# WATER PURIFICATION CONTAMINATED WATER SOURCES

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# Water Purification - Contaminated Water Sources

How do water sources become contaminated with microorganisms?

Sewage

Sewage: Human wastes are often dumped directly into water sources. Potentially pathogenic bacteria (e.g., Salmonella, Shigella, Campylobacter, *Escherichia coli* strains, *Vibrio cholera*), viruses (e.g., Hepatitis A, Norwalk), and parasites (e.g., Giardia, Cryptosporidium) may be present in extremely high numbers.

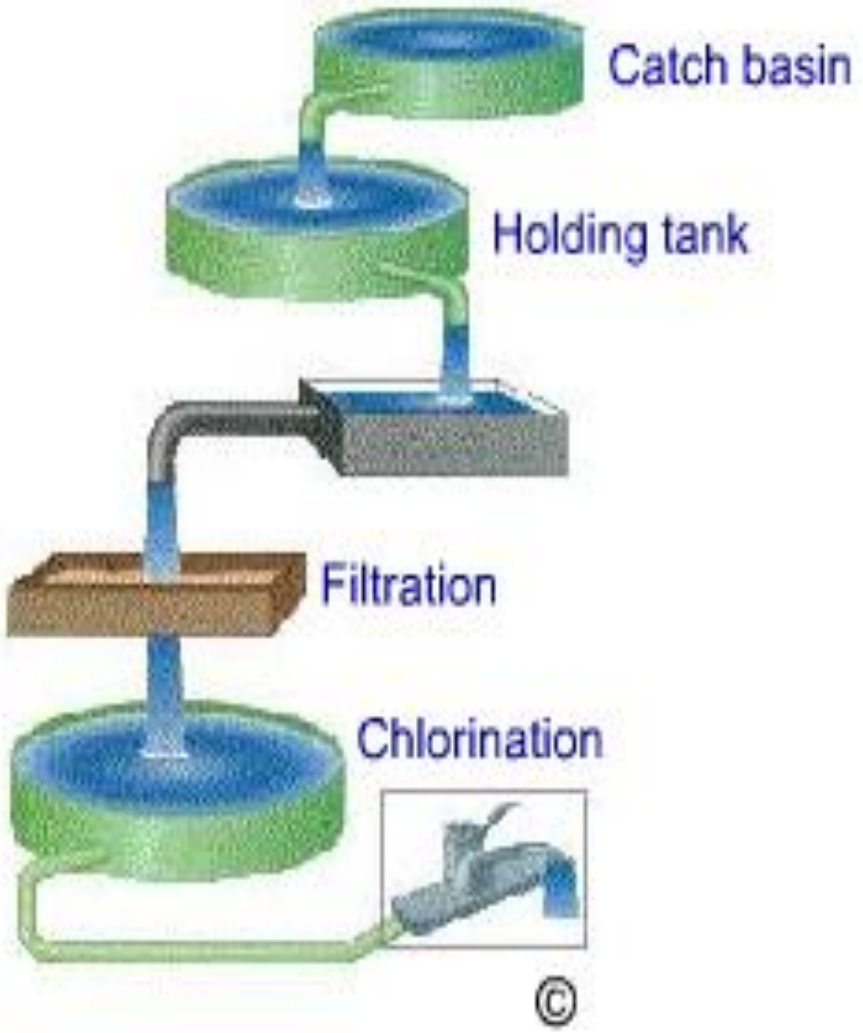
Animal Wastes

Animal Wastes: Animal wastes containing potentially pathogenic microorganisms may enter local water sources such as wells, lakes and reservoirs. This is particularly important in the spring when run off from melting snow increases the risk for contamination.

Wild Animals

Wild Animals: Wild animals may contaminate remote water sources. Lurking in that 'pure' mountain stream may be a whole variety of potentially pathogenic organisms. What do you think - is the beaver the natural host for Giardia or has it become infected from human contamination?

# Water Purification -
# Making Municipal Water Safe

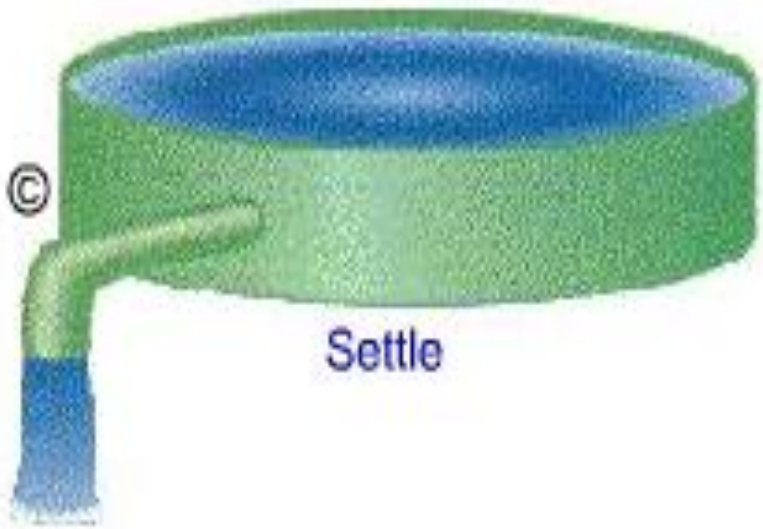


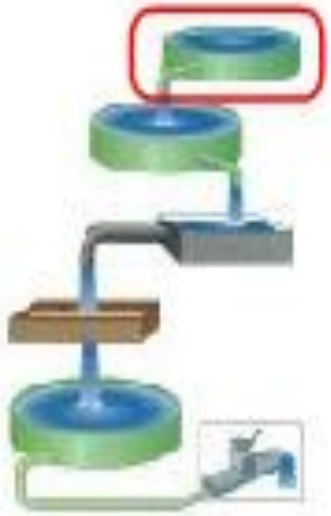
# Water Purification - Catch Basin

Water is collected and stored in a reservoir.

Over time, sedimentation helps to clarify the water.

Copper sulfate may be added as pretreatment to restrict the growth of cyanobacteria and algae.



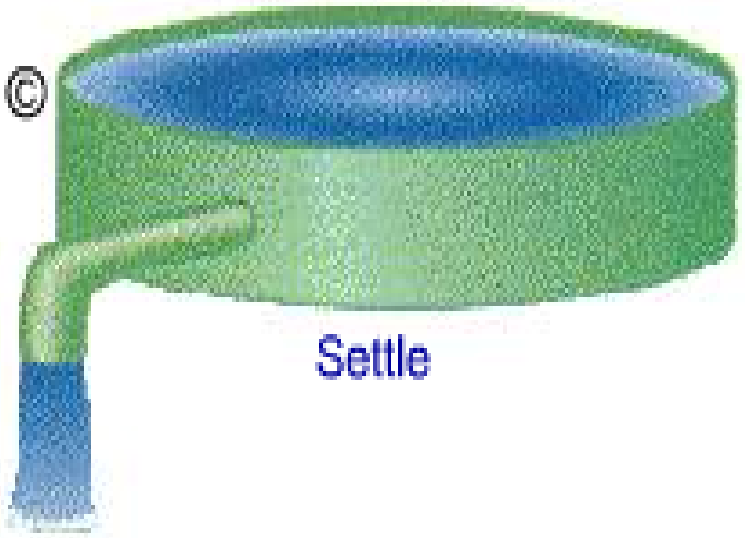



# Water Purification - Holding Tank

Water is pumped into tanks or holding ponds to allow further sedimentation.

