Solving Water Pollution in Nepal

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Abstract— **Nepalese are extremely vulnerable to severe health problems due to the severity of water pollution. Nitrate and nitrite contamination poses health threats such as methemoglobinemia while high levels of sulfates in drinking water run high risks of severe dehydration resulting from diarrhoea. However there are a lack of convenient, readily affordable and efficient methods to treat this type of water pollution. Hence, there is an urgent need to address such limitations of existing methods.**

Our objective is to investigate the adsorptions of nitrate, nitrite, and sulfate through the use of natural materials commonly found in Nepal: spent tea leaves, water lettuce, and coconut husks to achieve the aforementioned objective.

The powdered form of each of the three materials are soaked in a solution containing a fixed concentration of contaminant ions. The mass of the powder and the duration of soaking is varied (mass: 0.2g, 0.5g and 1.0g and duration: 30 minutes, 150 minutes, 1440 minutes). The solution is then filtered and tested using ion chromatography to determine the remaining concentration of ions that are not adsorbed. The different variables allow us to determine the ideal material and conditions to remove the greatest amount of the pollutant ions.

Based on our results, water lettuce is the most effective material to remove all three ions. Its ideal mass is 0.2 gram and generally the duration of soaking is 30 minutes. Our hypothesis that water lettuce is the most effective material due to the presence of amine functional group is thus verified.

However, coconut and spent tea leaves have proven to be more effective than water lettuce for longer duration of soaking. Coconut is able to remove the most nitrite and sulfate at 150 minutes while tea waste is able to remove the most nitrate at 1440 minutes. We postulated that different materials have different ideal adsorption duration. However, water lettuce was identified as the greatest potential excellent adsorbent since it is able to remove the highest amount of sulfate at both 30 minutes and 1440 minutes.

The removal of nitrate challenged our hypothesis as several of the experiments showed that the concentration of nitrate increases after treatment with the materials. We postulated that negative adsorption had occurred. This is possible due to the presence of solvent (water) in the materials itself. Another possibility is the deprotonation of hydroxyl group in the materials.

In considering the potential for commercialization, we considered the strength of each of the three materials at different duration of soaking. We also take into consideration the challenge in maximising exposed surface area of the material in the solution due to the difficulty in keeping the powder completely suspended.

Keywords- water pollution; adsorption

I. INTRODUCTION

As water pollution remains a serious problem in Nepal, the water quality and its availability to Nepalese have been significantly compromised. Nepalese are hence vulnerable to severe health problems due to consumption of highly contaminated drinking water. One area of concern would be nitrate contamination resulting from excessive use of fertilisers for agriculture production[1]. For instance, in Nepal's Kathmandu Valley, nitrate concentrations of 25mgN/L in 2008 have far exceeded World Health Organisation (WHO) guidelines of 12mgN/L[2]. Nitrate being reduced to nitrite pose further health risks because high nitrate/nitrite consumption has notoriously been proven to harm infants, commonly causing methemoglobimia or blue-baby syndrome and can increase the risk of gastric cancer[3] too. Furthermore, high sulfate concentrations of more than 400mg/L arising from the leaching of sulfate compounds from minerals such as gypsum or oxidation of sulfide minerals such as sedimentary rocks have made water unpleasant to drink[4]. There is a high risk of severe dehydration resulting from diarrhoea due to high levels of sulfates in drinking water[5].

Currently, to mitigate the problem of water pollution, some of the common ways employed to remove these contaminants are ion-exchange, reverse osmosis and chemical precipitation. Often, ion-exchange is associated with high capital and operating cost. Capital and operating cost can be as high[6] as £0.48 M per 10^3 m^3/day and £0.17/m^3 respectively[7]. Such high cost hinders widespread development of water treatment plants across the country, limiting the distribution and accessibility of portable water significantly. Reverse-osmosis tend to suffer from the instability of the membranes in salty or acidic conditions and fouling by inorganic and organic substances present in waste water[8]. Additionally, these techniques need pre-treatment or even additional treatments[9].

