Arab Academy for Science, Technology, and Maritime Transport (AASTMT)
Cairo Campus
College of Computing and Information

UNR1601

Climate Change and Water Management
Ch [03] – Pollution & Man-made Impacts

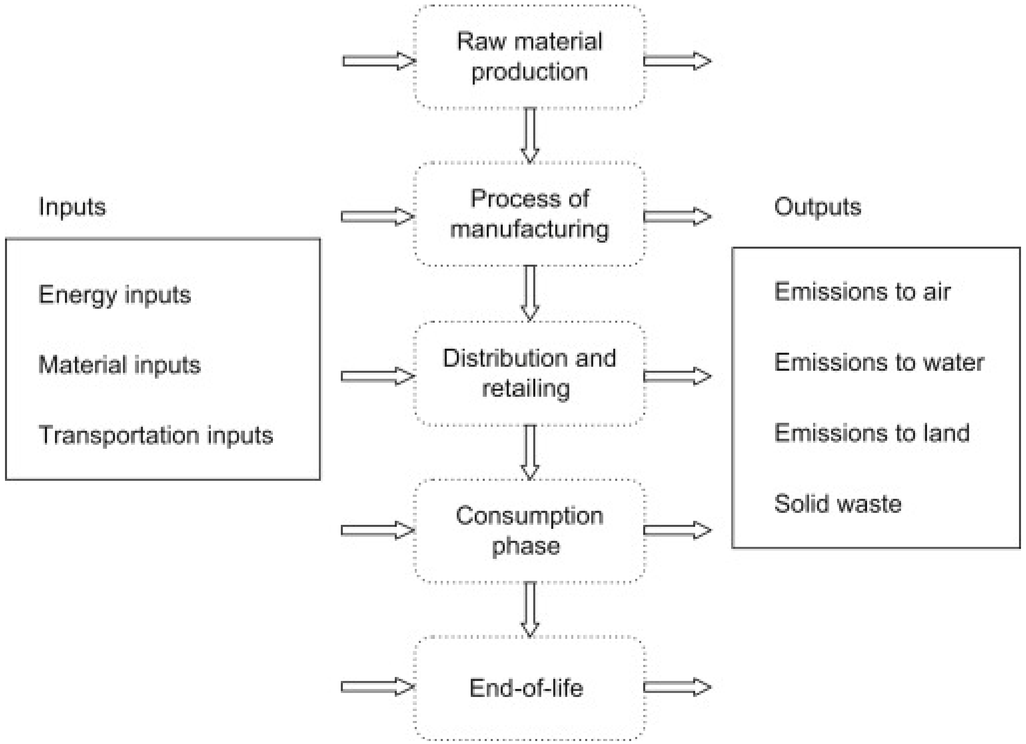
Dr. Ayman Mohamed Hamza
Construction & Building Engineering Department, Faculty of Engineering and Technology, AASTMT, Cairo Campus

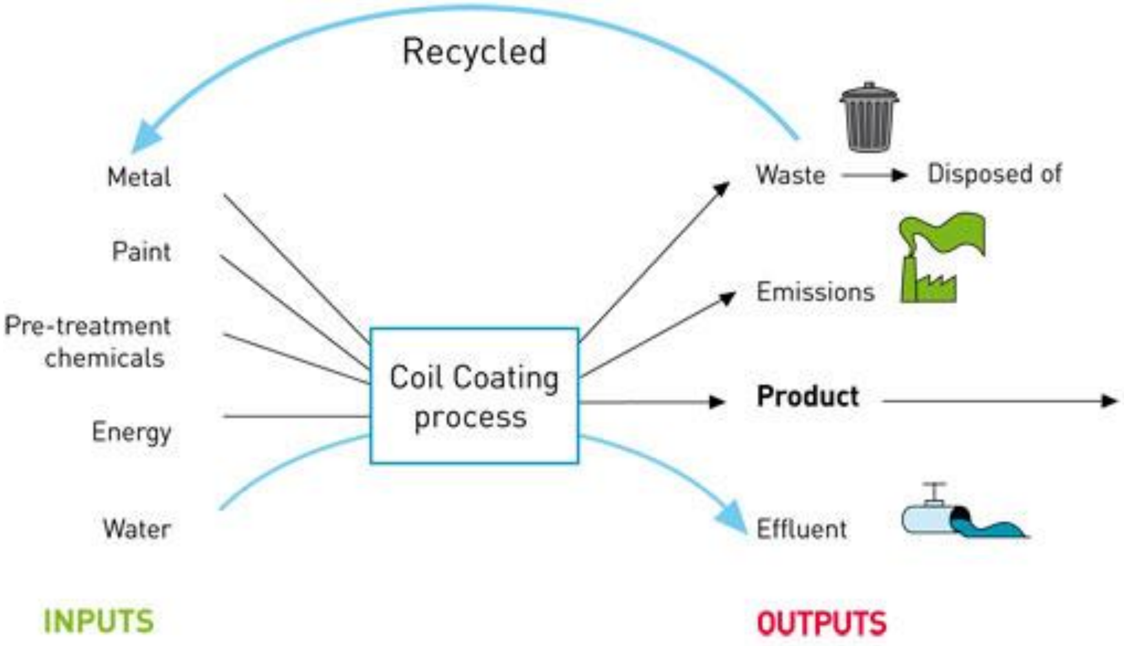
Environmental Aspect

Environmental Aspect is

the Features of a company's *operations*, *processes*, *activities*, *products*, or *services* that can have an **impact** (**good or bad**) on the **environment**.

These aspects could be **inputs** or **outputs** during ***the life cycle assessment*** of a product or a service.



