1

Introduction

1.1 The natural water cycle is shown in Figure 1.1.

1.2 The human-affected water cycle is shown in Figure 1.2.

1.3 In Figure 1.2, water is extracted from different water resources and is treated before being consumed by water consumers. Water consumers then generate wastewater. The generated wastewater (raw wastewater) is treated and is sent back to the natural water cycle. Another route is that the treated wastewater is sent back to the water consumer. This alternative route is doable if raw wastewater is treated to a very high quality.

1.4 The relation of water and water plants is shown in Figure 1.3. Then, water users are the same as wastewater generators.

1.5 There are four main water resources. They are as follows:
   (a) Surface water
   (b) Groundwater
   (c) Treated wastewater
   (d) City potable water

1.6 Surface water and groundwater are primary water resources, while treated wastewater and city potable water are secondary water resources.

1.7 "Treated wastewater" is economically the most favorite water source for industrial users and irrigation in agriculture.

1.8 Using city potable water from the city's potable water distribution network could be acceptable for small industries and small agricultural activities when the required water is less than 200 m^3/h.

1.9 The main differences between surface and groundwater are summarized in Table 1.1.

1.10 Surface water has less stable flowrates. For instance, river water levels will rise and fall during different seasons (less water in summer and more water in spring). If you are using river water as your source of water, you need to account for the varying water flowrates by adding a water tank to store the water in case of seasons with low water level. Groundwater, on the other hand, will have a more stable flowrate.

1.11 Surface water also has less stable temperature. Again, this is primarily dependent on the season changes. Temperature for groundwater is more stable

