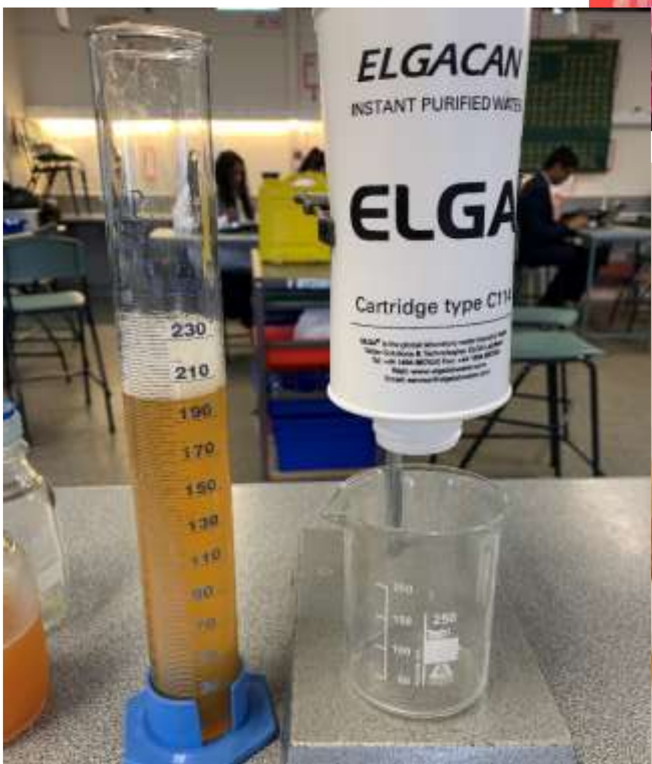
Eggsellent Removal of Heavy Metals



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1.0 Abstract

A research investigation was conducted to find a natural and cost-effective way to remove heavy metals from water. Heavy metal contamination is a serious environmental issue in water systems across the globe, for a range of reasons, including industrial leakages, mining run-offs, and more. Many people struggle in the search for safe drinking water due to contamination of their waterways. The consumption of heavy metals in drinking water can have far-reaching impacts on bodily functions. Many heavy metals are systemic poisons (lead, mercury) and others have serious impacts on the central nervous system, leading to memory loss, fatigue, and depression. (William, n.d.).

The question being asked in this research had two parts: (i) does calcium carbonate, in the form of eggshells, remove heavy metal ions from an aqueous solution, and if so, (ii) does surface area of eggshell particles have an impact on the effectiveness of the process?' To test the initial part of the question, solutions of iron ions ($Fe^{2+}_{(aq)}$) were prepared and the starting concentration of these was estimated by titration with freshly standardised, acidified potassium permanganate.

Once the starting $Fe^{2+}_{(aq)}$ ion concentration was known, three experimental samples of test solution were exposed (for 5 days) to eggshells that had been ground up to a medium particle size. The resulting $Fe^{2+}_{(aq)}$ ion concentrations were determined, again by titration with acidified potassium permanganate. It was found that all test solutions had reduced levels of $Fe^{2+}_{(aq)}$ ions, after eggshell exposure.

To test the second part of the question, standard solutions of iron ions ($Fe^{2+}_{(aq)}$) were exposed (for 5 days) to three surface area variables of eggshells (coarse, medium and very fine (blended). The resulting $Fe^{2+}_{(aq)}$ ion concentrations were determined, once again by titration with standard acidified potassium permanganate. It was found that the coarse eggshells absorbed the greatest levels of $Fe^{2+}_{(aq)}$ ions after 5 days exposure. This was followed by medium shell particle size, and least effective was finely blended eggshell. These results were not expected, as it was hypothesised that the finest particle size would provide the greatest surface area for iron absorption. In reality, the fine particles became clogged and did not allow penetration of the iron solution, so the solution rested on top and was unexposed, for a large part of the exposure period.

It was concluded that eggshell does have the capacity to absorb $Fe^{2+}_{(aq)}$ ions from water, but not as efficiently as commercial filters (ELGA). When varying the particle size of the eggshell, it was found that roughly crushing the shells provided the most effective medium for reducing iron content. This was due to ease of contact between eggshell and solution. Subsequently, it could be recommended that using eggshell for the absorption iron ions from water could be a cheap, effective method in real-life settings of contamination of water supplies with limited filtration resources. Further experimental work into testing the effectiveness of this method for reducing other hazardous ions ($Pb^{2+}_{(aq)}$ and $Hg^{2+}_{(aq)}$) is recommended.

2.0 Introduction

Throughout our world, water contamination of heavy metals is high, especially in countries where poverty is extremely common. (Rehkopf, L, 2020). Countries including Cambodia, Indonesia, Malaysia, Thailand and Vietnam are some of the most affected by heavy metal contamination. (Dang, 2019) Common heavy metals that are found in water sources are arsenic, copper, nickel, chromium, and lead (Lenntech, 2020). Metals such as Iron, Manganese, Copper, and Zinc are essential nutrients for life that are found within our water systems, but when there is a concentration that is too high for the volume of water, the water is then contaminated and can be hazardous.

Heavy metals that are found in water commonly occur by the weathering of rocks and soil which then contaminates water by precipitation runoff. (Lenntech, 2020). Mankind, and human activities can have far-reaching negative impacts on the cleanliness of water. Mining, coal-burning powerplants and acid rain are all mass contributing factors resulting in contaminated water. (Lenntech, 2020). Large cities in poor countries are often vulnerable to the impact that water contamination. This is due to the population density and the high consumption of water, and issues like water may not be treated appropriately or adequately, before return to circulation for human consumption.