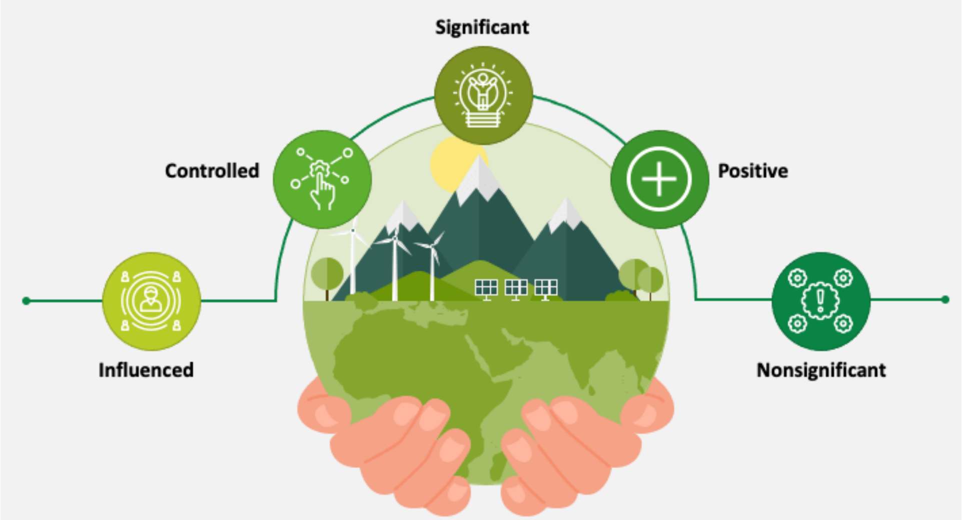


Reasons for Identifying Environmental Aspects

Once the environmental aspect and the cause of that aspect have been identified, the next step is to identify the potential environmental impacts associated with it that may adversely affect the environment and human health.

So the **Reasons for Identifying Environmental Aspects are :**

- **Guide the setting** of new environmental objectives and targets as part of the commitment to continual improvement
- **Focus operational controls** on significant environmental aspects
- **Reduce risks** from significant environmental aspects
- **Identify training** needs



Classification of Environmental Aspects

Environmental Impact

An environmental impact is defined as

any change to the environment, whether adverse or beneficial, resulting from activities, products, or services. The adverse ***effects could be on the air, land, water, and wildlife or the inhabitants*** of the ecosystem.

❑ **Types of Environmental Impacts:**

- **Direct Impacts:**

Occur through direct interaction of an activity with an environmental component.

- **Indirect Impacts** (secondary)**:**

The impacts which are not a direct result of the activity, often produced away from or as a result of a complex impact pathway.

- **Cumulative Impacts:**

Consist of an impacts that are created as a result of the combination of several activities. *These impacts are combined with the cumulative effects of other past, present and reasonably foreseeable future projects*.

Environmental Impact

Pollution, contamination, or destruction that occurs as a consequence of an action, that can have short-term or long-term ramifications is considered an environmental impact. **Pollution is Classified on the basis of the form (*source*) into** (natural and man-made).

- **Natural Impact:**
  - **Physical** Impact (***Wind***, ***Earthquakes***, ***volcano***,..).
  - **Biological** Impact (***Bacteria***).
- **Man-Made Impact:**
  - **Global warming**
  - **Ozone layer depletion**
  - **Acid rain**
  - **Air, water, or land Pollution**
  - **Loss of biodiversity**

Global warming

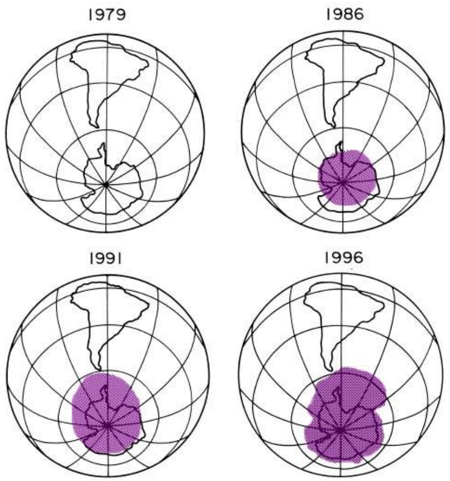
Increase in the average temperature of the earth's atmosphere and oceans, especially a sustained increase sufficient to cause climatic change. This phenomenon is ***due to a build-up of greenhouse gases*** in the atmosphere.

Source	Result	Output	Outcome	Impact	Solution
Industry	Carbon dioxide (CO_2)	greenhouse	Climatic Change	Floods caused soil erosion then destroy the crop and famine	**Clean production**
Open burning	Methane (CH_4)	Global warming			**BAT& BEP**
Transportation	Nitrous oxide (N_2O)				**Solid waste strategy**

Note :
BAT : Best Available Technique & BEP : Best Environmental Practice

Ozone Depletion

Ozone layer depletion, is **reduction of the amount of ozone in the stratosphere**. Depletion begins **when *chlorofluorocarbons (CFC's)* get into the stratosphere**.



Source	**Result**	**Output**	**Outcome**	**Impact**	**Solution**
Refrigerator Industry	CFC	Reducing O3	Layer depletion	Increase ultraviolet radiation	Implement **Montreal Protocol** (Replace halon, CFC)
Firefighting	Halons			Skin Cancer	
Plastics Manufacture				weak Immune System	

Acid rain

Rainfall made so acidic by atmospheric pollution that it causes environmental harm, chiefly to forests and lakes. ***The main cause is the industrial burning*** of coal and other fossil fuels*, the waste gases from which contain Sulphur and nitrogen oxides* which combine with atmospheric water to form acids.

