Water Use, Management, and Pollution

I. Water covers more than 70% of the Earth's surface with a total volume of more than 1,4040 million km^3 (or 370 billion gallons). That's a ridiculously large amount! If the surface of the Earth were smooth, an ocean 3 km deep would cover the entire planet.

II. Water availability and use
   A. Water is needed for nearly every human activity and the availability of water determines where these activities can take place.
   B. About two thirds of the water that enters streams and rivers happens during floods and is too large or violent to be very useful. What is needed is stable runoff that occurs year round, but most of this occurs in uninhabited regions or where lack of technology or finances makes it difficult to use. There is, however, about 1,500 km^3 of renewable water per person per year worldwide.
   C. As you might guess, this water is not equally distributed. There are countries with abundant water and those with severe, chronic shortages.
   D. Sometimes the reason for a water shortage is natural - lack of rain, dry winds, rivers changing course. In other cases, shortages are caused by human activity - increased population, urban growth, agriculture, contamination by sewage. Without money for wells, storage reservoirs, delivery pipes, or sewage management, people can't use the water available to them.
   E. Sometimes poverty is the reason for a lack of water. Most people living in slums in large cities get their water from vendors but the quality is often questionable and costs 10x that of piped city water.
   F. Water is not like other resources in that it can be reused many times. **Withdrawal** is the total amount of water taken from a lake, river, or aquifer for any purpose. Most of this water is returned to circulation in a form that can be used again, although at other times it is returned in a polluted state. There are two types of water use:
      1. Consumptive use includes water that is used for human activities. This water is used up or "consumed" in the process (*e.g.*, irrigation).
      2. Non-consumptive use occurs when the water is returned and available for use again even if it is polluted (*e.g.*, washing, flushing wastes, coolants). Degradation refers to a change in water quality due to contamination or pollution so that it is unsuitable for other purposes. The total quantity may be the same but the quality is degraded so the water is no longer as valuable as it was.
   G. Water is used in three main sectors: domestic, industrial, and agricultural. Worldwide, agriculture accounts for about 69% of total water use but the use by sector varies from country to country. Poorer countries have little industry and limited domestic use and in many developing countries irrigation is inefficient and uses more water. In these countries, irrigation is usually accomplished by flooding the entire field. Normally this water would be available for reuse but it is often contaminated with fertilizer or pesticides. A given amount of water used by industry has much more value than the same water used by agriculture so this could change the use of water as countries industrialize.

III. Consequences of Overdrawing Water

A. Generally, about the half the water we withdraw would be still be available for use if we could protect it from contamination. Many societies, including ours, have always treated water as if it is an inexhaustible resource. It is generally considered cheaper to dump water we have used and get new water than to clean it or to make sure it is clean. Water is a renewable resource but renewal takes time and we often withdraw it faster than it is renewed.

B. Effect on surface water

1. Some years are naturally dry. This means that if we regulate our water use based on "good" years, we will experience shortages in dry years. Surface water flow can drop to 30% approximately every 20 years.
2. There is ecological damage caused by damming and diverting water. These include flooding, loss of water downstream, loss of wetlands, and blocking fish migration.
3. If insufficient treatment of polluted water is done, there is increased pollution downstream.

C. Effect on groundwater

1. If water is withdrawn faster than the recharge rate, there is less for human use. The water table drops when water is withdrawn faster than the natural recharge rate. Agricultural users suffer before residential users because of the heavy use in irrigation.
2. A falling water table can decrease surface water. In wetlands, the water table is just below the surface and they will dry up if it drops. When springs and seeps dry up, there is no supply to rivers and streams which dry up in turn.
3. When underlying groundwater is removed, the land above can collapse, causing sinkholes. This is called **land subsidence**. In coastal areas this can cause flooding if the land drops below sea level. When this occurs quickly it is called a **sinkhole**.
4. When groundwater is withdrawn, seawater can move in to replace it so that freshwater reservoirs become contaminated. This is called **saltwater intrusion**.

IV. How Do we acquire more water?

A. **Seeding clouds** and **towing icebergs**

1. Clouds form when tiny droplets of water form on particles in the air. This can be done artificially by releasing particles in the atmosphere on which the droplets can form. This is now being done in several countries, although China has the largest program. There is some concern about the health risks that can result from the main chemical used - silver iodide. There is also concern that increased rainfall in one area will decrease it in another area.
2. Icebergs can be towed from the Arctic or Antarctic to supply freshwater to countries that need it. It is unclear whether it is economically viable to tow icebergs long distances.

