



2.6. Emissions from the Oil&Natural Gas Industry

High levels of carcinogens have been determined from industrial air emissions. Unsafe emissions may be due to improper production process, poor maintenance practices and internal operational process problems. Many of the chemicals discharged in to the atmosphere during the leakage periods were found particularly sever to children.

The oil and gas industry is the largest industrial source of emissions of volatile organic compounds (VOCs), a group of chemicals that contribute to the formation of ground-level ozone (smog). Exposure to ozone is linked to a wide range of health effects, including aggravated asthma and premature death.

The oil and natural gas industry also is a significant source of emissions of methane, a greenhouse gas that is more than 20 times as potent as carbon dioxide. Emissions of air toxics such as CO, CO₂, SO₂, NO_x, benzene, ethylbenzene, and n-hexane, also come from this industry. Air toxics are pollutants known, or suspected of causing cancer and other serious health effects.

2.7. Some Causes of Industrial Air pollution

1. **Burning of Fossil Fuels:** Fossil fuel is a natural fuel such as coal or gas, formed in the geological past from the remains of living organisms by exposure to heat and pressure in the Earth's crust over millions of years.

When fossil fuels, especially coal, are burned for energy, many impurities are released, including sulfur dioxide and nitrogen oxides. When these pollutants disperse through the atmosphere or dissolve in rainwater, they cause the phenomenon of acid rain. Acid rain is a term referring to a mixture of wet and dry deposition (deposited material) from the atmosphere containing higher than normal amounts of nitric acid (HNO₃) and sulfuric acid (H₂SO₄). Acid rain from air pollution damages vegetation, causes changes in soil chemistry and pollutes waterways.



2. Exhaust from factories and industries: Manufacturing industries release large amount of carbon monoxide, hydrocarbons, organic compounds, and chemicals into the air thereby depleting the quality of air.

Petroleum refineries also release hydrocarbons and various other chemicals that pollute the air and also cause land pollution. Oil refineries cause smog and air pollution. Oil refineries emit various chemicals every day. These include metals like lead which makes it hard for children to learn. They also include very small dust particles called PM10, that get deep into our lungs and harms our ability to breathe.

3. Mining operations: Mining operations like drilling, blasting, hauling, collection, and transportation are the major sources of emissions and air pollution. Mining is a process wherein minerals below the earth are extracted using large equipment. Some of the nonfuel minerals mined, such as stone, which is a nonmetallic or industrial mineral, can be used directly from the earth. Metallic minerals, which are also nonfuel minerals, conversely, are usually combined in nature with other materials as ores. These ores must be treated, generally with chemicals or heat to produce the metal. Dust and coal particles stirred up during the mining process, as well as soot released during coal transport, contributes to emissions and respiratory problems.

4. Industrial chimney wastes: Better dispersion of pollutants emitted by tall chimneys leads to better dilution in the air and thus lower local concentrations of pollutants. This has however led to pollution being dispersed more widely and to transboundary air pollution. Air pollutants spread on the largest area, through designed chimneys depends on several points:

- 1) Desired height of chimney.**
- 2) The speed throwing pollutants from the chimney.**
- 3) The wind speeds.**
- 4) The physical properties of pollutants.**

2.8. Solutions for Air Pollution

- 1. Use public mode of transportation:** Encourage people to use more public modes of transportation to reduce pollution.
- 2. Conserve energy:** Switch off fans and lights to reduce consumption of electricity. Large amount of fossil fuels is burnt to produce electricity. You can save the environment from degradation by reducing the amount of fossil fuels to be burned.
- 3. Understand the concept of Reduce, Reuse and Recycle:** Do not throw away items and reuse them for some other purpose.
- 4. Emphasis on clean energy resources:** Clean energy technologies like solar, wind and geothermal are on high these days. Governments of various countries have been providing grants to consumers who are interested in installing solar panels for their home. This will go a long way to curb air pollution.
- 5.** Ensure that houses, schools, restaurants and playgrounds are not located on busy streets.
- 6.** Plant trees along busy streets as they remove particulates, carbon dioxide and absorb noise.
- 7.** Industries and waste disposal sites should be situated outside the city preferably on the downwind of the city.





2.9. Examples:

2.9.1. Emissions Calculations Using Fuel Analysis:

Fuel analysis can be used to predict emissions based on the application of mass balance. The presence of certain elements in fuels may be used to predict their presence in emission streams. These include toxic elements such as metals found in coal; as well as other elements such as sulfur, that may be converted to other compounds during the combustion process.

