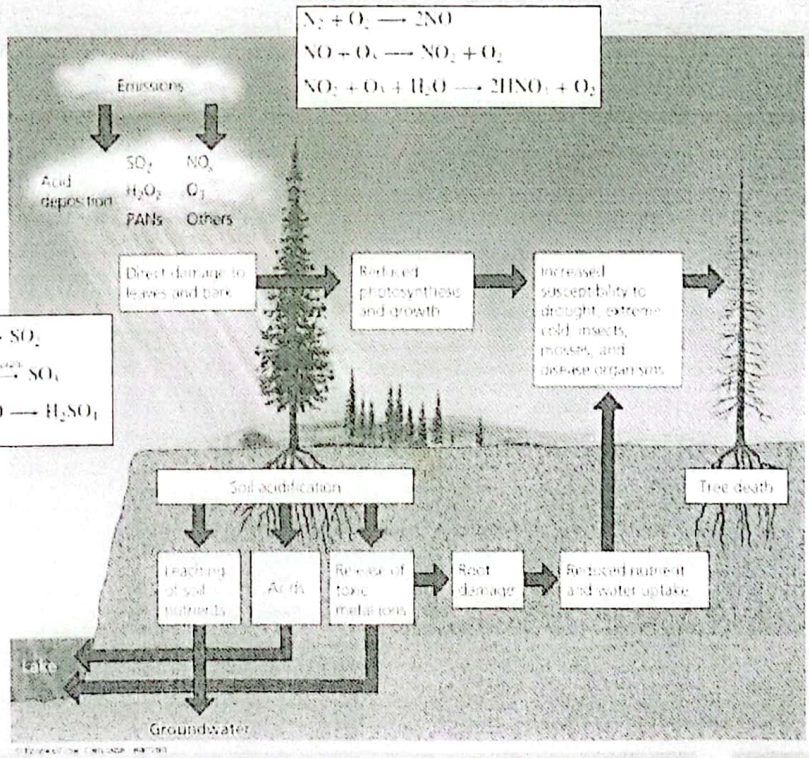
المطر الحامضي ⇐ $SO_x + H_2O \rightarrow H_2SO_4$

Acid Rain

One way in which SO2 is removed from the atmosphere is the formation of acid rain

من الطرق يلي بتتم إزالة SO_2 فيها من الجو

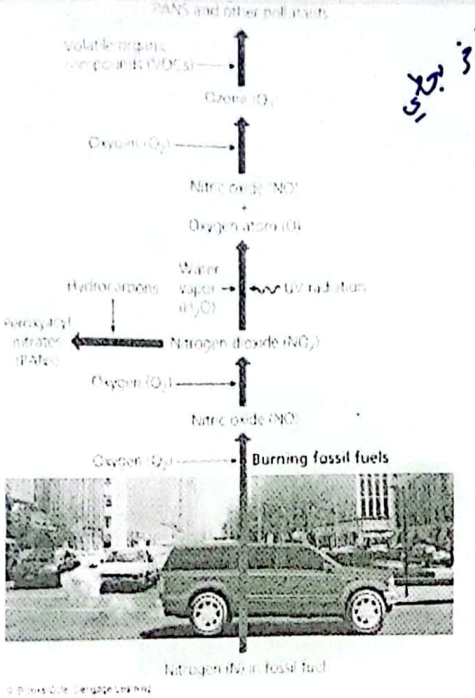
- contains high levels of sulfuric or nitric acids
- contaminate drinking water and vegetation
- damage aquatic life
- erode buildings
- Alters the chemical equilibrium of some soils

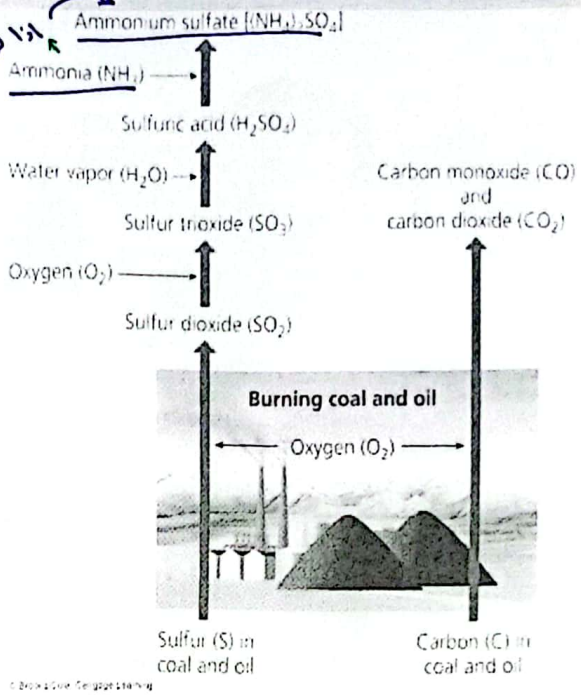


هو يلي مسيطر على الأمطار الحامضية اكثر من NO_x

تتحفز تفاعلات من light

Photochemical Smog





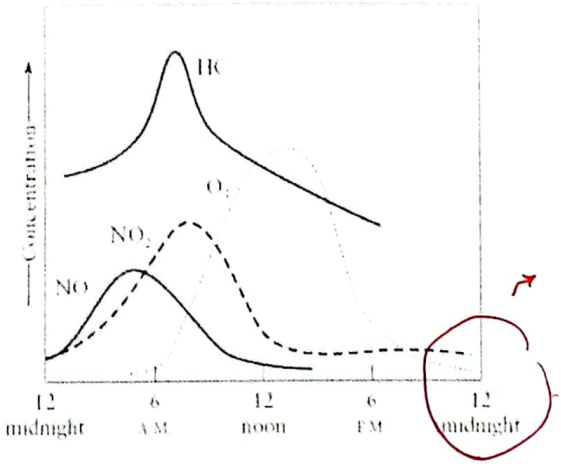
Simplified Reaction Scheme

* Hydrocarbons + Nox + Sunlight → photochemical smog (oxidants)

➢ primary oxidants produced: ozone (O_3), formaldehyde, peroxyacetyl nitrate (PAN)

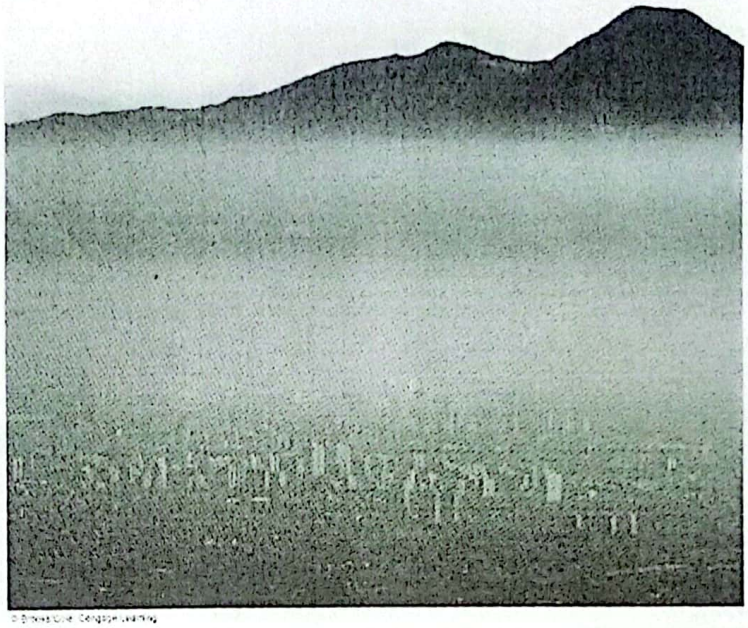
اكثر تفاعلات حتو اجيبة بالمناطق ضبابية وغيرها

NO_2 + light	→	NO + O
O + O_2	→	O_3
O_3 + NO	→	NO_2 + O_2
O + HC	→	HCO·
HCO· + O_2	→	HCO_3
HCO_3 + HC	→	Aldehydes, ketones, etc.
HCO_3 + NO	→	HCO_2 + NO_2
HCO_3 + O_2	→	O_3 + HCO_2
HCO_x + NO_2	→	Peroxyacetyl nitrates



بلشت تتلاشى

Photochemical Smog in Santiago, Chile



بتحمينا من الـ UV

Ozone Depletion

استنفاد طبقة الأوزون

سماكة الطبقة ⇐ (0.5 → 1.5) cm

- Ozone (O_3) is an eye irritant at usual urban levels, but urban O_3 should not be confused with stratospheric O_3, 7 to 10 mile above the earth's surface.
- The latter acts as an ultraviolet radiation shield, and its alteration can increase the risk of skin cancer as well as change the ecology in unpredictable ways.

مهيج للعين

تقريباً على بعد 12km من سطح الأرض

تغيرها ممكن يسبب زيادة خطر الإصابة بسرطان الجلد وتغير البيئة بشكل غير متوقع

Ozone in the upper atmosphere is created when oxygen reacts with light energy ($h\nu$):

$$O_2 + h\nu \rightarrow O + O$$
$$O_2 + O \rightarrow O_3$$

كيف بنتج غاز O_3

Light energy also destroys ozone:

$$O_3 + h\nu \rightarrow O_2 + O$$

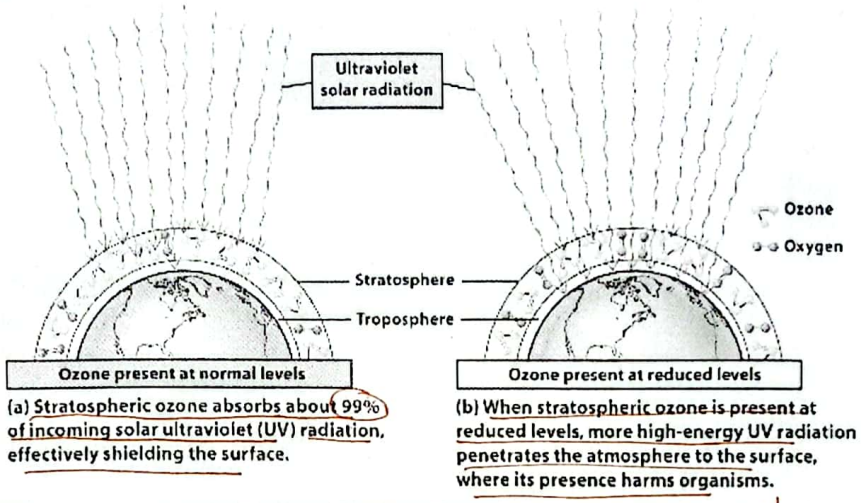
بس بيجي عليه UV بيكسر O_3 بيكسره $O_2 + O$ ⇐ cyclic عملية

This is the mechanism by which ozone prevents ultraviolet radiation from reaching earth's surface.

بهاي الطريقة طبقة الـ ozone بتحمينا من الـ UV

الـ Ozone يحمي الأرض من UV اللي هو جزء من الطيف الكهرومغناطيسي بأطوال موجية أقصر من الضوء المرئي

✓ Ozone Protects earth from UV radiation Part of the electromagnetic spectrum with wavelengths just shorter than visible light



(a) Stratospheric ozone absorbs about 99% of incoming solar ultraviolet (UV) radiation, effectively shielding the surface.

(b) When stratospheric ozone is present at reduced levels, more high-energy UV radiation penetrates the atmosphere to the surface, where its presence harms organisms.

بعلك لو طبقة الأوزون حماي كانت حتى سميكة اد يصير في أشعاعات من UV ويسبب أمراض صحية

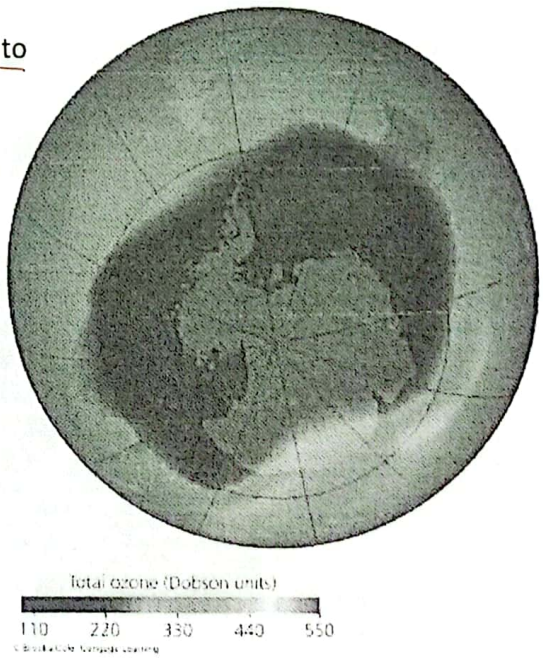
* على خط الاستواء بكون عنا أعلى سماكة للطبقة
* بالأقطاب ممكن توصل سماكة الطبقة 1 DU

وحدة الـ Ozone

تبعطي سماكة الطبقة

Dobson units (DU) were developed to measure ozone concentration:

1 DU= 0.01 mm of O_3 at 1 atm and 0°C



At midlatitudes the ozone concentration is typically about 350 DU, at the equator it is 250 DU, and in the Antarctic region it is only 100 DU.

كل منطقة وكم سُمك الطبقة عندها

كيف بعمل سحك طبقة الاوزون ؟

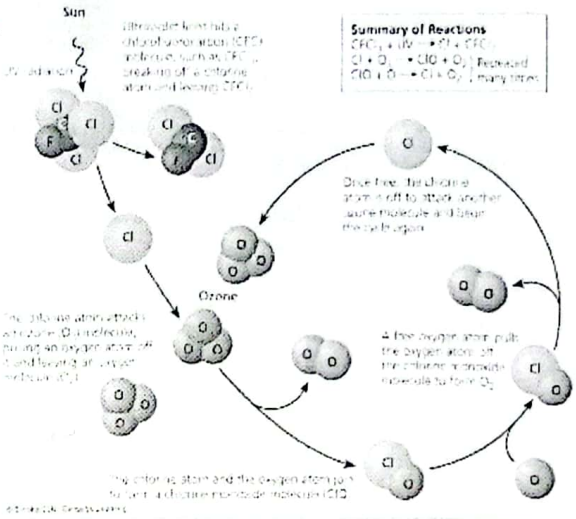
How O_3 is Depleted in the Stratosphere?

- Widespread use of certain chemicals has reduced ozone levels in the stratosphere, which allows for more harmful ultraviolet radiation to reach the earth's surface

معرفة دولياً ← هو مجموعة مركبات من C, F, Cl

مركبات تسبب تفكك طبقة الأوزون

- The chlorofluorocarbons (CFCs). chemicals that found wide use in aerosols and refrigeration systems and are responsible for climate change as well as the depletion of the protective ozone layer in the stratosphere.



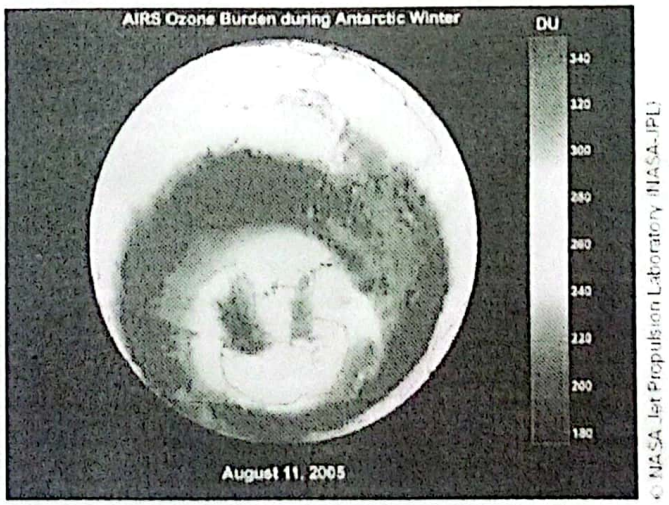
- Two of the most important CFCs are trichlorofluoromethane, $CFCl_3$, and dichlorodifluoromethane, CF_2Cl_2, both of which are inert and not water soluble and, therefore, do not wash out of the atmosphere.

أقلة على CFCs

عنا Cl بتفاعل مع O_3 بكون ClO
هذا ClO بتفكك لـ O + Cl
الـ O بتفاعل مع O ثانية بكون O_2
الـ Cl اللي هاد free. بروح بتفاعل مع O_3
وارجع عيد الحكي كله

The ozone hole & risks

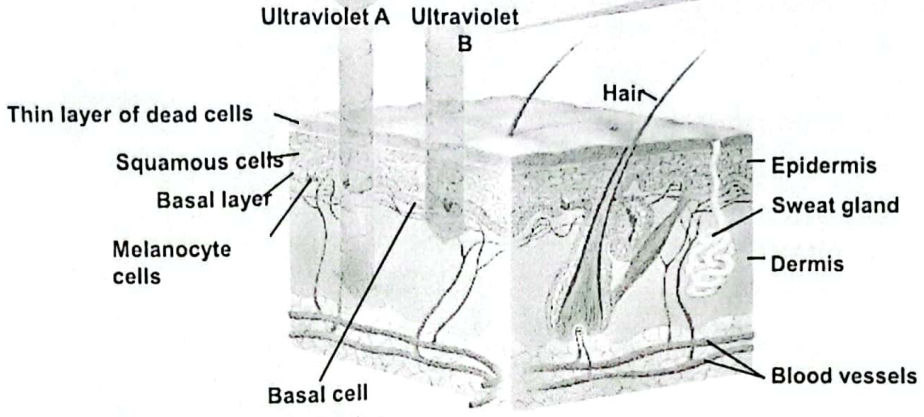
There indeed was a huge monster hole right in the middle of the South Pole.

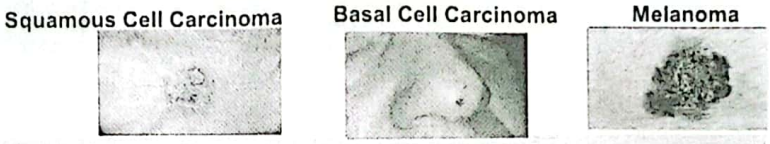


وين مناطق الاكثر سمك والعكس

This long-wavelength (low-energy) form of UV radiation causes aging of the skin, tanning, and sometimes sunburn. It penetrates deeply and may contribute to skin cancer.

This shorter-wavelength (high-energy) form of UV radiation causes sunburn, premature aging, and wrinkling. It is largely responsible for basal and squamous cell carcinomas and plays a role in malignant melanoma.





* تأثير الـ UV على الانسان
سرطان بالجلد

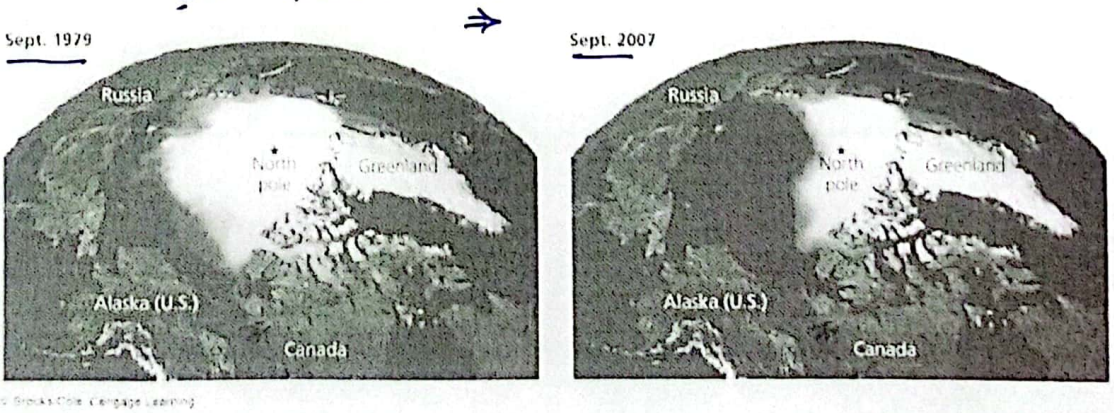
التغير المناخي والاحتباس الحراري

Climate Change

- The overwhelming scientific consensus is that the earth's atmosphere is warming rapidly, mostly because of human activities, and that this will lead to significant climate change during this century.

الجو يسخن بسرعة بسبب الانشطة البشرية وهذا ج بسبب تغير مناخي

صم في انكماش للقطب الشمالي



Temperatures in the Past ?

