CHAPTER 1: INTRODUCTION

1.1 Engineering

Engineering is a profession that applies mathematics and science to utilize the properties of matter and sources of energy to create useful structures, machines, products, systems and processes *(Davis and Cornwell, 2010)*.

Engineering may be defined as the application, under constraints of scientific principles, to the planning, design, construction, and operation of structures, equipment, and systems for the benefit of society *(Sincero and Sincero, 1996)*.

Engineering is the profession in which a knowledge of the mathematical and natural sciences gained by study, experience, and practice is applied with judgment to develop ways to economically utilize the materials and forces of nature for the benefit of human society.

In other words, Engineering may be defined as the application, under constraints of scientific principles, to the planning, design, construction and operation of structures, equipment and systems for the benefit of the society.

If the tasks performed by environmental engineers were examined, it would be found that the engineers deal with the structures, equipment and systems that are designed to protect and enhance the quality of the environment and to protect and enhance public health and welfare.

1.2 Environmental Engineering

Environmental Engineering is defined as the application of engineering principles, under constraint, to the protection and enhancement of the quality of the environment and to the enhancement and protection of public health and welfare *(Sincero and Sincero, 1996).*

Environmental Engineering is concerned with engineering problems in the field of environmental sanitation, water supplies, disposal of or recycle of wastewater and solid wastes along with public health and the elimination of industrial health hazards, , and the effect of technological advances on the environment *(ASCE, 1977)*.

In general, Environmental engineering is focused on:

- Environmental engineers have the responsibility control of water, soil and atmospheric pollution and noise pollution
- To design, build and operate water and wastewater treatment plants.
- To build and operate solid waste collection, transportation and disposal systems
- To carry out environmental assessment of projects and products
- To provide inputs in decision making regarding the environmental issues of development sector and welfare of public
- To predict the level of pollution and design control mechanisms and products

1.3 Engineering Project

Any engineering project, large or small, a product being designed, or a service to be provided encompasses within its implementation a series of decisions made by engineers. Sometimes these decisions turn out to be poor and or not appropriate.

A far greater number of decisions, however, made hundreds of times a day by hundreds of thousands of engineers, are correct and improve a lot of the human civilization, protect the global environment, and enhance the integrity of the profession. Because so few engineering decisions turn out poorly, engineering decision making is a little-known and rarely discussed process. Yet, when a decision turns out to be wrong, the results are often catastrophic. Often Engineers and Doctors are put on the same footing by the career choosers, however, a doctor can harm only one person at a time while engineers have potential to harm thousands at a time through incorrectly designed systems. *(Vesilind and Morgan, 2004).*

1.4 Engineering decisions

Engineering decisions could be based on:
(1) Technical feasibility
(2) Economic Viability
(3) Socially Acceptable
(4) Environmental friendly

1.4.1 Technical feasibility

Technical decisions are quantifiable and can be evaluated and checked by other competent professional engineers.
When carrying out technical analysis, we often do not have all the information we need to make decisions. Therefore, we must make assumptions. These assumptions, of course, must be made using the best available data with a (sometimes liberal) sprinkling of good judgment.

Exercise 1: A town with 4000 residents wants to establish a municipally owned and operated solid waste (garbage) collection program. They can purchase one of three possible trucks that have the following capacity:

Truck A: 8 m^3 Truck B: 6 m^3 Truck C: 4 m^3

If the truck is to collect the refuse every day, and the truck will have to make only one trip per day to the landfill, which truck or trucks will have sufficient capacity?

1.4.2 Cost-Effectiveness Analysis (Economic Viability)

Engineers, typically find themselves working for an employer or client who requires that various alternatives for solving an engineering problem be analyzed on the basis of the cost.

For example, if a municipal engineer is considering purchasing refuse collection vehicles and finds that the following alternatives to buy the Truck

- Expensive trucks: Higher compaction, reduces volume, reduces no. of trips per day
- Inexpensive trucks: lower compaction, requires more trips per day

How does the engineer know which is less expensive for the community?

Choosing the lowest total cost alternative (given all cost data) would be the most rational decision. *(Vesilind and Morgan, 2004)*.