My purpose in doing this experiment was to develop an understanding of the pollution toll of heavy metals on waterways and to see if local communities could use a freely available resource (calcium carbonate found in any shell type) to reduce the toxicity of their water. Iron ions ($Fe^{2+}{}_{(aq)}$) were selected for use because they are a good model for other heavy metals that can be found in water supplies, and they can be effectively measured in a school laboratory by titration. we decide that it would be the best measure to find if the interference of eggshells could have a role to play in the decrease of heavy metals within water. Eggshells have a high content of calcium carbonate ($CaCO_3$) which, at a molecular level, can combine with the Fe^{2+} ions. Therefore, in theory, when the solid eggshells are removed from the solution, they take $Fe^{2+}{}_{(aq)}$ out of the water and what remains is H_2O, in a more purified state.

The consumption of heavy metals has a long-lasting effects on those who consume polluted water. The brain is one of the most affected organs, suffering damage to the central nervous system, leading to memory loss, fatigue, and often, depression (William, n.d.). Given that *'access to clean water and sanitation'* is one of the UN Sustainable Development Goals (UN STD's, January 2016) then it is vital that we take action. At the time of release of the Goals, UN Secretary-General Ban Ki-moon said "*The seventeen Sustainable Development Goals (SDGs) are our shared vision of humanity and a social contract between the world's leaders and the people,"* I believe it is our combined responsibility to ensure clean drinking water for all, but especially the poor and vulnerable, and belief this motivates me to find effective, cheap treatments for water purification.

3.0 Hypotheses

3.1 Hypothesis 1

If eggshells are trialed for their ability to absorb iron ions, over multiple trials (3) then it will be found that the iron concentrations reduced in all trial cases.

Independent variable: iron solution A, B, C
Dependent variable: molarity of the solution after absorption period.
Controlled factors: Amount of solution, the molarity of the solution, temperature of the solution, potassium permanganate standardisation, number of trials, titration apparatus.

3.2 Hypothesis 2

If the eggshells already reduced the iron concentrations of A, B,C and then an ELGA® filtration device is used to further absorb iron, then it will be found that ELGA® has a further impact of the removal of iron ions from the solution.

Independent variable: Iron solutions A, B, C from experiment 1.
Dependent variable: molarity of the solution after passing though the ELGA® filtration device.
Controlled factors: Amount of Fe^{2+} solution, the molarity of the solution, temperature of the solution, potassium permanganate concentration, number of trials, titration apparatus.

3.3 Hypothesis 3

If the eggshell is crushed to varying degrees providing increased surface area for contact, then the higher the surface area of shell for the $\mathbf{Fe^{2+}}$ to contact, the higher the absorption of Fe^{2+} by the calcium carbonate. Therefore, the molarity of the $\mathbf{Fe^{2+}}$ will be reduced greater by resting in the ‘finely blended’ eggshell.

Independent variable: the amount of ‘Crush’ for each test of eggshells variables.
Dependent variable: molarity of the Fe^{2+} solution after absorption period.
Controlled factors: weight of eggshells, volume of Fe^{2+} solution, starting molarity of Fe^{2+} solution, absorption period (5 days), temperature of solution (room temperature), titration apparatus, potassium permanganate concentration (0.0187mol L^{-1}).

4.0 Materials and Methods

4.1 Preparation of standard iron solution ($Fe^{2+}_{(aq)}$)

Apparatus:

- Iron sulphate crystals
- Spatula
- Electronic balance
- Dry funnel
- Measuring tray
- De-ionised water
- 1L volumetric flask
- Pen and labels

Method:

1. Turn on electronic balance, re-zero, place the measuring tray in position and re-zero
2. Using the spatula measure out 11.12 grams of iron sulphate (see calculations for mass in appendix 1)
3. Using a dry funnel transfer the iron sulphate into the volumetric flask
4. Once all the visible crystals in the flask, wash any residues on the funnel into the flask using de-ionised water and fill to 1 litre.
5. Cork the flask and invert several times to ensure full dissolving of the solute.
6. Label the flask with name of solution, concentration, and date prepared and store for later use.

Photo 1a: Weighing iron sulphate crystals

1b. Iron solutions

4.2 Estimation of iron content in the prepared aqueous solution using standard potassium permanganate ($KMnO_{4\,(aq)}$)

Theory: The concentration, in parts per million and as a molarity of the iron sulphate solution can be estimated through titration with standard potassium permanganate. The permanganate in burette is slowly titrated into a known volume (aliquot) of the iron solution. With each drop, the iron solution becomes pink but then fades back to clear. A permanent faint pink colour indicates that all Fe^{2+} ions have been used up, hence an endpoint. Sulphuric acid is added so that excess H^+ ensures the permanganate reacts with the iron.

Apparatus:

- Potassium permanganate solution (approx. 0.02 mL^{-1})
- Sample water containing Fe^{2+} of unknown concentration
- burette
- funnel
- 20.0 mL pipette
- pipette filler
- 3 x 100 mL conical flasks
- 3x 5.0 mL^{-1} $H_2SO_{4\,(aq)}$
- White tile

Photo 2A: Titration of iron solution with standard potassium permanganate

Independent Variable: Iron solution samples

Dependent Variable: The concentration of iron (Fe^{2+})

Control Factors: Molarity of potassium permanganate, the sulphuric acid added, the apparatus and method used, and means of determining endpoint (clear for 30 sec).

Reaction Equation: $MnO_4^-{}_{(aq)} + 5Fe^{2+}{}_{(aq)} + 8H^+{}_{(aq)} \rightarrow Mn^{2+}{}_{(aq)} + 5Fe^{2+}{}_{aq)} + 4H_2O_{(l)}$

1 : 5

Method:

1. Wash the burette through with a small volume of potassium permanganate (10 mL)
2. Fill the burette to the 0.0 mL mark with permanganate solution
3. Using a pipette, transfer 3 x 20.0 mL aliquots of iron solution to 3 conical flasks
4. Add 5.0 mL^{-1} $H_2SO_{4\,(aq)}$ to each flask (xs $H^+{}_{(aq)}$)
5. Place a white tile under the flask before titration to make end point more visible
6. Slowly titrate the permanganate solution into iron solution, swirling gently
7. Observe the end point when flask contents remain permanently pink (or for 30 sec)
7. Record the volume of the permanganate titre required for each aliquot of iron solution and calculate the concentration of the iron solution from the average of 3 titres.