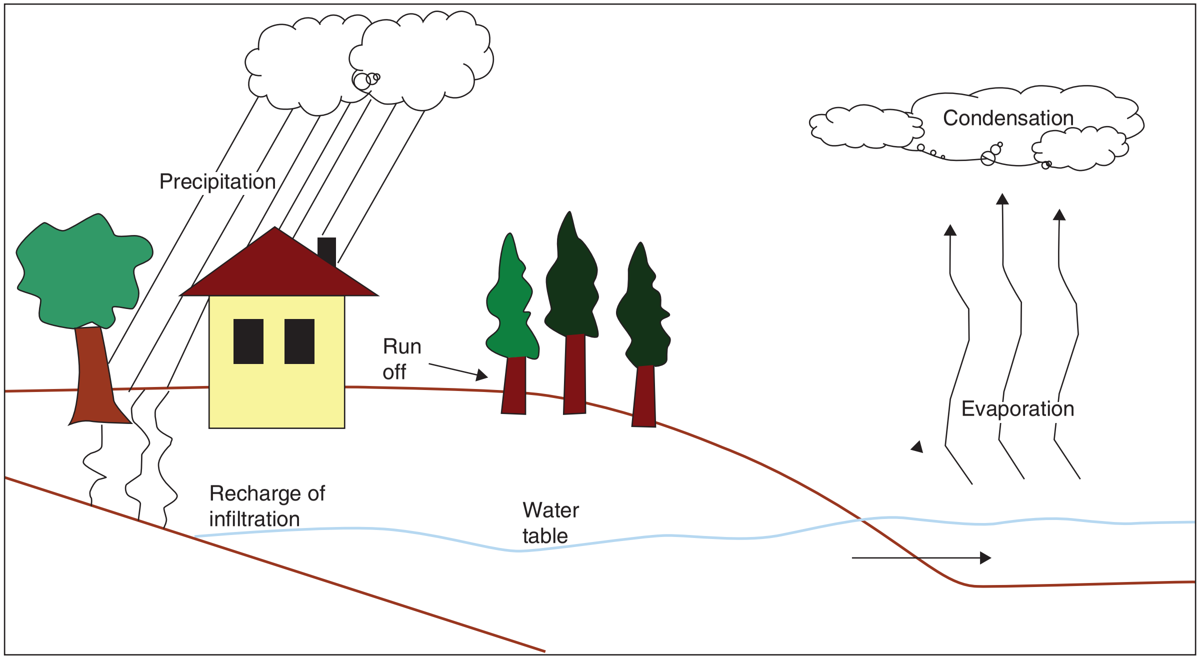
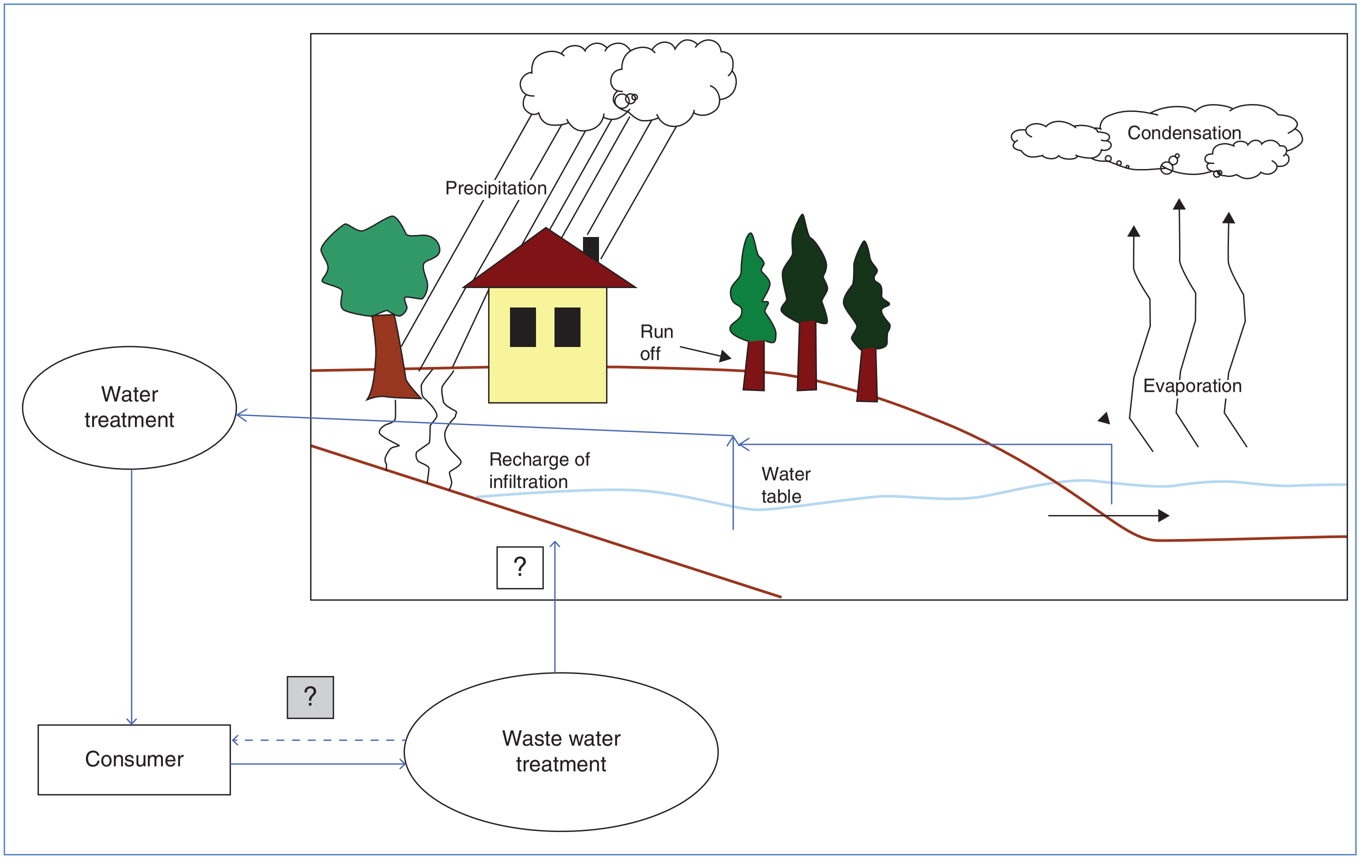

