CHEMISTRY

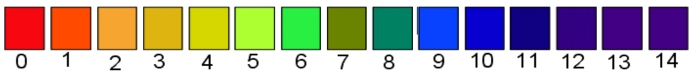
Investigating the quality of water samples

- Perform a firsthand investigation to use qualitative and quantitative tests to analyse and compare the quality of water samples

Introduction[1]

Acidity[2]

pH is the measure of how acidic or basic a substance is. It is measured through a logarithmic scale extending from 1 – 14, where 7 is neutral. Above 7 is basic and below it is acidic. pH can be determined by using a range of indicators that change colour according to pH or a pH meter, which provides an exact reading of the pH and is much more reliably than an indicator. A good indicator to use is universal indicator because it features a high pH range. The following chart determines the pH according to colour



[3]

pH of river systems have to be a narrow range in order for organisms and microorganisms to survive. The standard pH for a river is usually between 6.5 to 8.5. If the pH rises or decreases below that range, organism may die or experience serious damage:

- Fish's eyes, gills, and skin are damaged and they are more susceptible to fungal infections and diseases if the pH is out of the normal range.
- The change in pH could also reduce the biological availability of metals and nutrients.
- It could also increase the toxicity of ammonium and aluminium.

[11] Chemistry 2 HSC by Geoffrey Thicket
[2] http://www.ozcoasts.org.au/indicators/ph_coastal_waterways.jsp
[3] http://www.teachnet.ie/tburke/2005/ph.html

- An increase in pH could also decrease the electrostatic forces that bind viruses to particles, allowing them to be released into the water environment.
- Shell growth of certain organisms is inhibited if the water becomes too acidic.

That is why pH must be maintained in the 6.5-8.5 range.

Salinity[4]

Salinity is the measure of salt concentration in a water sample. It is expressed in Practical Salinity units (PSU) or Parts per million (ppm). The average salinity levels for freshwater rivers is usually 1 g/kg ppm. Above that range or below it, aquatic life in the river will be impacted significantly:

- Many aquatic organisms rely on osmotic regulation, which use salts and water as a means of obtaining an isotonic internal environment. If the salt concentration is changed from the normal about, it will interfere with bodily functions of the organism
- Most freshwater bacteria and blue-green algae are homoiosmotic, that is, they maintain a set amount of salt concentration internally and therefore cannot tolerate changes to that amount, which might result in their death
- If salt concentrations are increased, many sensitive organism will die off
- It will reduce the amount of dissolved oxygen in the water
- Salt can also affect surrounding vegetation on the riverbank where an increase in salt concentration will result in leaf scorching, defoliation, branch and leaf death and inhibition of growth.

Dissolved oxygen

Dissolved oxygen is a measure of the amount of oxygen present in the water. Oxygen is high amounts is essential for aquatic life and water quality. Aquatic organism needs oxygen to respire and produce energy for their daily activities.

[4] http://www.cee.vt.edu/ewr/environmental/teach/gwprimer/group05/environ.html

Below 5 ppm of dissolved oxygen, organisms can die due to lack of oxygen and would feature respiratory distress. The following table shows the different levels of dissolved oxygen.

Dissolved oxygen (ppm)	**6-8**	**4-6**	**2-4**	**<1**
Water quality	Healthy	Moderately polluted	Severely polluted	Dead

A Source of dissolved oxygen is photosynthesis by aquatic plants and phytoplankton. Water can also become oxygenated by oxygen directly dissolving in the atmosphere;

$$O_2\,(g) \leftrightarrow O_2\,(aq)$$

However, if that concentration changes significantly it can have detrimental effects on the environment

- Low levels of oxygen can cause The immune system of fish are suppressed and therefore making them more susceptible to disease
- Low dissolved oxygen saturation doubles the toxicity of toxicants e.g. zinc, lead, and copper
- Depletion of oxygen from sediments on the river's bed can result in ammonia being released and reinforce the algal bloom

Total dissolved solids[5]

Total dissolved solids is a measure of all the organic and non-organic solid particles suspended or dissolved in a liquid. The normal healthy range that indicates a unpolluted waterway is a TDS reading of less than 1000 ppm. Above that range means that the waterway is degraded and said to be Brackish. TDS is usually influenced by industrial effluent, changes to water balance, or salt-water intrusion. It can cause toxicity levels through increase in salinity