4.3 Preparation of eggshell filtration system for iron removal and verification of its effects by titration with standard potassium permanganate ($KMnO_{4\,(aq)}$)

Theory: Calcium carbonate in eggshells are capable of absorbing heavy metals, like iron, from water (NPJ, Jacob et al, 2018). To trial this, a filtration medium with crushed eggshells was prepared and the iron rich water was exposed to the eggshell surface for a period of 5 days.

Apparatus:

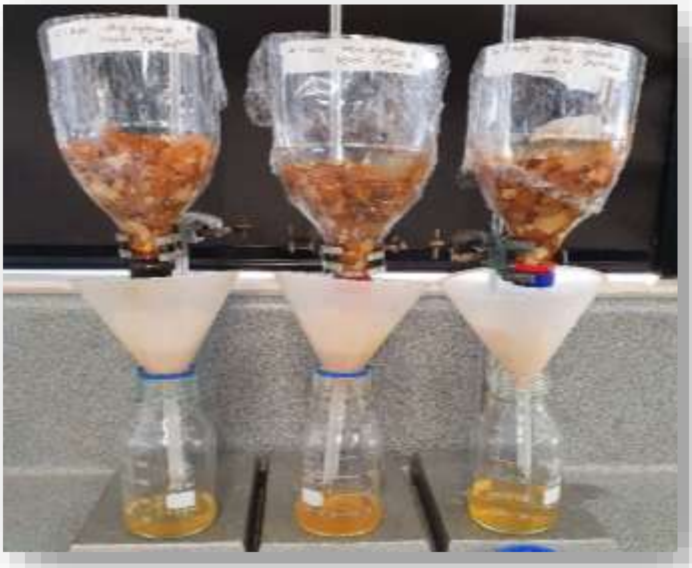
- Eggshells
- Plastic PET bottles for filtration medium
- Iron solution
- Glad-wrap

Method:

1. Crush 100 g eggshells and place in each of 3 inverted PET bottles, cut to required specifications
2. Pour 250 mL of iron solution into each pf the filtration media, ensuring caps are closed
4. Cover with cling wrap and leave filtration media to 'soak' for 5 days

Photo 3a: Preparation of eggshell filtration medium

Photo 3b: Completed filters with $Fe^{2+}_{(aq)}$ solution



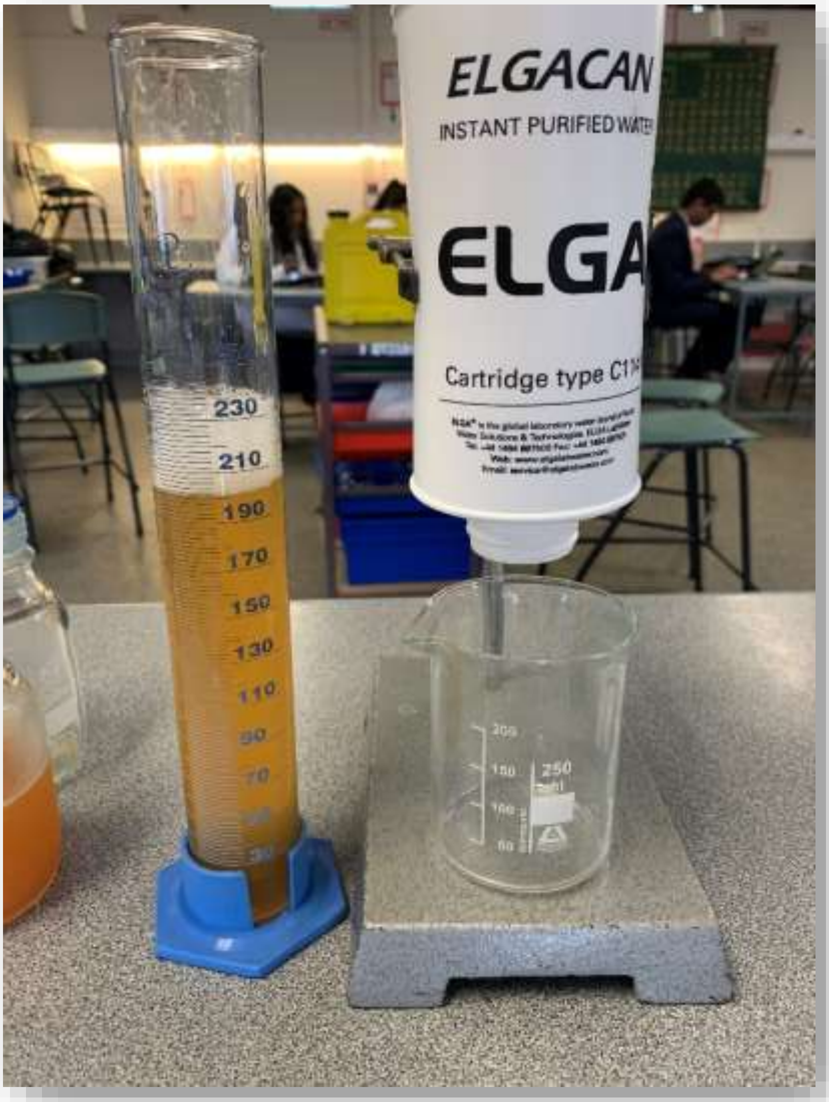
4.4 Preparation of ELGA© filtration system for iron removal and verification of its effects by titration with standard potassium permanganate ($KMnO_{4\,(aq)}$)

Theory: Commercial filtration cylinders are available for purification of household water. An example of one such filter is an ELGA© filter which can be used for home filtration systems or for making de-ionised water in schools. The iron solutions that went through the first eggshell filtrations were then passed through the ELGA© filter to see if it was possible to remove MORE of the iron.