Precipitation
Condensation
Run
off
Evaporation
Recharge of
infiltration
Water
table

Figure 1.1


Precipitation
Condensation
Run
off
Evaporation
Water
treatment
Recharge of
infiltration
Water
table
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Consumer
Waste water
treatment

Figure 1.2

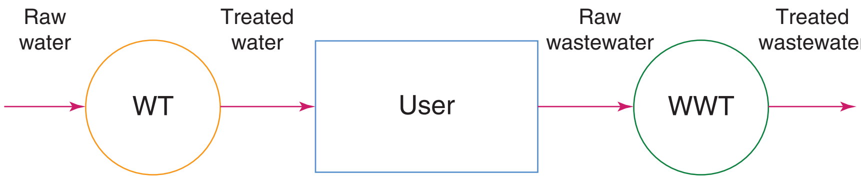

Figure 1.3

Table 1.1

1	Surface water	Groundwater
2	Generally, more expensive intake system	Generally, less expensive intake system, only well pump
3	Less stable flowrate	More stable flowrate
4	More fluctuation in water temperature	Less fluctuation in water temperature
5	More fluctuation in concentration of contaminants	Less fluctuation in concentration of contaminants
6	Generally higher suspended solids	Generally lower suspended solids
7	Generally higher turbidity	Generally lower turbidity
8	Generally higher dissolved oxygen (DO)	Generally lower DO
9	Generally lower alkalinity	Generally higher alkalinity
10	Generally lower total hardness (TH)	Generally higher TH
11	Generally lower concentrations of iron and manganese	Generally higher concentrations of iron and manganese
12	Generally lower chance of silica existence	Generally higher chance of silica existence
13	Generally lower chance of pathogenic existence	Generally higher chance of pathogenic existence
14	Generally lower concentrations of dissolved hydrogen sulfide and dissolved methane	Generally higher concentrations of dissolved hydrogen sulfide and dissolved methane
15	Generally lower concentrations of iron (Fe^{2+}) and manganese (Mn^{2+})	Generally higher concentrations of iron (Fe^{2+}) and manganese (Mn^{2+})

as weather conditions on the surface is unlikely to impact the groundwater conditions.

1.12 Concentrations of contaminants is also less stable for surface water. This means that concentrations of contaminants will go up and down. As such, for water systems designed with surface water, there should be a minimum of four different water analysis performed (spring, summer, winter, and fall) to capture as many variations of the water contaminants as possible to capture the worst-case scenario. For groundwater, this is not the case as the concentrations found in groundwater are more stable.

1.13 Turbidity in surface water is usually high. Turbidity is a parameter that measures the cloudiness of a fluid caused by particles. Groundwater conversely has low turbidity.
1.14 Surface water has low alkalinity, while groundwater has high alkalinity.
1.15 Surface water has high dissolved oxygen and groundwater has low dissolved oxygen. This is the reason that there are more chances of corrosion when using surface water.
1.16 Surface water has lower levels of iron and manganese, while groundwater has higher levels of these metals. This is the cause of the scaling (reddish-brown rust color) around taps/sinks in cabins using groundwater. These two metals tend to show up together as some ions tend to behave like twins. This is a good thing to keep in mind as if you know there is iron, there is also a high likelihood of manganese present as well.
1.17 Surface water has low total hardness (TH) and groundwater has high TH. This is evident when you see more scaling in tea kettles using groundwater as the source.
1.18 Surface water has low amount of dissolved gases and groundwater may have more dissolved gases. For example, there are some sources of groundwater that contain hydrogen sulfide (H_2S) gases dissolved in it, hence the reason for the rotten egg smell that you may notice. There are also cases of groundwater containing dissolved methane (CH_4) gas. It is good to be aware of such possibilities when evaluating groundwater as they could cause problems depending on its intended consumer.
1.19 Surface water may have more pathogens. This is the reason it is more critical to perform disinfection for surface water rather than groundwater that may contain fewer numbers of pathogens.
1.20 Surface water may have small amounts of silica (SiO_2) and groundwater may have big amounts of silica. Silica is more in volcanic areas and in deeper wells.
1.21 As a general rule we prefer groundwater as a source water because of its stability. However, when a huge amount of water is needed, not always groundwater can keep up. As a rule of thumb, when the required water is more than 1,000 m^3/h, it is not easy to find groundwater resources and a surface water is preferred.
1.22 There are four main water consumers. They are as follows:
(a) Humans
(b) Agriculture (including agronomy and animal husbandry)
(c) Industries
(d) Environment
1.23 The quantity and quality of water for these four consumers depends on the size and type of them.
1.24 Water for humans covers water used by people for drinking and other human needs.
1.25 Water for agriculture covers water needed for irrigation and also that used by animal husbandries. The quality of water required for this consumer is specific to each plant or to each animal. The agricultural engineers will perform tests