Aluminum sulfate (alum) may be added to increase flocculation of organic matter and increase sedimentation.

Aeration may be incorporated to increase microbiologic processing and decrease the organic load of the water.

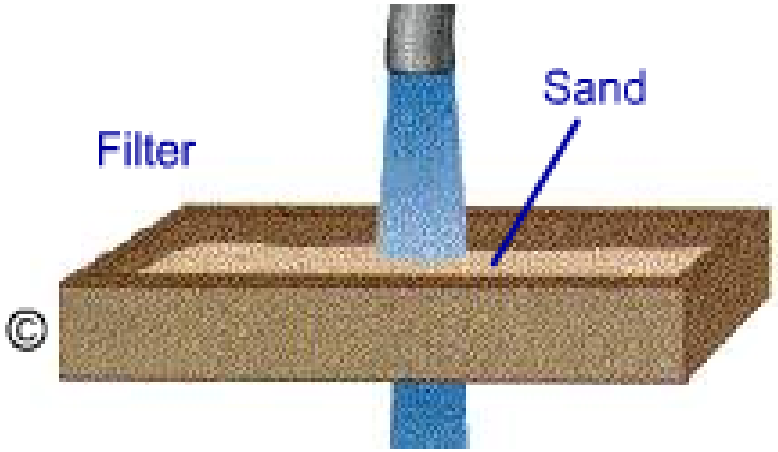


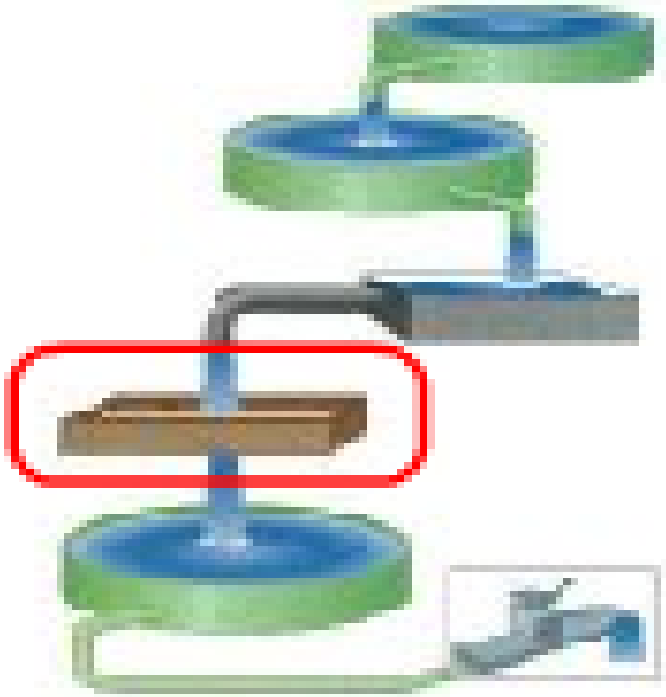

# Water Purification - Filtration

Water is filtered through sand or diatomaceous earth. This filtration step removes most bacteria, viruses and protozoa.

The use of rapid sand filters physically removes up to 99% of bacteria.

However, *Giardia lamblia* and Cryptosporidium cysts as well as viruses are not consistently removed.



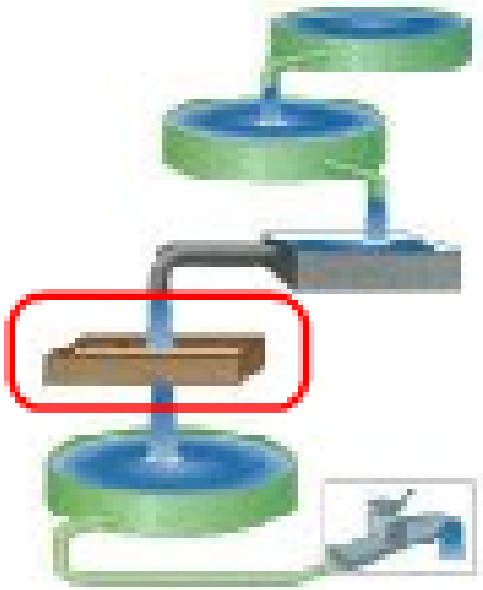
# Water Purification - Filtration

The use of slow sand filters is a more effective filtration system.

It is also a biologic process in contrast to the purely physical process of rapid sand filtration. Water is slowly passed over a bed of sand.

The sand particles are coated by a microbial biofilm to which organisms in the water adhere.

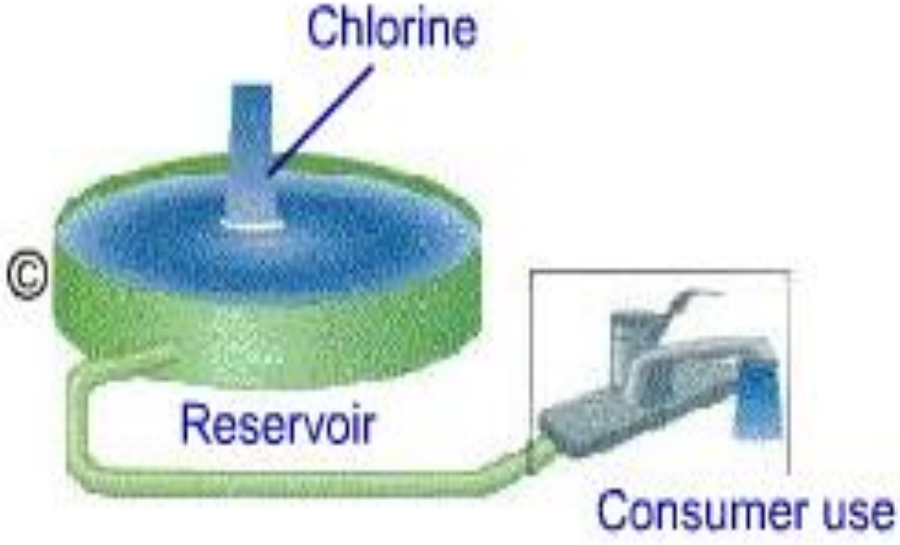
Further passage through activated charcoal removes organic contaminants that may cause odors or taste to the water.

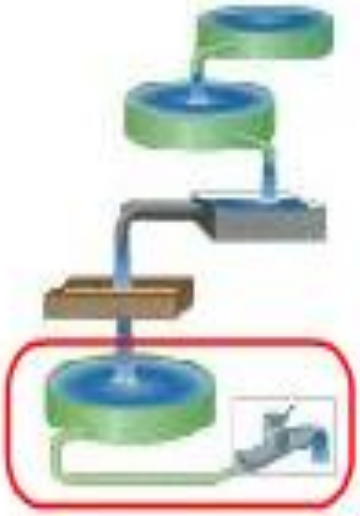


# Water Purification - Chlorination

Water is chemically disinfected (usually with chlorine gas).

Final chlorine concentration of 1-2 ppm ensures safe drinking water with minimal odor and taste.



# Water Purification -
# How Do We Know That The Water is Safe to Drink?

Water sample filtered through membrane filter

Membrane filter removed and placed in petri dish containing appropriate medium



One of the most common methods for detecting indicator organisms has been to filter specific volumes of water and then place the filter onto a selective agar plate.



The organisms are then counted and identified.

# Water Purification -
# How Do We Know That The Water is Safe to Drink?

It is becoming increasingly popular to replace the filter technique with the presence/absence test whereby water samples are inoculated directly into specific broth media and then examined for indicator organisms.