The basic equation used in fuel analysis emission calculations is:

$$\text{Equation } ER = R * PC * (MWp/MWf)$$

Where:

ER = pollutant emission rate R = fuel flow rate (lb/hr)

PC = pollutant concentration in fuel (%/100)

MWp = molecular weight of pollutant emitted (lb/lb-mole) MWf = molecular weight of pollutant in fuel (lb/lb-mole)

Example 1

Calculate the SO₂ emissions from the combustion of oil based on fuel analysis results and the fuel flow information.

fuel flow rate R = 46,000 lbs/hr

percent sulfur (% S) in fuel = 1.17

For every pound of sulfur (MW = 32 g) burned, 2 lb of SO₂ (MW = 64 g) are emitted.

$$ER = R * PC * (MWp/MWf)$$

$$= (46,000) * (1.17/100) * (64/32)$$

$$= 1,076 \text{ lbs SO}_2/\text{hr}$$



2.9.2 Calculating the Source Specific Emission Factor

An emission factor is the amount of pollutant emitted per activity. Activities are typically expressed in terms of material usage, e.g., tons of coal or gallons of oil fired. The basic equation used in emission factor calculations is:

$$\text{Emission Factor (EF)} = \frac{\text{Emission Rate (ER}_{\text{hourly}})}{\text{Activity (A}_{\text{hourly}})}$$

$$\frac{\text{lb of pollutant emitted}}{\text{ton of material}} = \frac{\text{lb pollutant emitted} * \text{hr}}{\text{hr ton of material}}$$

Example 2:

A Company operates a boiler that has an SO₂ emission rate (ER) of 51 lbs/hr. During the stack test, the coal firing rate was 6.7 tons/year. Calculate the SO₂ emission factor (EF).

$$\text{EF}_{\text{SO}_2} = \frac{51 \text{ lbs SO}_2/\text{hr}}{6.7 \text{ tons coal combusted/hr}}$$
$$\text{EF}_{\text{SO}_2} = 7.612 \text{ lbs SO}_2/\text{ton of coal}$$

2.9.3. Determining the Annual Mass Emission Rate

The annual mass emission rate is the product of the source specific emission factor multiplied by an annual activity rate. Some examples of an annual activity rate are tons of coal combusted per year or gallons of paint applied per year.

$$\text{Annual Emission (ER}_{\text{annual}}) = \text{Emission Factor (EF)} * \text{Activity (A}_{\text{annual}})$$
$$\frac{\text{lb of pollutant emitted}}{\text{yr}} = \frac{\text{lb pollutant emitted} * \text{ton of material}}{\text{ton of material} * \text{yr}}$$



Example 3

A Company burns 41,000 tons of coal during the year. What is the annual mass emission rate (ER) of SO₂?

$$ER_{\text{annual}} = 7.612 \text{ lbs SO}_2/\text{ton of coal} * 41,000 \text{ tons coal/yr} * 1 \text{ ton}/2000 \text{ lbs}$$

$$ER_{\text{annual}} = 156 \text{ tons of SO}_2/\text{yr}$$

2.9.4 Converting mg/m³ to ppm (or ppb) and ppm (or ppb) to mg/m³

$$X \text{ (mg/m}^3\text{)} = Y \text{ ppm}$$

$$C \text{ mg/m}^3 = C \text{ ppm} \times M \text{ (gmole)} \times P \text{ (atm)} / T \text{ (K}^\circ\text{)} \times R \text{ (L.atm / mole. K)}$$

$$C \text{ ppm} = (C \text{ mg/m}^3) \times T \text{ (K}^\circ\text{)} \times R \text{ (L.atm / mole. K)} / MW \text{ (gmole)} \times P \text{ (atm)}$$

Where

C= pollutant concentration in the desired units. MW= molecular weight of the pollutant in g/mole P= pressure of air (atm).... P(atm)= p(mmHg)/760 T= temperature of air (K)

0.08205 **L atm K mole** = R, the ideal gas constant R, the ideal gas constant

Example 4:

The ozone (O₃) level in Denver, Colorado, atmosphere was reported to be 2.50 ppm (2.50 μL/L).

Express this in mg/m³ at ambient conditions of 37 C° and 772 mm Hg.