Scientists analyze tiny air bubbles trapped in ice cores learn about past:

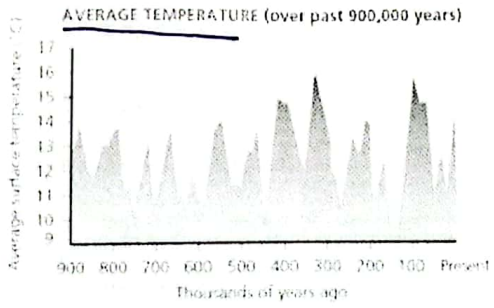
بحللوا فقاعة هواء محاصرة في الجليد بعرفوا منها عن الماضي كانها شو بلاقوا فيها

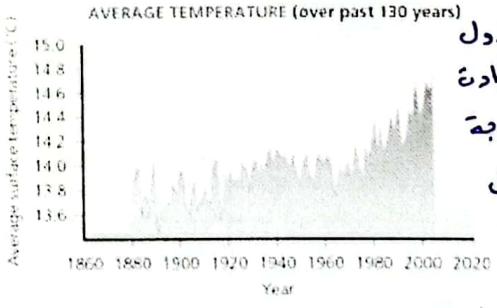
1. troposphere composition.
2. temperature trends.
3. greenhouse gas concentrations.
4. solar, snowfall, and forest fire activity.

ياخدوا طبقات على اعماق مختلفة ويقدروا يحددوا كم عمر هاي الطبقة.

* كل عقة بطبي تاريخ
* الطبقة هاي بياخدوها بذبوها بالمختبرات وبشوفوا شو الغازات يلي فيها
* وجدوا انه كل عقة في تركيز CO_2 اعلى من يلي تحته

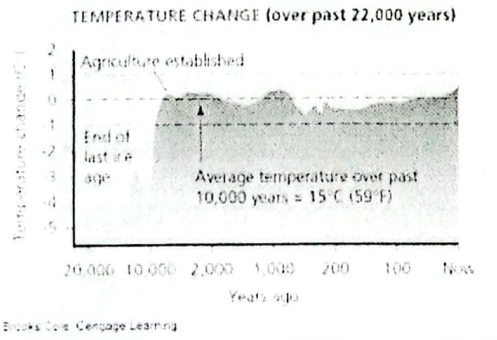
Estimated Changes

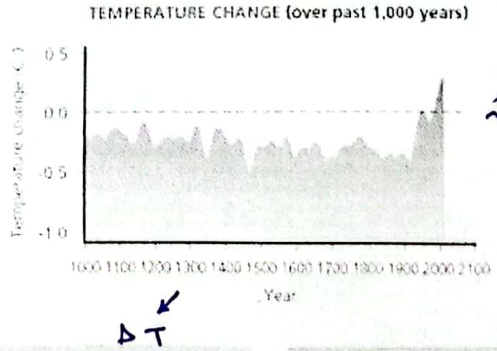




* آكد في الدول الحارة فازادة كبيرة بين درجة او درجتين

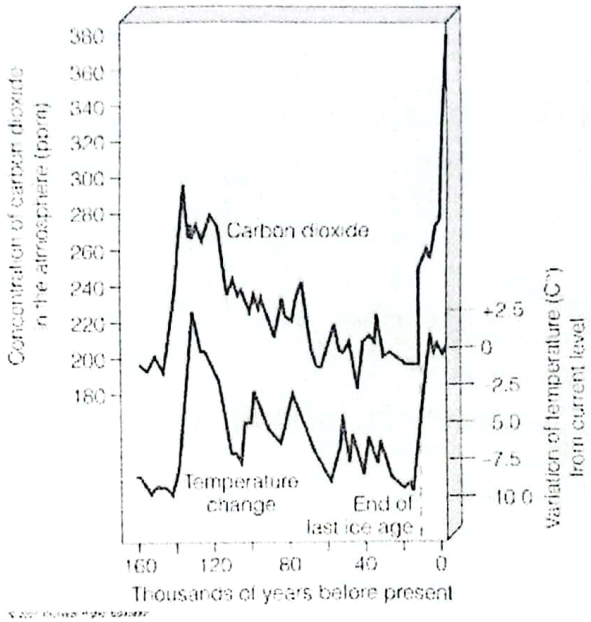
لكن في دول الباردة ازيادة كبيرة كانت عشر درجات وفوقه



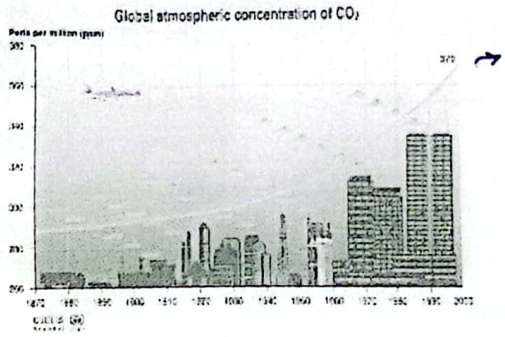


ΔT كيف بتتغير

Carbon Dioxide at highest levels



In 2005, an ice core showed that CO_2 levels in the troposphere are the highest they have been in 650,000 years.



كيف تركيز CO_2 زاد مع السنوات خاصة بعد الثورة الصناعية

تابعات التغير المناخي

Climate Change Consequences

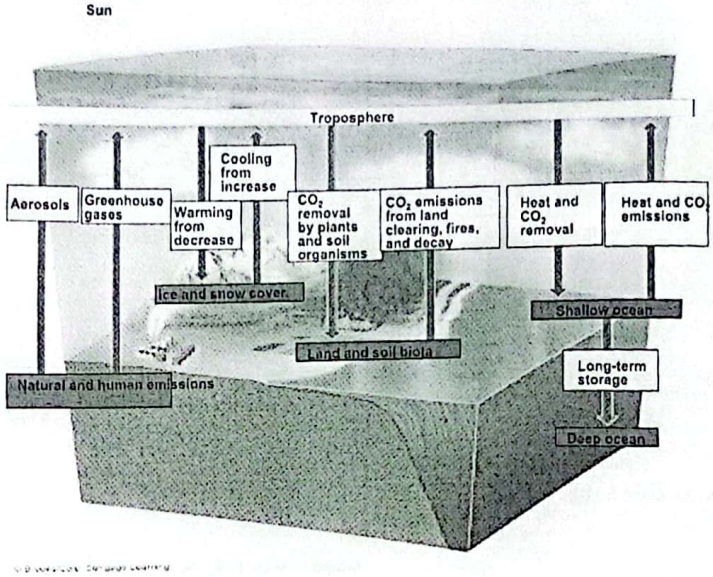
- 90–99% likely that lower atmosphere is warming
- 1906–2005: Ave. temp increased about 0.74°C
- 1970–2005: Annual greenhouse emissions up 70%
- Past 50 years: Arctic temp rising almost twice as fast as the rest of the earth
- Melting of glaciers and floating sea ice
- Prolonged droughts: increasing
- Last 100 years: sea levels rose 10–20 cm
- Warmer temperatures in Alaska, Russia, and the Arctic are melting permafrost releasing more CO_2 and CH_4 into the troposphere.

زيادة جفاف والتصحر

زيادة منسوب سطح البحر

تأثير صم

Greenhouse Gases Effect

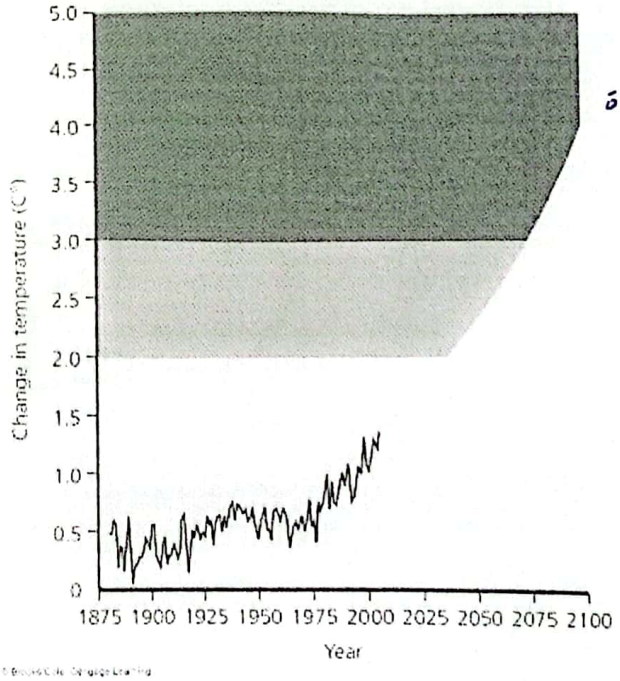


زيادة بيت ← البلاستيك او الزجاجي

الاشعة بتفوت بس ما بتطلع

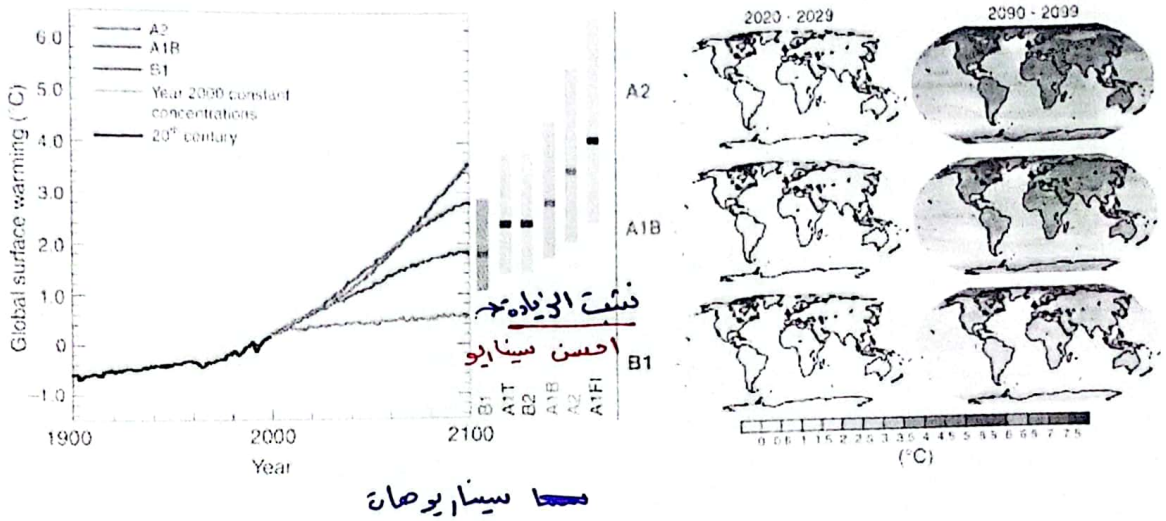
Measured Temperature and Projected Changes

- The projected rapid change in the atmosphere's temperature during this century is very likely to increase drought and flooding, shift areas where food can be grown, raise sea levels, result in intense heat waves, and cause the premature extinction of many species.



توقع زيادة الحرارة مع المستقبل

Temperature projections

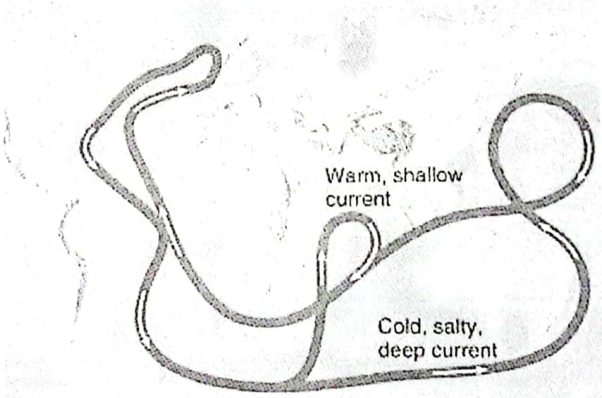


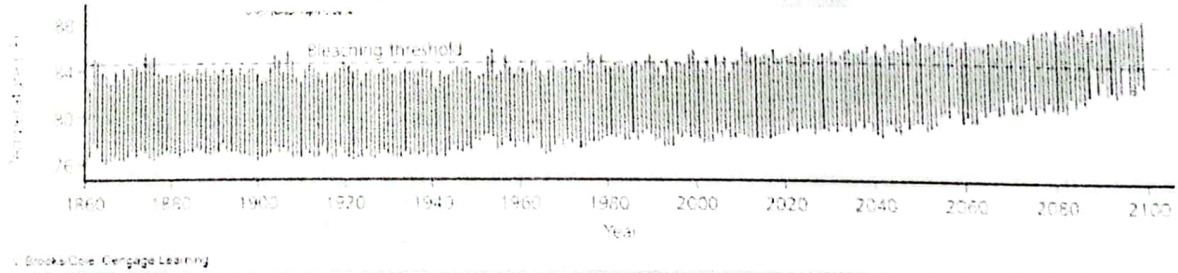
نسبة الزيادة

احسن سيناريو

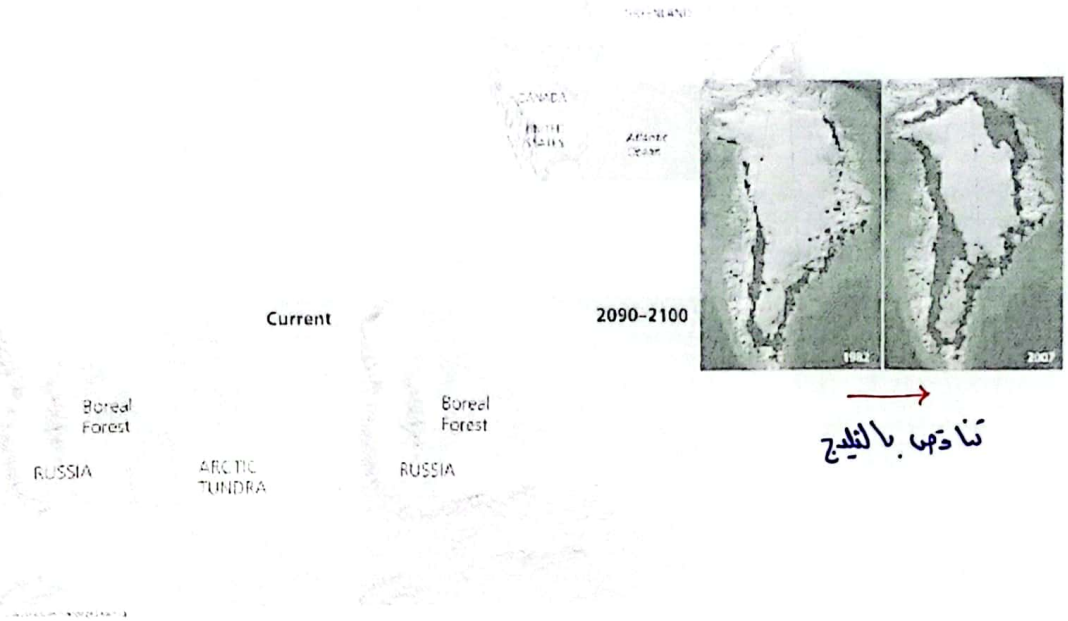
سيناريوهات

Changing Ocean Currents





Glacial Ice Melting & Decline in Arctic Tundra



climate change

CC Regional Impacts

North America	• Warming in western mountains is projected to cause decreased snowpack, more winter flooding and reduced summer flows, exacerbating competition for over-allocated water resources. • In the early decades of the century, moderate climate change is projected to increase aggregate yields of rain-fed agriculture by 5 to 20%, but with important variability among regions. Major challenges are projected for crops that are near the warm end of their suitable range or which depend on highly utilised water resources. • Cities that currently experience heat waves are expected to be further challenged by an increased number, intensity and duration of heat waves during the course of the century, with potential for adverse health impacts. • Coastal communities and habitats will be increasingly stressed by climate change impacts interacting with development and pollution.
Polar Regions	• The main projected biophysical effects are reductions in thickness and extent of glaciers, ice sheets and sea ice, and changes in natural ecosystems with detrimental effects on many organisms including migratory birds, mammals and higher predators. • For human communities in the Arctic, impacts, particularly those resulting from changing snow and ice conditions, are projected to be mixed. • Detrimental impacts would include those on infrastructure and traditional indigenous ways of life. • In both polar regions, specific ecosystems and habitats are projected to be vulnerable, as climatic barriers to species invasions are lowered.
Small Islands	• Sea level rise is expected to exacerbate inundation, storm surge, erosion and other coastal hazards, thus threatening vital infrastructure, settlements and facilities that support the livelihood of island communities. • Deterioration in coastal conditions, for example through erosion of beaches and coral bleaching, is expected to affect local resources. • By mid-century, climate change is expected to reduce water resources in many small islands, e.g. in the Caribbean and Pacific, to the point where they become insufficient to meet demand during low-rainfall periods. • With higher temperatures, increased invasion by non-native species is expected to occur, particularly on mid- and high-latitude islands.

CC Impacts

Very likely = 90% probable

Table SPM.3. Examples of possible impacts of climate change due to changes in extreme weather and climate events, based on projections to the mid- to late 21st century. These do not take into account any changes or developments in adaptive capacity. The likelihood estimates in column two relate to the phenomena listed in column one. (Table 3.2)

Phenomenon[a] and direction of trend	Likelihood of future trends based on projections for 21st century using SRES scenarios	Examples of major projected impacts by sector			
		Agriculture, forestry and ecosystems	Water resources	Human health	Industry, settlement and society
Over most land areas, warmer and fewer cold days and nights, warmer and more frequent hot days and nights	*Virtually certain*[b]	Increased yields in colder environments; decreased yields in warmer environments; increased insect outbreaks	Effects on water resources relying on snowmelt; effects on some water supplies	Reduced human mortality from decreased cold exposure	Reduced energy demand for heating; increased demand for cooling; declining air quality in cities; reduced disruption to transport due to snow, ice; effects on winter tourism
Warm spells/heat waves. Frequency increases over most land areas	*Very likely*	Reduced yields in warmer regions due to heat stress; increased danger of wildfire	Increased water demand; water quality problems, e.g. algal blooms	Increased risk of heat-related mortality, especially for the elderly, chronically sick, very young and socially isolated	Reduction in quality of life for people in warm areas without appropriate housing; impacts on the elderly, very young and poor
Heavy precipitation events. Frequency increases over most areas	*Very likely*	Damage to crops; soil erosion, inability to cultivate land due to waterlogging of soils	Adverse effects on quality of surface and groundwater; contamination of water supply; water scarcity may be relieved	Increased risk of deaths, injuries and infectious, respiratory and skin diseases	Disruption of settlements, commerce, transport and societies due to flooding; pressures on urban and rural infrastructures; loss of property

Indoor Air Pollution

Dr. Motasem Saidan

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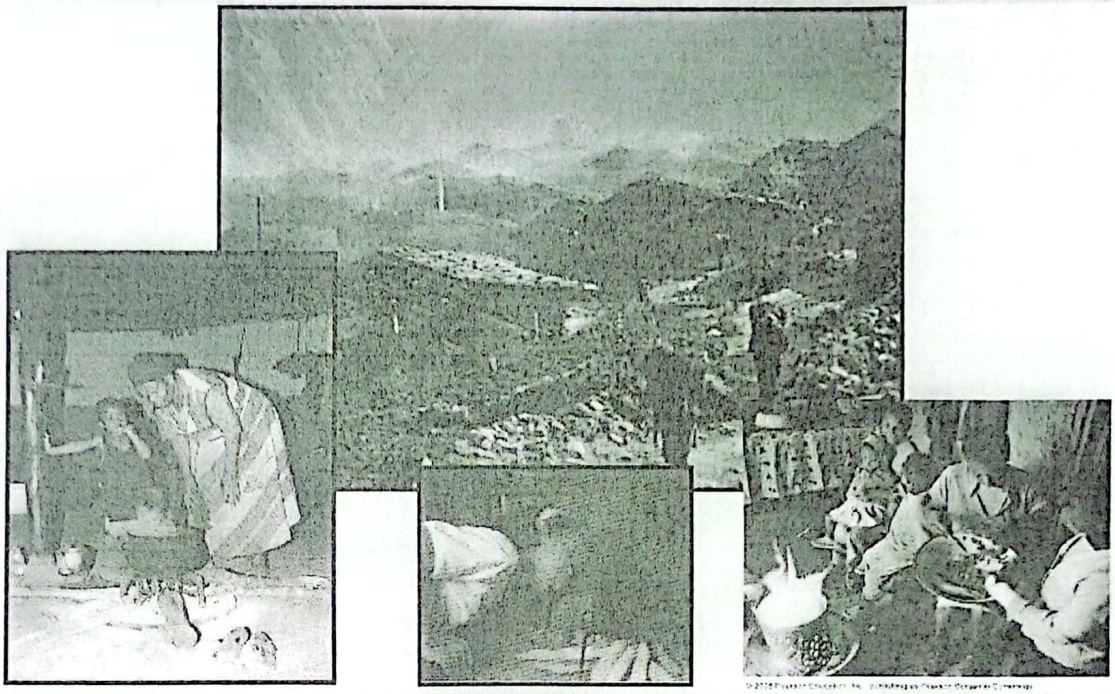
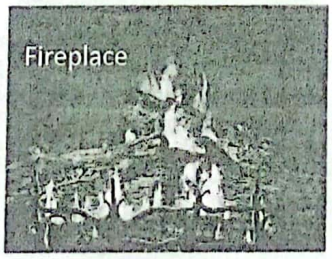
CAA ← clear air act