[5] http://www.scipub.org/fulltext/ajes/ajes311-6.pdf

- It can prevent the growth of certain species while promote the growth of other, consequently affecting the food chain
- Aquatic species declined due to the osmotic tolerances were exceeded due to increase in salinity
- High levels of TDS were found to be toxic to invertebrates
- Suspended particles could block sunlight and prevent aquatic plants and microorganisms from photosynthesising
- Reduces the amount of dissolved oxygen in the water

Hardness

Depending on the presence of certain ions in the water determines whether water is classified as hard or soft. Hard water is considered on that contains excess calcium and magnesium ions. Water hardness can be determined with a test kit or simply using soap to observe whether is forms lather or scum. If soap lathers in the water sample is it considered soft, while formation of scum an no lather determines its hardness. The following table shows the classification of hard and soft water

Total water hardness classification	soft	Moderately hard	hard	Very hard	Saline
Total hardness (ppm)	< 60	61 - 120	121 - 180	181 - 500	>500

Ions

Chloride[6]

Chloride ions do not exist alone, but exist as salts. They influence the amount of Total Dissolved Solids and salinity.

[6] http://www.env.gov.bc.ca/wat/wq/BCguidelines/chloride/chloride.html

So excess chloride ions can have the same effect on the environment as when the salinity or TDS levels increase or decrease.

- Excess chloride ions in the water can result in osmoregulation in aquatic organisms to be disrupted, damaging growth, reproduction and overall survival
- Increased salt concentration can enhance the effect of trace of metals in the river

However, chloride ions are essential ions in the river system as they are used for osmoregulation in organisms. Therefore, a decrease in chloride ions can influence bodily functions.

Sulphate[7]

Sulphate ions occur in small amounts in water. However, in excess sulphate ions react with oxygen to produce sulphuric acid, which is very toxic and changes the pH of the water. This will then result in damage to the food chain in the aquatic environment, resulting in the death of many aquatic organisms and disease. It is fatal to most organisms. Sometimes it does not cause instant death but reduces fish immunity making them susceptible to fungal infections and diseases such as 'red spot'. An example of this disease is shown in the image below

[7] http://www.moretonbay.qld.gov.au/environment.aspx?id=2164

Iron (II)

Iron (II) ions exist naturally in small amounts in water, but can be detrimental and poisonous if in excess. It can limit the growth of phytoplankton.

Phosphate[8]

Phosphate ions are naturally occurring in water river systems and are a nutrient for plants. However, excess phosphate ions can results in algal bloom due to eutrophication where phosphate ions are released into the environment due to human activity. Algal bloom is a problem because it blocks the sun when it dies and clouds the river, preventing photosynthesising organism from photosynthesising. When it is decomposed after death, a lot of oxygen is used up, resulting in lower concentrations of dissolved oxygen and as a result causing death of organisms.

Aim – to use qualitative and quantitative tests to analyse and compare the quality of water samples

Hypothesis – the water in Duck River will be polluted

Materials –

- Water samples from Duck River
- pH meter
- universal indicator
- salinity test kit
- phosphate test kit
- hardness test kit
- dissolved oxygen test kit
- soap
- nitric acid
- test tubes

[8] http://www.bradwoods.org/eagles/phosphate.htm

- beakers
- spatula
- electronic balance
- safety glasses
- gloves
- Silver nitrate solution
- Barium chloride solution
- Potassium thiocynate solution
- Hot plate
- Measuring cylinder

Risk assessment

Risk	Potential harm it can cause	Safety measures
Water samples from Duck River	▪ River water is abundant with microorganisms that can cause disease if exposed to naked skin or ingested	▪ Wear gloves and safety glasses ▪ Do not touch or drink contaminated water
Universal indicator[9]	▪ It is highly flammable ▪ It can cause irritation to eyes and skin	▪ Keep away from flammable material ▪ Wear gloves and safety glasses ▪ If contact occurs, wash immediately with water
Test kits	These kits contain dangerous chemicals that can cause harm if ingested or come into contact with skin or eyes	▪ Wear gloves and safety glasses ▪ Use with care and follow instructions ▪ If contact or ingestion occurs, wash with water and seek medical advice
Nitric acid[10]	▪ Can causes severe eye, gastrointestinal tract and skin burns if ingested or touched. ▪ Fatal if inhaled, irritates the	▪ Wash skin and eyes with copious amounts of water and seek medical attention immediately for all conditions

