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TiO_2: Water Treatment

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2: Water Treatment – What techniques are used to make water safe to drink?

In Britain almost every house is connected to a central water supply. We turn on the tap and the water flows. We need have no fear that tap water is impure or unsafe because we know it has been properly purified and treated with chlorine to kill microorganisms. Creating a system that delivers a reliable supply of safe drinking water to a nation like the UK requires a truly phenomenal amount of infrastructure, investment, knowledge and skill. Water companies collect water from a variety of sources and treat the water in several stages, before it is delivered to our houses through a network of pipes.

In many developing countries, water has to be collected from untreated sources such as rivers, lakes or wells. To make it safe, it needs to be treated by householders. We call this point of use (POU) treatment.

Where does our drinking water come from?

The three major sources for our water supply are:

- Aquifers – underground layers of water-bearing, permeable rock.

  Water travels slowly through permeable rock and impurities are filtered out. It is extracted through wells and is usually very pure. The land area around wells has to be carefully managed to avoid contamination with sewage, toxins from waste or chemicals from agriculture.

- Rivers

  River water can be fairly impure and needs to go through several stages of treatment to remove suspended particles and chemical contamination.

- Water from upland areas collected in reservoirs.

  This type of water is usually purer than river water but, as it is collected in peaty areas, is often brown in colour and contains dissolved iron or manganese ions which have to be removed.

Water from all sources has to be disinfected in the final stage of treatment. In almost all treatment works in Britain, this is done by adding chlorine.

Currently used water treatment techniques

Untreated water contains particles of different sizes, as well as dissolved ions, organic molecules, such as solvents, agrochemicals or dyes and microorganisms.

If the water is left to stand for a while, larger particles will settle to the bottom.

Flocculation

It is more difficult to remove suspended particles because they are not heavy enough to sink to the bottom. Metal ions are used to bind together several small particles to make larger particles which will then be heavy enough to sink to the bottom. This is called flocculation. This is where particles suspended in a solution separate out to form flakes.

Raw water contains suspended colloidal particles; often large negatively charged organic molecules that have been washed out of the soil or are breakdown products of leaves and plants.

Aluminium sulfate is a good flocculating agent and can be used to remove colloidal particles.

The Al^{3+} ion is a small ion with a high charge density. It attracts large negative ions to itself and forms a floc, a large particle that cannot be suspended in the water anymore.

The large particle can then be removed from the water under treatment. It can either be filtered out or left to settle as a sediment.

Adding the right amount of aluminium sulfate has to be carefully judged. There must not be more than 15 mg dm^{-3} left in the treated water. Concentrations above this are a health hazard.

Iron(II) sulfate or iron(III) chloride can also be used a flocculating agents. These salts are cheaper than aluminium sulfate. They work on the same principle: the Fe^{2+} or Fe^{3+} ions are small ions with a high charge density. They attract large, negatively charged ions and form large flocs. The treatment with iron salts does tend to give the water a slight metallic taste and it can also lead to staining of porcelain wash basins.

Filtration

In large scale water treatment works sand filters are used, sometimes enriched with activated carbon. This is carbon which has been specially treated to create a very porous material with a large surface area to volume ratio. 1 gram of activated carbon has a surface area of about 500 m^2. Activated carbon is very good at adsorbing organic molecules. Inorganic ions like metal ions or nitrate ions do not stick to the surface of activated carbon easily, so they are not adsorbed.

Micro-filter membranes are becoming more common and are useful for smaller scale operations. They use membranes with a particle size of 0.1–10 micrometers. They filter out small particles and even large bacteria.

Disinfection with chlorine

Chlorine is the most widely used drinking water disinfectant. It was first used about 100 years ago and, in countries with good water treatment infra-structure, has almost eliminated waterborne diseases.

Elementary chlorine is a powerful oxidising agent and can oxidise most chemicals.

When chlorine is added to water, this reaction takes place:

$$Cl_2 + H_2O \rightarrow HCl + HClO$$

This is a disproportionation reaction. The chlorine atoms that form HCl are reduced and the chlorine atoms that form HClO are oxidised.

