

Polluted water can contain many disease-causing organisms such as bacteria, viruses and parasites. Examples of such diseases are cholera, typhoid fever, hepatitis and dysentery. Major sources of pollutants are plant nutrients (phosphates and nitrates) and sediment. Sediment does not directly affect the quality of the water but it can help to transport harmful substances such as pesticides. This lesson describes the process of water treatment and describes the different stages involved.

Fig.1 Water suitable for drinking after treatment



To be suitable for consumption, water must fulfil certain criteria. It must be free from any *micro-organisms* and *parasites* that could be a danger to health and must meet specified *water quality standards*. The colour, odour and taste must also be acceptable to consumers. Most public water supplies must be *fluoridated*. In order to ensure the quality of our drinking water, the water must be treated and the quality must be constantly monitored to ensure that contaminated water is not consumed.

Where does our water come from?

Approximately 80% of our drinking water is sourced from surface water such as rivers, lakes and reservoirs. The other 20% of water comes from underground sources such as springs and wells.

Where is water stored?

Surface water is usually stored in large *reservoirs* before it is taken into a water treatment plant. Before it enters the treatment plant the water is often stored in large holding tanks or ponds to allow any suspended solids to settle. This also allows water to be *biologically degraded* by micro-organisms. At the same time the *UV radiation* in sunlight destroys some bacteria. However, if water is stored for too long it can become polluted by the atmosphere, by bird droppings, or by *algal growth*.

How is the water treated to make it suitable for drinking?

Screening

Water is passed through coarse screens where large floating debris (twigs, plastic bags etc.) are removed. The water is then passed through fine screens which remove much of the algal content. The water passes into large *settling tanks* where solids are allowed to settle.

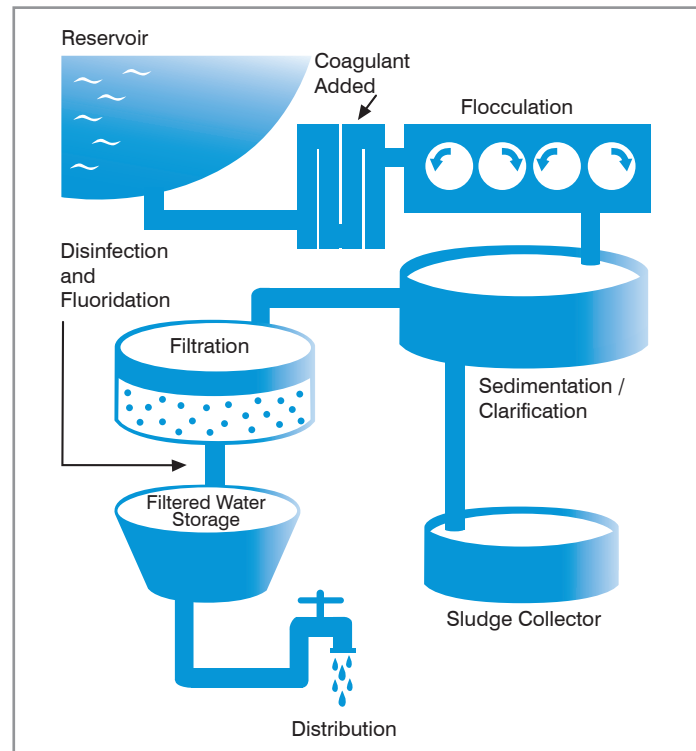


Fig. 2 Outline of water treatment process

Flocculation

This is the *coagulation* of finely divided particles into particles of greater size called *flocs* – hence the name flocculation. A *flocculating agent*, *aluminium sulphate*, $\text{Al}_2(\text{SO}_4)_3$, is added. It is most effective in the pH range 5.5 – 8.0. The flocculating agent is thoroughly mixed with the water and this causes the small suspended solids and organic matter to coagulate, forming larger particles. Sometimes *polyelectrolytes* are added to speed up the coagulation process. Polyelectrolytes are long chain molecules from which ions have been lost, leaving a charge on the *macromolecule*. Polyelectrolytes also help coagulation by preventing the filters from becoming clogged with small particles.