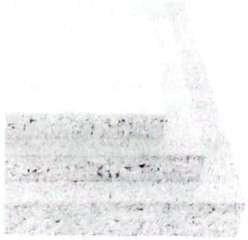
Indoor Air Pollution: Preface

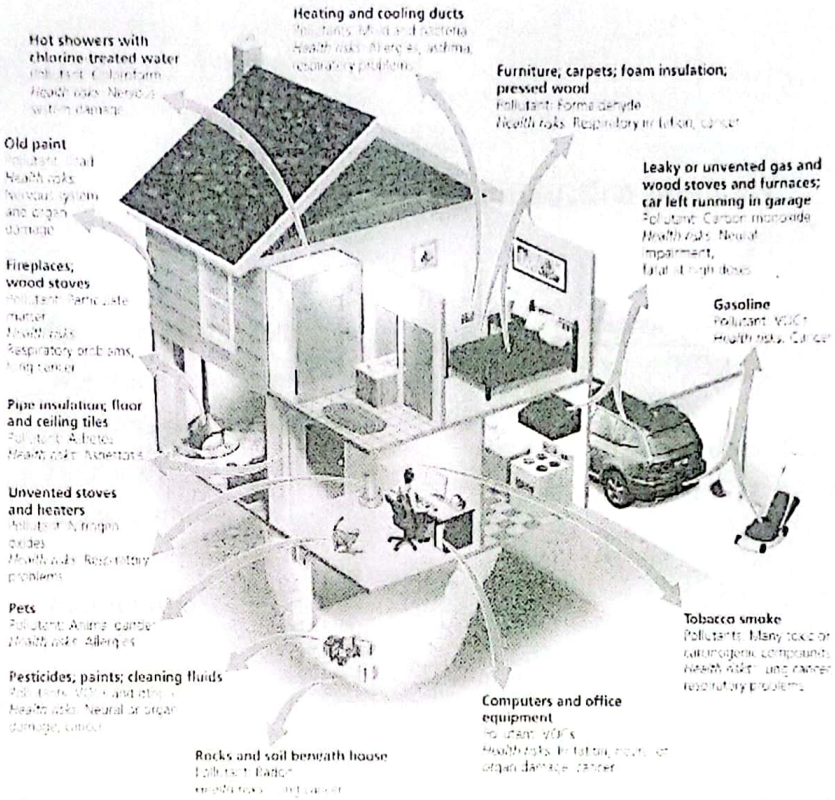
- Indoor air pollution is an environmental issue that is growing in public concern. The CAA addresses only outdoor air pollution, while mainly OSHA and building codes regulate indoor air quality.
- Most people spend the majority of their daily hours indoors.
- Numerous studies have shown that indoor air is contaminated by a wide variety of pollutants, with some being in higher concentrations than outdoor air. As a result, people are often more exposed to high concentrations of pollutants indoors than out.
- Exposure to some pollutants may be two to five times higher indoors than outdoors.
- At present, more than 900 compounds have been identified as potential sources of indoor air pollution and the list continues to grow (Brooks and Davis, 1992).

Indoor Air Pollution: Sources









Pollutant categories

على طبقات الجو يتسبب Ozone ← ملوث

Pollutant category	Example of substance	Typical source / cause
Inorganic gases	carbon monoxide; nitrogen dioxide; ozone	combustion processes; traffic emissions; reaction with organic compounds
Organic gases*	volatile organic compounds; formaldehyde	أي العطور و البخور building products; solvents; cosmetics
Non-biological particles	n/a	combustion; road pollution; industrial sources; air-borne soil and sand
Biological particles	dust / dust mites; pollen	naturally occurring bacteria and organisms

مضرة لو بتراكز عالية

اللي عنده طيور بفلاتر منهم

*Organic gases are usually made up of carbon and hydrogen molecules

Combustion Products

Sources	Combustion products
Gas stoves and appliances	Carbon monoxide (CO)
Wood and coal stoves	Nitrogen dioxide (NO_2)
Gas and propane engines	Sulfur dioxide (SO_2)
Fireplaces	Nitrogenated compounds (NO_x)
Tobacco smoke	Particulate matter (PM)
Candles and incense	
Mosquito coils	

وين يستخدموا الخشب ويجرّبوا للطبخ او للتدفئة

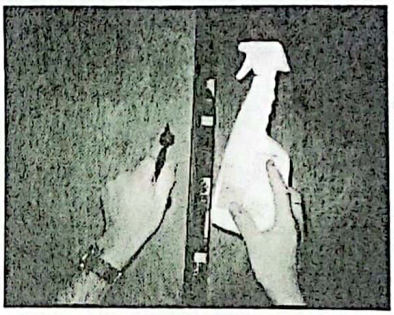
Indoor Smoke: Breaking Down Respiratory Defences

Solvents & Volatile Organic Compounds

Alkanes, aromatic hydrocarbons, alcohols, aldehydes, ketones

Sources:

- Solvents, fabric softeners, deodorizers and cleaning products
- Paints, glues, resins, waxes and polishing materials
- Spray propellants, dry cleaning fluids
- Pens and markers
- Binders and plasticizers
- Cosmetics: hair sprays, perfumes



Volatile Organic Compounds

The most diverse group of indoor air pollutants

Released by everything from plastics and oils to perfumes and paints

- Ex. formaldehyde, which leaks from pressed wood and insulation, irritates mucous membranes and induces skin allergies
- Ex. pesticides, which are found indoors more often than outdoors due to seepage

Acute:

- Irritation of eyes and respiratory tract
- General: headache, dizziness, loss of coordination, nausea, visual disorders
- Allergic reactions, including asthma and rhinitis

Chronic:

- Damage to liver, kidney, blood system and central nervous system (CNS)
- Some may cause cancer in humans (formaldehyde)

Examples of Hazardous VOC Sources

Compound	Indoor sources
acetaldehyde	floor materials, machine lubricants, wood products
benzene	furnishings, paints, varnishes, wood products, plastics tobacco
chloroform	fabrics, pesticides, soft furnishings
ethylbenzene	insulation products, polystyrene, paints, varnishes, plastics, photo-copiers
formaldehyde	floor materials, insulation products, paints, varnishes, fibre-board, chip-board, tobacco
tetrachloroethylene	caulks, sealants, dry-cleaning
toluene	adhesives, caulks, sealants, paint, thinners, dyes, cosmetics, inks

* التلوث الغير محسوس هو اسوء من يلي بحس فيه وبشمه

control بقدر اعمله

* الفورمالدهايد الهالو جينات اذا ارتبطت مع جزيء عضوي بكون الوضع مش تمام

مثل Cl, F وغيرهم مع C

Formaldehyde

- Although an organic compound, formaldehyde (HCHO) is not chemically classed as a VOC because of its low boiling point range of –19.5°C
- The emission rate in the indoor environment depends strongly on temperature and humidity.
- HCHO is the simplest and most common of the aldehydes range. At normal ambient room temperatures, it is colourless gas with a pungent suffocating odour (ECA 1990).

في 240 مادة كيميائيه

- Indoor formaldehyde is emitted from a wide range of sources, including tobacco smoke, combustion gases from gas appliances, disinfectants, water based paints, and paper products (WHO 1997).
- The most common form of formaldehyde is urea formaldehyde (UF) resin – the cause of significant indoor pollution due to its wide-ranging use.
- UF is used as the bonding agent in the production of particleboard, such as MDF and chipboard, plywood sheets, and UF foam insulation.

Temperature, humidity and air movement

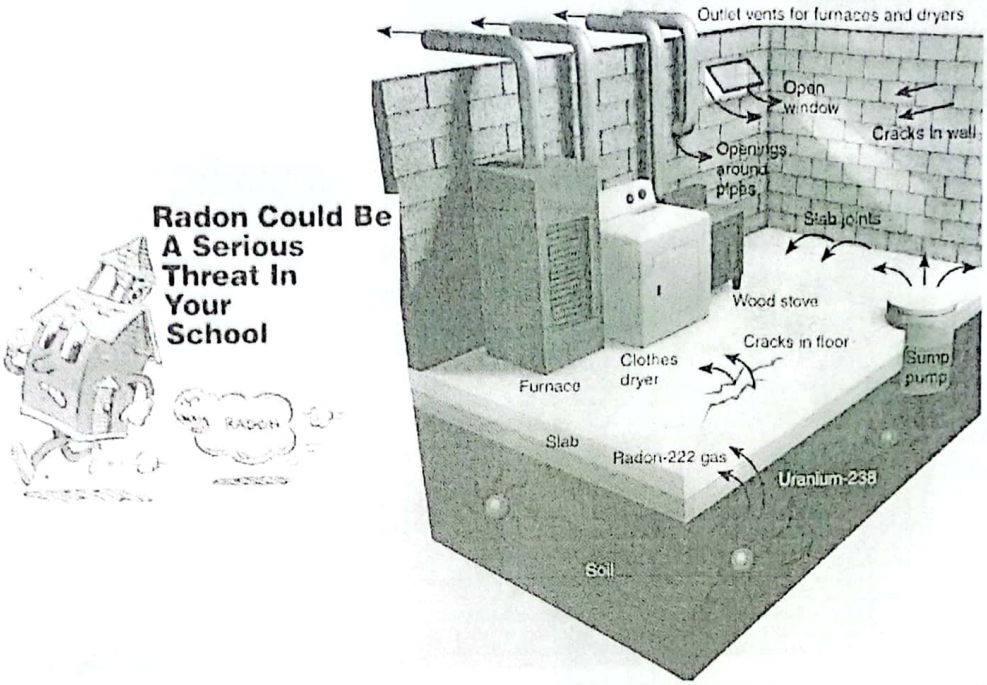
- The hygrothermal conditions have an affect on the rate of emission and activity of pollutants.
- Combined with air movement, these factors also play a key role in our overall well-being, or thermal comfort, inside buildings. Cumulatively, they are linked to symptoms associated with sick-building syndrome (SBS) and building related illness (BRI).
- Temperatures inside buildings are dependent upon outside temperatures, heat losses and gains, and the heating installation.
- Humidity depends on moisture generation from breathing, washing, cooking and bathing.
- Ventilation provides air for breathing, although excess ventilation can cause draughts, affecting our thermal comfort.

Room	Temperature range (°C)
bathrooms	26-27
bedrooms	17-19
hall/stairs/landing	19-24
kitchen	17-19
living room	20-23
toilet	19-21

Radon-222

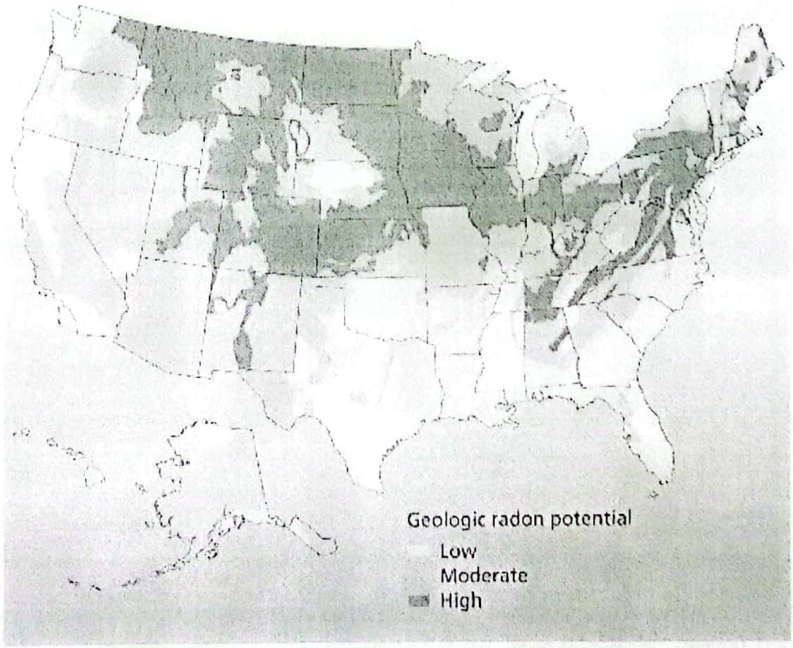
- colorless, tasteless, odorless, radioactive gas from decay of U-238 found in some soils & rocks
- Radioactive gas released from soil and rocks
- can seep into some houses (Highest levels occur in basements and on the ground floor)
- 55% of our exposure to radiation comes from radon
  - May harm lungs from long term exposure.
  - increases the risk of lung cancer
  - causes 20,000 deaths a year in the U.S.
- Reducing the risk
  - Sealing cracks in floors and walls
  - Simple systems using pipes and fans

Sources & paths of entry for indoor radon-222 gas



Radon risk across the US

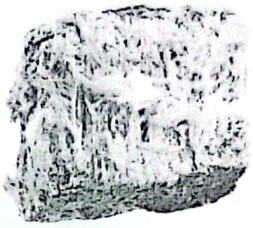
توزيع الخطورة كاميه

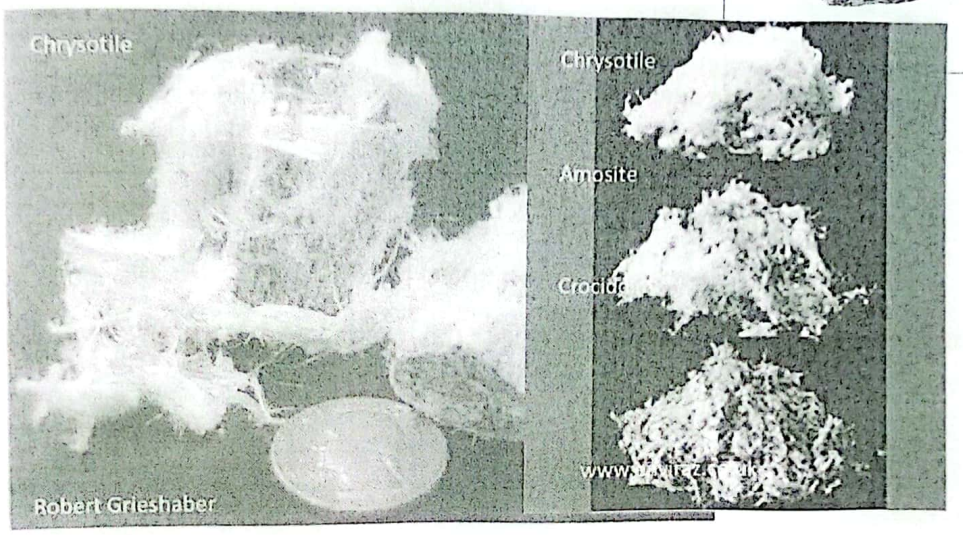


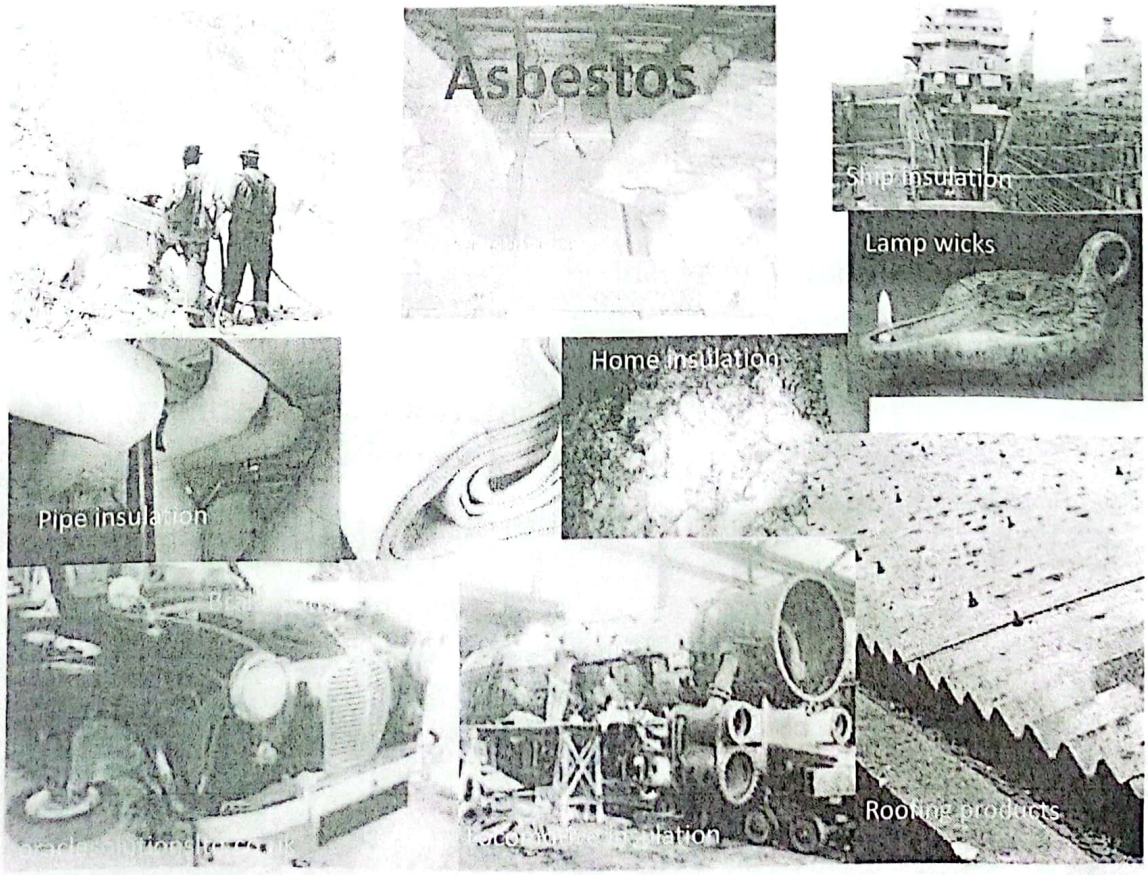
* بتطاير على شكل غبار
* مادة غير عضوية
* بتتجزب الرئة

Mineral Asbestos

* ممنوع دولياً بس مزالت بستخدم بالاماكن يلي بدها مركبتن سابق
* كان يستخدم بأفران في الفنون المعمارية







Asbestos

Sources:

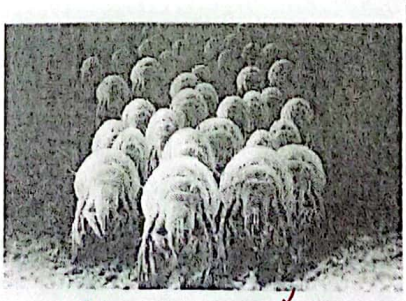
- Used for insulation and as fire-retardant: asbestos cement, floor and roof tiles, water pipes and others
- Levels increase if asbestos-containing materials are damaged
- Levels can be high in clothes of working parents

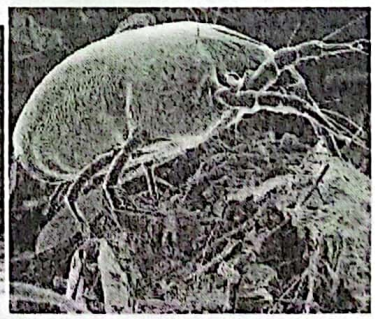
Health effects:

- No acute toxicity
- Asbestos results from occupational exposure
- Main risk for children: long-term exposure may cause cancer in adulthood

Living organisms can pollute indoors

- Dust mites
  - feed on human skin & dust
    - live in materials such as bedding & furniture fabrics
  - can cause asthma attacks & allergic reactions
- Fungi, mold, mildew, airborne bacteria
  - cause severe allergies, asthma, & other respiratory ailments
- Animal dander
  - worsen asthma





* وجود عث الكل
بس الوساخة الزيادة بتزيد تركيزه
* بقضي على الغلايا الميته

Transport and Dispersion of Air Pollution

Dr. Motasem Saidan

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Air Quality Dispersion Models

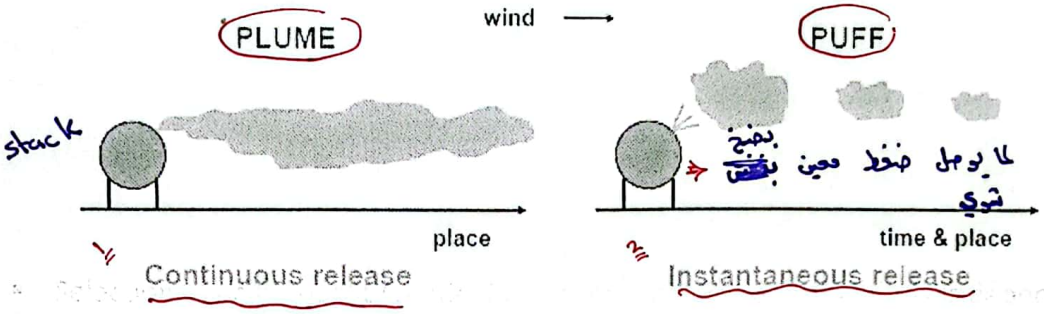
- Air quality dispersion models consist of a set of mathematical equations that interpret and predict pollutant concentrations due to plume dispersal and impaction.