and research which types of water are good for the plant or animal they are growing.

1.26 Water is used in heavy and light industries, too. It is rare to find an industry that water is not used in it at all.

1.27 The other group of consumers is the environment. Many experts do not classify this as one group of water consumer. However, the author believes this should be considered a consumer as all water we use eventually finds its way to the environment as the final destination.

1.28 For each of the four water consumers (human, agriculture, industries, and environment), there are stakeholders, which are stated in Table 1.2.

1.29 Governmental bodies are the group that specifies the requirements for which water is consumable by humans. On an international level, this body is the World Health Organization (WHO). Note that the WHO's standard for drinking water is generally more relaxed than governmental body water standards.

1.30 Unfortunately for the environment, it does not have a mouth to say "I like this water" or "I don't like this water." Hence, governmental bodies become the voice for the environment and regulates what can or cannot be released into the environment. This is not to say that the governmental bodies always know what is best and thus there are constant changes to regulations. Changes are common because the environment is very big but silent and it is not easy to predict its behavior.

1.31 When we refer to industries, we are talking about the three main users within industries, namely:
(a) Water for heating
(b) Water for cooling
(c) Water in/for process

1.32 Figure 1.4 shows all water routes in an imaginary industry. In addition to water specific to industry, we have potable water treatment and sewage treatment systems, as there are personnel working in each industry. Each industry may need a storm management system, too.

1.33 Why do we have anything other than "water in process"? Why are we listing heating and cooling as two other sectors? This is because there are generally

Table 1.2

	Stakeholder	Specific feature
Water for humans needs	Governments	Ever-tightening standards
Water for agriculture	Farm owners and sometimes governments	Depends on the type of plants or animals
Water for industries	Industry owners and sometimes government	May need very pure water
Water for environment	Governments	Ever-tightening standards, changing standards, many local standards