B. **Desalination** is the removal of the salt from seawater

1. This is currently not economically feasible but could work if a source of cheap, infinite energy were available. The environmental concerns include the danger to marine life being taken in with the water supply and the return of the concentrated salt water to the ocean.

C. **Dams and diversions** can be used to build reservoirs of water and to move water to where it is needed. Dams have several major problems.

1. They reduce water flow downstream, causing rivers to dry up and water levels in lakes to drop.
2. The flooding from the reservoir can displace people and destroy habitat.

3. They are inefficient. Dams can lose water by evaporation and seepage into the rock below the reservoir. This increases the salinity of the water downstream. Also, when the water slows, the sediment it carries tends to settle out, filling up the reservoir.

D. Making better use of wastewater
   1. **Gray water recycling** can make use of the water from sinks, showers, and laundry for washing cars, flushing toilets, irrigation, *etc.*
   2. Capture and use storm water.
   3. If wastewater treatment were improved, this water could be used for agriculture or reused for consumption rather than being discharged into the environment. This would require major campaigns to convince the public to accept it.
   4. Apply pressure to industry to conserve water.

E. It is estimated that we could cut our water use by 50-75% with little change in lifestyle, just by small changes in our habits.. Reducing our use is one way to effectively have more water. Remember that domestic use is only a small fraction of our total water use so these measures, while raising awareness of the issue, do little to actually conserve water. These include simple things like repairing leaky faucets and toilets and turning off faucets when not in use; using low-flow shower heads and shorter showers; using displacement devices in toilet tanks.

Water Pollution

I. Pollution is any physical, biological, or chemical change in water quality that adversely affects living organisms or makes water unsuitable for a desired use. It is important to realize that whether you consider water to be polluted depends on your perspective or what your intended use is.
   A. The water cycle covers the entire biosphere so water pollution can reach anywhere on the planet. Small amounts of pollutants can contaminate large volumes of water.
   B. Pollution, including that of water, is of two general types:
      1. **Point source** pollution is from a single, specific point of origin. *e.g.* factories, sewage treatment plants, oil wells. These sources are easy to identify, monitor, and regulate. We can usually divert waste from these sources and treat it before it enters the environment.
      2. **Non-point sources** of pollution generally don't have a specific point of origin. They include runoff from farms or urban areas, golf courses, construction sites, and parking lots.

II. There is a variety of types of water pollution.
   A. **Infectious agents** are pathogens that are carried in the water and cause disease.
      1. The main source of these pathogens is from untreated or improperly treated human waste. Pathogens also come from animal feedlots or fields near waterways.
      2. In developed countries, sewage treatment reduces the risk of infection and most water is chlorinated to kill pathogens.
   B. **Oxygen-demanding wastes**
      1. The amount of oxygen dissolved in water is a good indicator of water quality. Oxygen is added to the water by diffusion from the air and by photosynthesis of green plants, algae and cyanobacteria. Oxygen is removed from the water by respiration and decomposition.

2. The addition of organic matter, like sewage, stimulates oxygen consumption by decomposers. The amount of oxygen consumed by organisms in the water is called the **biochemical oxygen demand** (BOD). The amount of **dissolved oxygen** (DO) is also important because it determines whether organisms can survive or not.
3. Downstream from a point source, such as from a municipal sewage plant discharge, there is a decline in DO because of the increased BOD caused by the organic and/or nutrient load. Even further downstream, the DO increases again as the waste becomes diluted.

C. **Eutrophication**

1. Rivers and lakes that have clear water and low biological productivity are said to be **oligotrophic**. These waters are low in nutrients, especially phosphorous and nitrogen, which limits the growth of plankton. In the absence of plankton, the water is clear and light is able to penetrate to greater depth. The light supports the growth of **submerged aquatic vegetation** (SAV) and these plants produce oxygen. The SAV supports an entire ecosystem.
2. By contrast, **eutrophic** water is enriched with nutrients. Tributary streams bring in sediments and nutrients that supports the growth of plants. Over time, most lakes gradually fill in, eventually becoming marshes.
3. Human activities greatly accelerate this process in what is called **cultural eutrophication**. The increased nutrient load from human activity supports the rapid growth of plankton which, in turn, increases the turbidity of the water. The lack of light reduces the growth of SAV and the food chain collapses.
    a. In some cases, bacteria then decompose the resulting dead organic matter, depleting oxygen dissolved in the water. With no oxygen, fish cannot survive and then other predators further up the food chain disappear. The presence of plankton causes an unpleasant taste and odor that can make the water unsuitable for human consumption.
    b. Eutrophication can also occur in coastal marine waters.

