EOH3101 PRINCIPLES OF ENVIRONMENTAL HEALTH

Water Quality and Health
INTRODUCTION

Water on Earth

- About 3% is available only as fresh water
- Surface water — streams, rivers, ponds, lakes and wetlands
- Groundwater — aquifers, underground caverns and porous layers of rock
Types and percentages of water on Earth
Special properties of water

- High heat capacity
- High dissolving capacity

What is the Water Cycle?
The Water Cycle
Why is water important?

- The most valuable natural resource.
- The human body consists of 70% or more of water.
- Presence of water have a great impact on an area’s economy and health.
- Water is used for agricultural, industrial and overall community growth.
- Potable water helps prevent economic strains resulting from water-related illnesses affecting individual and community health.
HISTORY OF WATER QUALITY

Ancient Egyptians — used sedimentation apparatus and wick siphons. Some may have used alum to remove suspended solids in water.
Hippocrates Sleeve (a cloth bag) – invented in the 5th century BC to strain/filter rainwater.
Aqueducts – water supply system created by Roman engineers to supply water to cities
Early Quality Control

To control odor and taste problems, the Greeks and Romans used a variety of methods. For example, Diophanes (1st century B.C.) advised putting macerated* laurel leaves into rainwater. Later, in the first century A.D., Paxamus proposed that bruised coral or pounded barley, in a bag, be immersed in bad tasting water. In the 8th century A.D. the Arabian alchemist, Gerber, described various stills for purifying water that used wick siphons—a method that required a fibrous cord that would siphon water from one vessel to another.

*macerated: softening or breaking into pieces using a liquid
Desalination Experiment Begins

- **Desalination** – removing salt from sea water.
- **Sir Francis Bacon** (right) – compiled “**A Natural History of Ten Centuries**” in 1627.

This work recorded 10 experiments that dealt with water purification. Bacon believed that sea water could be purified if it were percolated through sand because he had read that an experimenter had been successful at purifying sea water by passing it through 20 vessels. He surmised that by digging a hole near the sea shore, water passing through the sand would be naturally purified. Pointing out that the water passed downward through the 20 vessels in the experiment he had read about, Bacon said his seaside experiment would cause it to pass upward. Presumably, salt particles were heavier than water, making it more difficult for them to move in the upward direction, and they would consequently be filtered out by the sand. If only he had been right.
Filtration is Illustrated

• The 17th century A.D. also saw the first known illustrations of sand filters. The Italian physician Lucas Antonius Portius wrote the “Soldier’s Vade Mecum” in 1685, which details a multiple sand filtration method. In this illustration, Portius described three pairs of sand filters—each pair consisting of a downward-flow filter and an upward-flow filter. Water entered the system’s settling compartment through a perforated plate that strained the water.

• Once the water had settled, it flowed from the top of the compartment through two funnels and down through the first filter. It then moved out through oblong openings in the bottom of the second filter and up through the second filter. The water continued in this same general pattern through the other two sets of filters.
He also described how pebbles had been placed near “the funnels of each partition,” and that smaller pebbles and larger sand grains produced the best water.

Portius further described his filtration plan as being an imitation of nature’s method of passing water through the “bowels of the earth.”
Early Filtered Water Methods for the Commons

- Filtration was becoming the water treatment method of choice for many communities. And town officials began to become concerned with supplying clean water to everyone, wrote Baker and Taras “inQuest for Pure Water”.

- Around 1703, the Parisian scientist Phillipe de La Hire (right) presented a plan to the French Academy of Sciences, proposing that every household should have a sand filter and rainwater cistern.

- His plan included an elevated, covered cistern, which would prevent freezing and keep out light, thus preventing the surface from growing a “greenish kind of moss.” The rainwater should then be passed through river sand and stored underground.