If a project is planned, an estimate of the benefits derived is compared in ratio form to the cost incurred. Should this ratio be more than 1.0, the project is clearly worthwhile, and the projects with the highest benefit/cost ratios should be constructed first because these will provide the greatest returns on the investment.

Internal Rate of Return (IRR) is an indicator to reflect the profit of the projects. The IRR is the "annualized effective compounded return rate" or "rate of return" that makes the net present value of all cash flows (both positive and negative) from a particular investment equal to zero. In more specific terms, the IRR of an investment is the discount rate at which the net present value of costs (negative cash flows) of the investment equals the net present value of the benefits (positive cash flows) of the investment.

Internal rates of return are commonly used to evaluate the desirability of investments or projects. The higher a project's internal rate of return, the more desirable it is to undertake the project. Assuming all projects require the same amount of up-front investment, the project with the highest IRR would be considered the best and undertaken first. IRR values of some of the projects in Nepal are shown in Table 1.1.

Table 1.1 Internal rates of return values

SN	Project Name	Capacity	Project Cost (Arab)	IRR (%)
1	Melamchi Water Supply Project	170 MLD	32.48	13.50
2	Kaligandaki A Hydroelectric Project	144 MW	31.70	15.00
3	Raxual- Kathmandu Railway (Estimated)	135 km	264	5.65
4	Upper Trishuli-3'B' Hydroelectric Project	37 MW	4.31	23.60
5	Butwal to Mahendranagar Transmission-II	132 kV	2.72	14.71

1.3.3 Environmental friendly and socially acceptable decisions

Engineering decisions are also based on the environmental impacts caused by the project activities which could be in planning, implementation or operation phase. The Environmental Impact of any project is evaluated through different assessment methods. When engineers work on projects, they need to assess the potential impact on the environment. This involves considering factors such as air and water pollution, greenhouse gas emissions, habitat destruction, and resource depletion. By conducting environmental assessments, engineers can identify and implement solutions that minimize adverse environmental impacts.

Engineers must also consider the social implications of their projects. This includes assessing the project's impact on local communities, public health, cultural heritage, and overall quality of life. Social analysis may involve engaging with stakeholders, understanding their needs and concerns, and incorporating their input into the engineering process.

By considering environmental and social factors, engineers can design projects that are not only technically sound but also contribute positively to society and the planet. This approach aligns with the principles of sustainable development and helps create a more responsible and equitable engineering practice.

1.5 Environmental Laws and Regulation

In Nepal, Environment Protection Act (EPA), 2076 and Environmental Protection Rules (EPR), 2077 guides the assessment. There are three levels of environmental study in Nepal as per project size.

1. **Brief Environmental Study (BES)** is performed as guided by schedule 1 of EPR. Few examples of the projects requiring BES are
   a. Hospitals from 16 beds up to 25 beds.
   b. Hotels or Resort from 25 beds to 50 beds
   c. Bridges up to 250 m.
   d. Municipal or urban roads.
   e. Up to 5 MLD water supply projects with treatment plant and sewer.
2. **Initial Environmental Examination (IEE)** is performed as guided by schedule 1 of EPR. Few examples of the projects requiring IEE are
   a. Hospital from 25 to 100 beds, Hotel and resort of 51 to 100 beds.
   b. Bridge above 250 m.
   c. New road construction of up to 25 km.
   d. Upgrading roads from 10 km to 50 km.
   e. Acquisition of forest area from 1 ha to 5 ha.
   f. Solar power plant upto 5 MW/ Hydropower upto 50 MW.
3. **Environmental Impacts Assessment (EIA)** is performed as guided by schedule 1 of EPR. Few examples of the projects requiring EIA are
   a. Hospital and hotels above 100 beds.
   b. Any projects acquiring National parks or conservation areas or forests above 5 ha.
   c. Hydropower production above 50 MW.

While carrying out an Environmental Assessment (EA) of a project, a no-project scenario is referred against the various alternatives which help to identify the environmental impacts and engineering or social mitigation measures. Similarly, **life cycle assessment (LCA) of products** is increasingly used in identifying the environmental impacts caused by the manufacturing process and use of the products.