Sedimentation/Clarification

The flocculated water is passed into the bottom of a series of large *settling or sedimentation tanks* where it rises very slowly. The heavy solid particles settle at the bottom of the tank under gravity; this process is called *sedimentation (or clarification)*. The clear water then rises to the surface where it is collected in channels that carry it on to the next tank. The sludge that remains on the bottom of the settlement tanks is removed. It must be handled carefully and disposed of in accordance with environmental regulations.

Filtration

At this stage almost 90% of solids have been removed. The final 10% are removed by passing the water from the settlement tanks through large sand filters, consisting of beds of sand, approximately 1 metre thick, with fine sand on top and coarse sand below, all supported on a layer of gravel that is on top of a bed of large stones. This rapid sand filter produces water that is now free of solids but may still contain harmful bacteria.

When the filters become clogged they are cleaned by *back washing*, i.e. pumping water and air up through them. The filtered solids rise with the water and flow over the top where they can be collected and disposed of in a similar way to the sediment from the settlement tanks. The sand and gravel re-settle in the correct order.

Slow sand filters are also used in some treatment plants in Ireland. These filters allow for both physical and chemical action. In a slow sand filter water slowly percolates down through the sand. Fine particles, micro-organisms, and microscopic plant life are retained in the sand bed. The slow sand filter produces high quality water, which needs little further processing. The sand bed must be emptied regularly for cleaning.

Chlorination

Chlorine acts as a *sterilising* agent. The addition of chlorine or chlorine compounds causes *oxidation*, killing most *pathogenic* micro-organisms present in the water.

A common method of chlorination involves the addition of *sodium hypochlorite* (NaOCl) to water. It reacts with water to form *hypochlorous acid* (HOCl) which is a very effective disinfectant.



Elemental chlorine (Cl_2 gas) is toxic in high concentration. Therefore it is used under strictly controlled conditions and a chlorine gas alarm is located in the vicinity of the storage and usage area.

Chlorine is only required in very small amounts, approximately 0.2 – 0.5 *p.p.m.* If too much chlorine is added it gives an unpleasant taste and smell, similar to swimming pool water. However, sufficient chlorine must be added to kill most bacteria present and to prevent recontamination before the water reaches our taps.

Fluoridation

It has been shown that fluoridated water helps to prevent the decay of tooth enamel. In the past, fluoride concentration of 1.0 *p.p.m.* appeared to give maximum benefit. However, it was recently recommended that the level of fluoride to be added to water be reduced to between 0.6 and 0.8 *p.p.m.*

Here in Ireland, *hydrofluosilicic acid* (H_2SiF_6) is the chemical used to fluoridate water. Other chemicals that can be added to water as a source of fluoride ions, F^- , include simple salts such as *sodium fluoride* (NaF), and calcium fluoride, (CaF_2). The compound *sodiumhexafluorosilicate*, (Na_2SiF_6), is commonly used as a fluoridation agent in other countries.

pH adjustment

The *pH* of a solution is a measure of the concentration of the hydrogen ions present in the solution. Ideally tap water should have a pH range of six to eight. If the water is too acidic (pH less than 6) it could cause corrosion of the water pipes resulting in the addition of toxic lead or copper compounds to the water. The acidity is reduced by adding a basic substance such as lime (calcium hydroxide, $\text{Ca}(\text{OH})_2$). Lime is used as a *neutralising agent* but it can lead to hardness in water if too much is added. If the water is slightly basic (pH above 7) the pH will need to be reduced to prevent limescale build-up. *Dilute sulphuric acid* (H_2SO_4) or *carbon dioxide* (CO_2) can be used to neutralise the base. The pH may be adjusted at any point in a treatment plant but it is generally done before fluoridation and the final filtration.

Storage

The water is usually stored in storage reservoirs to prevent contamination.

The Environmental Protection Agency (EPA) is an independent public body established under the Environmental Protection Agency Act, 1992. The EPA regulates and polices activities that might otherwise cause pollution. It ensures there is solid information on environmental trends so that necessary actions are taken. The EPA's priorities are protecting the Irish environment and ensuring that development is sustainable. It employs over 290 people who work in ten locations throughout the country.