Source	Result	Output	Outcome	Impact	Solution
Industry	S	*Sulfuric acid* (**H_2SO_4**)	Acid Rain	Destruction of forests	**Cleaner Production**
Open burning	N			Health Problem	**Solid waste Strategy**
				Building Damage	

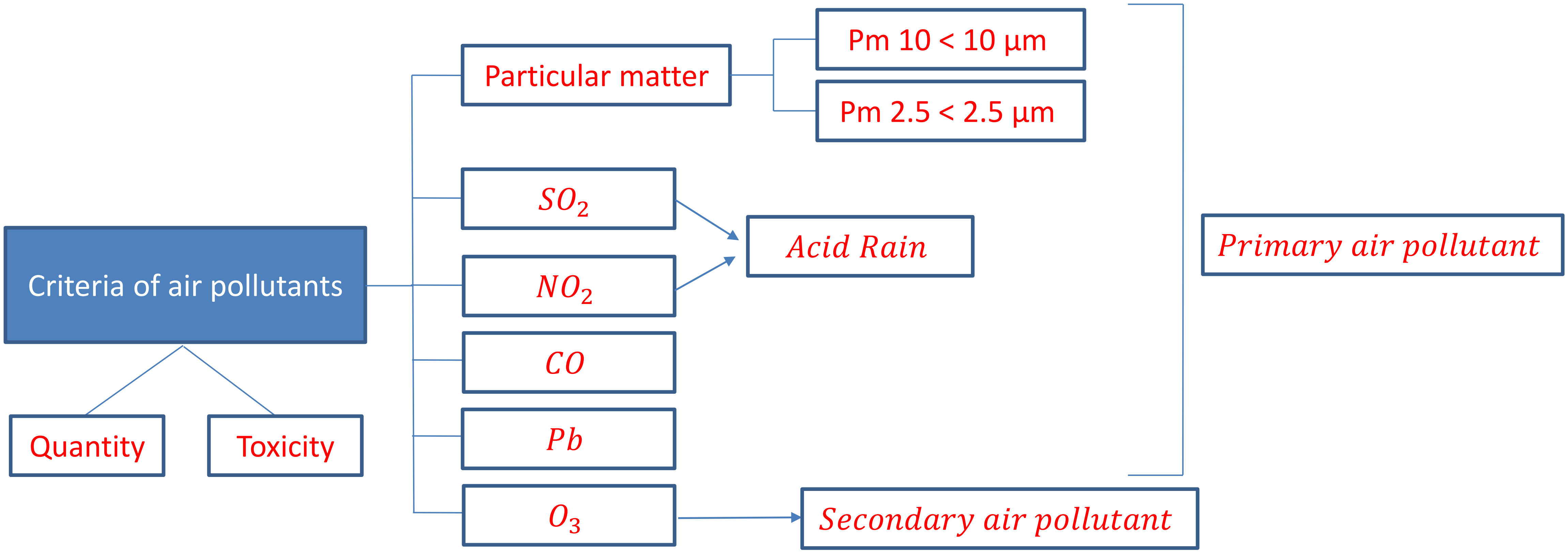
Air Pollution

Occurs when harmful or **excessive quantities of substances including gases, particulates, and biological molecules are introduced into Earth's atmosphere**. It may cause diseases and death of humans; it may also cause harm to other living organisms such as animals and food crops, and may damage the natural or built environment.

Source	Result	Output	Outcome	Impact	Solution
Industry	Air pollutant (Carbon dioxide (CO2) , Sulfur Oxides (SO_x), Carbon Monoxide (CO))	Loss of air quality (Air degradation)	Air pollution	Lung disease	**BAT& BEP**
Open burning				Cancer	**Cleaner Production**
Transportation				Respiratory infections	**Solid waste Strategy**

Gases Considered TO MEASURE AIR POLLUTION

Air quality index (AQI) is ***a measure used for reporting the daily air quality*, *by factoring the level of Pollution in the air***. Different countries use different indices for measuring air quality by monitoring some or all of the following Pollution: carbon monoxide, PM2.5, PM10, Nitrogen dioxide, ground Ozone (O3), Sulphur dioxide among others.



National Ambient Air Quality Standards

Pllutant	Level	Average time
Carbon Monoxide (CO)	9 PPm (10 mg/m3)	8 hrs
	35 PPm (40 mg/m3)	1 hr
Nitrogen Dioxide (NO2)	0.053 PPm (100 µg/m3)	Annual arithmetic mean
	0.100 PPm	1 hr
Ozone (O3)	0.075 PPm	8 hrs
Sulfur Dioxide (SO2)	0.03 PPm	Annual arithmetic mean
	0.14 PPm	24 hrs
	0.5 PPm	3 hrs (secondary Standard)
Particular matter (PM-10)	150 µg/m3	24 hrs
Particular matter (PM-2.5)	15 µg/m3	Annual arithmetic mean
	35 µg/m3	24 hrs
Lead (Pb)	0.15 µg/m3	3 month rolling average