The methods of decision making available to engineers stretch from the most objective (technical) to the most subjective (ethical). The inherent method of decision making is the same in all cases. The problem is first analyzed – taken apart and viewed from many perspectives. When all the numbers are in and the variables are evaluated, the information is synthesized into a solution *(Vesilind and Morgan, 2004)*.

Similarly, **Solid Waste Management Act, 2068**: This act addresses the management, disposal, and treatment of solid waste to reduce environmental pollution and promote better waste management practices.

Water Resources Act, 2049 is an act made to provide for the management of water resources. Also different policies, standards, guidelines like guidelines and standards for air pollutants, vehicular emissions, water and wastewater quality, climate change policy are also formulated.

1.6 Institution related to engineers in Nepal

In Nepal, Different institutions and associations are working in this sector.

1. **Nepal Engineering Council (NEC)** was formed under the Nepal Engineering Council Act, 2055 promulgated by then His Majesty the King on B.S.2055/11/27. Nepal Engineering Council Rules, 2057 has also been prepared and approved by then His Majesty's Government as per the provision of Clause 37 of the Act. The first Executive Council was formed on Magh 2056. The act was amended twice in 2076 and 2079 B.S.

   It directs the relationships of Nepalese Engineers with Public, Employers and Clients, Other Engineers. The major scope of the NEC is:
   - Licensing on the basis of exam
   - Registration of Engineer
   - Authorization of Certificates of academic qualification.
   - Recognition of academic institutions.
   - Produce and monitor the professional code of conduct.

2. **Nepal Engineers Association (NEA)** is an independent nonprofit organization of Nepalese Engineers. It was established in 1968 AD (2024 BS). NEA during 1968-1989 was successful in establishing this very organization. The organizing of the World Engineering Congress along with the first three national conventions were major milestones in this period. Nepal Engineers Association office is located at Lalitpur behind UNDP building. The main objectives to NEA are:
   - To promote development of engineering, science and technology in Nepal.
   - To promote fellowship, goodwill and cooperation assistance among the Nepalese engineers and safeguard their rights and interests.
   - To continuously enhance the highest professional ideals among the members and widen it.

3. **Society of Environmental Engineers Nepal (SEEN)** is an institution established by Environmental Engineers of Nepal. It works for the welfare or Environmental Engineering professionals of Nepal. Its head office is located at Babarmahal, Kathmandu. SEEN is governed by an executive committee of seven (7) members elected by the general members of the society. Some of the major responsibilities of SEEN includes
   - Enhancement of technical and professional competencies of its members.

- It works for the protection of the basic professional rights
- It supports the government and other agencies in the formulation of policies and strategies in related fields.
- SEEN is committed to carry out various professional activities that are intended to bring qualitative results to improve the sanitary and environmental conditions of the country.
- It aims to work in association with other professional bodies in Nepal and abroad.

4. **Society of Public Health Engineers, Nepal (SOPHEN)** was registered in Nepal in 1990 AD (2047 BS) as an independent professional organization by a group of Nepalese Engineers.

5. **Nepal Environment Society (NES)** is an institution that includes all the Environmental professionals of Nepal.

1.7 Values, Units and Dimensions

A quantity is described by values and units. Units simply describe what the quantity is about. While measuring and reporting an environmental quantity, both of these items need to be mentioned. For example, a river discharge of 500 m^3/s, a sand particle of 2 mm, snow mass of 500 km^3 in the Himalayas.

In the study of environmental engineering, it is quite common to encounter both extremely large quantities and extremely small ones.

The concentration of some toxic substance may be measured in parts per billion while the discharge of a large river may be measured with a larger unit. on such extreme values, it is useful to have a system of prefixes that accompany the units. Some of the most important prefixes are presented in **Table 1.2**

Thus, it is essential to use a practical and less scientific figure to represent the quantity under consideration. Specific symbols are also used to describe these quantities.

Dimension is a unique quantity that describes a basic characteristic of the measurement. Mass (M), length (L) and time (T) are three fundamental dimensions. Dimensions are descriptive but not numerical. They cannot describe how much; they simply describe what. For example, the length (L) dimension may be described in units as meters, inches or Angstrom.