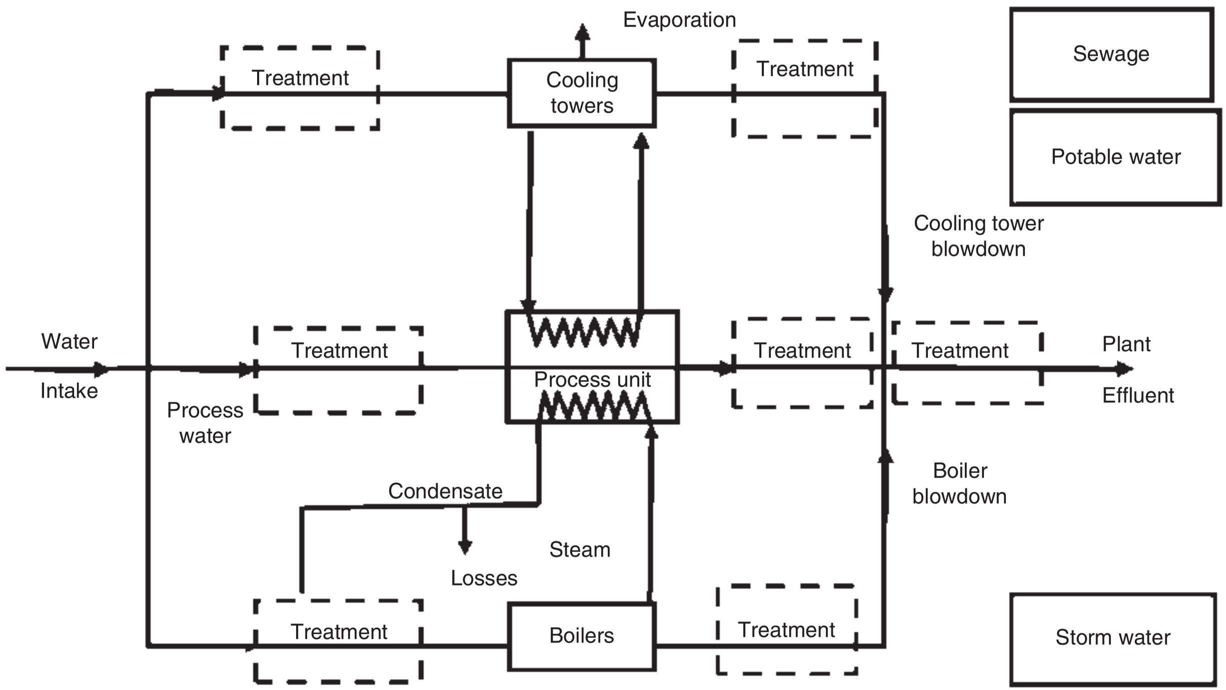
Evaporation
Treatment
Cooling towers
Treatment
Sewage
Potable water
Cooling tower blowdown
Water
Intake
Treatment
Process water
Process unit
Treatment
Treatment
Plant
Effluent
Boiler blowdown
Condensate
Steam
Losses
Treatment
Boilers
Treatment
Storm water

Figure 1.4

no process plants where we do a chemical or physical conversion at ambient temperature. We tend to require either high or low temperatures and such we need water for heating purposes and water for cooling purposes.

1.34 Water required for heating services is independent of which industry you are considering. For example, water for a boiler will be the same across the board whether it is in a Coca Cola® plant or in the oil industry. This solely depends on the boiler pressure.

1.35 Independency of the required water quality to the industry also applies to water for cooling. The cooling system/cooling tower for power plant or process plant will be the same.

1.36 As water is heavily recycled in heating and cooling loops of industries, the need for water is much less than the "recirculating water." Then, our need for water is named "makeup" water:
(a) Boiler makeup water
(b) Cooling tower makeup water
Similarly, in closed loop hot water and cold water circuits, there are exiting streams that need to exist to prevent accumulation of contaminants in water. Their names are as follows:
(a) Boiler blowdown water
(b) Cooling tower blowdown water
This concept is shown in Figure 1.5.

1.37 When water is required for a process, the quality of water is dictated by the process. The water used in process for a soda drink plant would be different from the quality of water used for an oil processing plant, gas process plant, pharmaceutical industry, or food industries.

1.38 Water in process is the most complicated sector as heating and cooling water has a larger pool of resources across industries that can clarify the water quality specifications. For process, there are many cases where even the water designer is not fully aware of the best water required for their process system. Finding help for these processes is harder as there are smaller groups of people who would be using similar processes, and most of the time, these processes are proprietary, and hence people are not ready to divulge details of their specifications.