Exposure Limits

<u>Exposure Limits defined in three ways:</u>

- **Time Weighted Average (TWA):**

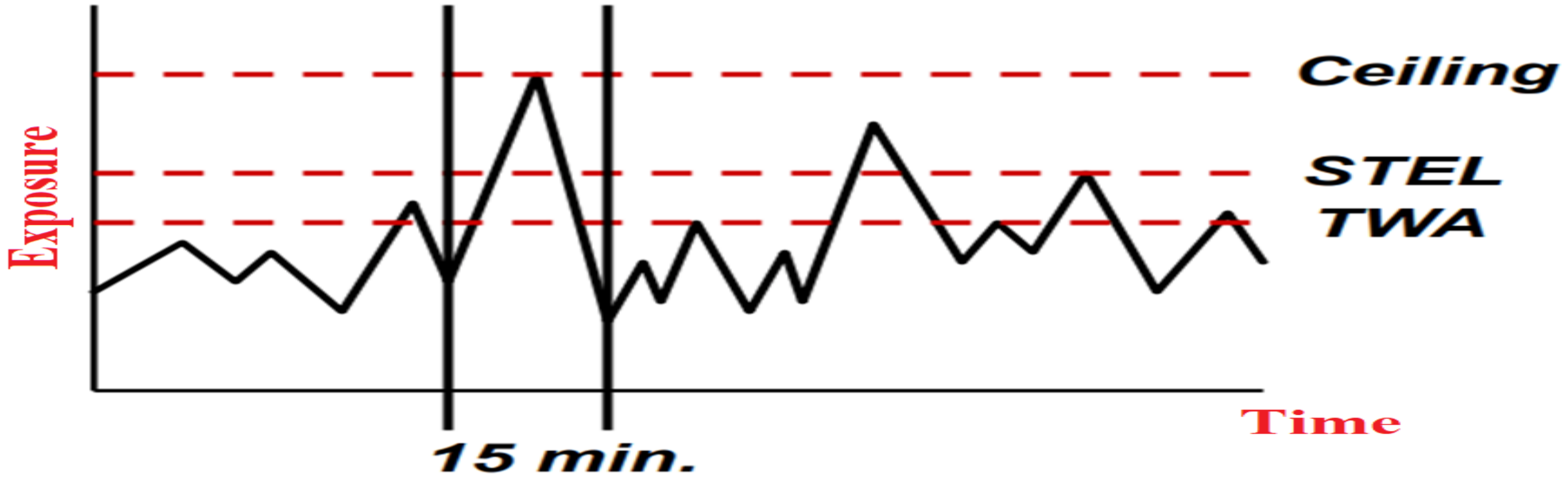
  is a method of calculating a worker's daily exposure to hazardous substances

- **Ceiling:**

  is the maximum concentration to which an unprotected worker may be exposed

- **Short Term Exposure Limit (STEL):**

  is the time-weighted average concentration of a substance over a 15 min period



Time Weighted Average (TWA)

Time-weighted average (TWA) **is a method of calculating a worker’s daily exposure to hazardous substances such as dust, fumes, chemicals, gases, or vapors**. It is averaged to an 8-hour workday or 40-hour week, along with the average levels of exposure to the hazardous substance and the time spent in that area.

TWA exposures for an eight hour work shift are calculated as follows:

$$E = (C_a T_a + C_b T_b + \dots\ CnTn\ ) / 8$$

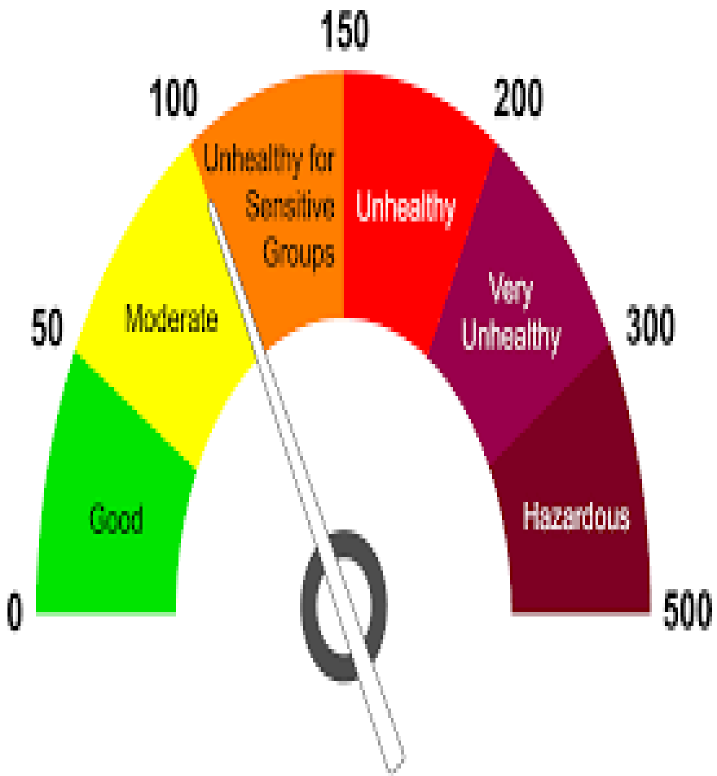
Where:

- E: the equivalent **exposure for the eight hour working shift**
- C: the **concentration during any period of time T** where the concentration remains constant
- T: the **duration in hours of the exposure at concentration C**

Exposure	Concentration	TWA
4 hours	100 ppm	50 ppm
8 hours	100 ppm	100 ppm
12 hours	100 ppm	150 ppm

Air Quality Index

Air quality index (AQI) is a measure used for reporting the daily air quality, by factoring the level of Pollution in the air. Different countries use different indices for measuring air quality by monitoring some or all of the following Pollution: carbon monoxide, PM2.5, PM10, Nitrogen dioxide, ground Ozone (O3), Sulphur dioxide among others.