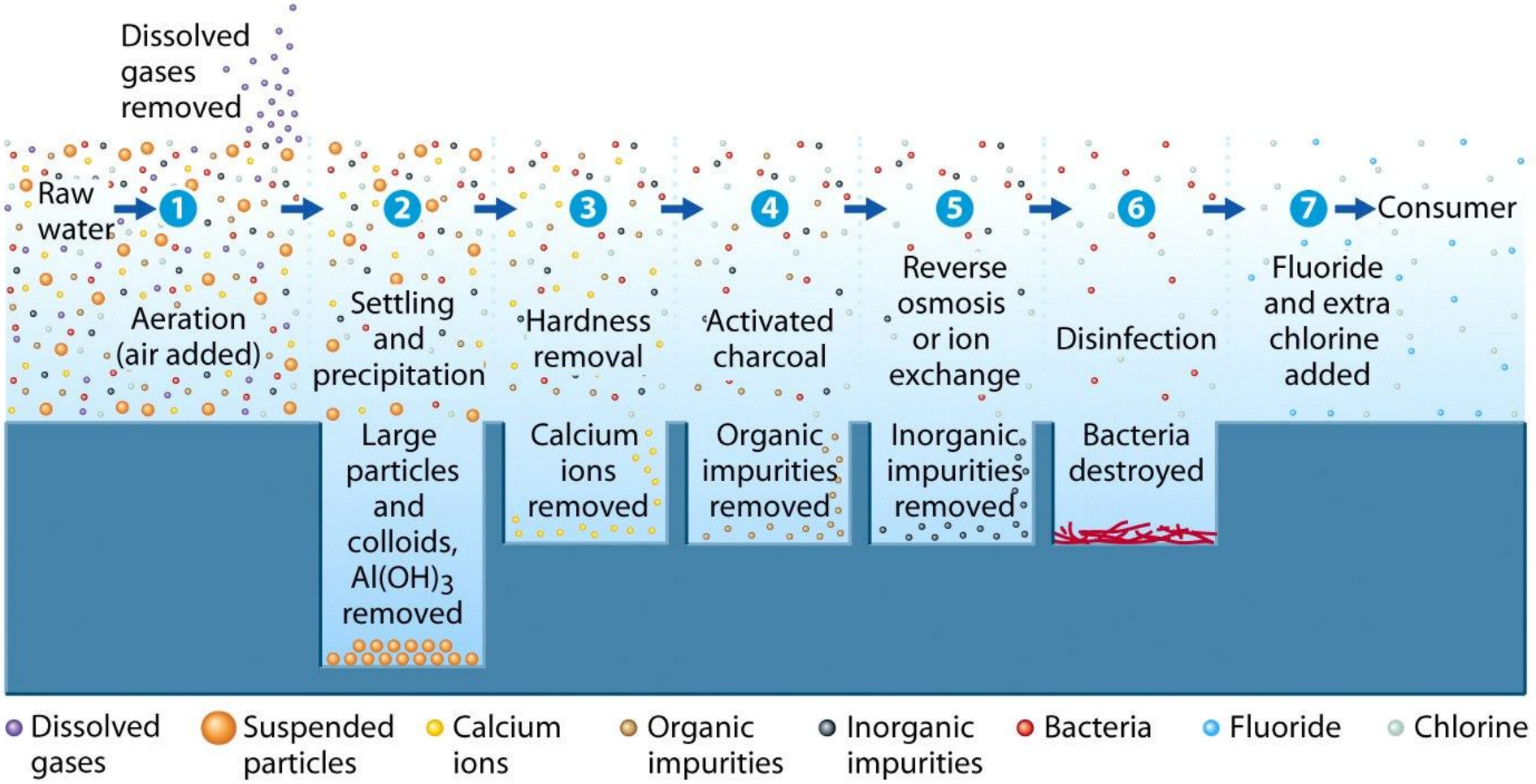
Consecutive or multiple samples containing indicator organisms indicate contamination.

# Water Purification - Standards of Water Safety

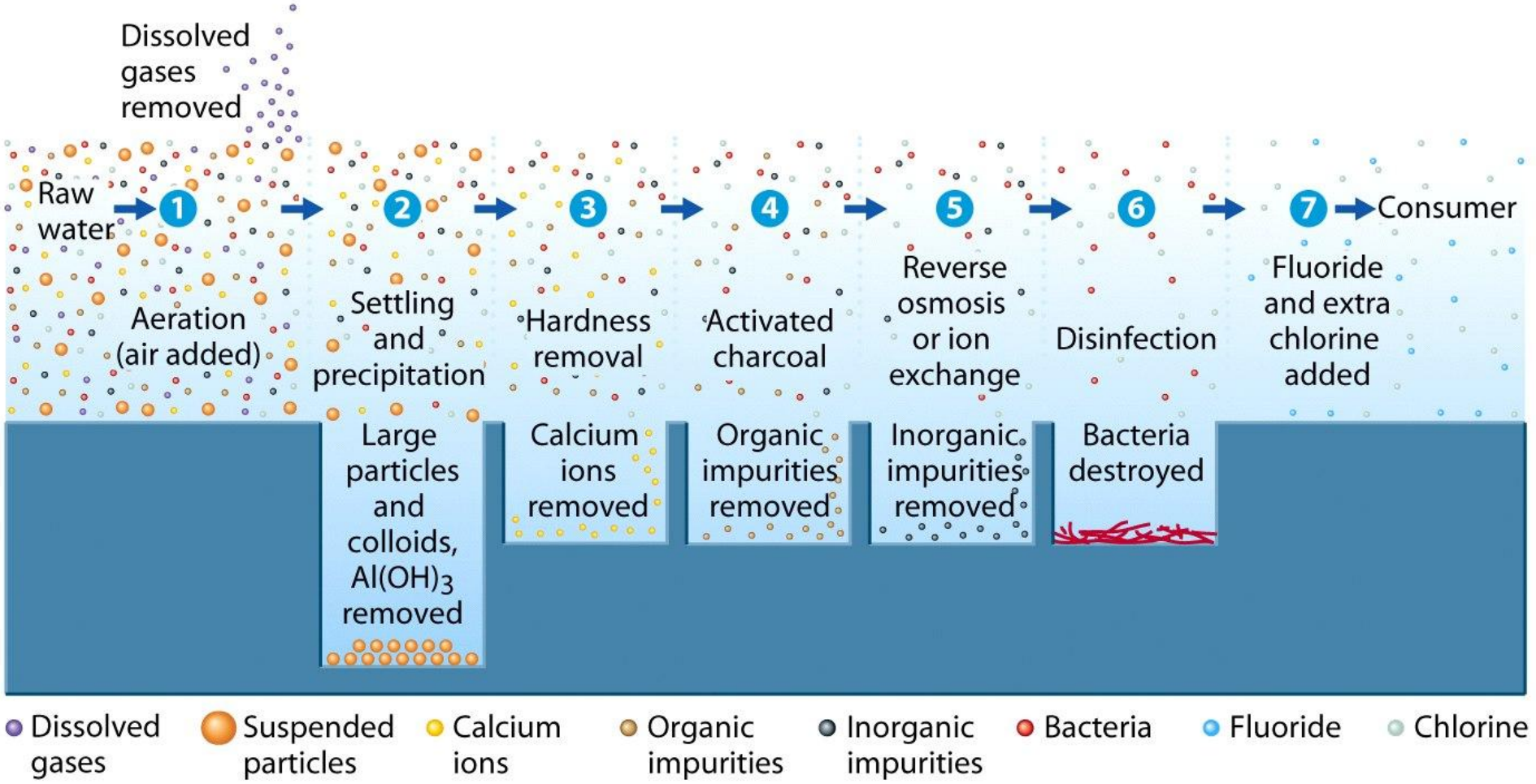
Dependent on the specific government regulation that varies between municipal and private water supplies, water is generally considered safe for drinking if there are either no coliforms or less than 5 indicator organisms per 100 ml of water.