[9] http://www.chemexper.com/
[10] http://www.chemexper.com/search/cas/7697372.html

	respiratory tract ▪ causes chronic bronchitis.	▪ Wear gloves and safety glasses at all times
Silver nitrate[11]	▪ Silver nitrate is corrosive and can cause severe burns to eyes, skin, gastrointestinal tract and respiratory tract. ▪ It is also very toxic to the environment, especially aquatic organisms	▪ Wear gloves and safety glasses ▪ If contact occurs, wash with large amounts of water and seek medical aid. ▪ If ingested, give patient milk or water and do not induce vomiting. Seek medical aid
Barium chloride[12]	▪ It is toxic if swallowed ▪ Harmful if inhaled	▪ Wear safety glasses and gloves ▪ Wash with water if contact occurs ▪ If inhaled, expose patient to fresh air and seek medical aid ▪ If ingested, seek medical aid immediately
Potassium thiocynate[13]	▪ It is an irritant and may irritate eyes, skin, gastrointestinal tract and respiratory tract	▪ Wear gloves and safety glasses ▪ If contact occurs wash with water ▪ If inhaled or ingested, seek medical aid

[11] http://www.chemexper.com/search/cas/7761888.html
[12] http://www.alfa.com/MSDS/35582.htm
[13] http://www.jtbaker.com/msds/englishhtml/p6181.htm

Procedure

1. Safety glasses, gloves and long plastic boots were worn
2. Water samples were obtained from Duck River by students. Plastic water bottles were obtained from three locations from the riverbank.

PART A – Quantitative tests

Acidity

3. The pH meter was calibrated in a buffer solution before being used
4. 100 ml of the sample river water was poured into a beaker
5. The protective cap of the pH meter was removed
6. The pH meter electrode was cleaned with distilled water before being dried by filter paper
7. The pH meter was turned on by the ON-OFF switch located on top
8. It was then dipped into the river water sample up to the immersion level
9. It was then left for 1 minute and the pH reading was recorded
10. Steps 3 – 10 were then repeated for the other samples of river water

Total Dissolved Solids (TDS)

11. The hot plate was preheated on minimum
12. An empty beaker was weighed using an electronic balance. results
13. 100 ml of river water was measured and added to the beaker
14. The beaker with the sample water was weighed again and the results recorded
15. The beaker containing the water was placed on the hot plate and left to boil in order for the water to evaporate completely.
16. After the water had evaporated completely, the beaker was removed and placed on the heat-proof mat to cool
17. The beaker was then weighed again and the results were recorded
18. The weight of the solid remaining was calculated

Dissolved Oxygen

19. The glass bottles were rinsed with the water sample three times before being filled to overflow where a small part of the sample spills over after the stopper had been placed on the opening.
20. The stopper was removed and five drop of Maganous sulphate solution and Alkali-Azide Reagent was added.
21. More water sample was added to fill the bottle completely.
22. The stopper was placed on top again with a small part of the solution spilling over. This is to ensure that no air bubbles are trapped inside and that might corrupt the reading
23. The glass bottle was inverted several times until the sample became a orange-yellow colour and a flocculent predicate will form if oxygen is present.
24. The sample was left to stand to allow the flocculent precipitate to settle
25. After two minutes, when the upper half of the bottle became limpid, 10 drops of sulphuric acid solution was added
26. The bottle was stoppered and inverted until all precipitate particles dissolved. The sample was ready for measurement when it is yellow and completely limpid
27. The cap was removed from the plastic beaker; it was rinsed with the solution in the glass bottle before being filled to the 5 ml mark. The cap was replaced
28. One drop of starch indicator was added through the hole in the cap and it was mixed carefully by swirling the beaker in a circle. The solution turned a violet to blue colour.
29. The pipette was pushed and twisted on the tapered end of the syringe ensuring an airtight fit. The plunger was pushed completely into the syringe
30. The tip of the syringe was inserted into the titrant solution and the plunger was pulled until the zero mark.
31. The syringe was placed in the cap port of the plastic beaker and the titrant was added slowly, drop by drop, and swirling the vessel after every drop. The titration solution was added until the solution in the beaker changed from blue to colourless.

