

Chemistry Research Task: Water

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Gather, process and present information on the range and chemistry of the tests used to:

- Identify heavy metal pollution of water
- Monitor possible eutrophication of waterways

Heavy Metals: Heavy metal pollution of water may be caused by unacceptable levels of the ions of arsenic, cadmium, copper, chromium, mercury, nickel, lead and zinc.

Heavy Metal Pollution in Water

Heavy metal pollution of water may be caused by the presence of unacceptable levels of the ions of arsenic, cadmium, copper, chromium, mercury, nickel, lead and zinc.

Simple techniques to identify the presence of heavy metals include precipitation and flame testing. Techniques to quantitatively determine heavy metals include volumetric and gravimetric analyses, colorimetry, chromatography and spectroscopy, particularly atomic absorption spectroscopy (AAS) and mass spectroscopy.

Concentration and Presence of Cations

The qualitative analysis of heavy metal ions is a relatively simple process. It can be achieved with atomic emission spectroscopy.

As atoms are heated to high temperatures (above 1500°C), some of the electrons become excited, and move out of their normal energy levels to higher energy levels. After a short time however, these electron fall back to their normal energy levels, and as they do this, excess energy is liberated as light. The energy emitted by the electrons is the same as the amount they absorbed when raised to their excited states. By passing the emitted light through a prism, we break it into its various wavelengths, and find that the emissions have occurred at just a few discrete wavelengths. This pattern of wavelengths is known as an emission spectrum. Each element's emission spectrum is unique, thus, we are able to test for the presence of several metal ions in one sample using atomic emission spectroscopy.

The quantitative analysis of heavy metal ions is somewhat more difficult, owing to the usually very low concentrations found in water. Precipitation and titration techniques have limited accuracy and significance due to the minute cation concentrations involved. However atomic absorption spectroscopy is a technique developed in the 1950s which allows for concentrations of metals to be measured one at a time. It uses the same principle as atomic emission spectroscopy, where each element has a unique emission spectrum. By

measuring the amount of light absorbed by a sample from a light source producing a wavelength identical to the wavelength emitted by atoms of the element being tested for, and comparing this to absorption from known concentrations, the concentration of the cation in the sample can be deduced to an accuracy of 1 part per billion.

Eutrophication: The process of eutrophication involves the increase in nutrient content of a body of water resulting in excessive growth of plants, which when they die, causes oxygen depletion during the decay process.

Eutrophication in Waterways

The extent of eutrophication of a waterway can be determined using tests which involve measurement of dissolved oxygen and nutrients, specifically phosphates and nitrates. Visible eutrophication tends to occur if the total nitrogen content is within or exceeds 400-600ppm and / or the total phosphorus concentration is within or exceeds 40-60ppm. These ranges correspond to an average Nitrogen:Phosphorous ratio of 10:1.

To avoid algal blooms the following concentrations should be maintained:

Nitrates	0.1 – 1 ppm
Phosphates	0.01 – 0.1 ppm

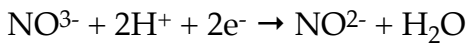
Quantitative measurement of Phosphates

Precipitation techniques are not accurate enough for measuring the concentration of phosphates in water, as too little precipitate is formed for accurate weighing. Instead, a sensitive colorimetric method is used.

To estimate phosphate concentration, a solution of ammonium molybdate $[(\text{NH})_4\text{MoO}_4]$ is added to the sample. This forms a pale yellow phosphomolybdate complex. When solid ascorbic acid is added, it produces an intense blue colour. The intensity can be measured with a colorimeter, and the hue compared to the colour produced by known concentrations of phosphate solutions. The concentration of phosphate can be accurately estimated using this technique. Accuracy ranges from 0.01 to 3 ppm.

Quantitative measurement of Nitrates

Again a colorimetric method is used. Nitrate is reduced to nitrite by flowing the sample through a tube of granulated cadmium.



Solutions of two organic compounds are added successively to the nitrite solution to produce an intense reddish-purple solution. Comparison of the absorbance of this solution with that from a nitrate solution of known concentration treated identically gives an accurate concentration of nitrates. Accuracy ranges from 0.02 to 2 ppm.

Gather process and present information on the features of the local town water supply in terms of:

- Catchment area
- Possible sources of contamination in this catchment
- Chemical tests available to determine levels and types of contaminants
- Physical and chemical processes used to purify water
- Chemical additives in the water and the reasons for the presence of these additives

Catchment Area

Warragamba Dam is Sydney's principle water storage dam. It is located 60 km west of Sydney in a narrow gorge on the Warragamba River and is one of the largest domestic water supply dams in the world. It has a capacity 2 million megalitres, almost 4 times the capacity of Sydney harbour.

The catchment area of Warragamba dam is approximately nine thousand square kilometres. Water is delivered from Warragamba dam to the Prospect Water Filtration plant by four kilometres of 2650mm pipelines, laid mainly in tunnel, to the Nepean River crossing, and then about 23km to Prospect by 2 trunk mains of 2100mm and 3000mm respectively.

