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ENGINEERING APPLICATIONS OF MEMBRANES/GEOSYNTHETICS

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Introduction

Engineering is a profession to convert natural resources and energy to uses of humankind, benefitting from the productive synergy between the fundamental and applied sciences under certain professional standards. Advances and innovations in engineering have been made possible through analysis of natural phenomena, materials and biota, and their synthesis as man-made replicates.

This lecture will cover a special topic of biomimicry on membranes leading to wide range of synthetic membranes applications in analytical chemistry, physics and medical research and industrial applications.

Biomembranes

In all branches of biology, membrane is a generic term referring to a thin-layer of outer boundary, primarily composed of lipids and proteins, providing a containment (separation) shell structure for the living cells and their internal compartments *(organelles)*. Additionally, the membranes *(plasma membranes)* provide selective two-way transport of vital chemicals between the outer and internal cell media; *in an engineering analogy*, namely:

- keeping the substances "that are toxic for the inner cell" out of the cell,
- filter out unneeded metabolic products generated in the cells and
- allow two-way of specific ions/nutrients into the cell and exit of the metabolic cell products for use in other cells in the organs.

Membrane structures also exist for groups of cells performing common functions *(tissues to organs)* and in macro-level organ systems *(such as muscular, skeletal, nerve, digestive, ..., reproduction and urineray systems)* to provide functional compartmentalization for many physiological processes, while protecting genetic material, regulating what comes in and out of cells, tissues and organs.

The fascinating multiple functions of cell membranes with unique structure of the ionic and polar head groups have become models in developing bio-mimicked synthetic membranes for ion separation leading to rational designs used in analytical chemistry, physics and medical research and industrial applications.

Geomaterials – "Non-Bio" Origin, Natural Inorganic Membranes

Similarly, studies on physical and chemical processes in geological systems, also have provided a wealth of scientific knowledge on "selective separation/filtration" properties of geomaterials. The typical examples of such geomaterials, used in

membrane engineering applications today, are the "clay minerals" with specific crystal structures; namely, smectides - layered silicates, zeolites - hydrated aluminosilicates with cation-exchange capacities and layered/double layered hydroxides - with anion-exchange capacities.
In addition to ion-exchange capacities, owing to their sorption/desorption properties, all clay minerals can be considered as "non-bio" origin natural membrane materials. *In an engineering analogy*, the geological formations, predominantly bearing clay minerals, can be considered as the natural water treatment units for a majority of ions, including immobilizing radioactivity in natural settings.

Synthetic Membranes
In recognition of effective selective separation/filtration features of the natural membranes, innovative use of synthetic materials, specifically, polymer, in membranes gained interest of scientists and engineers and major advances have been achieved in this field during the last three decades.
Synthetic membranes are principally made with linear, branch-chained and cross-linked polymeric materials. A majority of industrial membranes consist solely of synthetic polymers and the rest are composites of synthetics and natural polymers *(wool, cellulose, etc.)*, geomaterials and ceramics/sintered metal oxides.
In scientific and industrial applications, the membranes are used to provide tools for filtering of suspended solids and selective separation of mixed volatile/non-volatile substances in liquid or gas forms. Penetration of liquids and gases into the membranes is achieved under applied pressure, concentration difference and electric potential gradients on entry and exit sides of the membrane. Membrane types are classified in four groups as: *Micro (MF), Ultra* (UF), *nano* (NF) and *reverse osmosis (RO)*, based on the targeted size of the solids/molecules/ions to be filtered/separated.

Geosynthetics
The term geosynthetics refer to products made of polymeric materials used used in civil, environmental and mining engineering projects to provide certain functions, such as reinforcement, filtration, drainage, containment, barrier, surface erosion control, etc.
In contrast to delicate material nature of membranes, the geosynthetics require additional mechanical strength and longer-term durability under direct exposure to physically harsher load impacts in their engineering applications.
Common forms of geosynthetics, manufactured for use in numerus engineering applications, are: *geogrids, geotextiles, geonets, geomembranes, geosynthetic clay liners, geopipe, geofoam,* and *geocomposites.*

It should be kept in mind that the on-going research and innovative use of polymeric products are not limited to membranes/geomembranes; in this regard, in casual words, "*Sky is the Limit*" for polymer applications in the future.