32. The millimetres from the syringe scale was read off and then multiplied by 10 to obtain mg/L (ppm) oxygen value.
33. If the results are lower than 5 mg/L, the experiment was repeated.
34. Steps 19 – 33 were repeated for the other water samples

Salinity

35. The plunger was pushed completely down on the titration syringe.
36. The tip was inserted into the water sample and the plunger was pulled until the zero mark on the syringe
37. The sample in the syringe was added to the plastic vial
38. One drop of Diphenylcarbazone indicator and the vial was capped. The solution was swirled until it became a violet colour.
39. The cap was removed. While the vial was being swirled, nitric acid was added drop by drop until the sample turns yellow.
40. A pipette tip was inserted into the syringe and the plunger was pushed completely down.
41. The tip was inserted into the Reagent Titrant solution and the plunger was pulled until the zero mark.
42. The syringe was placed into the plastic vial and the titration solution was added drop by drop with constant swirling after each drop.
43. The titration solution was added until the sample turned from yellow to violet.
44. The millimetres were read off the syringe scale and multiplied by 40 to obtain the salinity in g/Kg (ppt).
45. These steps were then repeated for the other water samples

Hardness

46. The cap was removed from the small plastic beaker, it was then rinsed the water sample. It was filled to the 5 ml mark and the cap was replaced.
47. Five drops of Hardness Buffer through the cap port and it was mixed carefully by swirling the beaker in tight circles.
48. One drop of Calmagite Indicator was added through the cap port and mixed by swirling until the solution turned red-violet.
49. The plunger was pushed completely into the syringe. The tip was inserted into the HI 3812-0 EDTA solution and the plunger was pulled until then 0 mark.

50. The syringe tip was inserted into the beaker's cap port and the solution was added slowly drop by drop until the solution became purple. It was then mixed for 15 seconds after each additional drop until the solution turned blue.
51. The millimetres of the titration solution from the syringe scale and it was multiplied by 300 to obtain mg/L (ppm) calcium carbonate.
52. These were then repeated for the other water samples

PART B – Qualitative tests

Ions

Chloride ions

1. Water samples were acidified with several drops of dilute nitric acid.
2. Several drops of 0.1 mol/L silver nitrate solution to each water sample.
3. Results were recorded. The presence of a white precipitate indicates the presence of chloride ions.
4. This was then repeated for the other water samples

Sulphate ions

5. The water samples were acidified with several drops of dilute nitric acid.
6. Several drops of 0.1 mol/L barium chloride solution was added to the water sample.
7. Observations were recorded. The presence of sulphate ions would have been evident by a white precipitate.

Iron (II) ions

8. Add several drops of 0.1 mol/L potassium thiocynate solution to the water sample.
9. Observations were recorded. The presence of red colouration indicates the presence of iron (II) ions.

Phosphate ions

10. Using the phosphate test kit, the cap was removed from the plastic beaker and the beaker was rinsed with the sampled water.
11. It was then filled to the 10 ml mark
12. One packet of the reagent was added to the 10 ml of sample water in the beaker
13. The cap was placed again on the beaker, which was slowly mixed until the solids dissolved.
14. The cap was replaced again and the solution was transferred into the colour comparator cube. It was left to set for one minute
15. The colour which matches the solution in the cube was determined. The reading was recorded as mg/L of phosphate.

Hardness

16. 10 ml of the water sample was added to a test tube
17. 5 ml of soap was added to the test tube and it was stoppered
18. The test tube was then shook vigorously in a vertical direction
19. The presence of lather was observed – if lather forms, the water sample is classified as soft water, while if lather doesn't form, it is classified as hard water

Acidity

20. 5 ml of the water sample was added to a beaker.
21. A few drops of universal indicator were added to the beaker.
22. The colour change was observed and recorded.