There can be no *E. coli* or Enterococcus species as these strains are only found in the intestines of animals and indicate active contamination either by humans or animals.

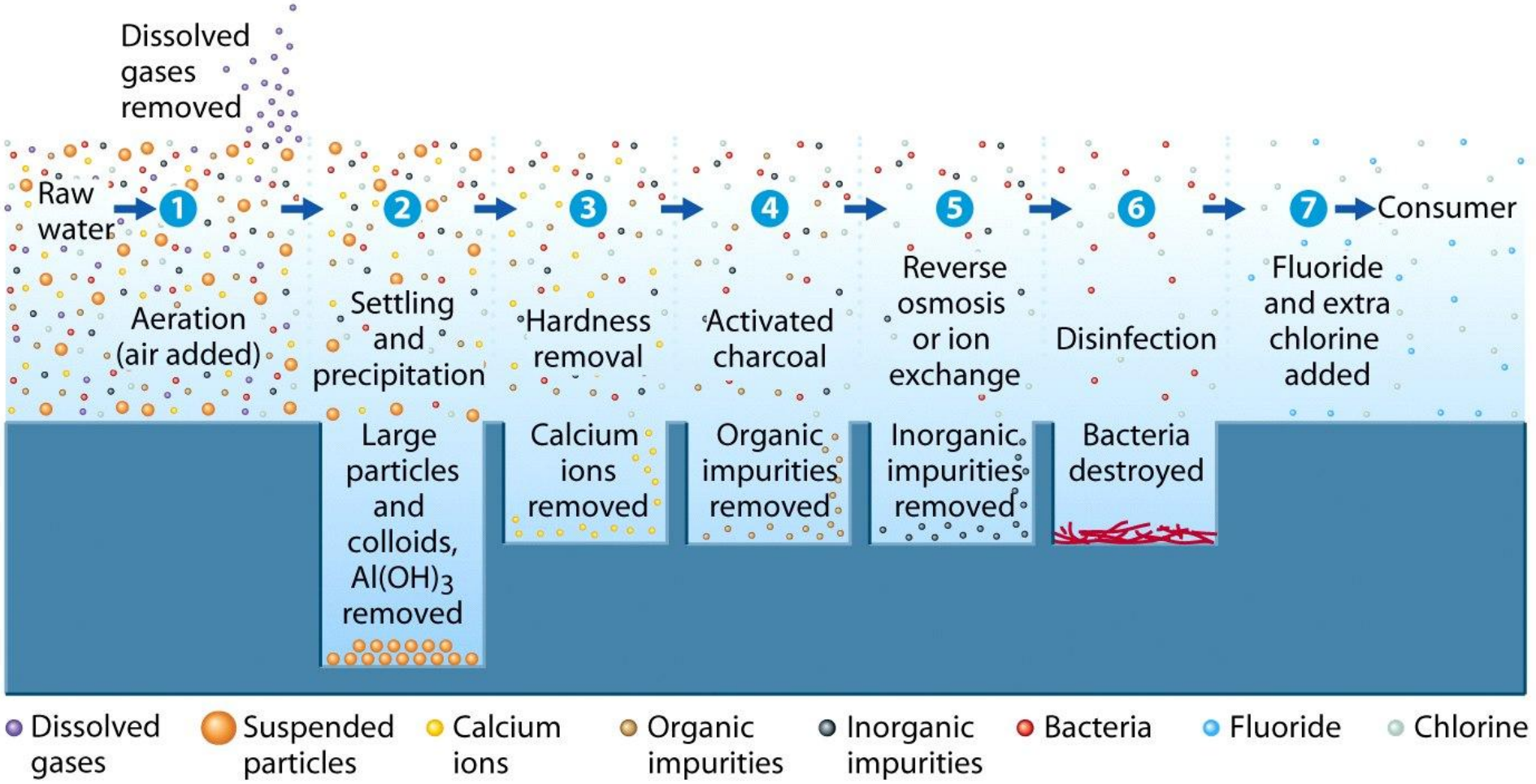
- Purification of Drinking Water (Step 1) - Aeration
  - Bubbling air through raw water removes dissolved gases
    - Hydrogen sulfide & organic compounds containing sulfur
    - Other volatile organic compounds
    - Helps oxidize other organics to carbon dioxide



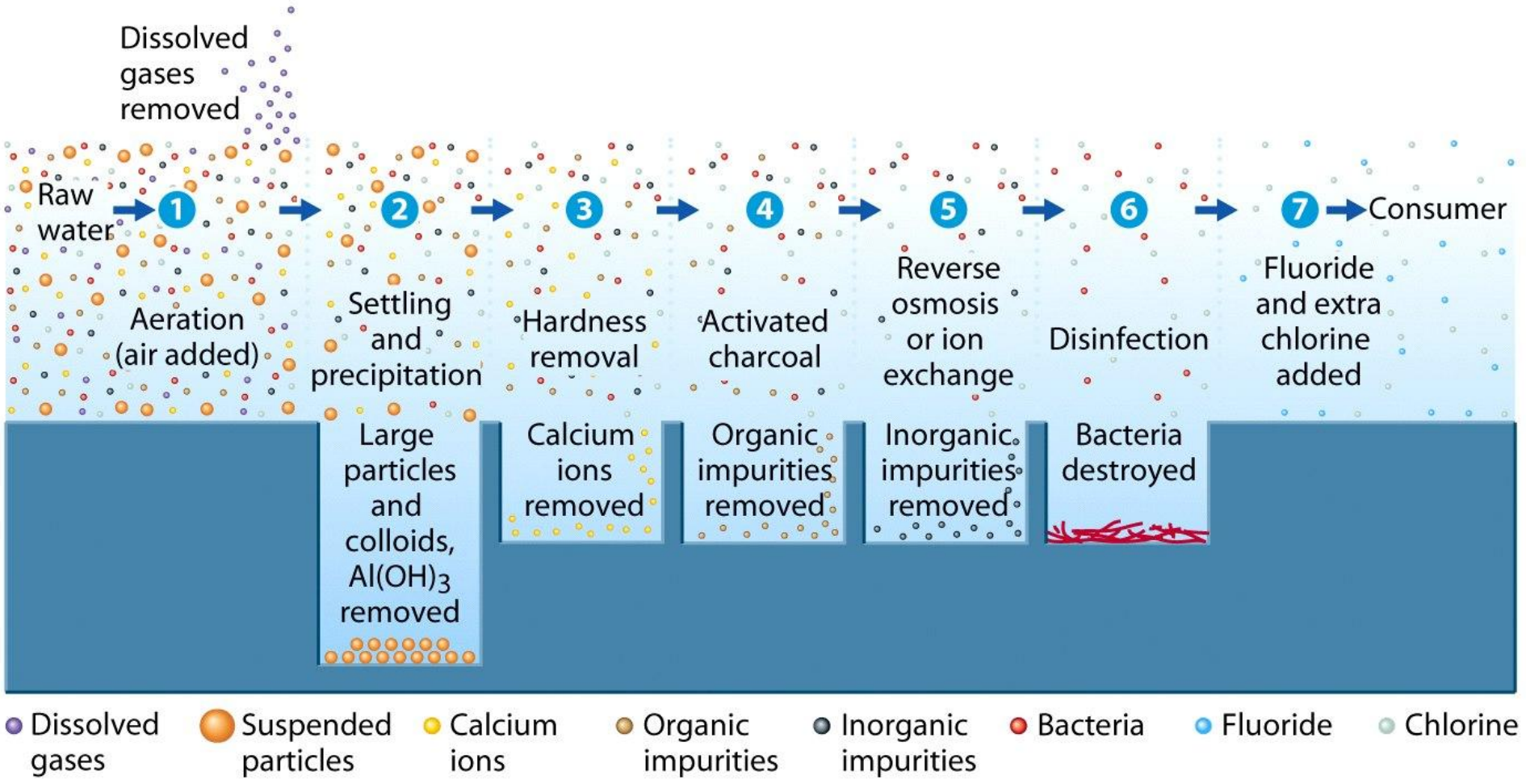
- Purification of Drinking Water (Step 2) - Settling & Precipitation
  - Water contains particles & colloidal material from natural sources
    - Settling allows particles > 1 μm to fall out of solution
    - Smaller colloidal particles (1 - 1000 nm) must be precipitated out
      - Typically negatively charged particles that never coagulate together