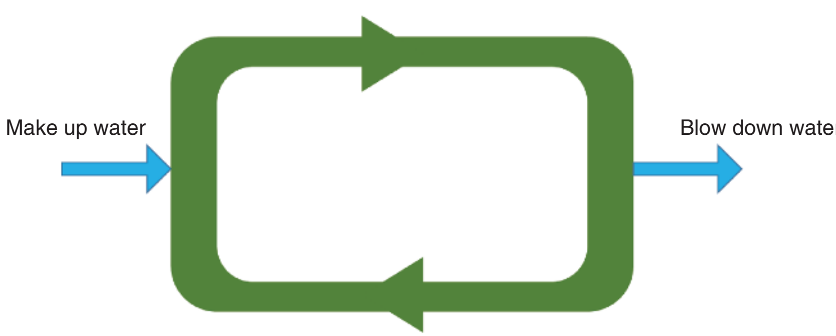

Figure 1.5

Table 1.3

Source of water	Required water	Users	Generated wastewater
Surface water, underground water	Treated water, potable water	Water for humans needs	Municipal wastewater
Surface water, underground water, city potable water, treated wastewater	Irrigation water, water for animals	Water for agriculture	In agronomy water is not generally collected In animal husbandry we may have generated wastewater
Surface water, underground water, city potable water, treated wastewater	Feed water	Water for industries Makeup for cooling towers, makeup for boilers (and steam generators and process users)	Industrial wastewater
Treated wastewater	Released water	Water for environment	NA

1.39 Table 1.3 shows a complete journey of water in different sectors.

1.40 The ease of municipal wastewater is that there are mainly two contaminants or two concerns. These are suspended solids (SS) or biochemical oxygen demand (BOD), which are organic materials. In the last decades, two more items were added to the list of contaminants to be removed from municipal wastewater: nitrogen (N) and phosphorus (P). Note that some areas and countries are still only concerned about the two contaminants SS and BOD.

1.41 Table 1.4 shows specific issues in each of four sectors of treatment industry.

1.42 In terms of water usage and wastewater generations, there are two sizes of industries:

(a) Large industries include oil and gas industries, power generation industries, mining industries (including extraction and mineral processing), pulp and paper, and metal fabrication industries.

(b) Small industries include food and beverage industries. The food and beverage industries are the most widespread industries.

As a rule of thumb, in small industries, there is more chance of having organic matters in their industrial wastewater.

1.43 Table 1.5 shows a non-exhaustive list of different water streams in industries.

1.44 Table 1.6 shows a non-exhaustive list of different wastewaters in industries.

1.45 In municipal sectors the standards for water and wastewater could be stated in different forms, which are shown in Table 1.7.

1.46 Theoretically, anything other than water (H_2O) is considered as a water contaminant.

1.47 All contaminants whether in water or wastewater are categorized into five different groups; see Figure 1.6.

Table 1.4

	Municipal	Industrial
Water	– Flowrates could be higher than flowrates in industrial sector – Water flowrate is changing and more likely to increase gradually – Existence of contaminants could be important even in ppb level – Color and taste of final product is important – Needs high efficiency filtration – Removal of all contaminants down to even trace could be needed – Pathogens may exist and should be dealt with – Less emerging new technologies is employed – Used chemicals should be food grade – Economical measures are very important – Public involvement is needed – Units are more visible to check ○ Regulatory/social issues exist	– Flowrates could be lower than flowrates in municipal sector – More challenges regarding removing non-common contaminants that exist – May need high or very high purity water streams – Units are generally pressurized and fully enclosed
Wastewater	– Flowrates could be higher than flowrates in industrial sector – Wastewater flowrate is changing and more likely to increase gradually. (One element of municipal water treatment and wastewater treatment plant is that you design for a “living body.” The population is increased and you need to forecast the population increase) – Very high surge in wastewater flowrate. Even after equalization tank the plant should be designed for several flowrates – Sewer network affects the quantity and/or quality of the wastewater received to treatment facility (dry weather flow, wet weather flow) – Tight budget is always an issue ○ Ever-developing new technologies aim for modification of existing plant to meet new standards, and/or higher populations is a big part of industry – Needs many permitting – Needs public involvement – Economical measures are very important	– Flowrates could be lower than flowrates in municipal sector – Could be highly contaminated – More challenges regarding removing non-common contaminants exist – Public interest about final destination of treated wastewater

1.48 Settleables are contaminants that sink to the bottom after a reasonable amount of time (e.g. less than half an hour). An example of a settleable is sand or clay.

1.49 Floatables will float to the surface of water in a reasonable amount of time (e.g. less than one hour). An example would be oil. Oil does not only occur in the oil industry but also in food, municipal wastewater, wastewater from car washes, airports, etc. The pulp and paper industry also has floatables, which are fibers.