Chloric acid or hypochloric acid (HClO) is a weak acid and partially dissociates in water:

$$HClO \leftrightarrows H^+ + ClO^-$$

The hypochlorite ion (ClO^-) can enter the cell wall of micro-organisms and change the structure of enzymes in the cell wall. The cell wall develops holes and is destroyed.

The amount of chlorine added in water treatment has to be enough to leave a residual amount of chlorine of about 40 mg dm^{-3} so that some chlorine remains in the water for 24 hours.

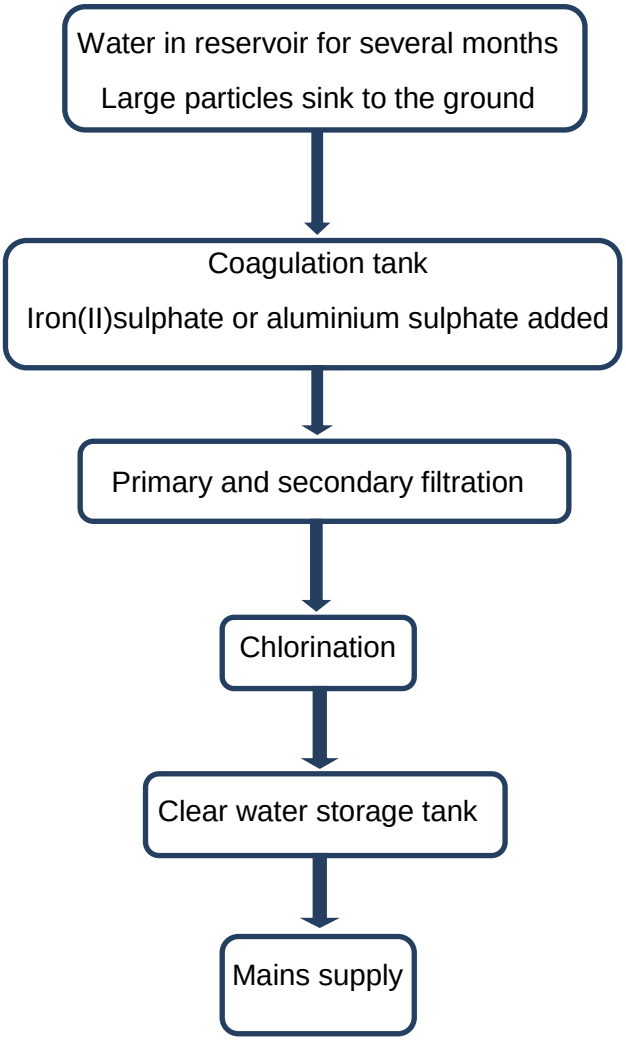

Figure: Flow diagram of current water treatment techniques.

POU water treatment

In situations where properly treated tap water is not available, water should be treated in the household, at the point of use. A range of POU treatment methods are available.

Most require a certain amount of operator knowledge or education and resources:

- Chlorine based tablets or chlorine bleach. This is fairly cheap, effective and easy to use.
- Iodine based tablets. They are suitable for recreational and short-term use. Over longer periods, the excess iodine may cause thyroid problems.
- Ozone treatment. This is an effective method. It leaves no residue, which can be seen as both as an advantage or a disadvantage. This method requires expensive mercury vapour lamps to generate the ozone in the presence of oxygen.
- Various types of filters: membrane, porous, ceramic or composite filters. Eventually, the filters have to be changed or disinfected.
- Boiling the water. A simple method, but very energy intensive.
- Various methods of solar disinfection.

It is also very important that clean or treated water is stored properly. Closed containers with taps or spouts are best. The narrow openings prevent contact with dirty hands which could cause re-contamination of the water.

Solar disinfection has the potential to be a good method for POU water disinfection because the sun's energy is used to kill microorganisms with no further energy requirements. Simple solar disinfection can be improved by using titanium dioxide as a photocatalyst.