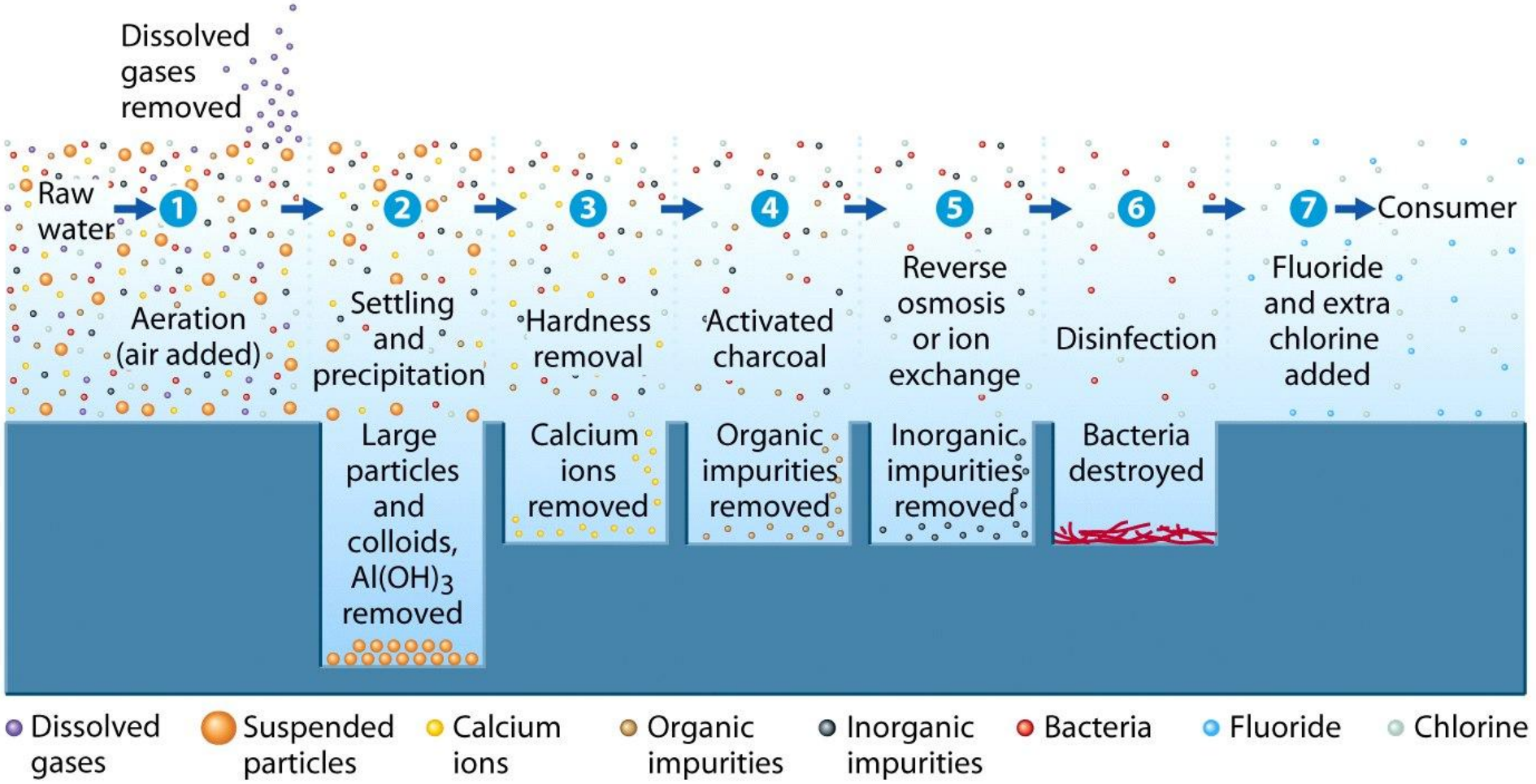
- Purification of Drinking Water (Step 2) - Settling & Precipitation
  - Suspended colloids can be removed using $Al_2(SO_4)_3$ (alum)
    - $Al^{3+}$ attracts negatively charged colloids
    - When pH is increased (addition of a base like *lime*, $Ca(OH)_2$)
      - $Al^{3+} + 3\ OH^- \longrightarrow Al(OH)_3\ (s)$