Index Value	Name	Color	Advisory
0 to 50	Good	Green	None
51 to 100	Moderate	Yellow	Unusually sensitive individuals should consider limiting prolonged outdoor exertion
101 to 150	Unhealthy for Sensitive Groups	Orange	Children, active adults, and people with respiratory disease, such as asthma, should limit prolonged outdoor exertion
151 to 200	Unhealthy	Red	Children, active adults, and people with respiratory disease, such as asthma, should avoid prolonged outdoor exertion; everyone else should limit prolonged outdoor exertion
201 to 300	Very Unhealthy	Purple	Children, active adults, and people with respiratory disease, such as asthma, should avoid outdoor exertion; everyone else should limit outdoor exertion
301-500	Hazardous	Maroon	Everyone should avoid all physical activity outdoors.

How to CALCULATE THE AQI

<u>The AQI is the highest value calculated for each pollutant as follows:</u>

a. Identify the highest concentration among all of the monitors within each reporting area and truncate in the following table.

b. Find the two breakpoints that contain the concentration.

c. Using the Equation, calculate the index

d. Round the index to the nearest integer.

Ozone (ppm) –	**truncate to 3 decimal places**
PM2.5 (µg/m3) –	**truncate to 1 decimal place**
PM10 (µg/m3) –	**truncate to integer**
CO (ppm) –	**truncate to 1 decimal place**
SO2 (ppb)	**truncate to integer**
NO2 (ppb) –	**truncate to integer**

How to CALCULATE THE AQI

Breakpoints for the AQI

$$I_P = \frac{I_{Hi} - I_{Lo}}{BP_{Hi} - BP_{Lo}} (C_P - BP_{Lo}) + I_{Lo}$$

Where:

I_P = the index for pollutant p

C_P = the truncated concentration of pollutant p

BP_{Hi}= the concentration breakpoint that is greater than or equal to C_P

BP_{Lo}= the concentration breakpoint that is less than or equal to C_P

I_{Hi} = the AQI value corresponding to BP_{Hi}

I_{Lo} = the AQI value corresponding to BP_{Lo}

How to CALCULATE THE AQI

Breakpoints for the AQI

O3 (ppm) 8-hour	O3 (ppm) 1-hour1	PM2.5 (µg/m3) 24-hour	PM10 (µg/m3) 24-hour	CO (ppm) 8-hour	SO2 (ppb) 1-hour	NO2 (ppb) 1-hour	AQI	
0.000 - 0.054	-	0.0 – 12.0	0 - 54	0.0 - 4.4	0 - 35	0 - 53	0 - 50	Good
0.055 - 0.070	-	12.1 – 35.4	55 - 154	4.5 - 9.4	36 - 75	54 - 100	51 - 100	Moderate
0.071 - 0.085	0.125 - 0.164	35.5 – 55.4	155 - 254	9.5 - 12.4	76 - 185	101 - 360	101 - 150	Unhealthy for Sensitive Groups
0.086 - 0.105	0.165 - 0.204	(55.5 - 150.4)3	255 - 354	12.5 - 15.4	(186 - 304)4	361 - 649	151 - 200	Unhealthy
0.106 - 0.200	0.205 - 0.404	(150.5 - (250.4)3	355 - 424	15.5 - 30.4	(305 - 604)4	650 - 1249	201 - 300	Very unhealthy
(2)	0.405 - 0.504	(250.5 - (350.4)3	425 - 504	30.5 - 40.4	(605 - 804)4	1250 - 1649	301 - 400	Hazardous
(2)	0.505 - 0.604	(350.5 - 500.4)3	505 - 604	40.5 - 50.4	(805 - 1004)4	1650 - 2049	401 - 500	Hazardous

AQI

Example:

Suppose you have an **8-hour ozone** value of **0.07853333**.

First, truncate the value to **0.078**.

Then refer to the 8-hour ozone **in table** 5 for the **values that fall above and below your value (0.071-0.085).**

In this case, the 0.078 value **falls within the index values of 101 to 150**.

Now you have all the numbers needed to use the equation.

$$\text{AQI} = \frac{(150 - 101)}{(0.085 - 0.071)}(0.078 - 0.071) + 101 = 126$$

So an ***8-hour value of 0.07853333 corresponds to an index value of 126***.

Liquid Pollution

Water pollution is **the contamination of surface or ground water**. This form of environmental degradation occurs ***when pollutants are directly or indirectly discharged into water without adequate treatment t***o remove harmful compounds.

Source	Result	Output	Outcome	Impact	Solution
Industry Marine transportation	All pollutant (Liquid wastes)	Water Quality degradation	Liquid Pollution	Death of aquatic animals	**Cleaner Production**
				Disruption of food-chains	**Minimize the use of pesticides**
Agricultural wastewater				Destruction of ecosystems	**Erosion and sediment control**

Liquid Pollution

- **Concentrations** most commonly expressed as ***mass of substance per unit volume of mixture***, e.g. mg/L, µg/L, g/m^3
- Alternatively, ***mass of substance per mass of mixture***, e.g. parts per million (**ppm**) or parts per billion (**ppb**)
- Occasionally, ***molar concentrations***, e.g. moles/liter (**M**).

- ***Molarity***: *The molarity (M) of a solution is used to represent the amount of moles of solute per liter of the solution.* $(\frac{n}{V})$

- ***Molality***: The molality (m) of a solution is used to represent the amount of moles of solute per kilogram of the solvent.

Water quality standards as recommended by WHO

Parameter	Highest Desirable Level	Maximum Permissible L
Total solid	500	1500
Color (pt co)	5	50
Turbidity (NTU)	5	25
Chloride	200	600
Iron	0.1	1
Manganese	0.05	0.5
Copper	0.05	1.5
Zinc	5	15
Calcium	75	200
Magnesium	30	150
Sulphate	200	400
Total hardness (CaCO3)	100	500
Nitrate	45	500
Ammonium	_	_
pH (unit)	7- 8	Min 6.5 Max 9.2

Concentration in mg/L except where noted

Source: WHO (1971

Water Quality Index

Combined score in a series of ***9 chemical and physical tests*** that indicate the overall quality of the particular body of water .