Table 1.5

Name	Consumer
Demineralized water	Feed water used in boilers
Ultrapure water	Feed water used in pharmaceutical industries and microchip manufacturing
Boiler makeup water	To feed boiler closed circuit
Cooling tower makeup water	To feed cooling tower closed circuit

Table 1.6

Name	Source of generation
Produced water	Oil and gas extraction facilities
(Contaminated) storm water	General for all industrial facilities where there are some outdoor operations
Spent caustic	Oil refineries
Sour water	Oil refineries, hydrocarbon gas processing facilities
Oily water	Oil refineries, meat processing units
Condensate	Exists in many industries using close system of steam heating, examples are refineries, molten sulfur processing, power plants, and food industries
Ion exchange regeneration waste	Wherever ion exchange is present in their systems, water and wastewater industries like power plants
Membrane reject stream	Facilities based on membrane separation
Dirty backwash water	Wherever depth filters are present in their systems, water and wastewater industries
Brine	Generally, from desalination plants
Flue gas desulfurization (FGD) wastewater	Uses scrubbing water for removing sulfur gas compound from flues gas, common in power plants
Dredged water	Water released from removed muds from floor of water bodies
Ash water	Contaminated water that is used for transferring ashes from combustion in coal-fired power plants
Landfill leachate	Water released from buried solid/semisolid wastes
Acid mine water	Water that went through abandoned mines
Tailing water	Mining industries
Ash water	Water mixed with coal in some coal-fired power plants
Boiler blowdown	Exiting stream from hot water loops in industries
Cooling tower blowdown	Exiting stream from cold water loops in industries

Table 1.7

Sector	Forms of limitations in standards
Water	Limits on concentration of contaminants
Wastewater	Limits could be either on concentration of contaminants or mass flowrate of contaminants

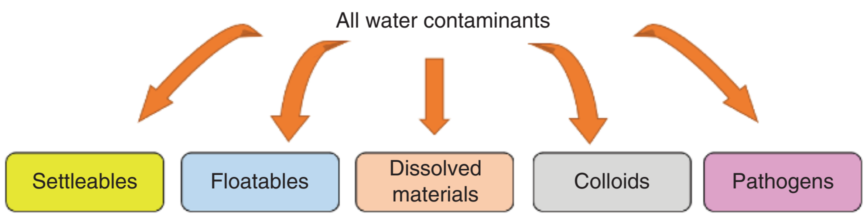

Figure 1.6

1.50 Dissolved materials are those dissolved in water. When they are dissolved, it cannot be seen in water with the naked eye. The first two groups, settleables and floatables, can be seen if there are large and/or in high concentrations. An example of dissolved contaminant is salt in water (which is an inorganic material dissolved in water) or sugar in water (which is an organic material dissolved in water). Air is another example of dissolved contaminant when it is dissolved in water.

Dissolved oxygen in water is what fishes and marine wildlife use to breathe.

1.51 Colloids are a category between dissolved materials and suspended materials from size view point; see Figure 1.7.

1.52 They possess some characteristics of suspended and some characteristics of dissolved contaminants. Generally speaking, any particle larger than 1 μm will be considered a suspended contaminant. If the density of the particle is higher than that of water, it will be a settleable, and if it has a lower density than water, it will be a floatable.

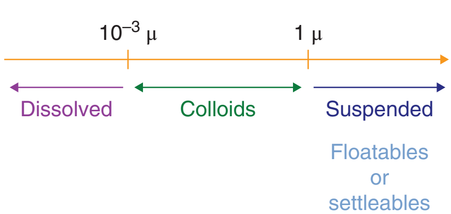

Figure 1.7

1.53 When the particle size of the contaminant is less than 1 nm, it falls under the category of dissolved contaminant. Colloid sizes are between 10^{-3} and 1 μ.

1.54 The last category of microorganisms can be considered on its own as it is very different from the other four categories. Pathogens are living organisms with tiny sizes.

1.55 Contaminants from the other side can be classified based on their material type. There could be many types of contaminants in terms of their material type.