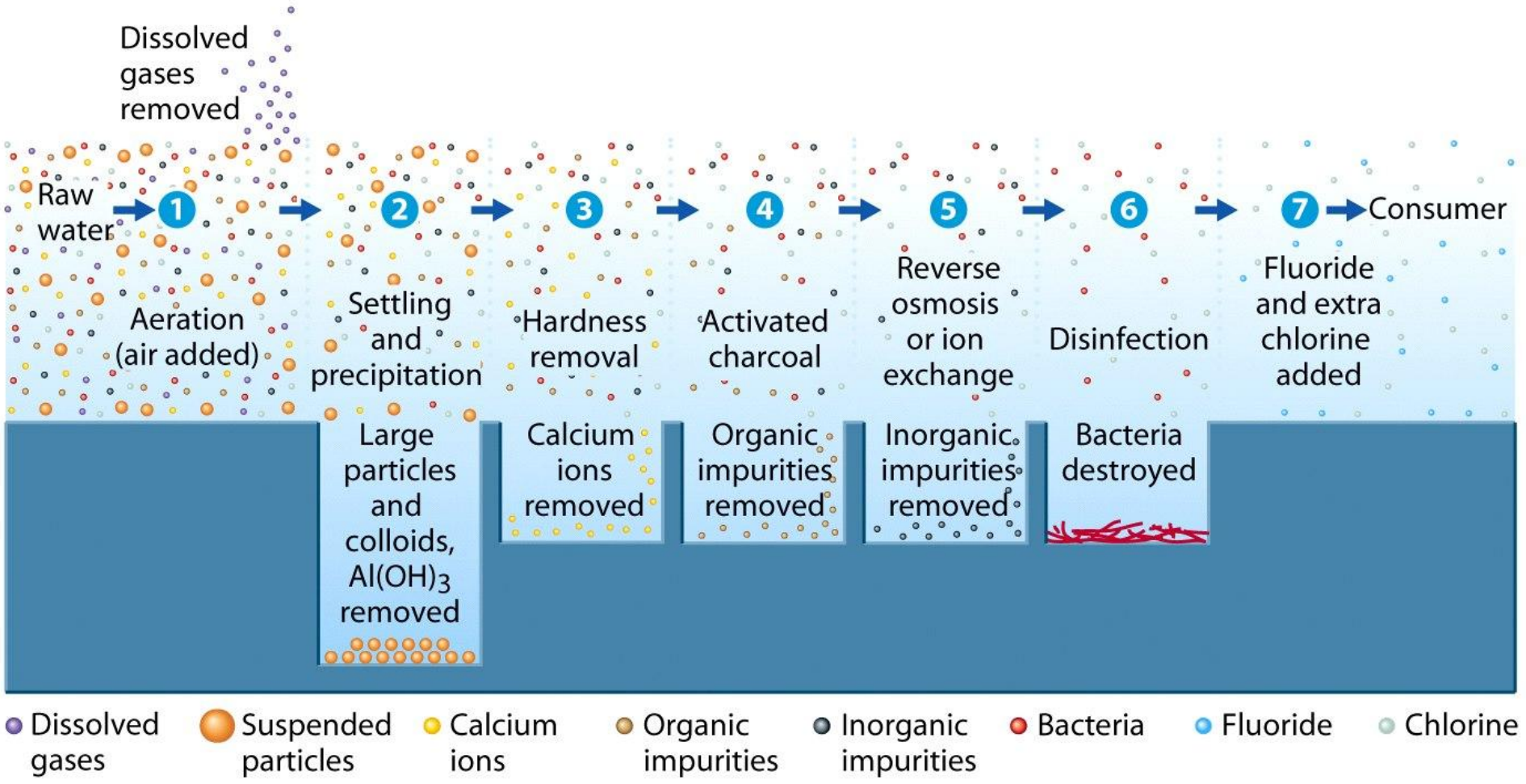
- Purification of Drinking Water (Step 2) - Settling & Precipitation
  - As you know $Al(OH)_3$ is gelatinous
    - Particles are trapped in sticky gel and precipitate out. Any remaining particles are filtered through bed of sand
    - Clarified water is better because it is aesthetically pleasing and particles adsorb toxins and microorganisms that cause disease



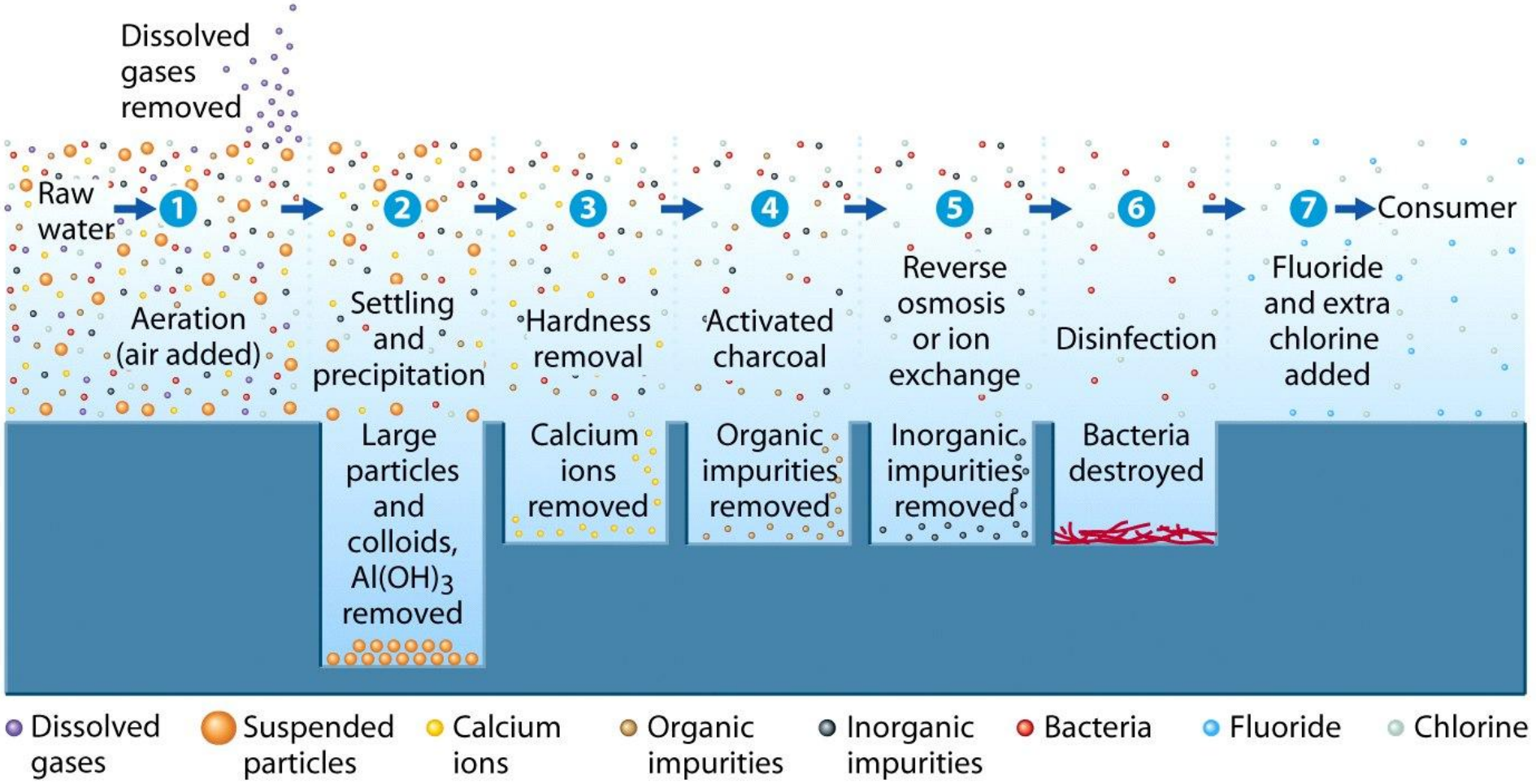
- Purification of Drinking Water (Step 3) - $Ca^{2+}$ and $Mg^{2+}$ removal
  - Calcium and magnesium ions make water hard.
    - Hard water precipitates soap - leaves soap scum and no lather
    - Remove $Ca^{2+}$ by precipitation with phosphate or carbonate
    - Remove $Mg^{2+}$ as hydroxide (by increasing pH)