The other main instruments from which it derives its mandate are the Waste Management Act, 1996, and the Protection of the Environment Act, 2003. The EPA has a wide range of functions to protect the environment. Its primary activities include:

- Environmental licensing
- Enforcement of environmental law
- Environmental planning and guidance
- Monitoring and reporting on the environmental status - air, water, waste, noise, land and soil
- Environmental research

The EPA's mission is to protect and improve the natural environment for present and future generations, taking into account the environmental, social and economic principles of sustainable development.

Water quality standards and monitoring requirements are set out in the European *Drinking Water Regulations 2000*. Each City and County Council must comply with these regulations and submit reports to the *Environmental Protection Agency (EPA)* every year.

You can find out more about the work of the **Environmental Protection Agency** at www.epa.ie or at www.sta.ie

How is water quality monitored?

The pH of water is constantly monitored throughout the treatment process. The water is also tested regularly for *E.coli* and other *coliform* bacteria. Wells are also checked for the presence of bacteria and agricultural effluent. Some places have fish in tanks near the outflow. The movement and behaviour of these fish is constantly monitored as they are very sensitive to impurities and become agitated if the water quality drops. Too much movement indicates poor water quality.

Syllabus Reference

Leaving Certificate Chemistry

Section 9.3 – Environmental Chemistry

Junior Certificate Science

Unit 2B3 – Types of Water Treatment

Learning Objectives

On completing this lesson students should be able to:

- Outline the process of water treatment used in Ireland
- Discuss each stage of the treatment process in detail
- Be aware of the need to protect and conserve our water
- Be aware of the benefits of having a reliable source of clean and safe water
- Understand the effects of consuming contaminated water.

General Learning Points

- Approximately 80% of our drinking water is sourced from surface water such as rivers, lakes and reservoirs. The rest comes from wells and underground sources of water.
- The main stages in water treatment are screening, flocculation, sedimentation (clarification), filtration, chlorination, fluoridation and pH adjustment.
- Chlorine is added to water to kill bacteria and fluorine is added to prevent tooth decay.
- Bacteria, viruses and parasites are all organisms that can contaminate water.
- Polluted water can cause such diseases as cholera, typhoid fever, hepatitis and dysentery.

Practical Activities

Mandatory Experiment – Leaving Certificate

To determine:

- (a) the amount of suspended solids (in p.p.m.) of a sample of water by filtration
- (b) the total dissolved solids (in p.p.m.) of a sample of water by evaporation
- (c) the pH of a sample of water.

Mandatory Experiment – Junior Certificate

OC30 – Conduct a qualitative experiment to detect the presence of dissolved solids in water samples, and test water for hardness (soap test).

True or False

Indicate whether the following are true (T) or false (F) by drawing a circle around T or F.

- | | |
|--|-----|
| (a) The main source of water in Ireland comes from underground wells. | T F |
| (b) Lime is added to purify water. | T F |
| (c) Untreated water is stored in settlement tanks. | T F |
| (d) Elemental chlorine can be used in water treatment. | T F |
| (e) Chlorine is added to give water a pleasant taste. | T F |
| (f) Bacteria are killed by adding chlorine. | T F |
| (g) Flocculation is the coagulation of small particles into larger ones. | T F |
| (h) The ideal pH for water is 9. | T F |
| (i) Fluorine is added to make our bones stronger. | T F |
| (j) Water quality checks are an ongoing process. | T F |

Check your answers to these questions on www.sta.ie

Examination Questions

2006 Leaving Certificate Higher Level

In the treatment of water for drinking, what is meant by the term flocculation?

Name a flocculating agent.

What substance is added to water to adjust the pH if the water is too acidic? Why is it undesirable to have the pH of water below 6?

2006 Leaving Certificate Ordinary Level

The treatment of drinking water for an urban supply consists of a number of stages. In the case of **any three** of the stages in the treatment process, state the treatment involved and why it is carried out.

2005 Leaving Certificate Ordinary Level

The following words all refer to stages in water treatment. These words are omitted from the passage below:

chlorination	filtration	flocculation
pH adjustment	fluoridation	sedimentation

Write in your answer book the omitted words corresponding to each of the numbers 1 to 6.