The water tests:

Chemical	Physical
• PH	• Turbidity
• Nitrates	• Fecal coliform
• Phosphates	• Total dissolved solids
• Dissolved oxygen	• Temperature Change
• Biochemical oxygen demand	

Some factors are more important than others so each measurement is multiplied by the weighting factor.

Weighted Arithmetic Water Quality Index Method

The weighted arithmetic index method is used to calculate the treated water quality index. The parameters for drinking water were used and compared with the allowable values for drinking water quality as recommended by the World Health Organization (WHO) in order to calculate a **WQI** as given in the following steps

1- Calculation of unit weight factor

$$\boxed{W_i = \frac{K}{Sum\ K}}$$

where W_i represents the weighting for the i^{th} determinant and this value varies from (0 to 1) and sum W_i= 1; and K : is a proportional constant.

2- Calculation of the quality rating scale (q_i), which reflects the comparative value of this determinant in the contaminated water with respect to its standard permitted value as follows:

$$\boxed{q_i = \frac{v_i - v_d}{s_i - v_d}}$$

where q_i represents the rating for the i^{th}determinant, and this value varies from 0 to 100: Vi is the observed value of the i^{th}determinant: $v_d$is the ideal value of the i^{th}determinant in pure water; and Si is the standard value of the ith determinant.

3- Calculation of water quality index using the following equation:

$$\boxed{\text{WQI} = W_1\, q_1 + W_2\, q_2 + \ldots.\ W_n\, q_n}$$

where: WQI has a value between 0 and 100 which indicates the quality of the water; n represents the number of parameters taken into consideration

Water Quality Index, status and grading of water quality

Water Quality Index Level	Water quality status	Grading	Possible usages
0-25	Excellent water quality	A	Drinking, Irrigation and Industrial
26-50	Good water quality	B	Domestic, Irrigation and Industrial
51-75	Poor water quality	C	Irrigation and Industrial
76-100	Very poor water quality	D	Irrigation
> 100	Unsuitable for drinking and fish culture	E	Restricted use for Irrigation

Land Pollution

<u>**Degradation of earth's land surfaces**</u> often caused by human activities and its misuse. Haphazard ***disposal of urban and industrial wastes, exploitation of minerals, and improper use of soil by inadequate agricultural practices are a few of the contributing*** factors.

Source	**Result**	**Output**	**Outcome**	**Impact**	**Solution**
Industry	Solid waste	Land degradation	Land Pollution	loss of fertile land	**Solid waste strategy**
Hazard Solid Waste				Effect on wildlife	**Recycle**
Agriculture				Cause Air pollution	**Cleaner production**

SOLIDS POLLUTION

Concentrations can be expressed as ***mass of substance per mass of solid mixture***, e.g. mg/kg, µg/g

1 mg/kg = 1 mg-substance per kg solid

= 1 part per million by weight

= 1 **ppm**

1 µg/kg = 1 microg-substance per kg solid

= 1 part per billion by weight

= 1 **ppb**

Environmental pollution & Environmental Degradation

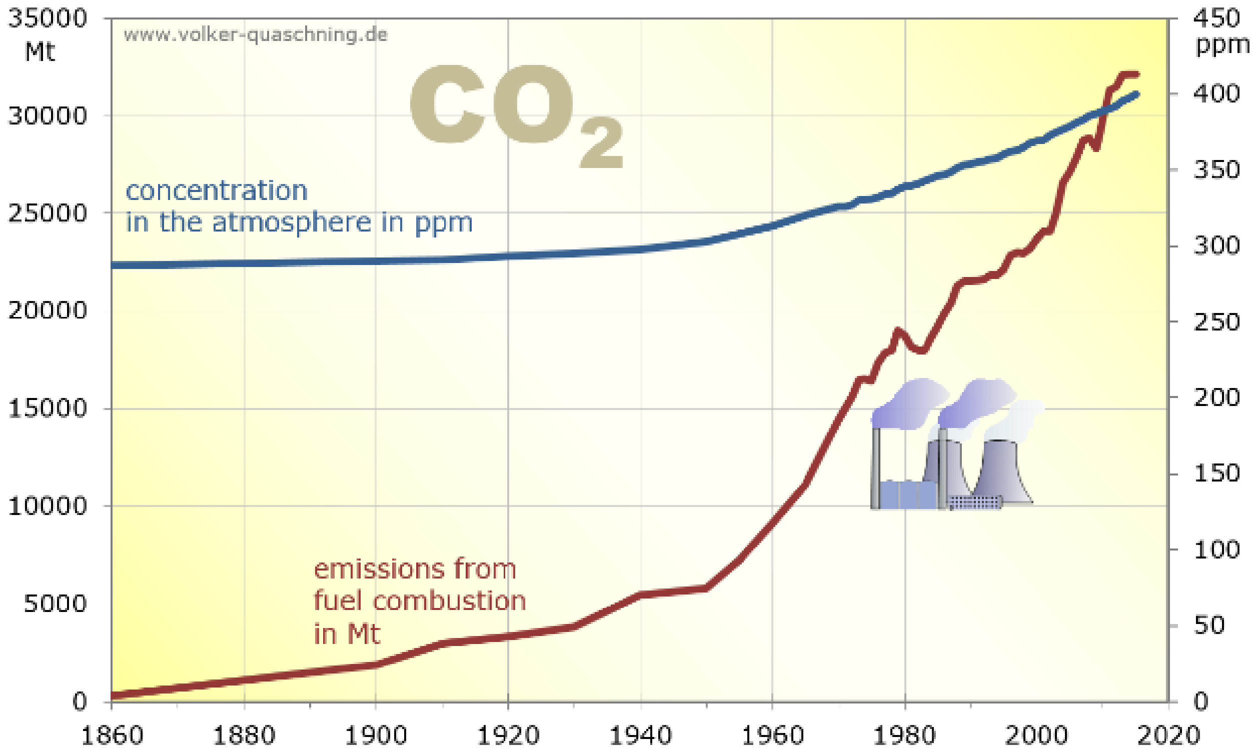
- **Environmental pollution** is defined as **the contamination of the physical and biological components of the earth/atmosphere system to such an extent that normal environmental processes are adversely affected**.
- There is a difference between Environmental Pollution & Environmental Degradation, both represent some kind of Environmental damage. **pollution is specifically related to the environment only**, while **Degradation is the destruction of any subject or matter**.
- Environmental pollution is increasing gradually and causing a serious impact on living organisms including humans.