- La Hire believed that rainwater treated using this method was the best water because it had not been “mixed with the salt of the earth as spring waters usually are.” And he believed that it could be stored for years, always staying fresh.
Approximately 100 years after La Hire proposed his rainwater filtration method, the first municipal water treatment plant was installed in Paisley, Scotland. This 1804 treatment plant consisted of concentric sand and gravel filters, and its distribution system consisted of a horse and cart. Three years later, Glasgow, Scotland, was one of the first cities to pipe filtered water to consumers. By 1827, slow sand filters designed by Robert Thom were put into use at Greenock, Scotland. Similar systems designed by James Simpson (right) were completed in London in 1829. Thom’s filters were cleaned by backwash, while Simpson’s required scraping. The Simpson design eventually became the English model throughout the world.

Throughout 19th century in London, slow sand filtration was the water treatment method of choice. However, the large area of land required to support their use caused some concern. The sand beds, which were two- to three-feet thick, covered acres of ground. Cleaning the beds was usually accomplished using a shovel and vigorous physical effort.
The large area of land required also interfered with land needs for city growth, wrote F.E. Bruce in the “History of Technology”. For example, the combined water treatment plants of 1849 London treated 44.4 million gallons of water a day. At a flow rate of three gallons per hour per square foot, 12 acres of land would be required to produce the needed water. By 1901, London required 215 million gallons per day of clean water. Obviously, slow sand filters could not keep up with this expanding city.
Because the need for clean water was growing quickly, rapid sand filtration was developed in the U.S. in the 1880s, wrote Baker and Taras. The two main design elements of Thom’s filter were incorporated into this new design—the false bottom and reverse-flow wash—becoming standard features of these filters.

Rapid sand filters used water jets or backwashes to clean the filter media and mechanical agitators to loosen debris. Treatment capacity was greatly increased using these new filters and land area requirements were greatly reduced, noted Baker and Taras. However, rapid sand filtration required pretreatments, such as coagulation and settling, to reduce the sediment load to the filter. Treatment to improve taste and odor of the water was achieved by the use of charcoal filtration, although it was not widely used at first because it was thought to be unfeasible for large supplies.
Links to Health Found

- It was also around this time that the first correlation between water quality and health were made, according to the AWWA’s “Water Quality Treatment Handbook”. In mid-19th century London, town officials noticed a decrease in cholera deaths during the 1849 and 1853 epidemics where slow sand filters had been installed.

- But even more convincing evidence emerged when John Snow (right) was able to trace multiple cholera deaths to a single pump in Soho, England, which had become contaminated by a nearby leaking sewer, wrote N.M. Blake in “Water for the Cities”. An interesting note to this story is that the users of this Broad Street well pump came from other parts of the town because they preferred the taste of the water. This is some of the first evidence that taste and clarity do not always indicate safe water supplies.

- Blake wrote that shortly after town officials realized contaminated water had been the culprit in these disease outbreaks, London enacted the Metropolitan Water Act of 1852, which required the filtration of all water supplied to the London area. This legislation is one of the first instances of governmental regulation of a water supply.

- The Metropolitan Water Act mandated that water companies move their intakes upriver where the water is fresher, than using water from the river Thames which was actually part of their own excrement, and moreover, have to pay for the privilege.
In the 1870’s, Dr Robert Koch (above) and Dr Joseph Lister (right) demonstrated that microorganisms existing in water supplies can cause disease. Since then, several countries such as US of America has relied on several processes of water treatment to progressively ensure the best and safer water quality.
The year 1906 saw the use of ozone as a disinfectant in Nice, France. Because of the equipment’s complexity and costs, ozonation was less prevalent in the United States.