Possible Sources of Contamination in this Catchment

The Warragamba dam catchment area encloses 5 main catchment systems located in an arc encircling the Sydney metropolitan area, mainly to the west, and south-west. If excessive pollution reaches these catchment areas, the water in Warragamba dam is consequently also polluted. This not only jeopardises the drinking water of about four million people, it can also impact on activities such as stock watering, irrigation, recreation and the ecological health of the native plants and animals in the catchments. Water quality in our catchments is affected by:

- Wastes and runoff from industry and urban development
- Poor sewage and stormwater management
- Agricultural activities
- Mining
- Forestry
- Chemical/fuel spills
- Erosion
- Uncontrolled bushfires

Chemical Tests Available to Determine Levels and Types of Contaminants

Biochemical Oxygen Demand (BOD)

Get Dissolved Oxygen (DO) level before → put in dark room at 20°C for 5 days → get DO after. Difference in DO = BOD

Salts and Cations

- Filter → evaporate → dry to constant weight → record weight.
- TDS by conductivity measurements.
- Atomic absorption spectroscopy to determine levels, Atomic emission spectroscopy to determine qualitatively.

Heavy Metals

Atomic Absorption Spectroscopy / Atomic Emission Spectroscopy

Bacteria and Micro-organisms

- E. Coli (which is an organism like Cryptosporidium and Giardia which signals the presence of sewage or animal faecal matter.
- To test for E. coli, a sample is placed on a suitable nutrient bed and incubated for 12 to 24 hours, during which time the individual bacteria grow into colonies that are large enough to count by eye.
- Results are report as colony forming units per 100mL of water, CFU/100mL. If there is more than 1 CFU/100mL, the water is not suitable for drinking; if more than 200CFU/100mL, the water is unsafe for swimming.

Physical and Chemical Processes used to Purify Water

Step 1 – Aeration

- Spray water into the air to increase the concentration of dissolved oxygen.

- Any hydrogen sulfide gas dissolved in the water is oxidised to sulfate ions and iron salts are also oxidised to insoluble iron oxides which can later be removed. Oxygenated water also has a more pleasant taste.

Step 2 – Flocculation

- Water in rivers and reservoirs contains small suspended particles. The diameter of these clay colloids are very small, and are prevented from settling due to the repulsion between their negative surfaces.
- These can be made to precipitate by a process called flocculation.
- Alum (aluminium sulfate) is added to the water to produce a gelatinous precipitate or floc of aluminium hydroxide. This jelly-like precipitate traps other suspended particles, including some microbes.
- $\text{Al}^{3+} + 3\text{H}_2\text{O}_{(l)} \rightarrow \text{Al}(\text{OH})_{3(s)} + 3\text{H}^+$
- The hydrogen ions produced in this hydrolysis reaction are attracted to the surface of the aluminium hydroxide flocs. The negative surfaces of the clay colloids are then attracted to the positive surfaces of the flocs and these larger particles settle out under gravity. Iron oxides and other soluble coloured compounds also adhere to the flocs.

Step 3 – Sedimentation – settling of the flocs

The treated water is allowed to stand in a settling tank so that the flocs settle to the bottom to form sludge. The sludge can be removed from these settling tanks periodically. By the end of step 3 about 95% of the suspended impurities (particle size >25 microns) have been removed.

Step 4 – Filtration

Water from the settling tanks is then passed through a filter containing the sand and gravel to remove the remaining suspended particles and to remove other minerals, bacteria and coloured matter. The water at this stage should now be clear. If the water is still coloured, it can be passed through layers of activated charcoal, which adsorbs the coloured matter onto its surface.

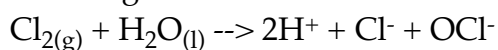
Step 5 – Chlorination and micro-biological tests

Water emerging from the filter is now chlorinated to kill bacteria and other microbes.

Chlorination process produces hypochlorite ions which kill the microbes.

Biochemists test the water for the presences of bacteria called coliforms (e.g. Escherichia coli) which are associated with pollution from animal manure.

Drinking water should contain on average less than two colony-forming units (CFU) per 100mL of water throughout the year. The chlorine level must be constantly monitored to assure that carcinogenic chlorinated alkanes are not produced.



Chemical Additives in the Water and the Reasons for the Presence of these Additives

- Chlorine added for disinfectant purposes. At a concentration of 1-2 ppm, the chlorine destroys bacteria and some viruses. If the starting water was reasonably clean and if the right amount of chlorine is used, there is no odour when it reaches the user.
- Fluorine (sodium fluoride) added at a concentration of 1ppm to the water supply generally just downstream of the chlorination plant. Fluoride is added to strengthen tooth enamel in growing children: it is a form of enforced medication. Does not improve the safety of the water. The decision to add fluoride is made by each state or water authority.