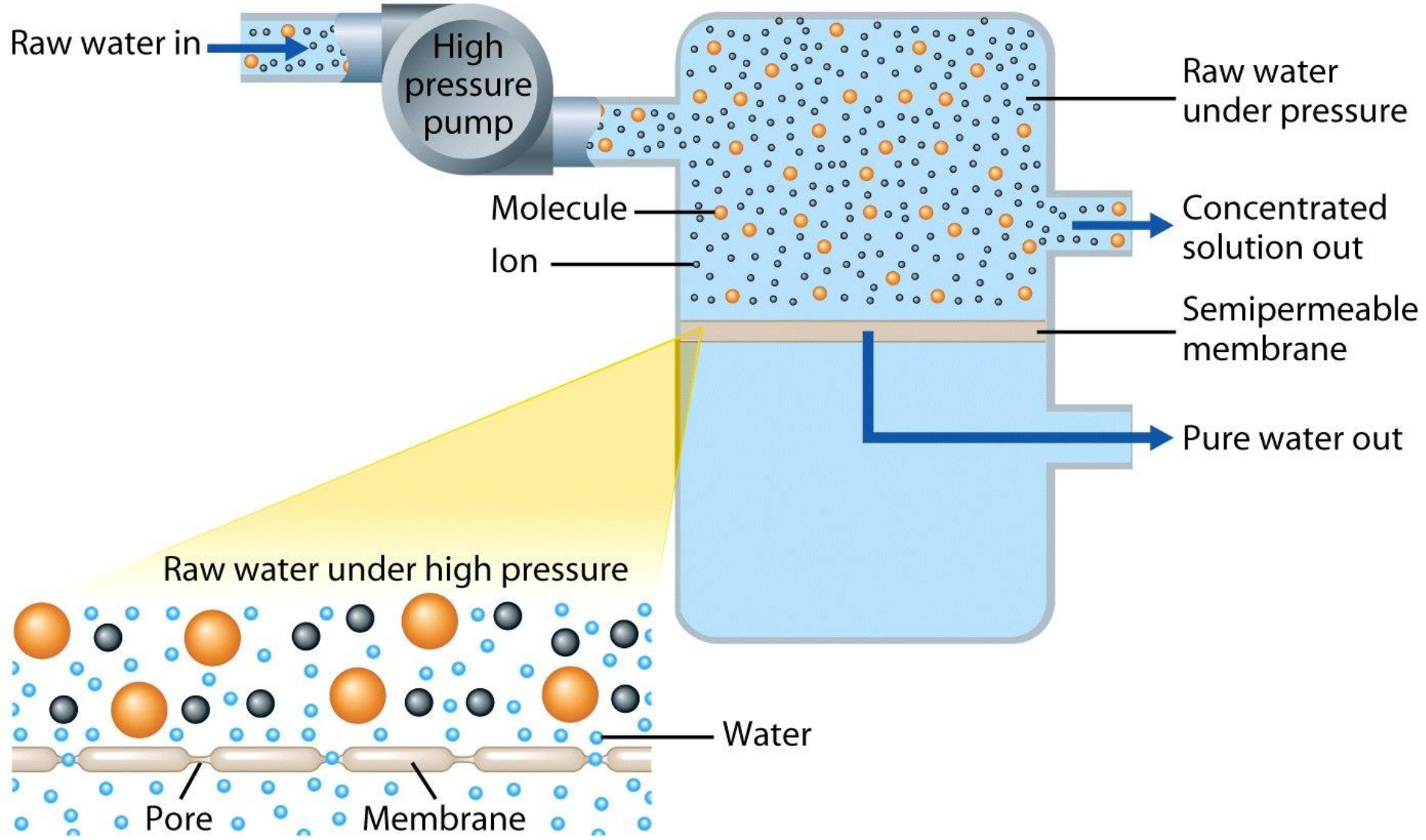


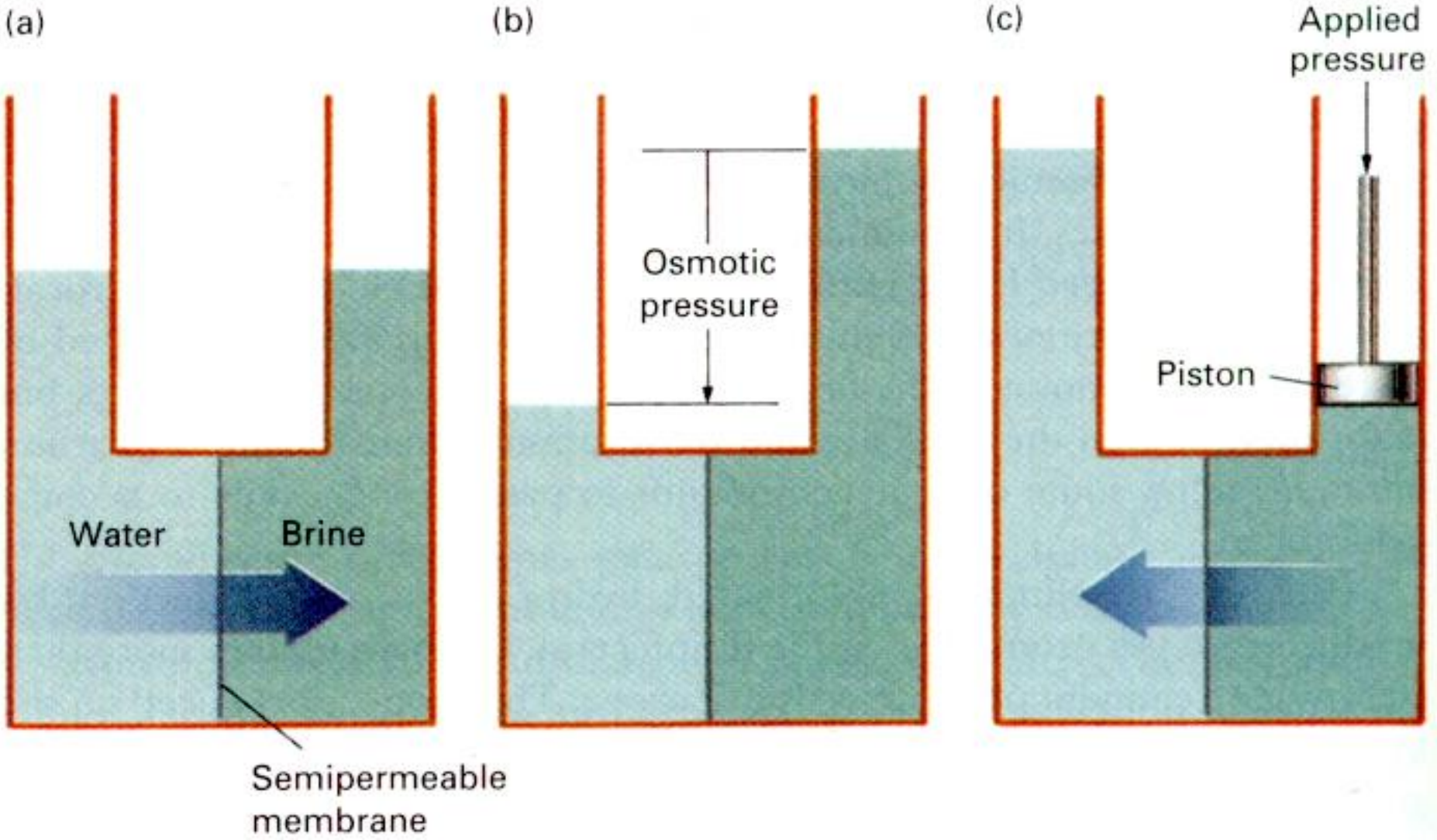
- Purification of Drinking Water (Step 4) - Remove Organic Material
  - Filter out organic pollutants by adsorption onto activated carbon
    - Removal of organics improves water odor, taste, and purity
    - Removes pesticides, chlorinated solvents.
    - Activated carbon filters used in homes commonly to filter tap water.
    - These filters have to be discarded when all adsorption sites occupied.