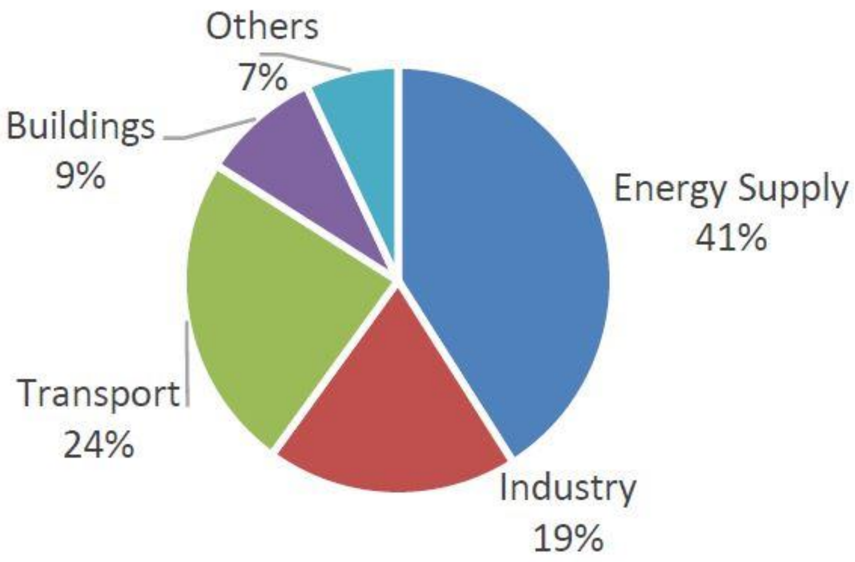
Environnemental Pollution & Environnemental Dégradation

parameter	Environnemental Pollution	Environnemental Degradation
Definition	Pollution is **damage** caused to air, water, soil, etc., because of pollutants. The pollutants can be of any kind and can harm any part of the environment.	Degradation is a **process** through which the natural environment is compromised in some way, **decreasing biological diversity** and health of the environment.
Factors	• High quantity of Exhaust gases. • Chemical effluents. • Transport. • Unprecedented Construction. • Ruinous agricultural policies. • The Population Explosion. • Unplanned Land-use policies.	• Natural factors such as drought, storms on sea, land and deserts such as hurricanes, tornadoes, carina and volcanic eruptions. These factors lead to land degradation through erosion. • Human factors which include deforestation, industrialization and urbanization. These factors lead to water, air and land pollution.
Types	• ***Air pollution.*** • ***Water pollution.*** • ***Land / Solid waste pollution.***	• ***Deforestation.*** • ***Desertification.*** • ***Extinction.*** • ***Emission.*** • ***Erosion***

Environmental pollution

The emissions of CO_2 in the atmosphere due to fuel combustion increases from nearly zero in the "pre-industrial" interval (about 1860) to a peak value of 33 Gt in 2018. The concentration of CO_2 in the atmosphere increases from 280 ppm in the pre-industrial intervals to about 415 ppm in May 2019 and the trend continues to increase as shown in the following Figures.





Greenhouse Gas Emissions

- **Sources and activity Data**
- **Emission Factors**
- **Global Worming Potential**
- **Totaling Emission**



How to calculate Greenhouse Gas Emissions

<u>Sources and activity Data</u>

An **activity that impacts the organization's operations and results in the emission of greenhouse gases**:

- **Natural Gas heating.**
- **Electricity use**
- **vehicle fuel.**
- **Air conditioning.**
- **Wastes sent to municipal landfill…**etc

<u>Greenhouse gases</u>

Carbon Dioxide (Co_2), Methane (CH_4), Nitrous Oxide (N_2O), Sulfur Hexafluoride (SF_6), Perfluorocarbons (***PFCs***), Hydrofluorocarbons (**HFCs**)

Global Warming Potentials for the gases

Greenhouse gases (GHGs) warm the Earth by absorbing energy and slowing the rate at which the energy escapes to space; they ***act like a blanket insulating the Earth***.

Different GHGs can have different effects on the Earth's warming.

Two key ways in which these gases differ from each other are ***their ability to absorb energy*** (their "***radiative efficiency***"), and ***how long they stay in the atmosphere*** (also known as their "***lifetime***").

The Global Warming Potential (GWP) was developed to allow comparisons of the global warming impacts of different gases. Specifically, ***it is a measure of how much energy the emissions of 1 ton of a gas will absorb over a given period of time, relative to the emissions of 1 ton of carbon dioxide (CO_2).***

The larger the GWP, the more that a given gas warms the Earth compared to CO_2 over that time period. *The time period usually used for GWPs is 100 years*.