Apparatus:

- Iron solution solutions from Exp 4.3
- an ELGA© filter
- collection bottles for filtered solutions

Photo 4a: Photo of the ELGA© filtration system for iron solutions



4.5 Preparation of 3 surface area variations of eggshell filtration media and verification of their effects by titration with standard potassium permanganate ($KMnO_{4\,(aq)}$)

Theory: Calcium carbonate has been seen to be capable of absorbing heavy metals, but it has been found (Expt 3) that some iron remains after 5 days exposure to eggshell media. It was hypothesised that if the eggshells were crushed more then increased surface area for contact with iron solutions would means greater iron absorbance. To trial this, three filtration media with **3 variables of crushed eggshells** were prepared and the iron rich water was exposed to the variable eggshell media for a period of 5 days.

Apparatus:

- Eggshells (3 crushed variables)
- Plastic PET bottles for filtration medium
- Cotton balls
- Iron solution
- Glad-wrap

Method:

1. Crush 100 g eggshells according to the following:
   (a) fine crush (in a food blender) (b) medium crush (c) normal' rough crush

Photo 5a: Image of three types of textured eggshells against the content of the ELGA filtration device.

2. Place crushed eggshells in each of 3 inverted PET bottles, cut to required specifications and place a cotton ball in the base of each filtration device.
2. Pour 250 mL of iron solution into each of the filtration media, ensuring caps are closed
4. Cover with cling wrap and leave filtration media to ‘soak’ for 5 days

5b. image of 3 different textured eggshells in iron solution

5c. image of 3 different textured eggshell after solution has been let out

5.0 Results

5.1 $Fe^{2+}_{(aq)}$ concentration: START - Before exposure to filtration.

Table 5.1A

Titre	Vol of 0.0187 mL^{-1} $KMnO_{4\,(aq)}$ to estimate 20.0 mL $Fe^{2+}_{(aq)}$ soln.	Concentration of $Fe^{2+}_{(aq)}$ soln. in $mol.L^{-1}$ (Calc: see app 1)	Concentration of $Fe^{2+}_{(aq)}$ soln. in ppm (Calc: see app 2)
1	2.70ml	0.0115 $mol.L^{-1}$ (3SF)	0.642275 $g.L^{-1}$ 642 ppm (3SF)
2	2.40ml		
3	2.30ml		
Average	2.467 mL		

5.2 $Fe^{2+}_{(aq)}$ concentrations: After 5 days exposure to eggshell filtration.

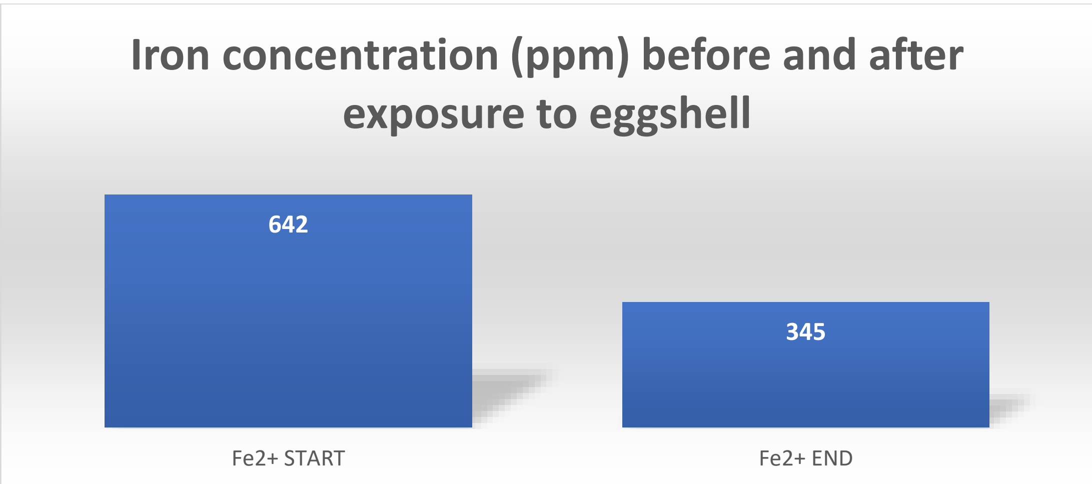
Table 5.1B

Titre	Vol of 0.0187 mL^{-1} $KMnO_{4\,(aq)}$ to estimate 20.0 mL $Fe^{2+}_{(aq)}$ soln.	Concentration of $Fe^{2+}_{(aq)}$ soln. in $mol.L^{-1}$ (Calc: see app 1)	Concentration of $Fe^{2+}_{(aq)}$ soln. in ppm (Calc: see app 2)
1	1.50 mL	0.00623 $mol.L^{-1}$ (3SF)	0.345057 $g.L^{-1}$ 345 ppm (3SF)
2	1.30 mL		
3	1.20 mL		
Average	1.333 mL		

Effect of 5 days exposure to eggshell filtration on Fe^{2+} concentration.