Table 1.2 Common Prefixes

Quantity	Prefix	Symbol
10^{-12}	pico	p
10^{-9}	nano	n
10^{-6}	micro	µ
10^{-3}	milli	m
10^{-2}	centi	c
10^{-1}	deci	d
10	deca	da
10^{2}	hecto	h
10^{3}	kilo	k
10^{6}	mega	M
10^{9}	giga	G

1.8 Size and scale of measurement

Exercise 2: Table 1.3 provides a list of selected particles and their sizes. Fill the blanks.

Table 1.3: Average size of the substances

Substances	**Size**			
	µm	**mm**	**cm**	**m**
Bacteria	1			
Sand		1		
Gravel			1	
39’ TV				1

Note: 1 meter (m) = 100 centimeter (cm) = 1000 millimeter (mm) = 10^6 micrometer (µm)

1.10 Concentration and density

The mass density or density of a material or a solution is defined as its mass per unit volume, or

$$\rho = \frac{m}{V}$$

Where ρ = density
M = mass
V = volume

In SI system, the base unit for density is kg/m^3.
Water in the SI system has a density of 1×10^3 kg/m^3, which is equal to 1 g/cm^3.
Whereas the concentration of a substance in a solution is defined as mass of solute per unit volume of the solution (including solute and liquid).

$$C_A = \frac{M_A}{V_A + V_B}$$

Where,

- C_A = concentration of A
- M_A = Mass of material A
- V_A = Volume of material A

In SI system, the basic unit for concentration is kg/m^3.

A typical example of the concentration of total dissolved solid in a polluted river like at Bagmati at Teku is 825 mg/L or 0.825 kg/m^3.

Since solutes in solution are often analyzed by weight the terms milligram per liter or microgram per liter is used. It is often assumed that the substance does not change the density of water. If such assumption is made and we recall that 1 mL water weighs 1 g, then

The use of mg/L is most common in water applications as the volume of the solution is usually determined as well as the mass of the solute. The unit ppm is typically used in sludges or sediments.

Exercise 3: 1 kg of soil sample was analyzed and found to contain 5.0 mg TCE. What is the TCE concentration in mg/kg, ppm and ppb?

1.11 Flow (discharge) rate

The flow rate can be expressed as volume of the liquid per unit time.

$$Q_V = V/T$$

Where,

- Q_V = Volumetric flow rate
- V = Volume of the liquid
- T= Time period

In SI system, the basic unit of volumetric flow rate is m^3/s.

The flow of water is measured in units of volume per unit time. Commonly used units for flow measurement are: liter per second (lps), liter per day (LD), millions liter per day (MLD), cubic meter per second (m^3/s).

1 m^3 = 1000 L , 1 MLD = 10^6 Liters per day

In engineering processes, the flow rate can be either volume flow rate or mass flow rate. Mass and volumetric flow rates are not independent quantities because the mass (M) of material passing a point in a flow line during unit time is related to the volume (V) of that material.

$$Q_M = M / T = (\text{Concentration X Volume}) / T$$

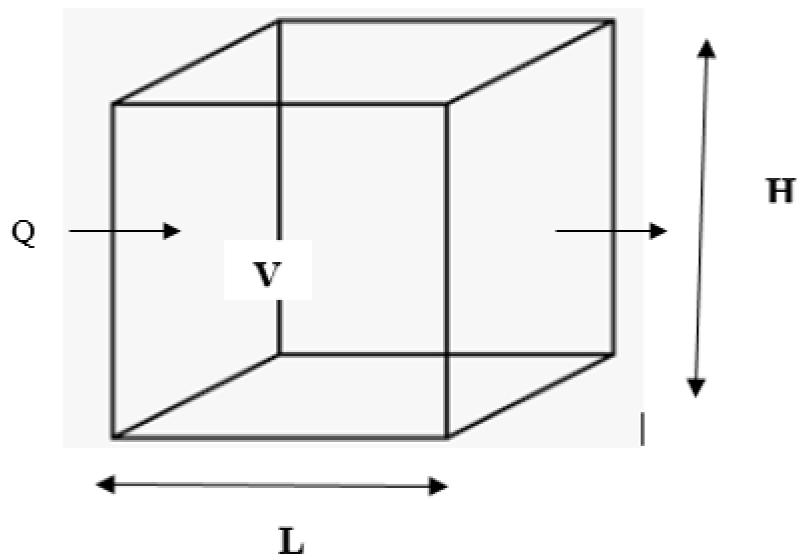
$$= \text{Concentration X Volumetric flow rate}$$