- **There are four generic types of models:**
  - **The Gaussian models** use the Gaussian distribution equation and are widely used to estimate the impact of nonreactive pollutants.
  - **Numerical models** are more appropriate than Gaussian models for area sources in urban locations that involve reactive pollutants, but numerical models require extremely detailed source and pollutant information and are not widely used
  - **Statistical models** are used when scientific information about the chemical and physical processes of a source are incomplete or vague and therefore make the use of either Gaussian or numerical models impractical.
  - **Physical models** require fluid modeling studies or wind tunneling. This approach involves the construction of scaled models and observing fluid flow around these models.

* اختيار ال اعلمه يلي بدي استخدمه بعتمد على

- Selection of an air quality model for a particular air quality analysis is dependent on *the type of pollutants being emitted*, *the complexity of the source*, and *the type of topography surrounding the facility*.

* نوعين من release



DOWNWIND DILUTION BY MIXING WITH FRESH AIR

* Gaussian Distribution

- The Gaussian distribution equation uses relatively simple calculations requiring only two dispersion parameters (i.e. σy and σz) to identify the variation of pollutant concentrations away from the center of the plume.

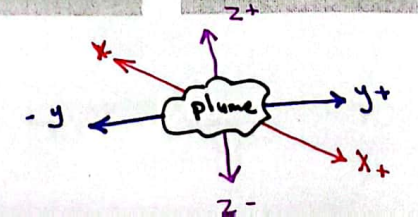
$$\chi = \frac{Q}{2\pi\sigma_y\sigma_z u} e^{\frac{-1}{2}\left(\frac{y}{\sigma_y}\right)^2} \left\{ e^{\frac{-1}{2}\left(\frac{z-H}{\sigma_z}\right)^2} + e^{\frac{-1}{2}\left(\frac{z+H}{\sigma_z}\right)^2} \right\}$$

Where:

χ	=	ground level pollutant concentration (g/m^3)
Q	=	mass emitted per unit time
σ_y	=	standard deviation of pollutant concentration in y (horizontal) direction
σ_z	=	standard deviation of pollutant concentration in z (vertical) direction
u	=	wind speed
y	=	distance in horizontal direction
z	=	distance in vertical direction
H	=	effective stack height

function of الاحوال الجوية و الطبوغرافية

χ مع



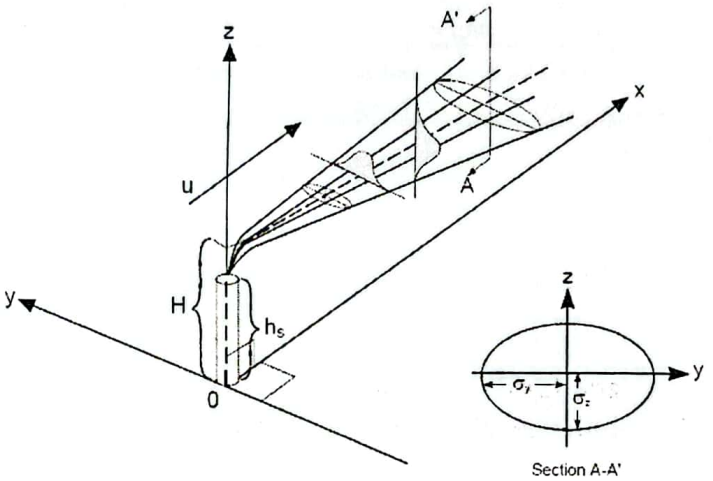
Z = zero

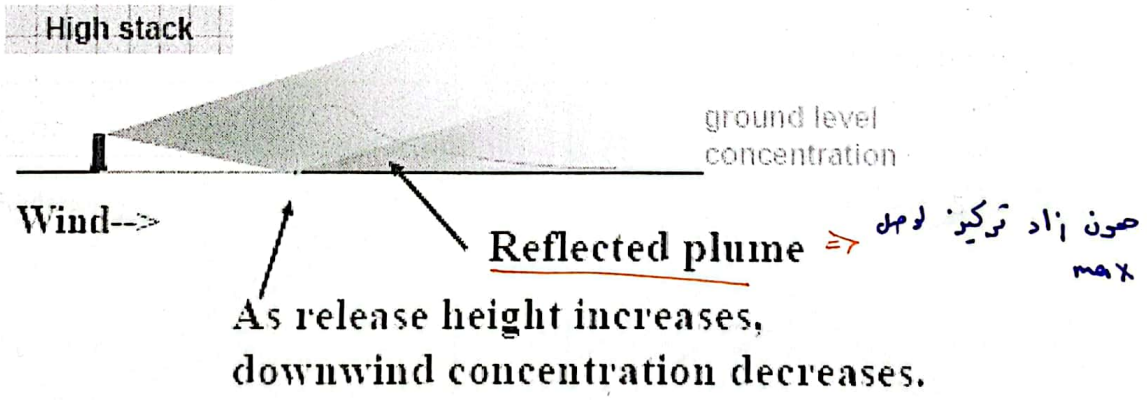
✓ This distribution equation determines ground level pollutant concentrations based on time-averaged atmospheric variables (e.g. temperature, wind speed).

عشان اشتغل على هذا الموضوع لازم افرض

In order for a plume to be modeled using the Gaussian distribution the following assumption must be made:

- The plume spread has a normal distribution
- The emission rate (Q) is constant and continuous
- Wind speed and direction is uniform





=> صون زاد تركيز لوهل max

Stability Classifications

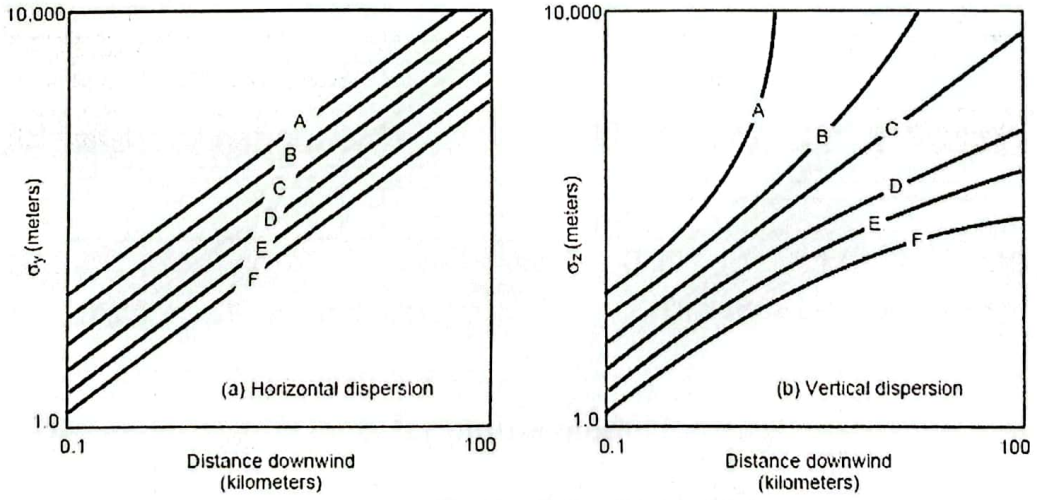
- For the dispersion estimation and modeling purposes, the levels of stability are classified into six stability classes based on five surface wind speed categories, three types of daytime insolation, and two types of nighttime cloudiness.
- These stability classes are referred to as Pasquill-Gifford stability classes:

Surface wind	Insolation			Night	
Speed (at 10 m) (m/s)	Strong	Moderate	Slight	≥ 4/8 low cloud cover	≤ 3/8 cloud cover
< 2	A	A-B	B	-	-
2-3	A-B	B	C	E	F
3-5	B	B-C	C	D	E
5-6	C	C-D	D	D	D
> 6	C	D	D	D	D

* Thinly overcast

Note: Neutral Class D should be assumed for overcast conditions during day or night.

A: extremely unstable	D: Neutral condition
B: Moderately unstable	E: Slightly stable
C: Slightly unstable	F: Moderately stable



Gaussian form of plume equation

$$\langle C\rangle(x,y,z) = \frac{Q_m}{2\pi\sigma_y\sigma_z u}\exp\left(-\frac{y^2}{2\sigma_y^2}\right)\times\left\{\exp\left[-\frac{(z-H_r)^2}{2\sigma_z^2}\right]+\exp\left[-\frac{(z+H_r)^2}{2\sigma_z^2}\right]\right\}$$

Top View of plume

--> Wind

$\langle C\rangle(x,y,z)$ = Ave. conc. (20-30 min ave)

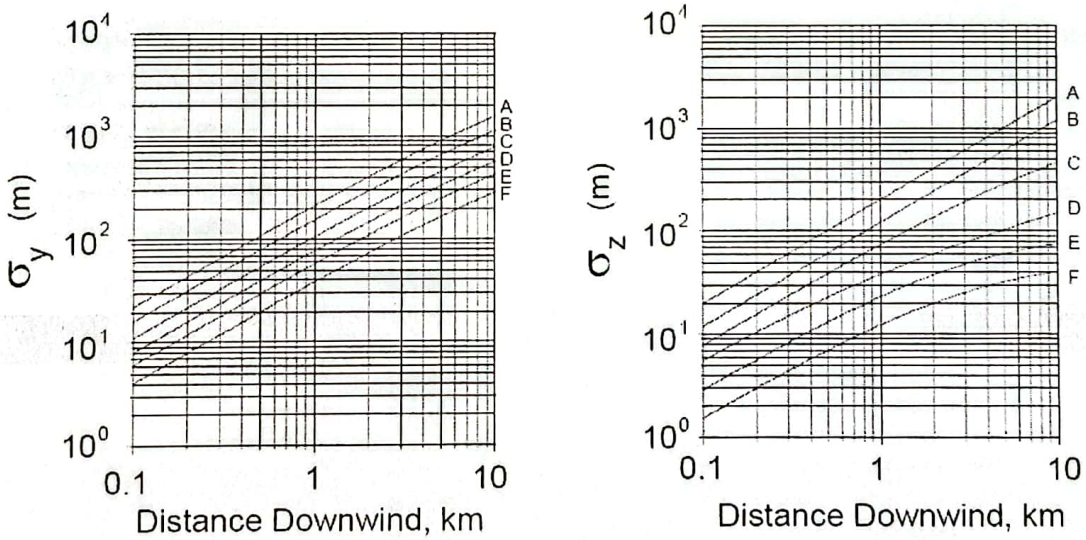
Q_m = Release rate (mass/time)

σ_y, σ_z = Dispersion coefficients = f(stability class, downwind distance)

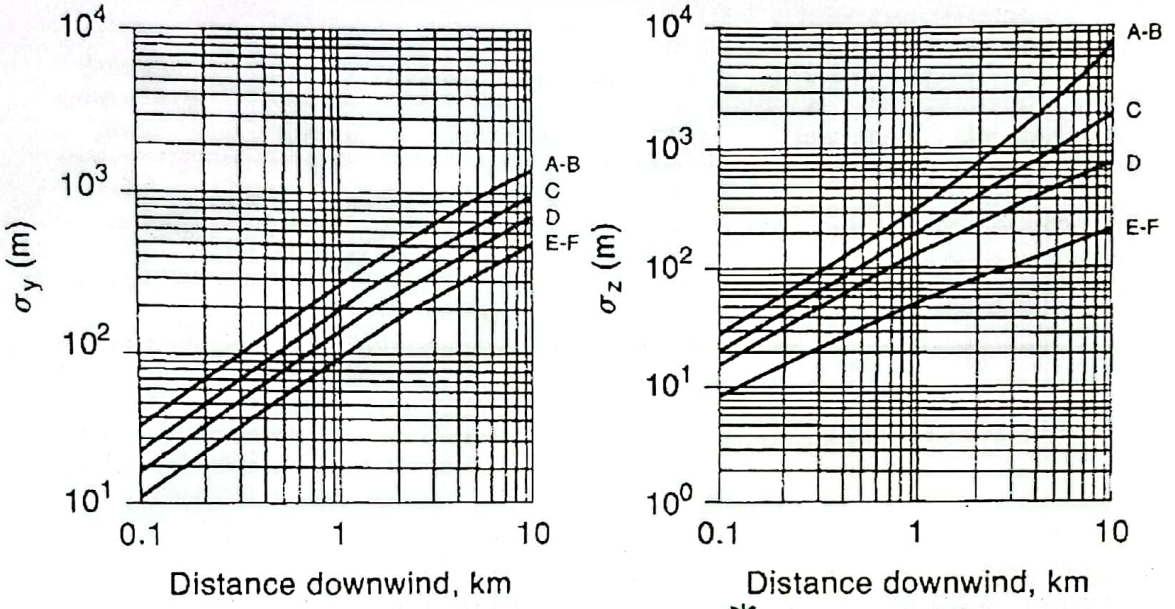
u = Wind speed (length/time)

y, z = Coordinates (length)

H_r = Release height (length)



Dispersion coefficients for plume model for rural releases.



Dispersion coefficients for plume model for urban releases.

Table 5-2 Recommended Equations for Pasquill-Gifford Dispersion Coefficients for Plume Dispersion[1,2] (the downwind distance x has units of meters)

Pasquill-Gifford stability class	σ_y (m)	σ_z (m)
Rural conditions		
A	$0.22x(1 + 0.0001x)^{-1/2}$	$0.20x$
B	$0.16x(1 + 0.0001x)^{-1/2}$	$0.12x$
C	$0.11x(1 + 0.0001x)^{-1/2}$	$0.08x(1 + 0.0002x)^{-1/2}$
D	$0.08x(1 + 0.0001x)^{-1/2}$	$0.06x(1 + 0.0015x)^{-1/2}$
E	$0.06x(1 + 0.0001x)^{-1/2}$	$0.03x(1 + 0.0003x)^{-1}$
F	$0.04x(1 + 0.0001x)^{-1/2}$	$0.016x(1 + 0.0003x)^{-1}$
Urban conditions		
A–B	$0.32x(1 + 0.0004x)^{-1/2}$	$0.24x(1 + 0.0001x)^{+1/2}$
D	$0.22x(1 + 0.0004x)^{-1/2}$	$0.20x$
D	$0.16x(1 + 0.0004x)^{-1/2}$	$0.14x(1 + 0.0003x)^{-1/2}$
E–F	$0.11x(1 + 0.0004x)^{-1/2}$	$0.08x(1 + 0.0015x)^{-1/2}$

A–F are defined in Table 5-1.

* في حال بدي اوجدهم بدون ما استخدم السمات بطلعهم من المعادلات هنزول حيث X هون هي عبارة عن ال distance

Table 5-1 Atmospheric Stability Classes for Use with the Pasquill-Gifford Dispersion Model[1,2]

Surface wind speed (m/s)	Daytime insolation[3]			Nighttime conditions[4]	
	Strong	Moderate	Slight	Thin overcast or >4/8 low cloud	≤3/8 cloudiness
<2	A	A–B	B	F[5]	F[5]
2–3	A–B	B	C	E	F
3–4	B	B–C	C	D[6]	E
4–6	C	C–D	D[6]	D[6]	D[6]
>6	C	D[6]	D[6]	D[6]	D[6]

Stability classes:
A, extremely unstable
B, moderately unstable
C, slightly stable
D, neutrally stable
E, slightly stable
F, moderately stable

[3]Strong insolation corresponds to a sunny midday in midsummer in England. Slight insolation to similar conditions in midwinter.
[4]Night refers to the period 1 hour before sunset and 1 hour after dawn.

Table 5-2 Recommended Equations for Pasquill-Gifford Dispersion Coefficients for Plume Dispersion[1,2] (the downwind distance x has units of meters)

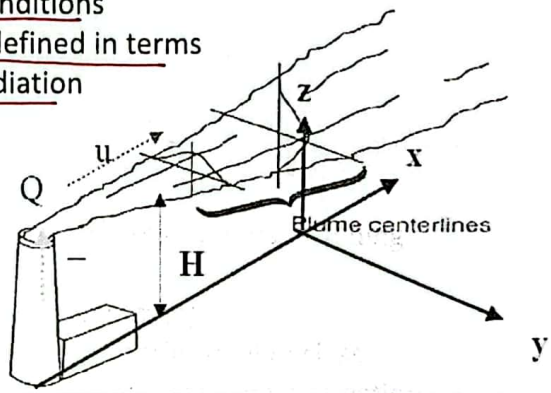
Pasquill-Gifford stability class	σ_y (m)	σ_z (m)
Rural conditions		
A	$0.22x(1 + 0.0001x)^{-1/2}$	$0.20x$
B	$0.16x(1 + 0.0001x)^{-1/2}$	$0.12x$
C	$0.11x(1 + 0.0001x)^{-1/2}$	$0.08x(1 + 0.0002x)^{-1/2}$
D	$0.08x(1 + 0.0001x)^{-1/2}$	$0.06x(1 + 0.0015x)^{-1/2}$
E	$0.06x(1 + 0.0001x)^{-1/2}$	$0.03x(1 + 0.0003x)^{-1}$
F	$0.04x(1 + 0.0001x)^{-1/2}$	$0.016x(1 + 0.0003x)^{-1}$
Urban conditions		
A–B	$0.32x(1 + 0.0004x)^{-1/2}$	$0.24x(1 + 0.0001x)^{+1/2}$
D	$0.22x(1 + 0.0004x)^{-1/2}$	$0.20x$
D	$0.16x(1 + 0.0004x)^{-1/2}$	$0.14x(1 + 0.0003x)^{-1/2}$
E–F	$0.11x(1 + 0.0004x)^{-1/2}$	$0.08x(1 + 0.0015x)^{-1/2}$

A–F are defined in Table 5-1.

Gaussian Model Assumptions

Gaussian dispersion modeling based on a number of assumptions including

- Source pollutant emission rate = constant (Steady-state)
- Constant Wind speed, wind direction, and atmospheric stability class
- Pollutant Mass transfer primarily due to bulk air motion in the x-direction
- No pollutant chemical transformations occur
- Wind speeds are >1 m/sec.
- Limited to predicting concentrations > 50 m downwind
- σy and σz depend on the atmospheric conditions
- Atmospheric stability classifications are defined in terms of surface wind speed, incoming solar radiation and cloud cover



Plume Dispersion Equations

- **Ground-level concentration due to an elevated source (z=0 , H)**

$$C(x,y,0) = \frac{Q}{\pi \bar{u} \sigma_y \sigma_z} \exp - \left[\frac{y^2}{2\sigma_y^2} + \frac{H^2}{2\sigma_z^2} \right]$$

- **Ground-level concentration due to an elevated source, directly downwind of the source at ground level (Center Line), (y=z=0 , H)**

$$C(x,0,0) = \frac{Q}{\pi \bar{u} \sigma_y \sigma_z} \exp \left[\frac{-H^2}{2\sigma_z^2} \right]$$

- **If the emission source is at ground level with no effective plume rise then**

$$C(x,y,z)=\frac{Q}{\pi\sigma_y\sigma_z\bar{u}}\exp\left[-\frac{1}{2}\left(\frac{y^2}{\sigma_y^2}+\frac{z^2}{\sigma_z^2}\right)\right]$$

- **Ground Level Center Line –Ground Point Source (y = 0, H = 0)**

$$C(x,0,0;0)=\frac{Q}{\pi\bar{u}\sigma_y\sigma_z}$$

- **Maximum Ground Level Concentration**

The ground level concentration at the center line is

$$(C)_{\max}=\frac{2Q_m}{e\pi uH_r^2}\left(\frac{\sigma_z}{\sigma_y}\right).$$

where, **e = 2.71**

The maximum occurs at

$$dC/d\sigma_z=0 \quad \Rightarrow \sigma_z=\frac{H}{\sqrt{2}}$$

at the distance x_{max} for which $\sigma_z=\frac{H}{\sqrt{2}}$

overcast ⇐ غيوم عالية

Example 5-1

On an overcast day a stack with an effective height of 60 m is releasing sulfur dioxide at the rate of 80 g/s. The wind speed is 6 m/s. The stack is located in a rural area. Determine

a. The mean concentration of SO_2 on the ground 500 m downwind.
b. The mean concentration on the ground 500 m downwind and 50 m crosswind.
c. The location and value of the maximum mean concentration on ground level directly downwind.