Table 5.1C

START Concentration of $Fe^{2+}_{(aq)}$ soln. in ppm	END Concentration of $Fe^{2+}_{(aq)}$ soln. in ppm	CHANGE in Concentration of $Fe^{2+}_{(aq)}$ soln. in ppm
642 ppm (3SF)	345 ppm (3SF)	297 ppm (3SF) drop



5.3 $Fe^{2+}_{(aq)}$ concentrations: START - Before exposure to ELGA© Filter

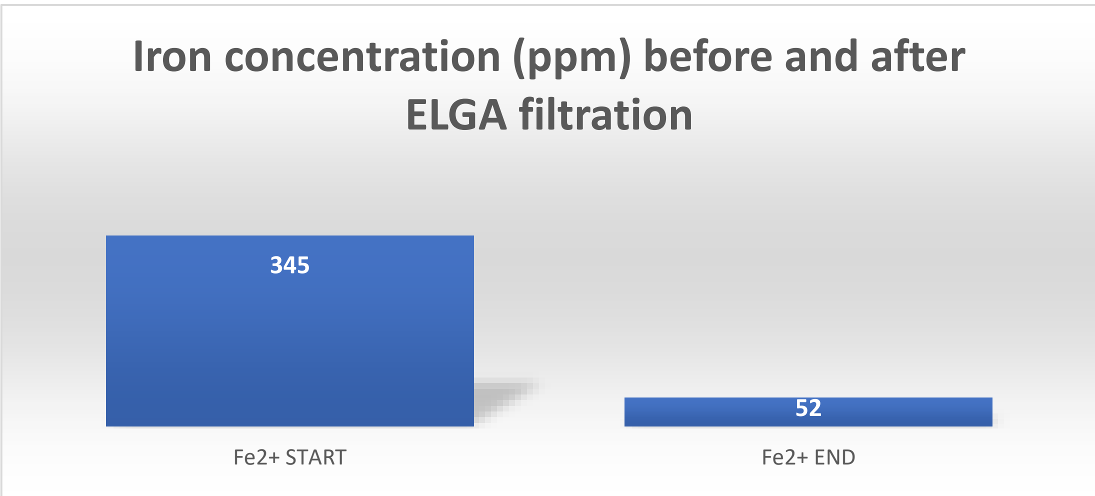
Table 5.2A

Solution being exposed to ELGA© Filter	START Concentration of $Fe^{2+}_{(aq)}$ soln. in ppm
Eggshell treated solution from Exp 1	**345 ppm (3SF)**

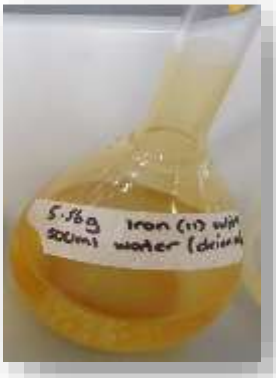
$Fe^{2+}_{(aq)}$ concentrations: After exposure to ELGA© Filter

Table 5.2B

Titre	Vol of 0.0187 mL^{-1} $KMnO_{4\,(aq)}$ to estimate 20.0 mL $Fe^{2+}_{(aq)}$ soln.	Concentration of $Fe^{2+}_{(aq)}$ soln. in $mol.L^{-1}$ (Calc: see app 1)	Concentration of $Fe^{2+}_{(aq)}$ soln. in ppm (Calc: see app 2)
1	0.200 mL	**0.000935 $mol.L^{-1}$ (3SF)**	**0.05221975 $g.L^{-1}$ 52 ppm (3SF)**
2	0.200 mL		
3	0.200 mL		
Average	**0.200 mL**		



FILTRATION TRIAL # 2



5.4 New $Fe^{2+}{}_{(aq)}$ solution:

Concentration before exposure to 3 variables of eggshell filtration (coarse, medium, fine ground)

Table 5.3A

START Concentration of $Fe^{2+}{}_{(aq)}$ soln. in ppm	START Concentration of $Fe^{2+}{}_{(aq)}$ soln. in ppm
5.56g $FeSO4.7H_2O$ in 500mL H_2O (later diluted to 750mL)	Stock solution ($FeSO_4.7H_2O$) = m/M = 5.56/278 = 0.0200 mol Fe^{2+} in 500 mL H_2O (0.02/0.500L) = 0.04 mol.L^{-1} later dilution (0.02/0.750L) = 0.0267 mol.L^{-1} starting conc. Fe^{2+} = 1117 ppm

5.5 $Fe^{2+}{}_{(aq)}$ concentrations: After 5 days of eggshell filtration

Table 5.3A - Coarse grind of eggshell

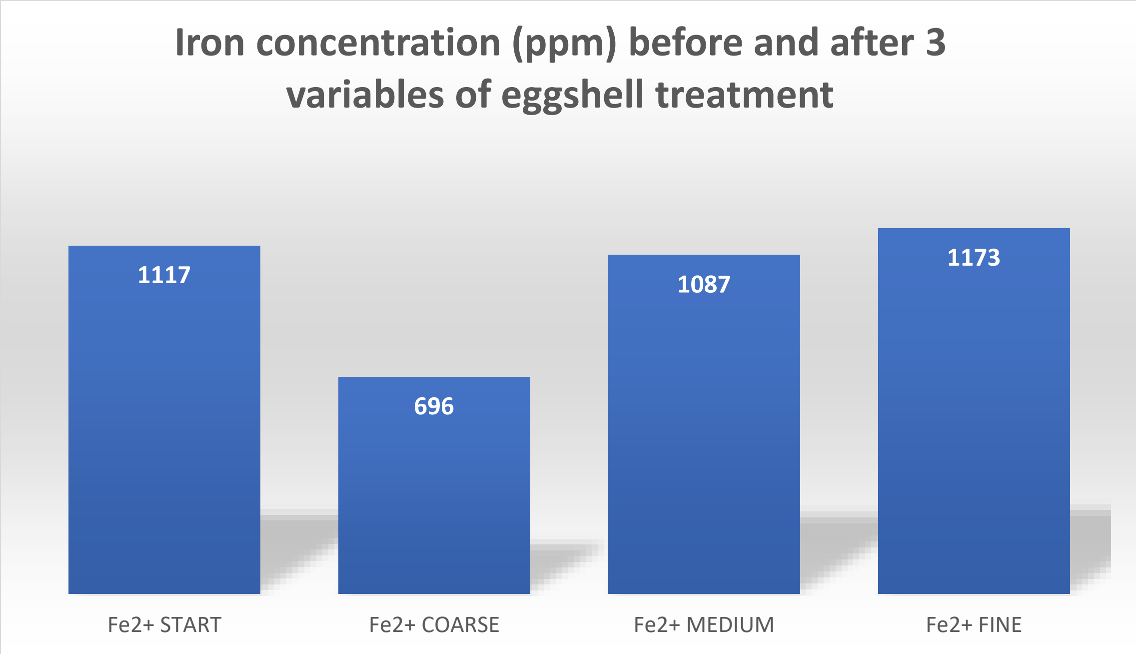
Titre	Vol of 0.0187 mL^{-1} $KMnO_4{}_{(aq)}$ to estimate 20.0 mL $Fe^{2+}{}_{(aq)}$ soln.	Concentration of $Fe^{2+}{}_{(aq)}$ soln. in mol.L^{-1} (Calc: see app 1)	Concentration of $Fe^{2+}{}_{(aq)}$ soln. in ppm (Calc: see app 2)
1	2.60 mL	0.0125 mol.L^{-1} (3SF)	696 ppm (3SF)
2	2.50 mL		
3	2.90 mL		
Average	2.667 mL		