GWPs ***provide a common unit of measure***, which allows analysts to add up emissions estimates of different gases (e.g., to compile a national GHG inventory), and allows policymakers to compare emissions reduction opportunities across sectors and gases.

Global Warming Potentials

Are there alternatives to the 100-year GWP for comparing GHGs?

The United States primarily uses the 100-year GWP as a measure of the relative impact of different GHGs. However, the scientific community has developed ***a number of other metrics that could be used for comparing one GHG to another***. These metrics may differ based on timeframe, the climate endpoint measured, or the method of calculation.

GWP:

a number that represents the relative contribution of a gas toward global worming. there are three main factors to calculate this number:

- **FIRST:** the ***concentration*** of this gas
- **Second:** how long the molecule live in the atmosphere? (Global atmospheric ***lifetime***)
- **Third:** how much ***IR radiation that molecule actually absorbs***?

Greenhouse gases Potency and lifetime

The Global Warming Potential (GWP) **is a measure of how much energy the emissions of 1 ton of a gas will absorb over a given period of time, relative to the emissions of 1 ton of carbon dioxide (CO_2).**

Greenhouse Gas	Chemical Formula	Global Warming Potentials for 100 years	Atmospheric Lifetime (years)
Carbon Dioxide	Co_2	1	50 - 200
Methane	CH_4	25	12 +/-3
Nitrous Oxide	N_2O	298	120
Hydrofluorocarbons	HFCs	12 – 14,800	1.5 - 264
Perfluorocarbons	PFCs	6,500 – 9,200	3,200 – 50,000
Sulfur Hexafluoride	SF_6	22,800	3,200

Source: Environmental Protection Agency

Emission Factor

A ratio corresponding to the amount of a greenhouse gas emitted as a result of a given unit of activity.

Grams of carbon Dioxide per KWh of Electricity (**g CO_2/KWh**)

Kilograms of Methane per Metric tonne of Municipal Solid Waste (**Kg CH_4/t**))

Grams of Nitrous Oxide per L of propane (**g N_2O / L**)

Pounds of Carbon of per mile of vehicle Travel (**lb CO_2/mi**)

Short tons of Methane per British thermal unit of Natural Gas (**ton CH_4/Btu**)

Greenhouse gases Potency

Example:

Suppose a natural gas **bill value equal to 14356m^3**. The burning of the natural gas ***emits*** **CO_2**, **CH_4**, and **N_2O**. The ***emission factor*** for these gases are 1879, 0.037, and 0.033 g/m^3 respectevily. **Calculate GWP**.

Solution:

- ***The emissions*** of $CO_2 =$ 14356 x 1879 = **26974924 g CO_2**
- The emissions of $CH_4 =$ 14356 x 0.037 = **531.172 g CH_4**
- The emissions of $N_2O =$ 14356 x 0.033 = **473.748 g N_2O**

$$GWP = \frac{26974924}{10^6} \times 1 + \frac{531.172}{10^6} \times 25 + \frac{473.748}{10^6} \times 298 = \mathbf{27.1615\ t\ CO_2\ e}$$

Greenhouse gases Potency

Gasoline-powered passenger vehicles per year Example:

The truck needs **1 gallon to move a distance of 22.2 miles**. The **average vehicle miles** traveled (VMT) through a year is 11,520 miles. The **ratio of carbon dioxide emissions to total greenhouse gas emissions** (including carbon dioxide, methane, and nitrous oxide, all **expressed as carbon dioxide equivalents**) for passenger vehicles was **0.994** (EPA 2021). The **amount of carbon dioxide emitted per gallon** of motor gasoline burned is **8.89×10^{-3}** metric tons, as calculated in the "Gallons of gasoline consumed. ***Determine annual greenhouse gas emissions per passenger vehicle.***

Solution:

Greenhouse gas emissions per year = $8.89 \times 10^{-3} \times 11{,}520/22.2 \times 1/0.994$

= **4.640 metric tons CO_2E/vehicle /year**

Greenhouse gases Potency

Number of incandescent bulbs switched to light-emitting diode bulbs Example:

A **9 watt light-emitting diode (LED)** bulb produces the same light output as a 43 watt incandescent light bulb. Assuming an **average daily use of 3 hours**.

Calculate the **reduction of carbon dioxide per light bulb** switched from an incandescent bulb to a light-emitting diode bulb Knowing that,

the weighted average carbon dioxide emission rate for delivered electricity was **0.7087 metric ton CO2 per megawatt-hour**, which accounts for losses during transmission and distribution (EPA 2020).

Solution:

Saving energy per year=

(43 - 9)x 3 x 365 x 1 /1,000 = **37.2** kWh/year/bulb replaced.

reduction of carbon dioxide per light bulb =

37.2 x 0.7087 x 1 MWh/1,000 kWh x = $\mathbf{2.64 \times 10^{-2}}$ metric tons CO_2/bulb replaced

Greenhouse gases Potency

Home electricity use Example:

In 2019, 120.9 million homes consumed 1,437 billion kilowatt-hours (kWh) of electricity. On average, **each home consumed 11,880 kWh** of delivered electricity. The **average carbon dioxide output rate for electricity generated** was **0.401 metric ton CO_2 per megawatt-hour**, assuming transmission and distribution **losses of 7.3%**.

Determine the emission of CO_2 per home.

Solution:

The emission of CO_2 per home =

$11{,}880 \times 0.401 \times 1/(1-0.073) \times 1/1{,}000 =$ **5.139 metric tons CO_2/home**.

Thank You !