Solution

a. This is a continuous release. The ground concentration directly downwind is given by Equation 5-51:

$$C(x,0,0) = \frac{Q_m}{\pi\sigma_y\sigma_z u}\exp\left[-\frac{1}{2}\left(\frac{H_t}{\sigma_z}\right)^2\right] \qquad (5\text{-}51)$$

From Table 5-1 the stability class is D.

The dispersion coefficients are obtained from either Figure 5-11 or Table 5-2. Using Table 5-2:

$$\sigma_y = 0.08x(1 + 0.0001x)^{-1/2}$$
$$= (0.08)(500\text{ m})\{1 + (0.0001)(500\text{ m})\}^{-1/2} = 39.0\text{ m},$$
$$\sigma_z = 0.06x(1 + 0.0015x)^{-1/2}$$
$$= (0.06)(500\text{ m})\{1 + (0.0015)(500\text{ m})\}^{-1/2} = 22.7\text{ m}.$$

Substituting into Equation 5-51, we obtain

$$C(500\text{ m}, 0, 0) = \frac{80\text{ g/s}}{(3.14)(39.0\text{ m})(22.7\text{ m})(6\text{ m/s})}\exp\left[-\frac{1}{2}\left(\frac{60\text{ m}}{22.7\text{ m}}\right)^2\right]$$
$$= 1.45 \times 10^{-4}\text{ g/m}^3.$$

b. The mean concentration 50 m crosswind is found by using Equation 5-50 and by setting $y = 50$. The results from part a are applied directly:

$$C(500\text{ m}, 50\text{ m}, 0) = C(500\text{ m}, 0, 0)\exp\left[-\frac{1}{2}\left(\frac{y}{\sigma_y}\right)^2\right]$$
$$= (1.45 \times 10^{-4}\text{ g/m}^3)\exp\left[-\frac{1}{2}\left(\frac{50\text{ m}}{39\text{ m}}\right)^2\right]$$
$$= 6.37 \times 10^{-5}\text{ g/m}^3.$$

c. The location of the maximum concentration is found from Equation 5-53:

$$\sigma_z = \frac{H_t}{\sqrt{2}} = \frac{60\text{ m}}{\sqrt{2}} = 42.4\text{ m}.$$

From Figure 5-10 for D stability, σ_z has this value at about 1200 m downwind. From Figure 5-10 or Table 5-2, $\sigma_y = 88$ m. The maximum concentration is determined using Equation 5-52:

$$C_{max} = \frac{2Q_m}{e\pi u H_t^2}\left(\frac{\sigma_z}{\sigma_y}\right)$$
$$= \frac{(2)(80\text{ g/s})}{(2.72)(3.14)(6\text{ m/s})(60\text{ m})^2}\left(\frac{42.4\text{ m}}{88\text{ m}}\right)$$
$$= 4.18 \times 10^{-4}\text{ g/m}^3. \qquad (5\text{-}52)$$

Example (Process Safety Book, Page 208)

Chlorine is used in a particular chemical process. A source model study indicates that for a particular accident scenario 1.0 kg of chlorine will be released instantaneously. The release will occur at ground level. A residential area is 500 m away from the chlorine source. Determine

a. The time required for the center of the cloud to reach the residential area. Assume a wind speed of 2 m/s.

b. The maximum concentration of chlorine in the residential area. What stability conditions and wind speed produces the maximum concentration?

c. Determine the distance the cloud must travel to disperse the cloud to a maximum concentration

Air Pollution:

Air Quality & Monitoring

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Air Quality

- Air Quality is a dynamic and complex environmental phenomenon exhibiting large temporal and spatial variation.
- The temporal and spatial variations in atmospheric levels of pollution, which is the essence of air quality, are caused by
  - (a) changes in the pollutant source(s) emission rates, and
  - (b) changes in meteorology and topography,

which provide the mechanisms for chemical reactions of pollutants in the atmosphere and for the control and removal of atmospheric pollutants.

EPA → Enviromental potection agency

Clean Air Act (CAA)

- The EPA defines ambient air as "that portion of the atmosphere external to buildings, to which the public has access."
- The CAA regulates only pollution that enters the outside air. This includes emissions from stacks, chimneys, vents and any other functionally equivalent openings. These are called point source emissions, or area emissions depending on their size.
- The CAA also regulates mobile and fugitive emissions that are released directly into the atmosphere.
- What the CAA does not regulate is indoor air pollution, or air pollution confined to private property, such as occupationally exposed emissions.

National Ambient Air Quality Standards

- EPA must establish National Ambient Air Quality Standards (NAAQS) for every pollutant that has been designated a "criteria" pollutant.
- EPA has promulgated National Ambient Air Quality Standards for six criteria air pollutants:
  - ozone,
  - particulates (PM10 and PM2.5),
  - sulfur oxides,
  - carbon monoxide,
  - nitrogen dioxide and
  - lead.
- Unlike the other NAAQS pollutants, ozone is not directly emitted, but rather is formed in the atmosphere by the interaction of volatile organic compounds (VOCs) and nitrogen oxides (NOx) in the presence of sunlight. The control of ozone is, thus, based on regulating emissions of VOCs and NOx.
- The value of a standard depends largely upon the time period over which the measurement is averaged.

Types of NAAQS

There are two types of NAAQS specified in Section 109 of the CAA:

- **Primary standard:** "Health-based" standards used to protect human health and the environment. This health-based standard must protect the most sensitive segments of the population, such as children, the elderly and asthmatics.
- **Secondary standard:** (enviromental - based) Designed to protect general public welfare and prevention of damage to public property (animals, plant life, and property).

- Both primary and secondary NAAQS specify the maximum concentrations of these pollutants that can be present in the ambient air.

هدف الي بحددوا قديش مسموح من الإ نبعاثات

NAAQS (Primary & Secondary)

Pollutant	Primary Standard (Health Related)		Secondary Standard (Welfare Related)
	Average	Std. Level (Concentration)	
CO	8-hour	9 ppm (10 mg/m³)	No Secondary Standard
	1-hour	35 ppm	No Secondary Standard
Pb	Maximum Quarterly Average	1.5 µg/m³	Same as Primary Standard
NO_2	Annual Arithmetic Mean	0.053 ppm (100 µg/m³)	Same as Primary Standard
O_3	Maximum Daily 1-hr Average	12 ppm (235 µg/m³)	Same as Primary Standard
	4th Max Daily 8-hr Average	0.08 ppm (157 µg/m³)	Same as Primary Standard

Pollutant	Primary Standard (Health Related)		Secondary Standard (Welfare Related)	
	Average	Std. Level Concentration		
PM_{10}	Annual Arithmetic Mean	50 µg/m³	Same as Primary Standard	
	24-hour	150 µg/m³	Same as Primary Standard	
$PM_{2.5}$	Annual Arithmetic Mean	15 µg/m³	Same as Primary Standard	
	24-hour	65 µg/m³	Same as Primary Standard	
SO_2	Annual Arithmetic Mean	0.03 ppm (80 µg/m³)	3-hour	0.50 ppm (1300 µg/m³)

وحيد
مقلق

Hour avg بناخد خلال ساعة مثلاً عشرين قراءة و بناخد الـ avg قائم بنسمي measurment

و بقارنوا مع standard

Air Monitoring

- Monitoring of the air quality can be very complex, since it requires the collection of data that allows for a resolution of the dynamic nature of air quality in terms of its spatial and temporal variation.
- Ambient air quality monitoring can be defined as a (systematic) long-term assessment of air pollutant levels in our communities.
- This monitoring is usually undertaken to characterize air quality in *urban areas*, *near large point sources of air pollution* or *where there are sensitive environmental receptors*.
- The ability to assess the air quality of a region will depend on (accurate and representative data describing existing conditions and dispersion models) which can be used to better predict future pollution levels.

- In general, ambient air monitoring networks are typically used to:
  - characterize local, regional, and national air quality conditions
  - assess health impacts
  - assess effectiveness of control programs
  - help form the basis for new control programs
  - assess source impacts
  - provide information to the public

➢ The CAA directed EPA to set primary and secondary standards that would "provide an ample margin of safety" and require EPA to establish acceptable levels of concentration or "criteria" in the ambient air for ~~five~~ six pollutants.

➢ Those ~~five~~ six pollutants were: sulfur dioxide (SO_2), particulate matter (TSP), carbon monoxide (CO), ozone (O_3), and nitrogen dioxide (NO_2). In a later version of the act, lead (Pb) was added and ozone was adopted as the photochemical oxidant indicator of volatile organic compound (VOC) precursors.

monitoring نوعين من
1- stationary
2- mobile

Stationary monitoring

على مدار السنة مثلاً background كل سنة كم وتتوقع الـ trend وهذا بدي كيف الالتزام

A stationary monitoring network should yield the following information: تقدم

(1) background concentration levels,
(2) highest concentration levels,
(3) representative concentration levels in high-density areas, → complex يعني في ازدحام مباني يعني
(4) the impact of local sources, ← ذي يلي حوالين المستشفى هذا حرفة تاعه
(5) the impact of remote sources, and → للمناطق البعيدة
(6) the relative impact of natural and anthropogenic sources
نسبي من مصنع الإسمنت

Spatial scales include

على بعد كيلو متر
microscale (1-100 m),
middle scale (100 m-0.5 km),
neighborhood scale (0.5-4.0 Km),
Urban scale (4-50 Km),
Regional scale (10 – hundreds of Km)

Relationship of the Scale of Representativeness and Monitoring Objectives

Siting scales	Monitoring objectives
Micro, middle, neighborhood, (sometimes urban)	Highest concentration affecting people
Neighborhood, urban	High-density population exposure
Micro, middle, neighborhood	Source impact
Neighborhood, region	General/background concentration

Mobile Monitoring

سيارات متحركة و هي بتتحرك بشكل عينات وبتحللها

- Mobile monitoring is accomplished from a movable platform, i.e., an aircraft or vehicle.
- Atmospheric transport and chemical transformation processes occur in the region between the source and the receptor.
- By using mobile platforms containing air pollution instrumentation, one can obtain data to help understand the formation and transport of photochemical smog, acidic deposition, and the dispersion of air pollutants from sources.
- Mobile monitoring platforms may also be moved to *hot spots*, areas suspected of having high concentrations of specific air pollutants. These areas may *be* nearby locations downwind of a large source or a particular location that is an unfavorable receptor due to meteorological conditions. Vehicular and aircraft monitoring systems can also be moved to locations where hazardous chemical spills, nuclear and chemical plants accident have occurred.

Air quality in Jordan

Element	Jordanian Standard 1140-1996 Maximum Limit	Average Time for Measuring	AAEP National Ambient Air Quality standard-2001 Maximum Limit
SO2	0.135 ppm	1 hour	0.14 ppm
SoO2	0.130 ppm	24 hour	0.03 ppm
SO2	0.03 ppm	Yearly	35 ppm
CO	26 ppm	1 hour	9 ppm
CO	9 ppm	8 hours	
TsP	260 µg m³	24 hour	
TSP	75 mg/cum	Yearly	
NO2	0.21 ppm	1 hour	

Element	Jordanian Standard 1140-1996 Maximum Limit	Average Time for Measuring	AAEP National Ambient Air Quality standard-2001 Maximum Limit
NO2	0.05 ppm	24 hour	
		Yearly	0.053 ppm
NO2	0.05 ppm	1 hour	
H2S	0.03 ppm	24 hours	
H2S	0.01ppm	Seasonally	1.5 µg m³
Pb	1 µg m³	Yearly	
Pb	0.5 µg m³	24 hours	150 µg m³
PM10	120 µg m³	Yearly	50 µg m³
PM10	70 µg m³		

* الواجهة الأردنية

Air quality in Jordan

- Air quality is a problem in low area, high density hotspots of vehicular traffic and industrial activity.
- Most polluting emissions come from ① vehicles, ② industries, and ③ residential activities.

Table 1. Pollutant emissions from vehicles and industries (2004)

Source of emissions	NO_x	SO_2	TSP
Road transportation (%)	79[a]	20[b]	39
Other diesel (%)	0	0	1
Air transport (%)	2	1	14
Industry (%)	7	30	18
Electricity production (%)	11	48	29
Total (t)	72,000	123,000	6,500

Sources: AFD, 2006, except for [a] Average corresponding to emissions ranging from 53,063t (AFD, 2006) and 67,160t (Transport chapter). [b] Average corresponding to emissions ranging from 24,240t (AFD, 2006) and 25,994t (Transport chapter).

- Nevertheless, the vehicle fleet is relatively old, with about 33 percent of the vehicles produced before 1990. Old cars are still maintained and used, contributing significantly to emissions. As Amman and South Amman host about 69 percent of all Jordanian vehicles, they represent a major hot spot for air pollution.
- Emissions from the industrial sector mainly originate from the cement plants in Fuheis and Rashidyia, the industrial area of Hashimyeh near Zarqa, power plants and phosphate and potash industries in Aqaba, and others. Among these, mining is the most important contributor to air pollution, accounting for about 62 percent of the TSP, 78 percent of the PM10 and 39 percent of the NOx generated by industry.

Table 2. Main sources of emissions and monitoring institutions

Location	Main source of emissions	Monitoring institutions (stations)	Pollutants monitored	Frequency of monitoring
Fuheis	Cement plant	MoEnv (RSS)	PM10	every 2 days
Rashidya	Cement plant	MoEnv (RSS)	NO_x, CO, SO_2, TSP	once a month
Hashimyeh (near Zarqa)	Refinery, power plant, steel industries, quarries	MoEnv (RSS) through - Ibn Al Anbari school for SO_2, H_2S, PM10 - Um-Shamak school for SO_2, H_2S, PM10 - Electrical training centre for SO_2, CO, PM10	SO_2, H_2S, PM_{10}, CO	every hour at Ibn Al-Anbari school for SO_2 and H_2S [a]
Remote areas[b]	Phosphate mines	RSS	PM10	n.a
Aqaba	Phosphate to acid plant	ASEZA (RSS)	SO_2, NO_x, CO, HF	once a week
	Power plants	n.a	n.a	n.a
GAM	Traffic	MoH (RSS) through - Ein Jalout School Shmeisani - Civil Defense - Abu Nusair - Ali Ben-Abi Taleb Mosque Marka - Al Hussini Mosque Down Town (City Center)	TSP, PM_{10}, Pb	n.a

Sources: AED, 2006, except for [a] monitored data at Ibn Al-Anbari school
Notes: [b] including Al Albad; n.a = not available

Air Pollution:

Control of Stationary Sources

Dr. Motasem Saidan

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Control of Stationary Sources

Control of Stationary Sources:

- Particulate Matter
- Gaseous Emissions

Particulate Matter

- Most of the air pollution produced by stationary sources results from the incomplete combustion of fuel or industrial processing
- The types of inorganic and organic air pollutants stationary sources emit are dependent on the specific process operations

Examples: Fossil fuel fired boilers emit ash, sulfur dioxide, nitrogen oxides and mercury, and or vanadium if contained in the fuel. Metallurgical plants can emit a variety of metal dusts, including iron oxides and sometimes fluorides and chlorides. Industrial plants manufacturing inorganic chemicals will emit various waste gases depending on their product. Odorous organic waste gases can also be emitted from organochemical and petrochemical plants.

Industrial pollutant sources

Industrial pollutant sources such as these and others can be categorized into several groups based on their specific process operation:

- **Process Operations:**

  Process operations with incomplete chemical reactions, which include combustion due to unconverted reactants, or a reaction having a final yield that is less than expected theoretical conversion.

- **Atmospheric Releases:**

  Atmospheric releases of process's secondary components or impurities of raw materials.

- **Auxiliary Losses:**

  The auxiliary losses of compounds such as volatile organic solvents from fugitive sources or inorganics such as carbon disulfide and hydrogen sulfide in rayon production and fluorine compounds as in the production of aluminum.

N_2O → 250 ضعف تأثيره على الإحتباس الحراري CO_2

- **Waste Emissions:**

* Emissions of malodorous substances or oxidation compounds in the exhaust from oxidation, heating or drying processes.

Releases from these categories can originate from a variety of emission points and may not be centrally collected before entering the atmosphere.

- Air release emission points, from industrial process operations, can be categorized as stack, duct, vent, fugitive and area
- Fugitive emission points are release points, which are unconfined in a stack or duct before reaching the atmosphere.
- Therefore, whether an emission source is considered a point or fugitive source is dependent on whether the release is confined or unconfined in a stack or duct prior to atmospheric release.

Confined ← محصور ← تعاملت مع التهريب وتحكمت فيه

Industrial Process Operation Air Emission Points and Categories

Process Operation	Fugitive Sources
Reactors vents	Valves
Distillation systems	Pump seals
Vacuum systems	Flanges/connectors
Combustion stacks	Compressors
Blow molding	Open ended lines
Spray drying and booths	Pressure relief devices
Extrusion machines	Equipment cleaning/maintenance
Surface Area Sources	**Handling, Storage, Loading**
Pond evaporation	Storage tank breathing losses
Cooling tower evaporation	Loading/unloading
Wastewater treatment	Line venting
Land disposal	Packaging and container loading

اعلى تقليل او امنع

- Pollution control can be achieved through common sense solutions such as the installation of effective control technology, changes in production processes and the implementation of pollution prevention techniques.
- Compliance with emission standards and the successful attainment of air quality standards depends in large part on the application of appropriate stationary source control measures.

PM Control Procedures

particulate matter

- Control procedures for stationary sources of pollution include:
  1. the use of tall smokestacks, → add on unit, اعلى احتواء لا fogmate
  2. changes in plant operations, and
  3. installation of effective control devices

- The control strategy required for an industrial environmental impact is a four step process:
  (1) elimination of the problem source or operation,
  (2) modification of the source operation,
  (3) relocation of the source, and
  (4) selection and application of the appropriate control technology.

* اذا نوعية الاول او الثانية ما رح احتاج الرابعة

لانه رح يصير بدي معدن حتى اوصله لـ اعالجه

Exhaust Stacks

- Exhaust stacks do not reduce emissions from a stationary source; rather they reduce the local effects of the pollution by elevating the exhaust stream to a point where it can be more effectively dispersed.

- High exhaust stacks were an inexpensive solution in the absence of expensive control technology. For years elevated stacks were used with the nearby communities in mind. A belief was widely held that elevated stacks reduced the likelihood that pollutants would have any effect on neighboring populations.

- Utility and smelter operations have traditionally used tall stacks (200m to 400m) in order to reduce the amount of ground-level concentrations of sulfur dioxide (SO2). However, this did not always eliminate the problem, but instead simply transferred it to another location.

- This approach was used for many years, until concern arose over the regional and transboundary spread of harmful toxics. For example, there is great concern over the spread of acid rain from one region to another.

Plant Operations

- Compliance with emission standard may require the use of control technology, but many industrial operations have reduced emissions by (**changing operational methods**.)

- Some of these changes include (**pre-treating process materials**,) fuel or material substitution, and changes in the manufacturing process. As an example of how pre-treating raw materials can be an inexpensive solution to pollution control, industry has discovered that significant reductions in particulate matter and sulfur emissions can be achieved by a technique called coal washing. Pre-treating raw materials in this manner not only reduces the amount of fly ash released from coal, but it also reduces the amount of inorganic sulfur released as well.

- Another way to comply with emission standards is to **substitute cleaner fuels** during the refining process. Natural gas and low-sulfur fuel oil are just two examples of fuels that emit less pollution during combustion. However, cleaner fuels can be more expensive and can increase national reliance on foreign fuel sources.

- Reduction in emissions from stationary sources can also be accomplished through increased attention to **plant maintenance**.

- Plants that release significant quantities of pollutants into the environment frequently do so as the result of improperly maintained equipment. This is especially true of combustion equipment.

- **Adequately scheduled maintenance** must be performed to reduce both the exhaust and amount of fugitive emissions released from vats, valves, and transmission lines. Periodic maintenance also reduces the likelihood of spill-related accidents by discovering faulty equipment before problems occur.

Control Technology

- A final way to reduce emissions from stationary sources is through the use of advanced, add-on control technology.

- Control devices can destroy or recover gaseous compounds or particulate matter for proper disposal or re-use.

- The pollution control operations used to destroy or capture gases include combustion, adsorption, absorption, and condensation.

- Control devices that implement these processes include thermal incinerators, catalytic incinerators, flares, boilers, process heaters, carbon absorbers, spray towers, and surface condensers.