Table 5.3B - Medium grind of eggshell

Titre	Vol of 0.0187 mL^{-1} $KMnO_4{}_{(aq)}$ to estimate 20.0 mL $Fe^{2+}{}_{(aq)}$ soln.	Concentration of $Fe^{2+}{}_{(aq)}$ soln. in mol.L^{-1} (Calc: see app 1)	Concentration of $Fe^{2+}{}_{(aq)}$ soln. in ppm (Calc: see app 2)
1	4.10 mL	0.0195 mol.L^{-1} (3SF)	1087 ppm (3SF)
2	4.30 mL		
3	4.10 mL		
Average	4.167 mL		

Table 5.3C - Fine grind of eggshell

Titre	Vol of 0.0187 mL^{-1} $KMnO_4{}_{(aq)}$ to estimate 20.0 mL $Fe^{2+}{}_{(aq)}$ soln.	Concentration of $Fe^{2+}{}_{(aq)}$ soln. in mol.L^{-1} (Calc: see app 1)	Concentration of $Fe^{2+}{}_{(aq)}$ soln. in ppm (Calc: see app 2)
1	4.70 mL	0.0210 mol.L^{-1} (3SF)	1173 ppm (3SF)
2	4.50 mL		
3	4.30 mL		
Average	4.50 mL		


Iron concentration (ppm) before and after 3 variables of eggshell treatment
1117
696
1087
1173
Fe2+ START
Fe2+ COARSE
Fe2+ MEDIUM
Fe2+ FINE

6.0 Discussion

Experiment 1.
The first experiment was conducted to find if iron (Fe^{2+}) of a molarity of approximately 0.01mol L^{-1} can be verified using standard potassium permanganate ($KMnO_4$). The outcome of the test was that the molarity was 0.0115mol L^{-1} therefore the test showed that $KMnO_4$ is a measurable indicator of molarity for iron ions in an aqueous solution.

Experiment 2.
Secondly, 250ml of the iron solution of 0.0100 mol L^{-1}, was then placed with 100g of roughly crushed eggshells in 3 filtration media. The Fe^{2+} solution was then left exposed to the eggshells for a period of 5 days. Allowing the iron solution access for 5 days to the absorption medium it was hoped to result in optimal removal of aqueous iron from solution. This proved to be the case with starting iron solution concentration of 642 ppm reducing to 345 ppm after exposure. This represents a 46% drop in iron concentration. Given that the removal of iron ions was not complete in experiment 2 a discussion with the college laboratory technician led to the suggestion that secondary filtration with an ELGA filter may further remove iron ions. Subsequently it was decided that filtrates from experiment 2 would pass through an ELGA filter.

Experiment 3.
In this experiment, the filtrates from experiment 2 containing 345 ppm of Fe^{+2} ions were passed through an ELGA filter. ELGA filters that are produced by ELGA LabWater (UK) generally operate under mains water pressure. However, in this experiment, gravity was the acting force on the filtration this resulted in the process being slow. After a number of hours an adequate supply of aqueous solution was generated to then conduct a potassium permanganate ($KMnO_4$) titration to estimate the iron (Fe^{2+}) in the solution. The resultant drop in Iron was from the starting, 345 ppm to 52 ppm. By using the ELGA filter there was an 85% decline in contamination of iron in the solution. The content of the ELGA filter is a small crushed substance, by the found effectiveness of the ELGA filter, it was decided that a test would be conducted to see if the surface area is increased by crushing the eggshell to a similar size as the content of the ELGA filter.

Experiment 4.
This experiment was conducted to find the effectiveness of the surface area if it is increased by crushing the eggshells so that they replicate the granules in the ELGA filter. Three different particle sizes of eggshells were created, course, medium and fine. It was found that having the eggshells granulated to very fine particle size lead to ineffective removal of Fe^{2+}. Due to the ineffective penetration of the iron solution to the eggshell there was a lack of contact to allow the transfer of the iron. In image 5c the filtration medium in the right- hand-side shows the solution sitting above the eggshells. By the iron solution not having a good flow around the eggshell the exchange of iron ions to the eggshell was not occurring. It is assumed that by having the eggshells so fine that there a substance that is going into the solution which is being read by the potassium permanganate as iron (Fe^{2+}). The best and most effective method was the use of the course crushed eggshells, where the starting solution of 1117 ppm reduced to 696 ppm, a 37% reduction in iron ions. This finding was unexpected, as it was thought that the best iron filter would be fine eggshells, followed by medium, then coarse. However, these other variables became waterlogged and gave less ion removal that the coarse variable.