D. **Red tide** is a bloom (population explosion) of microorganisms called dinoflagellates. Some of these produce toxins that are deadly to fish and cause symptoms in humans including headaches, joint pain, burning muscles, blurred vision, memory loss and long term damage to brain, liver, pancreas, kidneys, and immune system. The blooms are caused by runoff from agricultural waste, fertilizer, human sewage, and other nutrients into near-shore water.

E. Some toxic **inorganic pollutants** are naturally released from rocks by weathering and carried by runoff into lakes or rivers, or percolate into groundwater aquifers. Human activities such as mining, processing, using, and discarding minerals accelerate this process thousands of times over natural rates.

1. The chemicals of greatest concern are heavy metals such as mercury, lead, tin, and cadmium.
2. Note that urban and suburban development increase run off which can increase the pollutants reaching waterways.

F. Thousands of different natural and synthetic **organic chemicals** are used to make pesticides, plastics, pharmaceuticals, pigments, and other products that we use everyday. Many of these chemicals are highly toxic and exposure to even low concentrations can cause birth defects, genetic disorders, and cancer. Some can persist in the environment and thereby pose a serious threat to human health.

G. **Sediment** is carried naturally by rivers to lakes and oceans but the rates of erosion have been greatly accelerated by human activity. Erosion from farmland, overgrazed pastureland, construction sites, mining sites, and stream banks all contribute to the sediment load in a waterway.
    1. Smaller particles in sediment can cloud water, blocking light. It coats SAV, eggs of aquatic organisms, and clogs the gills of fish and filter feeders.
    2. Sediment is a problem because it fills lakes and reservoirs, clogs shipping channels, makes it difficult to purify drinking water, and smothers coral reefs and aquatic organisms which live on the bottom of rivers, lakes and oceans.
        a. Natural ecosystems normally have very little run off. Most precipitation is either absorbed by vegetation or infiltration. This water is slowly released into ground water and purified. As forests are cleared, there is more run off which carries soil and sediment.
        b. As sediment is deposited in streams, rivers, or shallow coastal waters, fisheries are destroyed.
        c. A certain amount of sediment is important because it provides nutrients which find their way into the food chain.
    3. The nutrients in the sediment also contribute to eutrophication.

H. Certain human activities can increase the water temperature in an area. This is called **thermal pollution**. Water temperature is usually much more stable than air temperature so aquatic organisms are not well adapted to rapid temperature changes. Also, oxygen solubility decreases as temperature increases, which adversely affects many organisms.
    1. The cheapest way to remove excess heat from an industrial facility is to pump water from the ocean, river, or lake, use it to absorb the heat, and then return it to the source.
    2. The thermal plume created can sometimes be beneficial as it promotes the growth of a richer food supply for birds, fish, and aquatic mammals. The danger is that a sudden plant shutdown can cause a thermal shock which can kill them.

III. Water pollution control and reduction can be accomplished by better use of the land and careful disposal of waste.

A. **Source reduction** is the cheapest and most effective way to reduce pollution. Increased awareness of water pollution can help us change farming practices to reduce runoff. Industry can recycle or reclaim materials that might otherwise be discarded.
    1. Preserving wetlands, which act as natural water purifiers, can also reduce pollution of ground and surface waters.
    2. Cultural eutrophication can be avoided by being aware of the causes and controlling the release of phosphates and nitrates into waterways.

B. Human sewage must be treated to decrease the nutrients being added to water as well as to remove pathogens.

C. Remediation can be used to improve the quality of polluted water.
    1. Containment methods confine or restrain dirty water to prevent further pollution. Absorbent material is used on surface spills to soak up contaminants and various chemical treatments can eliminate pollutants.
    2. Bioremediation is the use of living organisms to remove pollutants from water. This is done either in open lagoons or in containers of space is limited.