Results

Acidity

The table below shows the results collected for the pH of three water samples

Sample	**pH meter**			**Universal indicator colour**	
	T1	T2	Average	T1	T2
1	6.6	6.8	6.7	Yellow green	Yellow green
2	6.7	6.9	6.8	Yellow green	Yellow green
3	6.8	6.10	6.9	Green	Green

Hardness

The table below shows the quantitative and qualitative hardness results for the water samples

Sample	**Hardness (quantitative) {mg/L $CaCO_3$}**			**Hardness (qualitative)**		
	T1	T2	Average	T1	T2	
1	75	90	82.5	Produced lather	Produced lather	Soft
2	78	96	87	Produced lather	Produced lather	Soft
3	105	102	103.5	Produced lather	Produced lather	Soft

Salinity

The table below shows the water sample's measure of salinity

Sample	**Salinity {ppm}**		
	T1	T2	Average
1	1.6	1.6	1.6
2	1.6	1.6	1.6
3	1.8	1.8	1.8

Dissolved oxygen

The table below shows the dissolved oxygen saturation in the water samples

Sample	**Dissolved Oxygen {mg/L O_2}**		
	T1	T2	Average
1	5.0	5.3	5.15
2	2.3	2.7	2.5
3	5.5	5.4	5.45

Presence of ions

The table below shows the types of ions present in the water samples

Sample	**Presence of phosphate ions**			**Presence of chloride ions**			**Presence of sulphate ions**			**Presence of iron (II) ions**		
	T1	T2	T3	T1	T2	T3	T1	T2	T3	T1	T2	T3
1	No	No	No	Yes	Yes	Yes	No	No	No	No	No	No
2	No	No	No	Yes	Yes	Yes	No	No	No	No	No	No
3	No	No	No	Yes	Yes	Yes	No	No	No	No	No	No

Total dissolved solids

The table below shows the total dissolved solids (TDS) acquired after evaporating a water sample

	Mass (grams)
Mass of beaker	52.01
Mass of beaker and water	102.01
Mass of water sample used	50
Mass of beaker and water sample after heating	52.62
Mass of total dissolved solids	0.61

Discussion[14]

Acidity

Normal range for river = 6.5 – 8.5

Results obtained from Duck River = 6.7, 6.8, 6.9

The water samples obtained from Duck River were found to be of standard and healthy pH, where the water is neither too acidic nor too basic. This means that there is minimal pollution in the river and that many aquatic organisms thrive in the river due to its suitable pH. This is good news for the environment as it was concluded that the river's pH is suitable for life and there is no pollution interfering with this value.

Hardness

Normal range for river =

Total water hardness classification	soft	Moderately hard	hard	Very hard	Saline
Total hardness (ppm)	< 60	61 - 120	121 - 180	181 - 500	>500

Results obtained from Duck River = 82.5, 87, 102 ppm

[14] Chemistry 2 HSC by Geoffrey Thicket

The river samples from Duck River appear moderately hard according to the hardness classification. It was observed that the qualitative test, where soap was used to produce lather was successful, reinforcing that fact that the water is still soft going onto hard. It is a very healthy value for the water, surprisingly, and therefore shows that no pollution or excess salts exist in the waterway. This may be because it is open for new water to replace the old so that there is no build up of salts.

Salinity

Normal range for river = 1 ppm

Results obtained from Duck River = 1.6, 1.6, 1.8

The water is saline more than usual, and this is also reflected in the slightly hard result obtained for hardness. The water in Duck river is slightly saline and would probably would not have a large impact on organisms because it is not a huge difference however, the last location sample from Duck River is more saline than the others.

Dissolved ions

Normal range for river = phosphate, sulphate, chloride and iron (II) ions exist in small amounts in the river

Results obtained from Duck River = phosphate, sulphate and iron (II) were not present, but chloride ions were

The presence of chloride ions may explain the slight hardness and salinity levels tested. However, as this is only a qualitative test, not a quantitative test, the exact concentrations of the ions were not known, so the procedure was not reliable enough to produce results that can be used to draw accurate conclusions. The ions that were said to be not present are naturally occurring in small amounts in the water, which may explain why the results produced shows their absence as the small concentration could not be detected by the qualitative tests.