The most important process parameters for selecting air pollution control equipment are **the exhaust gas characteristics** obtained from emissions tests and **process or site characteristics** obtained from a field survey

Exhaust Gas Characteristics

قياس او فحوصات بالمختبر

- Total exhaust gas flow rate
- Exhaust gas temperature
- Required control efficiency → شو كمية الـ pollutant العالقة بهذا الغاز وشو المواصفة من وزارة البيئة فنحقق اقل من المواصفة كم الكفاءة لازم تكون
- Particle size distribution
- Particle resistivity ← مقاومة للأجسام يلي اذا تصطدم فيها (مثلاً تصير بالفلتر)
- Composition of emissions
- Corrosiveness of exhaust gas over operating range → في احماض او قواعد ؟!
- Moisture content
- Stack pressure
- Exhaust gas combustibility and flammability properties → قابل للاحتراق ولا لا ؟!

Process or Site Characteristics

- Reuse/recycling of collected emissions → reuse بقدر اعمله بالبروسيس نفسها ؟!
- Availability of space ← عندي مساحات واسعة سواء كانت افقية او عامودية
- Availability of additional electrical power → في عندي اسئل بقدر ادخلها عليها واطلع منها طاقة منرجعها ؟!
- Availability of water
- Availability of wastewater treatment facilities → ممكن يكون عندي adsorption في waste water
- Frequency of startup and shutdowns ← تأثير فيبورجيكال
- Environmental conditions
- Anticipated changes in control regulations → وزارة البيئة اج تغير مواصفاتها ولا ثابتة
- Anticipated changes in raw materials
- Plant type – stationary or mobile

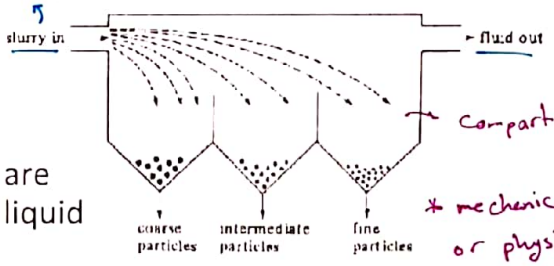
السلايدين هدول بحطوين توجيه شو اد اسئل يلي استخدمها

Control Devices for Particulate Emissions

- Technologies used to control particulate matter focus on removing particles from the effluent gas stream.
- Many factors (such as particle size and chemical characteristics) determine the appropriate particulate control device for a process.
- Devices most commonly used devices to control particulate emissions include:
  - Gravity settlers (often referred to as settling chambers)
  - Mechanical collectors (cyclones)
  - Electrostatic precipitators (ESPs)
  - Scrubbers
  - Fabric filters
  - Hybrid systems
- In many cases, a combination of multiple devices yields the best collection efficiency. For example, a settling chamber can be used to remove large particles from the exhaust stream before it enters an electrostatic precipitator where smaller particles are removed.

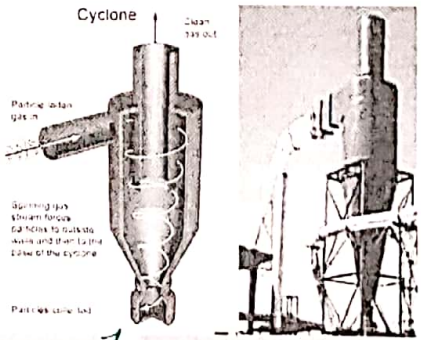
EQUIPMENT

Gravity settlers (often referred to as *settling chambers)*



- Gravity settlers, or gravity settling chambers, are used industrially for the removal of solid and liquid waste materials from gaseous streams.
- Advantages accounting for their use are simple construction, low initial cost and maintenance, low pressure losses, and simple disposal of waste materials.

Mechanical collectors (cyclones)



- Centrifugal separators, commonly referred to as *cyclones,* are widely used in industry for the removal of solid and liquid particles (or particulates) from gas streams.

نفس مبدأ مكنسة الكهرباء (vacum)

in → fabric media → out

Fabric filters (bag houses)

* لازم اضبط الحرارة من 300 لتحت

- Filtration process may be conducted in many different types of fabric filters. Differences may be related to:

بلتقط الـ dust

  - Type of fabric
  - Cleaning mechanism
  - Equipment
  - Mode of operation

- Gases to be cleaned can be either "pushed" or "pulled" through the bag house.
- In the pressure system (push through) the gases may enter through the cleanout, hopper in the bottom or through the top of the bags.
- In the suction type (pull through) the dirty gases are usually forced through the inside of the bag and exit through the outside.

* الفائدة الجايية منها ينتج عنها عالي maintenance

Baghouse Filter

- similar to conventional home vacuum cleaner
- Efficiency:
  - >99.5% for <1 µm diameter
  - >99.8% for >5 µm diameter

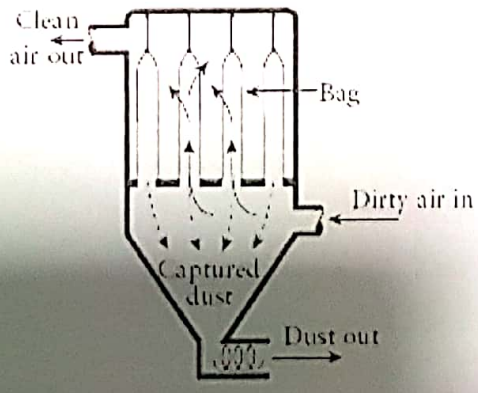
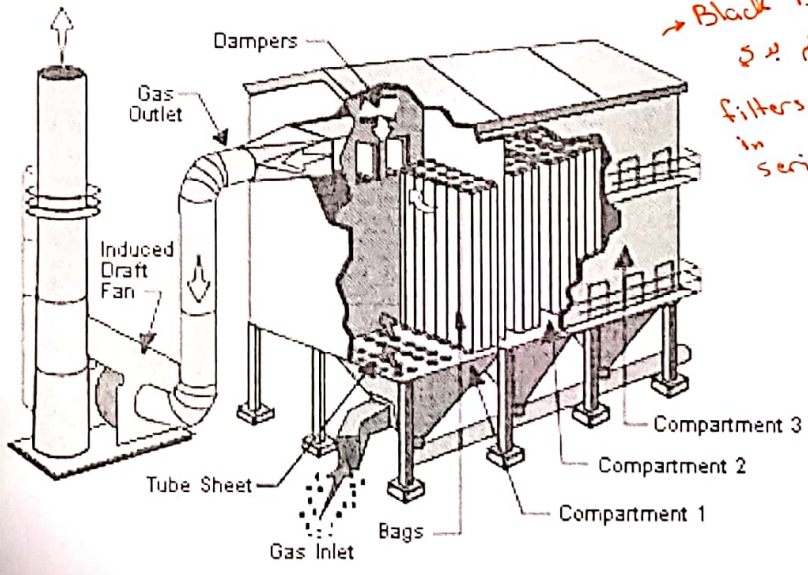


Figure 13. Reverse Air Fabric Filter



→ Black Box يجوز فيه كم بدي عدد الـ filters in series

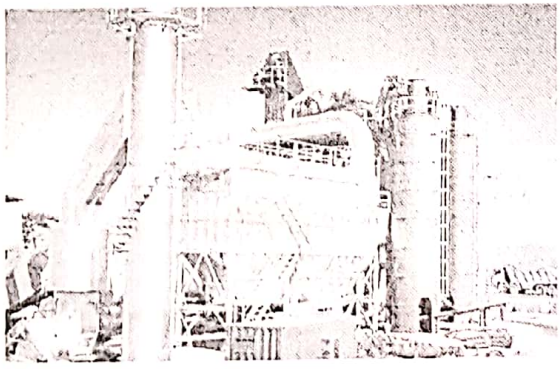
- Fabric filter materials:
  1. Natural fibers (cotton & wool)
     Temperature limit: 80 °C
  2. Synthetics (acetates, acrylics, etc.)
     Temperature limit: 90 °C
  3. Fiberglass
     Temperature limit: 260 °C

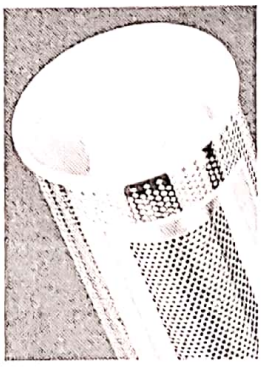
- Cannot be used for
  - wet air systems
  - corrosive gases
  - gases above 260oC

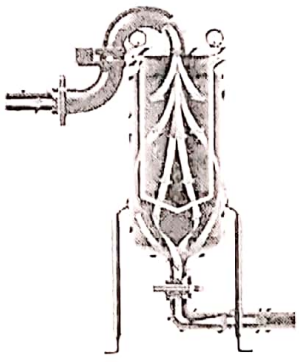
- Cleaning:
  1. Shaker
  2. Reverse air
  3. Pulse jet

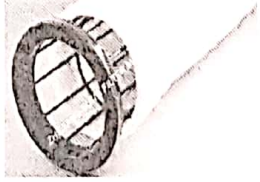
Fabric filters (bag houses)

لازم يكون فيها فتائح / mesh number









- ***Hybrid systems*** are defined as those types of control devices that involve combinations of control mechanisms-for example, fabric filtration combined with electrostatic precipitation.

- Four of the major hybrid systems found in practice today include:
  - Wet electrostatic precipitators,
  - Ionizing wet scrubbers,
  - Dry scrubbers, and
  - Electrostatically augmented fabric filtration.

Cyclones physical system,

physical system

ممكن احط اكثر من cyclones بحيث series بحيث يمر الي طالع من الأول داخل بالثاني

- ✓ can be used for 50-100 µm size particles and down to 10 µm
- ✓ simple economical unit:
  - no moving parts
  - relies on inertial effects

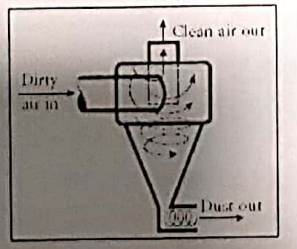
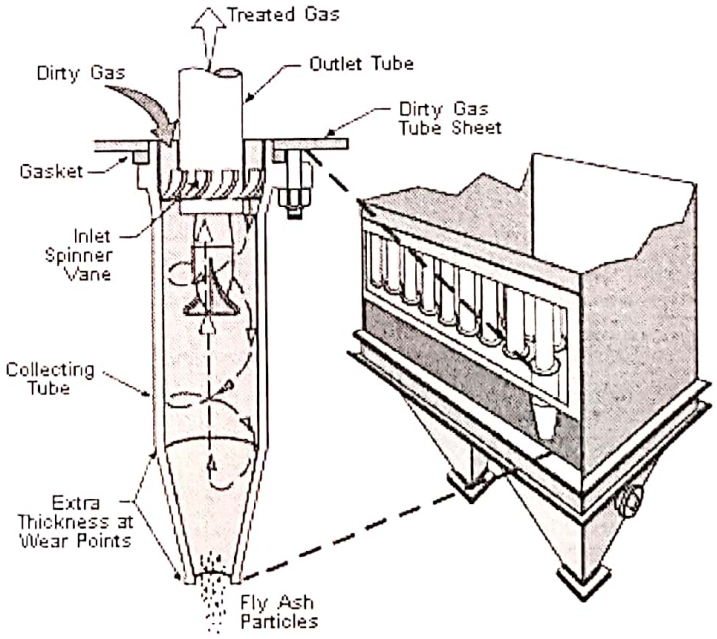
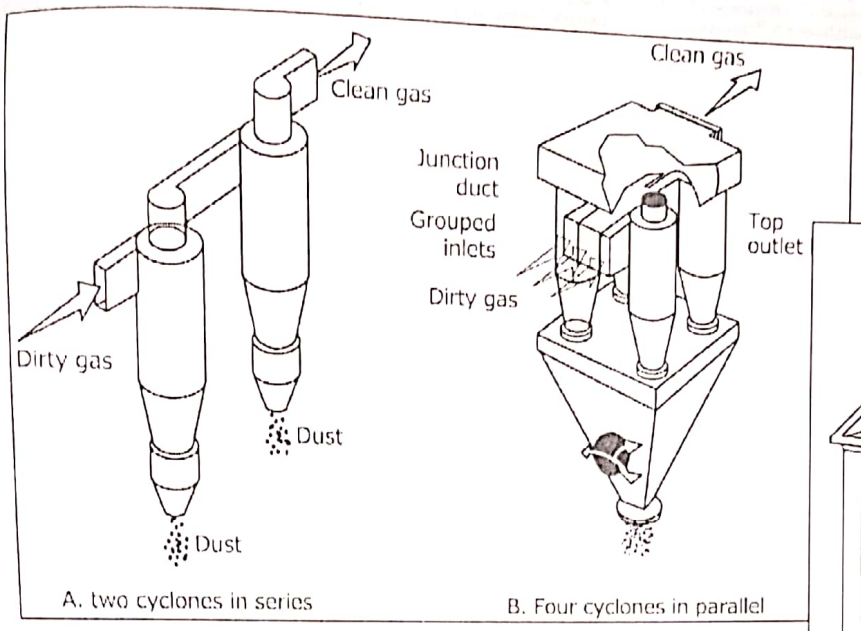


Figure 2. Small-Diameter Multi-Cyclone Collector



* مع نقصان القطر من الأسفل الهواء اذ يتجه للأعلى دائه يبعد عن اي ملامسة



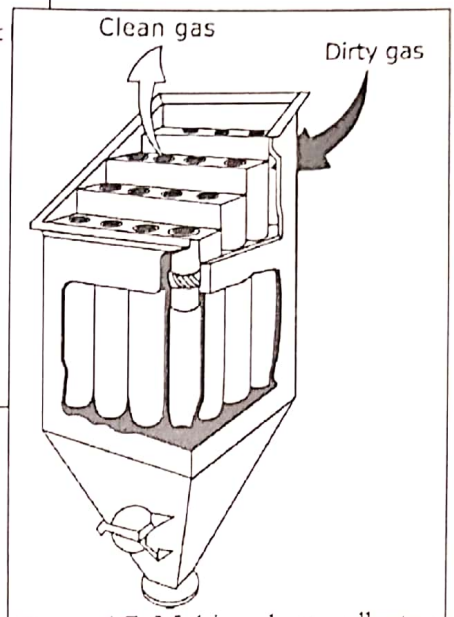


Figure 6-7. Multi-cyclone collector

For particle sizes greater than about 10 µm in diameter, the collector of choice is the cyclone

حتى اسوي الـ design

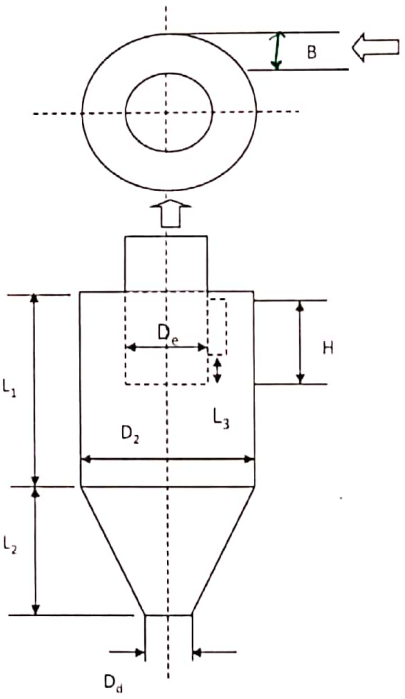
The particle size collected with 50% efficiency, termed the cut diameter:

$$d_{0.5} = \left[\frac{9\mu B^2 H}{\rho_p Q_g \theta}\right]^{1/2}$$

يعني انه لو وصل كفاءة د 50٪

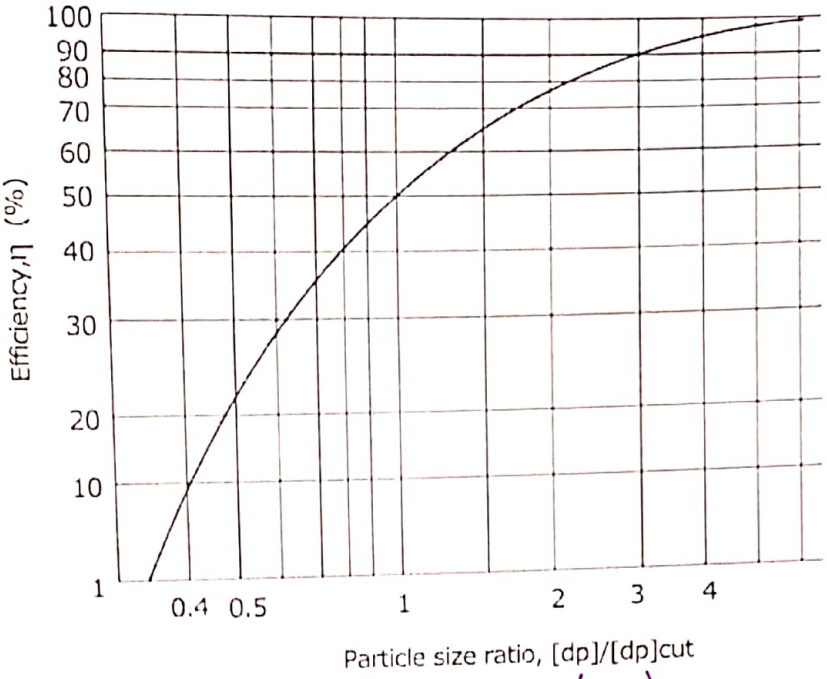
صحيح انا طلعت الـ geometry ✗ كيف اطلع الكفاءة ؟! صون انا بدي اشوف كم الـ design ✗ d0.5 بحيث يعطيني removal بكفاءة معينة

$$\theta = \frac{\pi}{H}(2L_1 + L_2)$$



$d_{0.5}$ = cut diameter at 50% removal
μ = dynamic viscosity of gas, Pa-s
B = width, m
H = height, m
ρ_p = particle density, kg/m3
Q_g = gas flow rate, m3/s
θ = effective number of turns

كم لفة بلف اي بتجيب الـ particle من لوصل لتحت



* علاقة الكفاءة بـ particle size

الـ particle اللي بدي اشيله حسب معادلة $d_{0.5}$

* ممكن يجيب انا جدول في كفاءات و Diameters يقلك احسبلي الـ parameters اللي بسؤال

Example

Given:
$D_2 = 0.5$ m
$Q_g = 4$ m^3/s
T = 25 °C
$\rho_p = 800$ kg/m^3

* For standard Cyclone:

B يوجد من D_2 $\Rightarrow$ $(B = 0.25\ D_2) = 0.13$ m

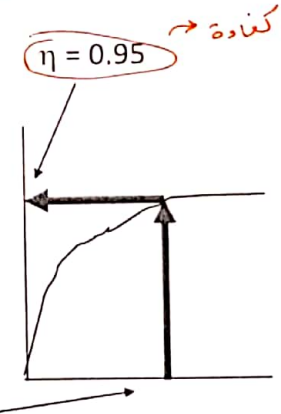
H يوجد $(H = 0.5\ D_2) = 0.25$ m

L_2, L_1 يوجد $(L_1 = L_2 = 2\ D_2) = 1$ m

L_2, L_1, H من B يوجد

$$\theta = \frac{\pi}{0.25}\left(2(1)+1\right) = 37.7$$

Q = What is the removal efficiency for particles with ave diameter of 10 μm?



$$d_{0.5} = \left[\frac{9(18.5x10^{-6})(0.13)^2(0.25)}{(800)(4)(37.7)}\right]^{0.5} = 2.41x10^{-6}$$

$$= 2.41(\mu m)$$

@ d =10 μm $\Rightarrow$ $\frac{d}{d_{0.5}} = \frac{10}{2.41} = 4.15$

ratio يوجد

efficency او جد عشان

* ممكن يطلعني η و يقلك اي size particle عليها بنشال

Electrostatic Precipitator (ESP)

- high efficiency, dry collector of particulates
- high electrical direct current potential (30-75 kV)