Significant improvements to water treatment in the latter part of the 19th century included the development of rapid sand filters, improved slow sand filters and the first application of chlorine and ozone for disinfection. At the turn of the century, chlorination became the most popular method in civilised countries and the number of dysentery and cholera cases plummeted.
By the 1920’s, the use of filtration and chlorination had virtually eliminated epidemics of major waterborne diseases from the American landscape. These two decades also saw the development of dissolved air flotation, early membrane filters, floc blanket sedimentation and the solids-contact clarifier.
Functions of water in the human body

1. Protect body organs and tissues
2. Help dissolve minerals and other nutrients to make them accessible to the body
3. Regulates body temperature
4. Lubricates joins
5. Lessen the burdens on the kidneys and liver by flushing out waste products
6. Helps prevent constipation
7. Carries nutrients and oxygen to cells
Regulates body temperature

Moistens tissues such as those in the mouth, eyes and nose

Protects body organs and tissues

Lessens the burden on the kidneys and liver by flushing out waste products

Helps prevent constipation

Helps dissolve minerals and other nutrients to make them accessible to the body

Carries nutrients and oxygen to cells

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WATER POLLUTION

Consists of any physical or chemical change in water that adversely affects the health of humans and other organisms.

Wastewater treatment is an important part of sustainable water use.
Case Study: Citarum River, West Java

1. Used for agricultural, water supply, industrial, sewerage purposes
2. The river flows from central West Java to the Java Sea
3. The river is very heavily polluted, since its basin supports about 5 million people
4. In 2008, the Asian Development Bank (ADB) called it “The Dirtiest River in the World”, and approved a loan of USD500 million to clean it up.
SEWAGE

Wastewater carried off by drains or sewers, contributes to enrichment (fertilization of water) and produces an oxygen demand as it is decomposed.

Microorganisms use the process of cellular respiration to break down sewage into CO$_2$, water and similar materials.

Biological Oxygen Demand (BOD) is the amount of oxygen needed by microorganisms to decompose sewage and other organic wastes.
A common home sewage system
OTHER TYPES OF WATER POLLUTION

Sediment pollution
Inorganic plant and algal nutrients
Inorganic chemicals
Radioactive substances
Thermal pollution
Sedimentation pollution
Algal blooms caused by excessive nutrients
**EUTROPHICATION**

Is the **nutrient enrichment** of oligotrophic lakes, estuarines or slow-moving streams, results in high-photosynthetic activity, which supports an overpopulation of algae.

**Artificial eutrophication** is enrichment of an aquatic ecosystem that occurs at an accelerated rate because of human activities such as fertilizer runoffs and sewage.
Eutrophic lake
Oligotrophic lake
SOURCES OF WATER POLLUTANTS

Point source pollution – pollution that enters the water at specific sites, such as pipes from industrial or sewage treatment plants.

Nonpoint source pollution – also called polluted runoff, comes from the land rather than from a single point of entry.

Three major sources of human-induced water pollution:

- Agriculture
- Municipalities (sewage and urban runoff)
- Industries
Point and nonpoint-source pollution
Figure 21.9 Sources of groundwater contamination. Agricultural practices, sewage (both treated and untreated), landfills, industrial activities, and septic systems are some of the sources of groundwater pollution. Once groundwater is contaminated, it does not readily cleanse itself by natural processes. We do not know the degree of groundwater contamination because access is difficult and because contaminants do not readily disperse (groundwater moves very slowly). (Figure is not drawn to scale.)
Groundwater contamination from a waste disposal site

Groundwater contamination from waste disposal site
At the Ayer Hitam Landfill in Puchong, Selangor, leachate (polluting wastewater from decaying waste) is treated before it is discharged into a stream. The hillock on the left is where waste has been dumped, compacted and layered with soil since the landfill opened in 1995 (The Star, 28 / 12 / 2004)
WASTEWATER TREATMENT

May include:

- **Primary treatment** (the physical settling of solid matter)
- **Secondary treatment** (the biological degradation of organic wastes)
- **Tertiary treatment** (the removal of special contaminants such as organic chemicals, nitrogen and phosphorus).
Wastewater treatment
Wastewater treatment
DISEASE-CAUSING AGENTS

Bacteria, viruses, protozoa and parasitic worms, are transmitted in sewage.

*E.coli*, the common intestinal bacterium, is used as an indication of the amount of sewage present in water and as an indirect measure of disease-causing organisms.