Solution: -

$$2.5 \text{ ppm} = 2500 \text{ ppb}$$

$$MW \text{ (O}_3\text{)} = 3 \times 16 \text{ g/mol} = 48 \text{ g/mol}$$

$$P \text{ (atm)} = 772 \text{ mmHg} \times 1 \text{ atm} / 760 \text{ mmHg} = 0.95 \text{ atm}$$



$$T (k^{\circ}) = 37 C^{\circ} + 273 = 310 K^{\circ}$$

$$\text{So.: - } C \text{ } mgm^3 = C \text{ } ppm \times MW \text{ (gmole)} \times P \text{ (atm)} / T \text{ (}^{\circ}K) \times 0.08205 \text{ L atm/K mole}$$

$$C \text{ } mgm^3 = 2.50 \text{ ppm} \times 48 \text{ gmole} \times 0.95 \text{ atm} / 310 \text{ k}^{\circ} \times 0.08205 \text{ L atm/k mole}$$

$$C \text{ } mgm^3 = 4.56$$

2.9.5. Converting ACFM TO SCFM

The volume of a gas varies with changes in pressure and temperature. In order to simplify comparison of gases, chemists adopted a set of standard conditions of temperature and pressure. The volume of a gas or volume flow rate of a gas at one temperature and pressure can be converted to its volume or volume flow rate at standard conditions by using the ideal gas equation which relates pressure, volume, and temperature. According to the ideal gas law:

$$Q_{std} = Q^{\circ} (T_{std}/T^{\circ}) (P^{\circ}/P_{std})$$

Where:

Q_{std} = gas flow rate at standard temperature and pressure Q_o = gas flow rate at actual conditions

P_{std} = pressure at standard conditions is 29.92 inches Hg or 1 atmosphere T_{std} = temperature at standard conditions is 70 F°

P_o = pressure at actual conditions (inches Hg) T_o = temperature at actual conditions (F°)

$$Q_{scfm} = \frac{Q_{acfm} * (460 + 70^{\circ} F) * P_o}{(460 + T_o) * P_s}$$

2.9.6. Converting SCFM TO DSCFM

Certain processes will generate moisture in the stack gas



$$Q_{dscfm} = Q_{scfm} * (1 - \% \text{ moisture})$$

This approach can only be used for exhaust flows < 5% moisture

For Combustion Sources: When direct measurements of stack gas flow rate are not available,

Q can be calculated using fuel factors (Fd factors):

$$Q_{dscfm} = \frac{F_d * 20.9 * H_{in}}{(20.9 - \%O_2) * 60 \text{ min/hr}}$$

Where:

Fd = fuel factor, dry basis

%O₂ = measured oxygen concentration, dry basis expressed as a percentage

H_{in} = heat input rate in MMBtu/hr

Where:

$$H_{in} = \frac{R * HHV}{10^6}$$

R = mass fuel rate in lbs/hr

HHV = higher heating value of the fuel in Btu/lb

The average Fd factors are provided in EPA Reference Test Method 19 for different fuels and are shown in Table 1. Also, in Table 1 are the higher heating values (HHV) of fuel.

Table 1.0 - Fuel Factors and Higher Heating Values

Fuel Type	F _d (dscf/MMbtu)	HHV(Btu)
Coal		
anthracite	10,100	12,300/lb
bituminous	9,780	13,000/lb
lignite	9,860	7,200/lb
Oil		
residual	9,190	150,000/gal
distillate	9,190	140,000/gal
Gas		
natural	8,710	1,050/scf
Wood	9,240/lb	5,200/lb
Wood Bark	9,600/lb	4,500/lb



Example 5

Company A operates a distillate oil-fired boiler. The fuel rate is 20 gallons of oil per hour. The percent O₂ in their exhaust gas is 2.1%. Determine the stack gas flow rate Q_{dscfm}.

Step 1 - Calculate the heat input rate (H_{in}) MMBtu/hr

$$H_{in} = (R * HHV) / 10^6$$

$$H_{in} = (20 \text{ gal/hr} * 140,000 \text{ Btu/gal} * 1\text{MM}) / 10^6$$

$$H_{in} = 2.8 \text{ MMBtu/hr}$$

Step 2 - Calculate the stack gas flow rate Q_{dscfm}

From Table 4, the F_d factor for distillate oil is 9,190 dscf/MMBtu.

$$Q = F_d * ((20.9) / (20.9 - \%O_2)) * (H_{in} / 60)$$

$$Q = 9,190 * ((20.9) / (20.9 - 2.1)) * (2.8 / 60)$$

$$Q_{dscfm} = 477$$