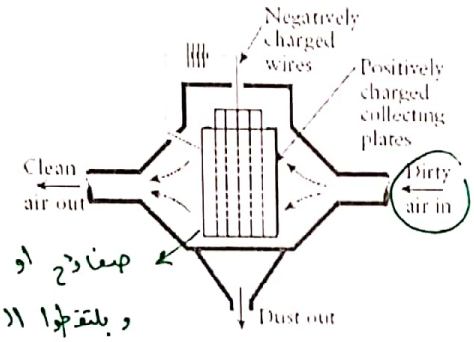
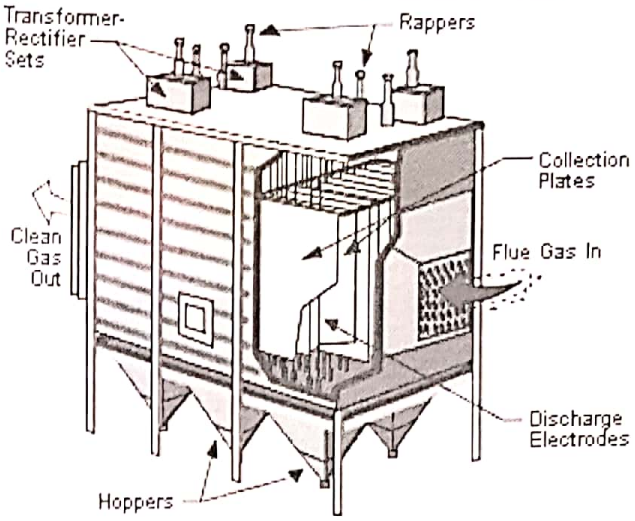
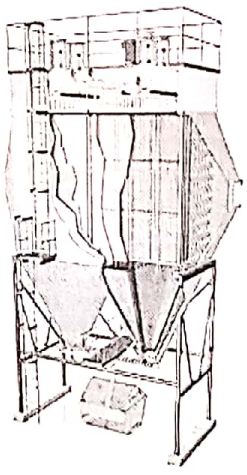


Figure 9. Conventional Electrostatic Precipitator

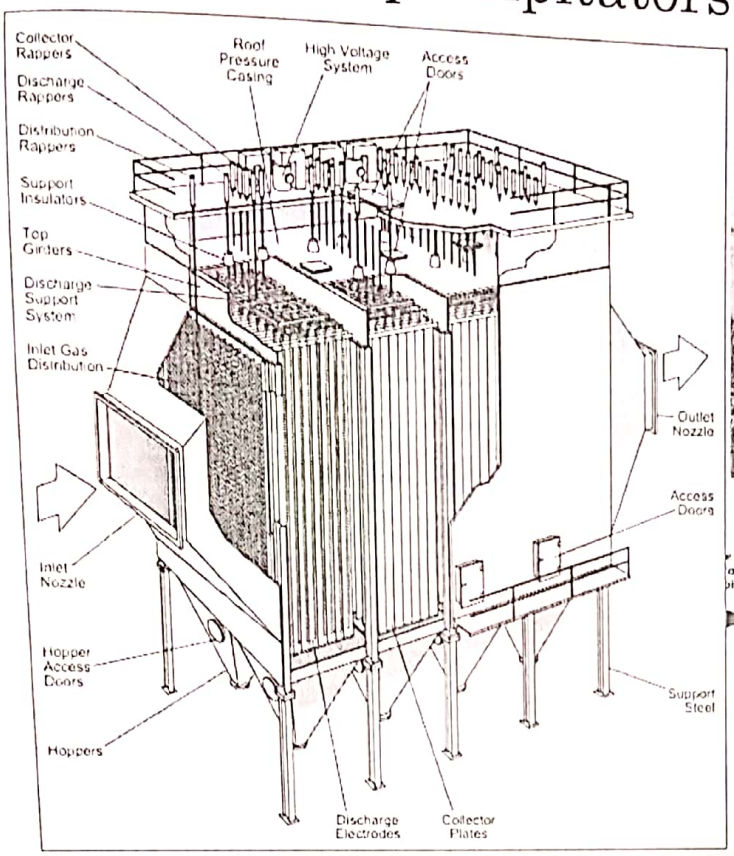


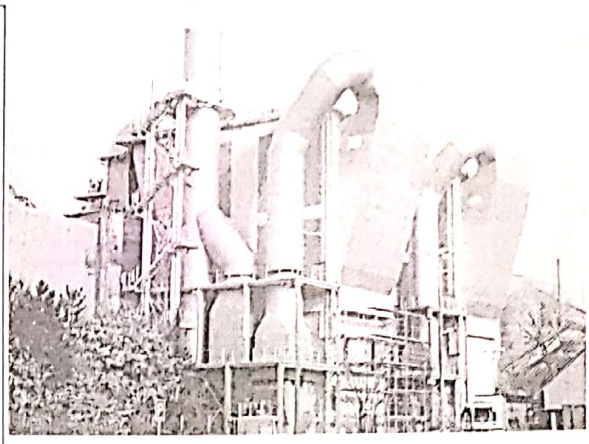
Electrostatic precipitators (ESPs)

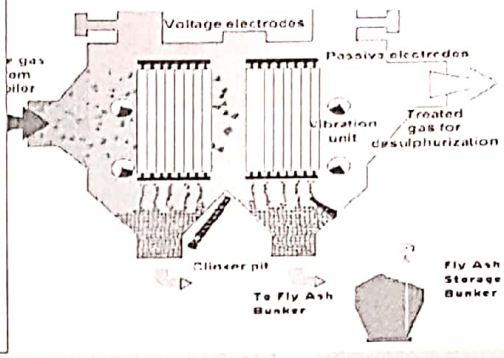


- They are satisfactory devices for removing small particles from moving gas streams at high collection efficiencies. They have been used almost universally in power plants for removing fly ash from the gases prior to discharge.
- Two major types of high-voltage ESP configurations currently used are tubular and plate. Tubular precipitators consist of cylindrical collection tubes with discharge electrodes located on the axis of the cylinder. Vast majority of ESPs installed are of the plate type.
- Collected particles are usually removed by rapping.

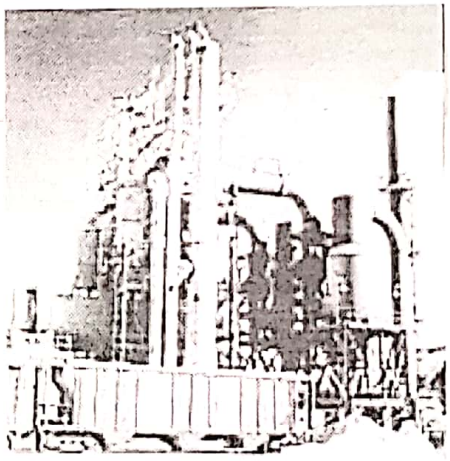
Electrostatic precipitators (ESPs)



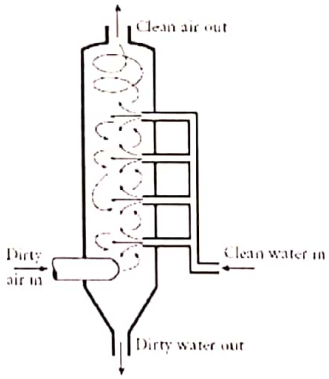




Wet Scrubber

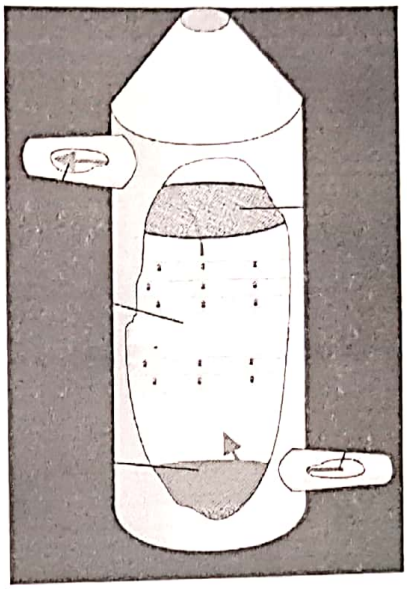


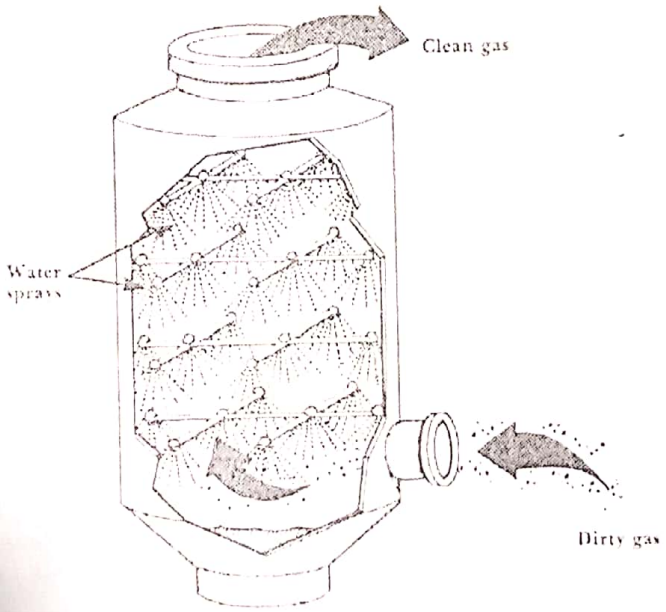
- can be used where
  - ✓ air is wet
  - ✓ corrosive
  - ✓ hot
  - ✓ where baghouses can not be used
  - ✓ for even higher efficiencies, a combination of a venturi scrubber and cyclone and can be used



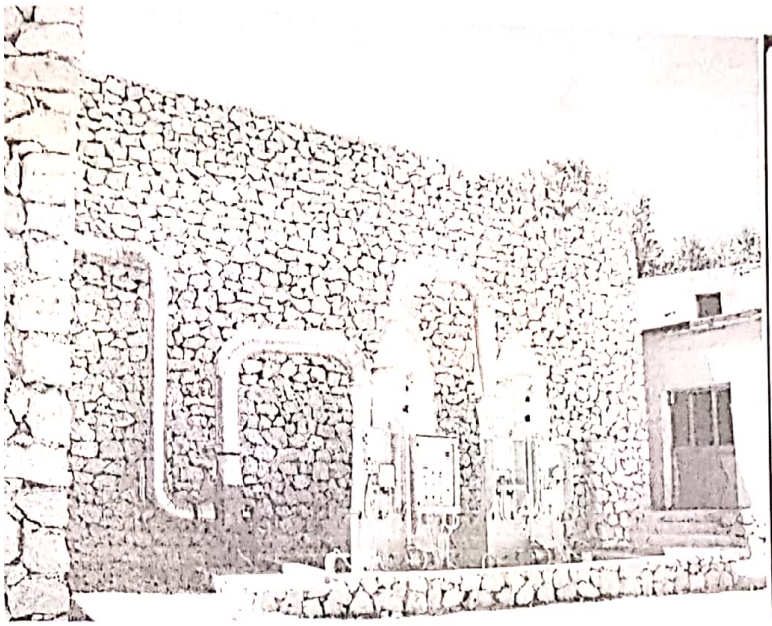
Scrubbers (venturi scrubbers)

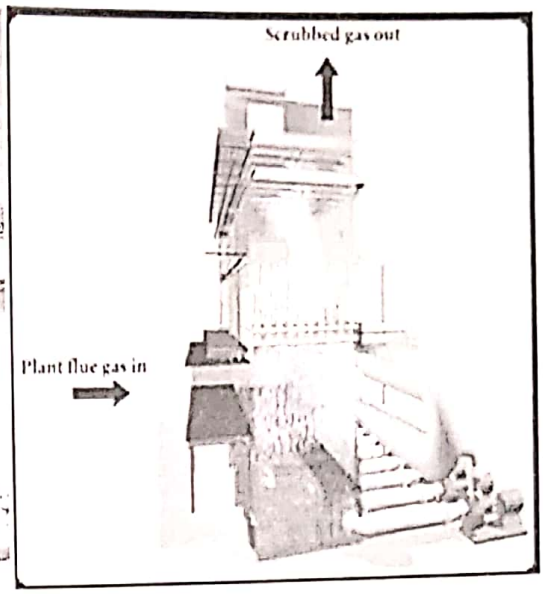
- Wet scrubbing involves the technique of bringing a contaminated gas stream into intimate contact with a liquid.
- Wet scrubbers include all the various types of gas absorption equipment.
- The term "scrubber" will be restricted to those systems which utilize a liquid, usually water, to achieve or assist in the removal of particulate matter from a carrier gas stream.



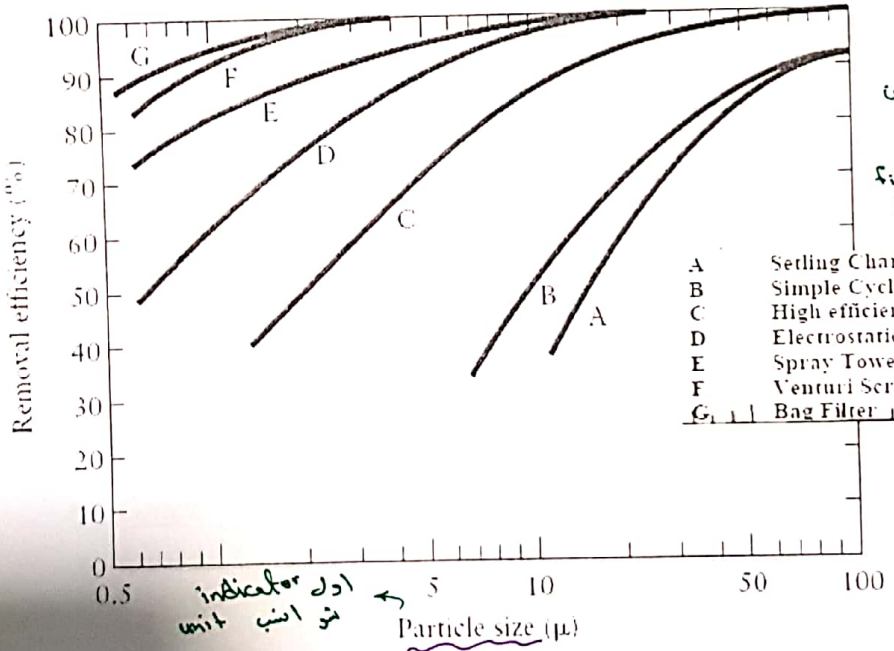


Scrubbers





Comparison of Air Pollution Control Devices



شو استنتج ؟!
حسب temp
اذا حرارة materials اقل من 250 c
بامكانك تستخدم filter bags

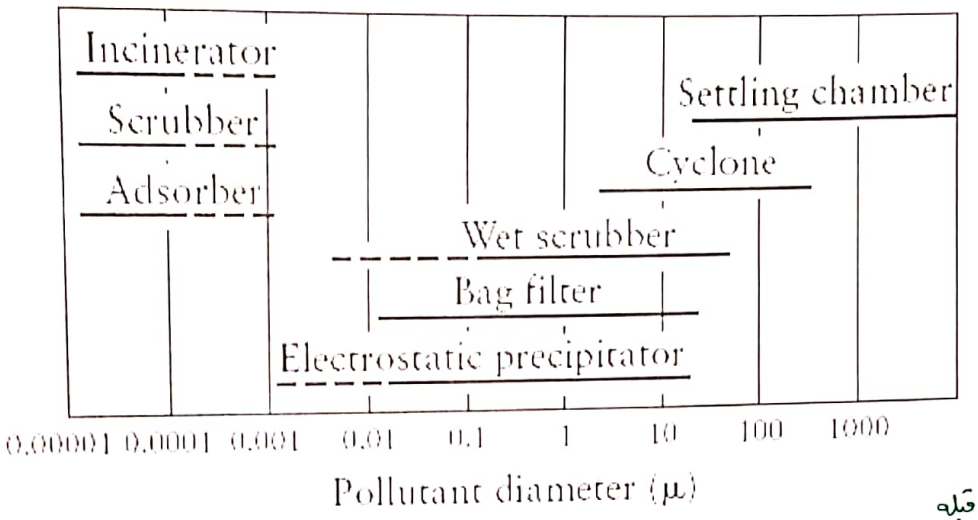
اذا حرارة عالية فوق 350 c
ابعد عن scrubber system

indicator اول شو انتب unit

بدي اعرف شو الحرارة يلي فيني وشو الـ materials المستخدمة ك rule of thumb

* high temp + corrosive ⇒ think about (physical + electrical)
cyclones + ESP ابعد عن الباقي ⇐

Effectiveness of Air Pollution Control Devices



Gaseous Emissions

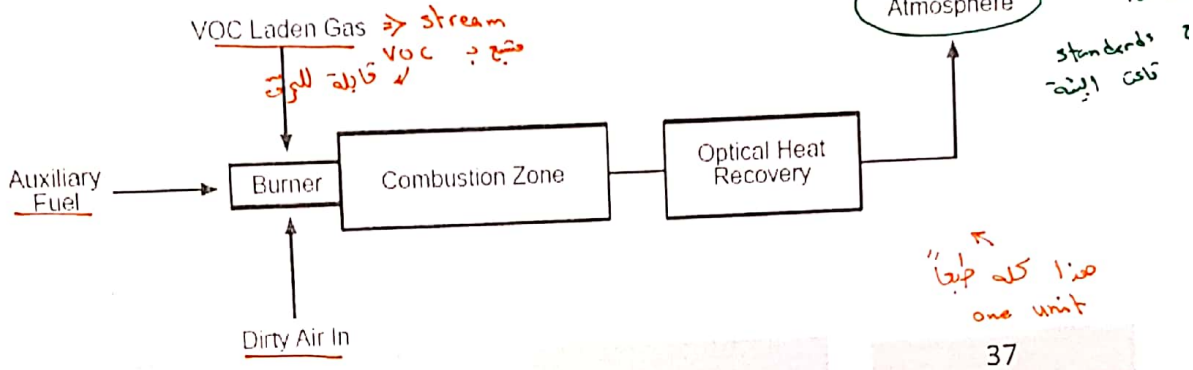
- The preferred method for controlling gaseous pollutants is with add-on control devices used to destroy or recover the pollutant.

Control Equipment for Gaseous Emissions:

- *Thermal (Incinerators)*
- *Catalytic Incinerators*
- *Flares*
- *Boilers and Process Heaters*
- *Carbon Adsorbers*
- *Absorbers*
- *Condensers*

Thermal Incinerator

- Thermal incinerators are commonly used to destroy volatile organic compounds (VOCs).
- In general, incineration involves the destruction of liquid, solid, or gaseous waste by a controlled burn at high temperatures.
- Incinerators are one of the most positive and proven methods for destroying VOC, with efficiencies up to 99.9% possible.



- **Applicable Pollutants:** Primarily volatile organic compounds (VOC). Some particulate matter (PM), commonly composed as soot (particles formed as a result of incomplete combustion of hydrocarbons (HC), coke, or carbon residue) will also be destroyed in various degrees.
- VOC destruction efficiency depends upon design criteria (i.e., chamber temperature, residence time, inlet VOC concentration, compound type, and degree of mixing) (EPA, 1992).
- Most thermal units are designed to provide no more than 1 second of residence time to the waste gas with typical temperatures of 650° to 1100 °C (1200° to 2000 °F).
- Studies based on actual field test data, show that commercial incinerators should generally be run at 870°C (1600°F) with a nominal residence time of 0,75 seconds to ensure 98% destruction of non-halogenated organics (EPA, 1992).