- Purification of Drinking Water (Step 5) - Reverse Osmosis
  - Ions are removed by reverse osmosis
    - Water is passed through semi-permeable membrane
    - Membrane passes solvent (water) but doesn't pass solute (ions)

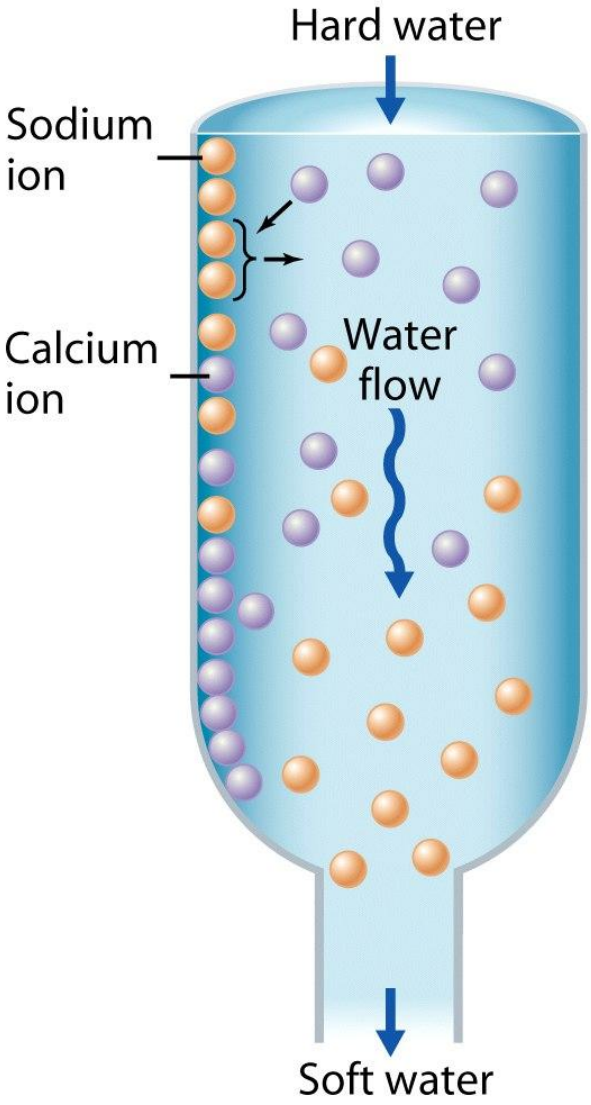



Raw water in
High pressure pump
Raw water under pressure
Molecule
Ion
Concentrated solution out
Semipermeable membrane
Pure water out
Raw water under high pressure
Water
Pore
Membrane

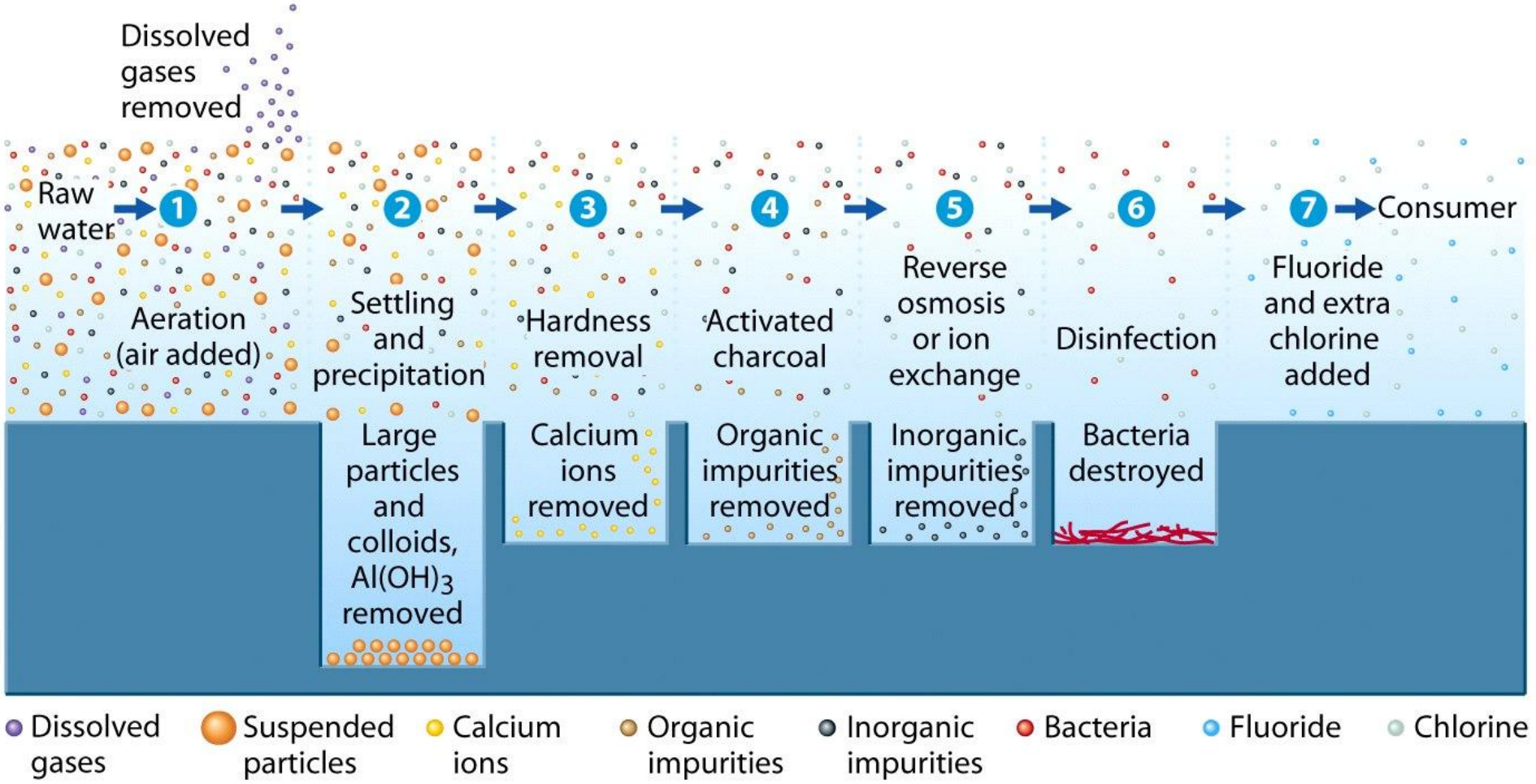



Joesten & Wood, World of Chemistry: Essentials, 2nd Ed.: Saunders, Orlando, FL, pg.412

- Softening of Drinking Water (Step 5) - Ion Exchange
  - Calcium and Magnesium make water hard. If you can exchange sodium ions for calcium and magnesium then water is soft
    - Can remove ions by reverse osmosis or exchange for softer ions using ion exchange resin
    - Resin is a negatively charged polymer with positively charged ions like sodium
    - Sodium is singly charged
    - Calcium and magnesium are doubly charged
    - Resin prefers to interact with more highly charged ions
    - Sodium is released from resin and water is softened.
    - Resin must be regenerated with sodium ions periodically



- Purification of Drinking Water (Step 6) - Disinfection by Chlorination
  - Previous five steps don't remove many bacteria and viruses
    - Must kill them with chemical treatment
    - Either chlorination or ozonation
    - Also can used physical treatment (UV light or boiling)
      - Boiling is expensive and not done on large scale



- Purification of Drinking Water (Step 6) - Disinfection by Chlorination
  - Hypochlorous acid (HOCl) is active chlorination agent
    - Active ingredient in bleach!
    - However, HOCl is not stable in concentrated form so it is prepared from chlorine
    - $Cl_2\ (g) + H_2O\ (l) \rightarrow HOCl\ (aq) + H^+\ (aq) + Cl^-\ (aq)$