Aluminium sulphate and / or a polyelectrolyte is added to water to help suspended solids clump together in a process called ____1____. Follow ing this addition the suspended solids are allowed to settle to the bottom of the ____2____ tanks. Bacteria in the water are destroyed by ____3____. Lime or acid is added to carry out ____4____. In Ireland ____5____ of water is carried out in urban supplies to help prevent tooth decay. The water is passed through beds of sand and gravel to remove any remaining suspended solids in a process called ____6____.

2004 Junior Certificate Higher Level

Give two ways in which water is purified before it is piped to our homes.

2003 Junior Certificate Higher Level

Why is fluoride added to water for domestic use?

For further examples of past paper questions
check www.sta.ie

Did You Know?

- The overall level of compliance with the 48 drinking water standards for public water supplies and group water schemes in Ireland in 2004 was 96.3% (97.6% for public water supplies and 90.6% for group water schemes).
- Domestic consumption accounts for over 60% of total demand of water in Ireland. Agricultural, commercial and industrial use account for the remaining 40%.
- Toilet flushing accounts for approximately 27%, personal washing uses up 38%, clothes washing 10% and dishwashing 7% of total domestic water demand.
- You can significantly reduce the amount of water you use for flushing by placing a drinks bottle full of water into the cistern of your toilet.
- Fluoridation of drinking water is carried out in Ireland, USA, Canada, New Zealand, Brazil, and parts of Eastern Europe. It is not carried out in Northern Ireland.
- The Forum on Fluoridation, established in 2000 by the Minister for Health Micheál Martin TD, recommended that the concentration of fluoride in water should be reduced because of the risk of developing a dental condition called “fluorosis”. A possible cause for this is the increased use of fluorine-containing compounds such as toothpaste and mouthwash.

- In Eastern Africa, the Masai tribe use UV radiation from sunlight to purify water. They put water in plastic bottles on the roofs of their huts and leave it for several hours. This kills most bactreia present, making the water much safer to drink.
- In 2002 over 1.1 billion people, 17% of the global population, did not have access to safe drinking water.
- Every year over 1.5 million people die from diarrhoeal diseases (including cholera) caused by the consumption of contaminated water. 90% of which are children under 5, mostly in developing countries.
- In Ireland we are fortunate enough to have a constant supply of clean water suitable for consumption at all times. It is estimated that each household in Ireland consumes approximately 300 litres of water each day.

Biographical Notes

Søren Peter L. Sørensen (1868 – 1939)

The pH scale was devised by Sørensen, a Danish biochemist as a measure of the hydrogen ion concentration of an aqueous solution. From 1901 he was head of the prestigious Carlsberg Laboratory, Copenhagen. He introduced the concept of pH, a scale for measuring acidity. Because the concentration of hydrogen ions (H^+) varies so widely in solutions, a logarithmic is needed to express it concisely. Mathematically the $pH = -\log[H^+]$. Pure water has a pH of 7, acidic solutions have a pH of less than 7 and alkaline solutions have a pH greater than 7.

Arnold O. Beckman (1900 – 2004)

One of the most influential scientists of the last century, many of his inventions are vital in today’s analytical science world. One of his most noted inventions was the pH meter. Originally developed to test acidity in citrus fruits, the electronic pH meter is now widely used to measure the pH of solutions.

Read more about other famous scientists at www.sta.ie

Revise the Terms

Can you recall the meaning of these terms? Reviewing the terminology is a powerful aid for recall and retention.

Micro-organisms; parasites; water quality standards; fluoridated; reservoirs; biologically degraded; UV radiation; algal growth; coagulation; flocculating agent; aluminium sulphate; polyelectrolyte; settlement tanks; sodium hypochlorite; hypochlorous acid; calcium hydroxide; neutralising agent; dilute sulphuric acid; carbon dioxide; pathogenic; sedimentation; back washing; sterilising agent; hydrofluosilicic acid; oxidation; elemental chlorine.

Check the Glossary of Terms for this lesson at www.sta.ie