Theoretical Reactor Temperatures Required for 99.99 Percent Destruction by Thermal Incineration for a 1-Second Residence Time

Compound	Temperature, °F
acrylonitrile	1,344
allyl chloride	1,276
benzene	1,350
chlorobenzene	1,407
1,2-dichloroethane	1,368
methyl chloride	1,596
toluene	1,341
vinyl chloride	1,369

لحتى يتم العرقة كم لازم الحرارة

← مفروض حتى مهم كيتو

Thermal Incinerator PM10 Destruction Efficiencies by Industry (EPA, 1996):

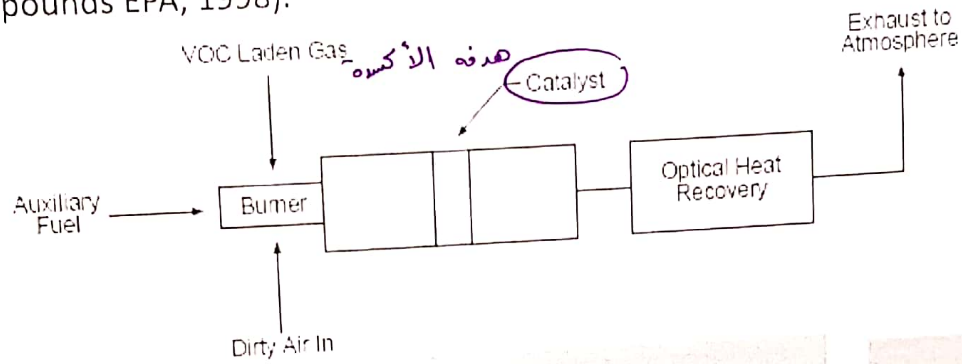
Industry/Types of Sources	PM_{10} Control Efficiency (%)
Petroleum and Coal Products Asphalt roofing processes (blowing, felt saturation); mineral calcining; petroleum refinery processes (asphalt blowing, catalytic cracking, coke calcining, sludge converter); sulfur mfg.	25 – 99.9%
Chemical and Allied Products Carbon black manufacturing (mfg); charcoal mfg; liquid waste disposal; miscellaneous chemical mfg processes; pesticide mfg; phthalic anhydride mfg (xylene oxidation); plastics/ synthetic organic fiber mfg; solid waste incineration (industrial)	50 – 99.9%
Primary Metals Industries By-product coke processes (coal unloading, oven charging and pushing, quenching); gray iron cupola and other miscellaneous processes; secondary aluminum processes (burning/drying, smelting furnace); secondary copper processes (scrap drying, scrap cupola and miscellaneous processes); steel foundry miscellaneous processes; surface coating oven	70 – 99.9%
Electronic and Other Electric Equipment Chemical mfg miscellaneous processes; electrical equipment bake furnace; fixed roof tank; mineral production miscellaneous processes; secondary aluminum roll/draw extruding; solid waste incineration (industrial)	70 – 99.9%
Electric, Gas, and Sanitary Services Internal combustion engines; solid waste incineration (industrial, commercial/ institutional)	90 – 99%
Stone, Clay, and Glass Products Barium processing kiln; coal cleaning thermal dryer; fabricated plastics machinery; wool mfg.	50 – 95%

Food and Kindred Products charcoal processing, miscellaneous; corn processing, miscellaneous; fugitive processing, miscellaneous; soybean processing, miscellaneous	70 - 98
Mining asphalt concrete rotary dryer; organic chemical air oxidation units; sulfur production	70 - 99.6
National Security and International Affairs solid waste incineration (commercial/institutional and municipal)	70
Textile Mill Products plastics/synthetic organic fiber (miscellaneous processes)	88 - 95
Industrial Machinery and Equipment secondary aluminum processes (burning/drying, smelt furnace)	88 -98
Lumber and Wood Products solid waste incineration (industrial)	70
Transportation Equipment solid waste incineration (industrial)	70 - 95

atalytic Incinerators

Catalytic incinerators operate very similar to thermal incinerators. The primary difference is that the gas, after passing through the flame area, passes through a catalyst bed to destroy essentially any oxidizable compound in an air stream.

- The catalyst has the effect of increasing the oxidation reaction rate, enabling conversion at lower reaction temperatures than in thermal incinerator units. Therefore, catalysts also allow for smaller incinerator size. Catalysts typically used for VOC incineration include platinum and palladium. Other formulations include metal oxides, which are used for gas streams containing chlorinated compounds EPA, 1998).



- The waste stream must be preheated to a temperature sufficiently high (usually from 300 to 900°F) to initiate the oxidation reactions.

- Catalyst Temperatures Required for Oxidizing 80% of Inlet VOC to CO2, °F for Two Catalysts

Compound	Temperature, °F	
	Co_3O_4	Pt - Honeycomb
acrolein	382	294
n-butanol	413	440
n-propylamine	460	489
toluene	476	373
n-butyric acid	517	451
1, 1, 1-trichloroethane	661	>661
dimethyl sulfide	-	512

Flares

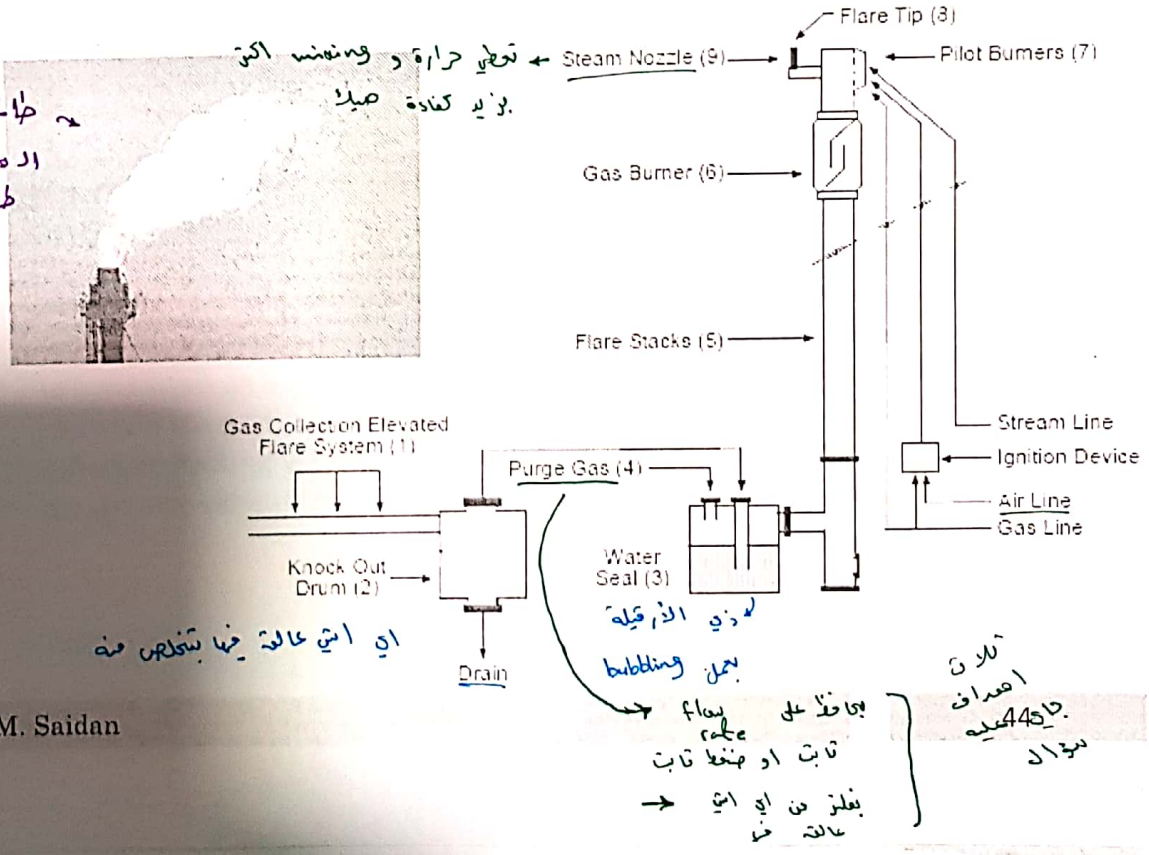
- Flaring is a VOC combustion control process in which the VOCs are piped to a remote, usually elevated, location and burned in an open flame in the open air using a specially designed burner tip, auxiliary fuel, and steam or air to promote mixing for nearly complete (>98%) VOC destruction.

- Flares are typically used as a last resort to dispose of gases that are of little recyclable value or are not easily combustible.

- Gases flared from refineries, petroleum production, and the chemical industry are composed largely of low molecular weight VOC and have high heating values.

- As in all combustion processes, an adequate air supply and good mixing are required to complete combustion and minimize smoke. The various flare designs differ primarily by their ability to mix air with the combustibles.

Steam-assisted Elevated Flare System



- The non-assisted flare consists of a flare tip without any auxiliary provision for enhancing the mixing of air into its flame. Its use is limited to gas streams that have low heat content and low carbon/hydrogen ratio that burn readily without producing smoke. These streams require less air for complete combustion have lower combustion temperatures.

هادي من paper حتى وطلوبة الهيدروجين .

NaOH و كلورين بطلع NaCl

← وطلع غاز كلورين ، بدخل املاح على electrochemical membrane بصير في تفاعلات ، تولد KCl بطلع KOH و بروم

Boilers and Process Heaters

- Boilers and process heaters are commonly used by production facilities to generate heat and power.
- Although their primary purpose to contribute to plant operations, they can also be used quite effectively as a pollution control device by recycling the pollutant for fuel.
- However, the only pollutants that can be used for fuel are those that do not affect the performance of the burner unit. For example, an exhaust stream can be used as supplementary fuel, but only if its fuel value is sufficient to maintain the combustion process. All volatile organic compounds (VOCs) have different heating values. If the pollutant stream is large and the heating value is high, the exhaust can be a primary source of fuel for the plant.

احسن بديل للكربون هو الهيدروجين

Bilateral ⇐ اتفاقية بين دولتين

Kyoto Protocol & Emissions Economics

193 دولة وقعت على protocol الـ

Dr. Motasem Saidan

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الحد من الإنبعاثات للغازات الدفيئة المتعارف عليها الـ 6 المذكورة من قبل وهم بطبيعة الحال CO_2

economic tool

Convention = protocol = agreement = treaties ⇐ اتفاقية بين اكثر من دولتين

* هي إزالة كاملة للـ emission خفض انبعاثات لنفس المستوى بلي بسنة 1990

تحت مظلة الأمم المتحدة

United Nations Framework Convention on Climate Change (UNFCCC)

- A global legal instrument (international agreement) to protect the climate system and stabilize GHG emissions

هي إزالة ⇐ ترجع الـ emission كاملة لقبل الـ 1990 (تثبت)

- The ultimate objective of the Convention is **"to achieve stabilization of atmospheric concentrations of greenhouse gases at levels that would prevent dangerous anthropogenic interference with the climate system**...
- Adopted in 1992, entered into force in 1994

صوت بمجلس شيوخ سنة 1994

- Status of participation: 189 Parties

امريكا و صين لسا ما وقعت

- Contains 2 annexes: ملحق

دول متطورة ← Annex 1: countries with obligations to take measures to mitigate the effects of climate change

دول نامية ← Annex 2: countries with obligations to provide financing to developing countries for their obligations under UNFCCC

* الدول يلي بـ Annex 2 عليهم التزامات اكثر من Annex 1

UNFCCC Principles

- Convention's principles of "equity" and "common but differentiated responsibilities" respond to the fact that, although climate change is a global issue and must be tackled as such, industrialized countries have historically contributed the most to the problem and have also more resources to address it. Developing countries are more vulnerable to its adverse effects and their technological, economic and institutional capacity to respond is generally lower.
- The "precautionary principle" responds to the dilemma that although many uncertainties still surround climate change, waiting for full scientific certainty before taking action would be too late to avert its impacts

Kyoto Protocol – key points

- Adopted at third Conference of Parties (COP) to the UNFCCC in Kyoto in 1997
- Entered into force on February 16th, 2005 after ratification of the Russian Federation
- Until June 2007, 174 countries covering 61.6% of global emissions have ratified the protocol
- Six emissions: CO2, CH4, N2O, PFCs, HFCs, SF6
- Binding emission reduction targets for Annex I countries of 5.2% below 1990 over 2008-2012
- Non-Annex I countries have no binding targets but must report on their actions
- Annex I countries can achieve targets through domestic policies and three market mechanisms
- Non-Annex I countries can participate to facilitate sustainable development

key points

- 1988 - Intergovernmental Panel on Climate Change (IPCC) established, body of scientists advising UN on climate change
- 1997 - Representatives of 161 nations met in Kyoto, Japan for a UN meeting on climate change
- Kyoto Protocol - agreement reached during meeting to reduce CO2 emissions from 39 developed countries to 5.2% below 1990 levels by 2012.
- 2001 US pulled out of the agreement.
- Russia's recent ratification was enough for the Kyoto Protocol to take effect.

Kyoto Protocol Mechanisms

1. ☐ **ET - Emissions Trading** (Carbon trading)

   AAU (Assigned Amount Units) are exchanged between Annex I countries

2. ☐ **JI - Joint Implementation**

   Annex I investors receive ERUs (Emission Reduction Units) by investing in a project in another Annex I nation which reduces GHG emissions

3. ☐ **CDM - Clean Development Mechanism**

   Annex I investors receive CERs (Certified Emission Reductions) by investing in a project in a non-Annex I nation which reduces GHG emissions

As the emission reductions from CDM projects are certified, unlike those for JI projects, they are termed Certified Emission Reductions (CERs). **one CER is equivalent to one ERU, assigned for a saving in any of the greenhouse gases equivalent in impact to one tonne of carbon dioxide emissions.**

Tonne Equivalent

- The different GHGs have different potentials to impact on Climate Change, so one ERU is awarded for emission reductions in any of the greenhouse gases equivalent in impact to one tonne of carbon dioxide (CO_2) emissions (1 t CO_{2e}).

➢ For example, methane (CH_4) has a global warming potential of 21; this means that one tonne of methane has the same climate change impact as 21 tonnes (t) of CO_2, and hence 1 t CH_4 = 21 t CO_{2e}. This means that landfill gas projects involving methane emission reductions can be particularly attractive, because they can generate large amounts of ERUs.

What Annex I countries can do . . . ?

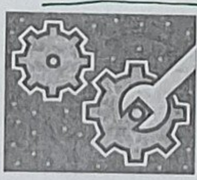
Limitations of CO2 emissions in developed countries (Annex I)

↓

4 options for companies

1/ Pay expensive fines.

2/ Carry out carbon reduction through **processes improvement**.



3/ Buy emissions credits on the **CO_2 market (ETS)**.

4/ Carry out carbon reduction through technology transfers in **CDM or JI project.**

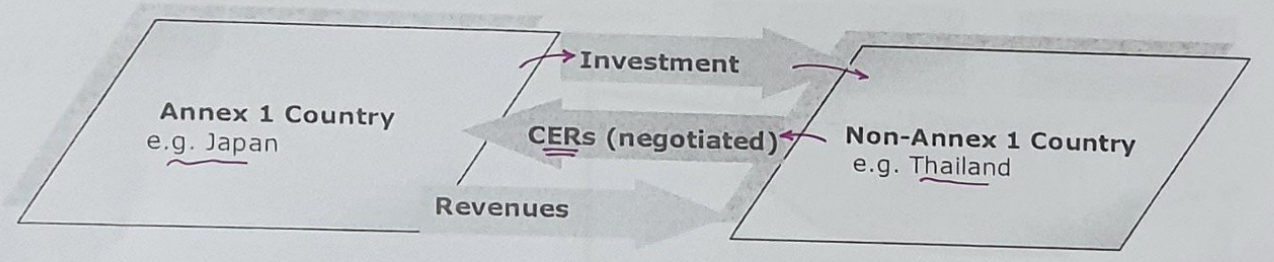
JI Project example

A UK company might seek to build a hydro power plant in New Zealand, that will displace electricity from the national grid. The project must replace an existing high greenhouse gas emitting source with a lower emitter; i.e. the reduction in emissions must be 'additional' to that occurring under a 'business as usual' scenario. The project would not, for example, generate emission reductions if it replaced a national electricity mix that was mostly composed of hydropower. Each project must have an agreed baseline against which the ERUs are calculated.

A UK company will be able to use the credits towards its emission reductions target under the EU Emission Trading Scheme (if it has such a target), or it could choose to sell the credits, either now (as a futures option or contract) or once they have been verified

How CDM works?

- Annex I country invests in GHG reduction project in non-Annex I country
- Annex I country receives CERs
- Non-Annex I country receives revenues from CERs

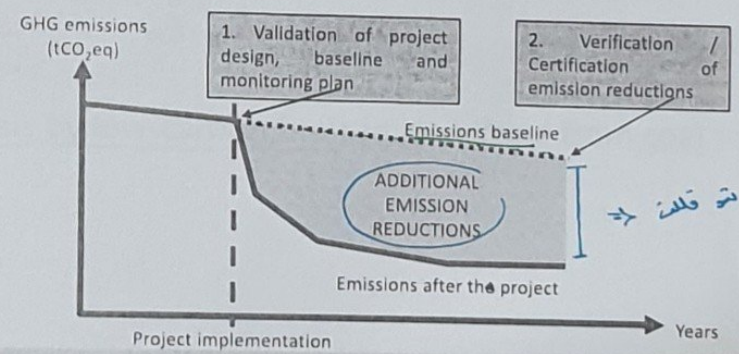


CDM Project example

An example of a CDM project would be the use of biomass to displace the use of diesel for electricity generation in the sugar production process in a developing country. To be eligible, a CDM project must replace a planned or existing high greenhouse gas emitting source with a lower emitter, and the reduction in emissions must be 'additional' to that which would occur under a 'business as usual' scenario. Each project will have an agreed baseline against which credits are calculated. Each project will also need to demonstrate its contribution to sustainable development in the host country, as determined by the host country Government.

CDM Eligibility

- Will the project reduce emission types under the Kyoto Protocol?
  CO2, CH4, N2O, HFCs, PFCs, SF6
- Does the country meet sustainable development requirements of the host country?
  - **Economy, e.g. creation of employment**
  - **Ecology, e.g. reduction of air pollution**
  - **Social, e.g. improved availability of public services**
- Are emission reductions additional?



CDM Eligibility

- Does the project fall into one of the seven project type categories?
  - End-use energy efficiency
  - Supply-side energy efficiency
  - Renewable energy
  - Fuel switching
  - Methane reduction
  - Industrial processes
  - Sequestration and sinks
- Does the project result in significant negative environmental impacts?
  - If "yes", then environmental impact assessment (EIA) required
  - Covers non-GHG impacts
  - Significant impacts may disqualify project for CDM
  - EIA brings additional costs to the company

The opportunities for reducing energy usage and lowering environmental impact

- Managing energy more efficiently performing energy assessment/audits, utilizing energy management training, and implementations programs
- Upgrading existing equipment < shifting to more energy-efficient processes (e.g. from wet to dry)
- Utilizing biomass fuels
- Utilizing waste fuels
- Replacing high-carbon fuels by low-carbon fuels (e.g. shifting from coal to natural gas)

* سلاح ذو حدين

- لانه كل واحد بدن يوفر فدهير الواحد يسترخص الاسعار المعروض عليه وهذا يلي خلى سعر Oil ten ينزل من 35 دولار إلى 35 بسنت

* كيف نفرض القوانين حاي

1- حط standard وراقب threat opertanities

2- تعفيز

* قدين عندي فالجن فوقه ال permit

Example 4.12: Say, a proposed CDM project involves use of ethanol to substitute 10% gasoline in a fleet of 1000 private cars. Assume that on average cars consume 0.1 litre of gasoline per km and the average annual travel is 10,000 km. Substitution of gasoline by ethanol does not result in any change in fuel use efficiency; therefore, the reduction in gasoline is equal to the amount of ethanol used in the cars.

The baseline for example 4.12 can be estimated as shown below.

Fuel consumption of a car per km (A)	= 0.1 litre gasoline (0.074 kg)
Average annual distance traveled per car (B)	= 10,000 km
Number of cars covered in the project (C)	= 1000
Emission factor of gasoline(kgC/ tonne) (D)	= 847 (IPCC default for gasoline)
Emission baseline (tonne CO_2) (E = AxBxCxDx44/12)	= (0.074x10,000x1000x0.847)x 44/12 = 2298.2
Project emission (tonne CO_2)	= 0.9x2298.2 = 2068.4*

* In project case 10% of gasoline consumption is replaced by ethanol, which is produced from organic sources and has zero GHG emissions. Therefore, only 90% of baseline gasoline used in baseline results in emissions during project case

Pollution Permit Trading

- It is a market-based approach to controlling pollution. By creating tradable pollution permits it attempts to add the profit motive as an incentive for good performance, unlike traditional environmental regulation based solely on the threat of penalties.
- Developed in the 70s and 80s, emissions trading was introduced in the US in 1990 to combat acid rain, but more recently it has grown in prominence as a way of tackling greenhouse gas emissions linked to climate change.
- Emissions trading is a central element of the Kyoto protocol in the form of the Clean Development Mechanism (CDM) and is the cornerstone policy of the EU, whose Emissions Trading System (ETS) is the largest in the world.
- Marketable pollution permits equate marginal abatement cost (MAC) across polluters so each firm compares their MAC with the price of the permit.

  - If MAC > price of permit: buy more permits, pollute more (cheaper to pollute)
  - If MAC < price of permit: sell more permits, pollute less (cheaper to clean up)

Example

There are three industrial firms in a cluster, with the following profiles:

Firm	Initial Pollution Level [units]	Marginal Abatement Cost [$]
A	70	20
B	80	25
C	50	10

The government wants to reduce pollution in the cluster to 120 units. It gives each firm 40 tradable pollution permits.

- Each firm has 40 permits. Therefore, **if no trading:**

A abates 70 – 40 = 30 x $20 = $600
B abates 80 – 40 = 40 x $25 = $1,000
C abates 50 – 40 = 10 x $10 = $100

Total abatement cost: $1700

However, if the equilibrium permit price is $20. so $20/permit:

both A and C want to sell permits to B since it is cheaper for them to clean-up rather than pollute – excess supply of pollution permits (not equilibrium).

A is indifferent since price = MAC, abates 70 – 40 = 30 x $20 = $600 (A has 40 permits)
B buys all permits from C, so ***zero*** abatement costs (B has 80 permits)
C sells all permits, so has to abate all original emissions 50 x $10 = $500
(C has 0 permits)

Total abatement cost: $1100