7.0 Hypotheses Outcomes.

7.1 Hypothesis 1: Supported.

(i) *If eggshells are trialed for their ability to absorb iron ions, over multiple trials (3) then it will be found that the iron concentrations reduced in all trial cases.*

Hypothesis 1 was supported by the results of the tests. The iron solution saw a drop in concentration and therefore the eggshells absorbed the Fe^{2+} ions from the solution and reduced the toxicity of the water.

7.2 Hypothesis 2: Supported.

(ii) *If the eggshells already reduced the iron concentrations of A, B,C and then an* ELGA® *filtration device is used to further absorb iron, then it will be found that* ELGA® *has a further impact of the removal of iron ions from the solution.*

Hypothesis 2 was supported by the results of the tests. The iron solution saw a dramatic change in the concentration of Fe^{2+} ions. The water that had passed through the ELGA© Filter had become clear and the molarity of the water also dropped to really low numbers.

7.3 Hypothesis 3: Unsupported

(iii) *If the eggshell is crushed to varying degrees providing increased surface area for contact, then the higher the surface area of shell for the* ***Fe^{2+}*** *to contact, the higher the absorption of Fe^{2+} by the calcium carbonate. Therefore, the molarity of the Fe^{2+} will be reduced greater by resting in the 'finely blended' eggshell.*

Hypothesis 3 was unsupported by the tests that were undertaken. They hypothesis stated that the greater the surface area, the smaller the eggshell was the more the iron concentration would decrease. By the results, the more the eggshell was crushed the less of an impact it had on removing the iron from the solution. In the case of the blended eggshells it showed an increase in iron found by titrating the Potassium Permanganate in the solution. This may show that by the eggshell being so fine that there was something in the egg that triggered the potassium permanganate to believe that it was iron.

8.0 Conclusions

8.1 Conclusion of effectiveness of $KMnO_4$ reagent

It has been found that standard acidified potassium permanganate is a effective reagent for estimating iron content in aqueous solutions. When used across four testing scenarios it delivered titres capable of being used in calculations to find iron concentrations.

8.2 Conclusion of effectiveness of eggshell as an absorption method

It has been found that the use of eggshell as an absorption medium is an effective tool. By titration with standard acidified potassium permanganate, it was found that the use of eggshells lead to 46% decrease of iron ions in the aqueous solution.

8.3 Conclusion of effectiveness of ELGA filtration device of iron solution

The experiment of using ELGA filtration device on the already reduced iron solution caused an even greater decrease of the iron content in iron solution. The beginning concentration of the solution was 345 ppm and resulted in only 52 ppm, this in turn is an 85% decrease in Fe^{2+} ions in the solution.

8.4 Conclusion of effectiveness by increasing surface area of eggshell as an absorption method of iron ions from a solution

It has been found that by increasing the surface area, crushing the eggshells to a finer texture, was not beneficial to the extraction of iron ions from the solution. This is most likely due the size of the granules, they were so tightly packed that the iron solution did not have free flow around the eggshells, allowing for the absorption of the iron ions. (See image 5c) The best size of eggshell for the absorption of iron ions is the rough crush of eggshells which is shown by the results of the titrations of acidified standard potassium permanganate. When using the fine crush of eggshell that had been put through a blender, it was found after titration that it was not only a failure at removing any iron ions, but it was a reading that was higher than the starting iron content. Thus, it shows that by having it blended it was adding something to the solution which the potassium permanganate picked up as being iron ions.

9.0 Recommendations

Having completed this investigation, I can make the following recommendations.

To governments, water authorities and local councils:
Where water filtration is being undertaken, inclusion of calcium carbonate (from crushed shells) might be a valuable inclusion in filtration beds.

To not for profit organisations and charities:
There is great importance in educating communities on the health and safety of clean drinking water. Contaminated water should be avoided and home filtration, with eggshells, is effective at removing some, if not all, of iron ions (Fe^{2+}) present

People living in remote areas that do not have access to clean water:
ELGA commercial filters are excellent at heavy metal removal. However, if access to these is not available, then eggshell filtration does have some removal capacity, and is an affordable alternative.

10.0 References

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12.0 Appendices

Appendix: Calculations used in this investigation

1. Calculation of mass of **oxalic acid** needed to make **0.035 mol.L^{-1}** solution

Oxalic Acid: $(COOH)_{2\,(s)}$

$M_r\,(COOH)_2 = 90.0$ g/mol^{-1}

Process:

1. Accurately weigh **3.15g** of oxalic acid $(COOH)_{2\,(s)}$
2. Using a dry funnel place all the crystals in a 1000 mL conical flask
3. Fill the flask to the calibration mark with deionized water
4. Invert many times to ensure crystals have dissolved
6. Label the flask.

5. **Concentration of oxalic acid solution:**

(a very good primary standard)

$$n\,(COOH)_2 = \frac{m}{M} = \frac{3.15}{90.00} = 0.035 \text{ mol}$$

$$c\,(COOH)_2 = \frac{\text{mol}}{\text{L}} = \frac{0.035 \text{ mol}}{1.00 \text{ L}} = \mathbf{0.035\ mol.L^{-1}}$$

This solution of oxalic acid was used to **standardize the $KMnO_4$** immediately before the permanganate is used for estimation of $Fe^{2+}_{(aq)}$.

2. Calculation of the **concentration of potassium permanganate** used for all $Fe^{2+}_{(aq)}$ estimations, by titration with **standard oxalic acid.**

Aim: Use 0.035 $mol.L^{-1}$ $(COOH)_{2\,(aq)}$ to standardize approx. 0.0200 mL^{-1} $KMnO_{4\,(aq)}$.