Their absence suggests that there is no excess of concentration of these ions and therefore the waterway of Duck River was not polluted.

Total Dissolved solids

Normal range for river = < 1 ppm

Results obtained from Duck River = 0.61 ppm

Duck River is considered unpolluted as the healthy range is below 1 ppm and the results obtained for a sample of water is 0.61 ppm, falling into the healthy range. This means that Duck River is unpolluted and does now have excess salts or dissolved solids. However, this was surprising because the appearance of the river is completely brown, showing the evident suspended particles in the water. This may not necessary mean that there are many dissolved solids as the time the samples were taken it had rained and the rain may have stirred the riverbed. The reason why one sample and one trial were produced for TDS was because of the time limits. There was not enough time to test all three samples twice or three times.

Dissolved oxygen

Normal range for river =

Dissolved oxygen (ppm)	6-8	4-6	2-4	<1
Water quality	Healthy	Moderately polluted	Severely polluted	Dead

Results obtained from Duck River = 5.15, 2.5, 5.45 ppm

The dissolved oxygen result shows that the water in Duck River is slightly polluted, which could be a problem for aquatic organisms, as they may not have enough oxygen to respire and therefore exhibit respiratory distress.

The lack of oxygen can also affect their reproducing ability.

The second location features 2.5 ppm, which may be incorrect as it does not correspond with the other trial tests and therefore it may be due to human error during testing. However, two trials were conducted and this is the average, so the location that sample was taken from must have not had any circulation of water and therefore oxygen was not able to be brought into the area by new water rushing in. It could also be the cause that it is severely polluted and the lack of circulation preventing running water from clearing it. This could have detrimental effects on wildlife and lead to their death. A way to manage this problem is to ensure that the blockage that is preventing water circulating is removed, all pollution is removed and that some wildlife could be transported to healthier waters.

General Discussion

With the presence of trials the reliability of the results was enhanced and can be accurately analysed to produce a valid conclusion. However, for the TDS part, there was only one sample and one trial due to time restrictions and therefore the conclusion can be doubted and reliability undermined. Throughout the experiment, the variables were controlled to ensure validity. For example, the volume of liquids, water samples, amount of chemicals added and the overall procedure was kept the same to ensure that the results were valid.

The reasons for not testing mercury (II), Cadmium (II) and chromium (II) ion concentration was because of the time restrictions and the absence of the teacher who had personal matters to address. Therefore, the heavy metal ions could not be determined, as the students were not familiar with the procedure.

The water samples were taken from three different locations on the riverbank to ensure that different areas which exhibit varying results were considered and taken into account. Water from different locations could be subject to different influences that might produce varying results.

The application of both qualitative and quantitative tests were used to enhance validity and accuracy of results.

By producing a general judgement about an issue using qualitative techniques can be reinforced by producing exact readings through quantitative methods where accurate conclusions can be drawn. Unfortunately, due to time restraints and lack of familiarity with the technique, quantitative results for ion concentrations could not be produced.

The hypothesis predicted was proved to be incorrect as Duck River was found to be unpolluted. On the contrary, according to the tests and their results, the water quality was proved to be of good standard and healthy for the thriving of living organisms, despite its polluted appearance.

The test kits used were much more efficient than taking samples to the lab and undertaking titration on a large scale. They provide the convenience of conducting the tests in the same location at the same temperature of the water instead of allowing the water samples to be affected by taking it to the lab.

Conclusion

The water in Duck River is not polluted as stated by the hypothesis. It had a healthy pH of 6.8, a reasonable level of hardness measuring approximately 87 ppm, which was found out to be slightly hard, but overall soap due to soap's ability to produce lather. The water was slightly saline with a measurement of approximately 1.7 ppm. Phosphate, iron (II) and sulphate ions were not found to be present, only chloride ions were. The dissolve oxygen saturation in the water was a moderate amount, with a level of 5.3 ppm. Moreover, despite its clouded appearance, it the river had a healthy TDS result of only 0.61 grams of solids dissolved. Overall, the conclusion was that Duck River is not polluted but a healthy environment.

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