The fecal coliform test determines the presence of *E.coli* in water.
E. coli culture

E. coli
Colony of *V. cholerae*
SCHISTOSOMIASIS

Schistosomiasis (also known as bilharzia, bilharziosis or snail fever) is a parasitic disease caused by several species of fluke from the genus Schistosoma.

Although it has a low mortality rate, schistosomiasis often is a chronic illness that can damage internal organs and, in children, impair growth and cognitive development. The urinary form of schistosomiasis is associated with increased risks for bladder cancer in adults. Schistosomiasis is the second most socio-economically devastating parasitic disease after malaria.

This disease is most commonly found in Asia, Africa, and South America, especially in areas where the water contains numerous freshwater snails, which may carry the parasite.

The disease affects many people in developing countries, particularly children who may acquire the disease by swimming or playing in infected water.
Life cycle of *Schistosoma* spp.
Water-borne diseases inflicted on humans and their agents

1. **Cholera** – *Vibrio cholerae*
2. **Dysentery** – *Shigella dysenteriae*
3. **Enteritis** – *Clostridium perfringes, other bacteria*
4. **Typhoid** – *Salmonella typhi*
5. **Infectious hepatitis** – *Hepatitis Virus A*
6. **Poliomyelitis** – Poliovirus*
7. **Cryptosporidiosis** – *Cryptosporidium sp.*
8. **Amoebic dysentery** – *Entamoeba histolytica*
9. **Ancylostomiasis** – *Ancylostoma sp.*
Salmonella typhi

Poliovirus

An infected wound caused by Clostridium perfringens

Shigella dysenteriae
Types of synthetic materials found in polluted water

1. Aldicarb – pesticide (damages the nervous system)
2. Benzene – solvent (blood problems, leukemia)
3. Carbon tetrachloride – solvent (may induce cancer, liver damage)
4. Chloroform – solvent (may induce cancer)
5. Dioxin – chemical pollutant (may induce cancer; may damage the immune and nervous systems and reproductive organs)
6. Ethylene dibromide (EDB)- (fumigant, pengasap) and polychlorinated biphenyls (industrial chemical) - (may induce cancer; may attack the liver and kidneys)
7. Trichloroethylene (TCE) – solvent (may induce cancer; may induce liver cancer in rats)
8. Vinyl chloride – plastic industry (may induce cancer)
The distribution of water resources in relation to human populations exacerbates global water problems
People in poor and less-developed countries lack access to safe drinking water and wastewater disposal.
A slum area in Mumbai, India. Do you think the people living here have access to clean drinking water?

Population growth is outstripping water supplies in countries such as India, China and Mexico.
International tensions over water rights could result in armed conflicts. Of particular concern are the Mekong River (left), Indus River, Ganges River, Tigris-Euphrates River, Jordan River and Nile River.
LONG TERM GOAL OF WATER MANAGEMENT

To provide a sustainable supply of high-quality water.

Sustainable water use — humans can use water resources into the future without harming the functioning of the hydrologic cycle or ecosystems.

Dams ensure a year-round supply of water in areas that have seasonal precipitation or snowmelt.

River diversion is sometimes used to increase the supply of water to a particular area.

Desalinization is the removal of salt from seawater or salty groundwater.
Desalinization of Seawater: Singapore’s Proud Moment

Singapore is less than 700km² in area, of which only around 10km² is water. Limited natural fresh water resources – and the high population density – make sourcing alternative supplies of potable water of great national importance. The Tuas seawater reverse osmosis (SWRO) plant has sufficient capacity to meet around 10% of Singapore’s demand.

Desalinization process

Water Supply for Singapore
1. Rain water – about 50%
2. From Malaysia – about 40%
3. RO water – about 10%
SPECIAL TOPICS

Methemoglobinemia / Blue Baby Syndrome (caused by nitrate contamination of drinking water)

Dental Fluorosis

Minamata Disease

Fluoride contamination in groundwater

Heavy metal contamination (Ca, Cu, Pb, Zn) of drinking water and river water

Aluminium residue in processed drinking water
Thank you for your attention!!