Set-up: Approx 0.0200 mL^{-1} $MnO_4^-{}_{(aq)}$ was placed in a burette and titrated into 10.0 mL aliquots of $(COOH)_{2\,(aq)}$ in conical flasks

Reaction:

$$2\,MnO_4^-{}_{(aq)} + 5(COOH)_{2\,(aq)} + 6H^+_{(aq)} \longrightarrow 2Mn^{2+}_{(aq)} + 10CO_{2\,(g)} + 8H_2O_{(l)}$$

2 : 5

Average titre of $MnO_4^-{}_{(aq)}$ required to oxidise 10.0mL $(COOH)_{2\,(aq)}$ = **7.50 mL**

$n(COOH)_2$ in 10.0 mL = c x v

= 0. 035 x 0.010

= 0.00035 mol

$n(MnO_4^-)$ in 5.10 mL = $\frac{0.00035 \text{ mol} \times 2}{5}$ (by reaction ratio)

= 0.00014 mol

$c\,(MnO4^-) = \frac{n}{v} = \frac{0.00014 \text{ mol}}{0.00750 \text{ L}} =$ **0.0187 $mol.L^{-1}$**

Note:

Concentration of potassium permanganate solution used for estimating $Fe^{2+}_{(aq)}$ ion concentrations in water, for this report was:

0.0187 $mol.L^{-1}$ $KMnO_{4\,(aq)}$

3. Typical calculation of the **concentration of $Fe^{2+}_{(aq)}$** by titration with standard **0.0187 mol.L^{-1} $KMnO_{4\,(aq)}$**.

Aim: Use 0.0187 mL^{-1} $MnO_4^-{}_{(aq)}$ to estimate the $Fe^{2+}_{(aq)}$ content in water samples.

Set-up: **0.0187 mL^{-1} $MnO_4^-{}_{(aq)}$** in burette titrated into **20.0 mL aliquots** of unknown concentration $Fe^{2+}_{(aq)}$ solution in conical flasks

Reaction:

$$MnO_4^-{}_{(aq)} + 5\,Fe^{2+}_{(aq)} + 8H^+_{(aq)} \longrightarrow Mn^{2+}_{(aq)} + 5\,Fe^{2+}_{(aq)} + 4H_2O_{(l)}$$

1 : 5

Using results from the first titration: **$Fe^{2+}_{(aq)}$ concentration: START - Before exposure to filtration.**

Result: **Vol of 0.0187 mL^{-1} $KMnO_{4\,(aq)}$ needed to estimate $Fe^{2+}_{(aq)}$ in 20.0 mL of iron solution = 2.467 mL**

n (MnO_4^-) in **2.467 mL** = c x v

= 0. 0187 x 0.002467

= 0.00004613 mol

n (Fe^{2+}) in 10.00 mL = 0.00004613 mol x 5 (by reaction ratio)

= 0.00023066 mol Fe^{2+}

$$c(Fe^{2+}) = \frac{n}{v} = \frac{0.00023066\ \text{mol}}{0.020\ \text{L}} = \mathbf{0.0115\ mol.L^{-1}\ Fe^{2+}_{(aq)}}$$

In parts per million, a litre of this solution would contain:

0.0115 mol.L^{-1} $Fe^{2+}_{(aq)}$ x mass of iron per mole

= **0.0115** x **55.85 grams** Fe^{2+}

= 0.6422 g Fe^{2+} in 1.0 L H_2O

= 0.6422 x 1000 mg Fe^{2+} in 1,000,000 mg H_2O

= **642 ppm $Fe^{2+}_{(aq)}$**

(Note: All iron concentrations after filtration in eggshells were calculated using this method).

RISK ASSESSMENT for PRACTICAL INVESTIGATIONS BHP 2020

Practical Activity: a brief description of what is planned

Experiments:

- Preparation of standard iron solution ($Fe^{2+}_{(aq)}$)
- Estimation of iron content in the prepared aqueous solution using standard potassium permanganate ($KMnO_{4\,(aq)}$)
- Preparation of eggshell filtration system for iron removal and verification of its effects by titration with standard potassium permanganate ($KMnO_{4\,(aq)}$)
- Preparation of ELGA© filtration system for iron removal and verification of its effects by titration with standard potassium permanganate ($KMnO_{4\,(aq)}$)
- Preparation of 3 surface area variations of eggshell filtration media and verification of their effects by titration with standard potassium permanganate ($KMnO_{4\,(aq)}$)

What are the possible Risks?

List the Hazards present in this activity that could pose a Risk.
Give each Risk a Risk Rating (eg High Risk, Medium Risk, Low Risk).

Getting iron sulphate on clothes and hands Inhalation of calcium carbonate Stain of potassium permanganate on clothing or work surfaces.	Consider: Chemical Thermal Biological Sharps Electrical Radiation Other Hazards

Control Measures?

Give details of how these risks will be managed.

The use of gloves, glasses and lab coat
Good ventilation within room
Supervising teacher and laboratory technician

Are there any activities that will require adult/ teacher supervision?

Use of electric blender
Titration of potassium permanganate at beginning stages of experiment

Facilities and Services that will be needed to do this activity safely.

Services	PPE	Safety Equipment
Electricity	Lab coat Glasses gloves	Override electrical switch Card underneath Burette and stand to prevent staining benchtop.

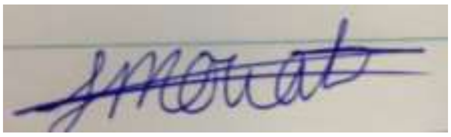
Disposal of Wastes and Cleaning Up

Are any wastes or hazardous products produced in this activity? If so, how will they be disposed of?

The titrated solution in conical flasks, they were given to the laboratory technician to dispose of correctly.

Risk Assessment indicates that this activity can be safely carried out.

This Risk Assessment has been carried out and checked by the following:

Student's Name (please print)::	Signature:	Date
Tailah Mowat		21/09/2020
Teacher/ Supervisor Name (please print)	Signature	Date
Ms Ann Burke Mr Darren Cox	 	22/9/2020

This RISK ASESSMENT: Initiated on 1.5.2020 and completed 21. 9 2020

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