$$Q_M = C_A \text{ X } Q_V$$

Mass flow rate of waste materials is also called as "waste load" which is often measured in kg/day. For example, the BOD or nutrient loads of a wastewater discharged from a community. Biological Oxygen demand (BOD) is measured in mg/L; therefore, this concentration should be multiplied by the wastewater flow rate to get the BOD load.

1.12 Hydraulic Retention Time

One of the most important concepts in treatment processes is retention time, also called detention time or even residence time. It is the time an average particle of the fluid spends in a container through which the fluid flows (which is the time it is exposed to treatment or a reaction). An alternate definition is the time it takes to fill the container.
Mathematically,



Let us assume, a tank of volume V with Length L, Width W and Height H and Q is the volumetric flow rate. Let us assume v is the velocity of water flowing through tank.

We know, Velocity (v) = Distance (L) / Time (HRT)

$$\text{HRT} = \frac{L}{v}$$

Multiplying both side by Cross sectional Area (A),

$$\text{HRT} = \frac{AL}{Av}$$

$$\text{HRT} = \frac{V}{Q} \quad \text{(Since, V= A.L and Q=A.v)}$$

The average retention time can be increased by reducing the flow rate Q or increasing the volume V, and decreased by doing the opposite.
In SI system, the basic unit of retention time is sec.

Exercise 4: A stream can have a sediment load of up to 2000 mg/L in the rainy season. The stream water has been diverted using a dam and is supplied to a treatment plant. The tapped flow is 25 lps (liters per second). Find the mass flow rate of the sediment in the influent pipe. If the treatment plant can remove 90 % of the suspended solids, find the concentration of sediments in the effluent of treatment plant?

1.13 Approximations in engineering calculations

Engineers are often called on to provide information not in its exact form but as approximations. For example, a KU engineering graduate may be asked by a client, such as a mayor of Dhulikhel, "what it might cost to construct a new wastewater treatment plant for the population of Dhulikhel?" The mayor is not asking for an exact figure but a tentative estimate.

Obviously, the engineer cannot in a few minutes conduct a thorough cost estimate. S/he would recognize the highly variable nature of land costs, construction costs, coverage of the municipality as it extends to rural areas as well, required treatment efficiency, etc.

Yet, the mayor wants a preliminary estimate – a number – and quickly!

In the face of such problems the engineer has to draw on whatever information might be available.

For example, s/he might know that the population of the community to be served is approximately 30,000. Next, s/he estimates, based on experience, that the domestic wastewater flow might be about 100 Liter per capita per day, thus requiring a plant of about 3 MLD capacity.

With room for expansion, industrial effluents, storm inflow and infiltration of groundwater into the sewers, s/he may estimate that 4 MLD capacity may be adequate.

Such domestic wastewater treatment plant, s/he is aware, cost about 25 crore (करोड) Nepali Rupees per MLD of influent wastewater treated.

S/he calculates that the plant would cost about 100 crore (1 Arba)Nepali Rupees. Giving him/ herself a cushion, h/she could respond by saying, "about **1 billion** Nepali Rupees".

This is exactly the type of information the mayor seeks. S/he has no use for anything more accurate because s/he might be trying to decide whether to ask for a budget of 1 billion or 1.5 billion. There is time enough for more exact calculations later.

Exercise 5: The wastewater treatment plant in Guheshwori receives 0.20 m^3/s of wastewater. The plant was established to directly serve a population of 2×10^5 in Gokarna and Chabahil area. The total project cost of the plant was half billion Nepali Rupees (NRs) in 1999. Estimate the per capita cost of the project in 1999 in (a) NRs / MLD of treated wastewater and (b) NRs/individual benefitted.