As such, our research focuses on the removal of the above mentioned contaminants (nitrates, nitrites and sulfates) in drinking water through more cost-effective and efficient means. We have decided to look into the area of biosorption. After careful deliberation, we have chosen coconut shell, spent oolong tea leaves and water lettuce as our adsorbent of contaminants. Coconut is one the commonly cultivated fruits in Nepal[10]. Moreover, not only does Nepal have a long history of cultivating tea, Nepalese are habitual to drinking tea[11]. Additionally, water lettuce, notoriously known to be a host plant, are found to be relatively widely present in Nepal[12] and has hence posed a threat to the ecology recently, as seen in the case of Tikauli Lake which is invaded by water lettuce and other organisms are adversely affected[13]. As such, coconut shell, spent tea leaves and water lettuce are readily available in Nepal, hence, proving the feasibility of keeping water treatment cost to the minimum when resources can be optimally utilised, while simultaneously, reducing disposal problems and .

Besides being economical, these chosen adsorbents have the potential to effectively remove contaminants in drinking water. The highly porous character[14] and large internal surface area[15] of coconut shell allow adsorption to occur efficiently. It has been found that oolong tea contains a high content of theanine[16] - a type of amino acid, indicating the presence of N-H functional groups (Fig 1). Besides oolong tea, water lettuce also contains amine groups[17]. N-H functional groups can act as chemical binding agents as they can be protonated and attract the negative anions[18] in the contaminated water.

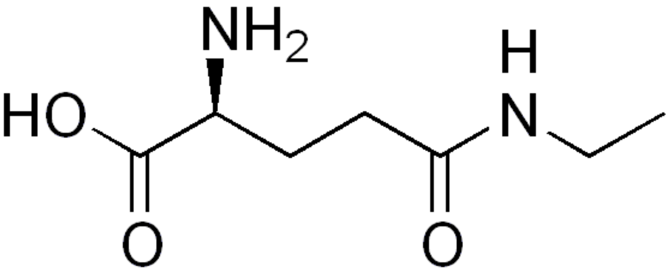

Fig 1. Chemical structure of theanine showing presence of N-H functional group

We would like to investigate and compare the relative effectiveness of coconut shell, spent oolong tea leaves and water lettuce in the removal of nitrate, nitrite and sulphate anions. In doing so, we hope to incorporate our findings to applications which can effectively remove these contaminants found in polluted water.

Our hypothesis is that water lettuce is the most effective because of the anime group, followed by tea waste and lastly coconut shell.

II. METHODOLOGY

2.1 PREPARATION OF SORBENTS

Oolong tea leaves were first prepared by soaking them in tap water at 90 °C for 10 min twice. After that, the tea leaves were recovered and were grounded to fine particles using mortar and pestle. After being grounded, the water lettuce was dried at 250°C for 20 minutes and then stored in a zip lock bag for future use[1].

The water lettuce were bought from Far East Flora Pte Ltd. Having washed the leaves of water lettuce with distilled water, they were grounded to fine particles using mortar and pestle. After being grounded, the water lettuce was dried at 250°C for 20 minutes and then stored in a zip lock bag for future use[2].

Coconut fruits were bought from Fairprice (Thailand Young Coconut) and the shell was extracted. The shell was then placed on a clean surface and broken into smaller pieces with the use of a hammer. These smaller pieces were grounded to fine particles using mortar and pestle. The fine dust particles were introduced into an oven at a temperature of 250°C for 20 minutes and then preserved in a clean container for future use[3]

2.2 PREPARATION OF SOLUTION MIXTURE OF ANIONS

0.805g of $ZnSO_4$. 0.945g of $Zn(NO3)_2$, 0.345g of $NaNO_2$, 0.710g of Na_2SO_4 were weighed with an electronic balance. These compounds were dissolved together in 80 cm^3 of distilled water to obtain 0.125 mol/dm^3 of NO_3^-, 0.0625 mol/dm^3 of NO_2^- and 0.125 mol/dm^3 of SO_4^{2-} .

2.3 EXPERIMENTAL PROCEDURES

Batch adsorption experiments were conducted to investigate the effect of the mass of sorbents used and contact time on the adsorption of NO_3^-, NO_2^- and SO_4^{2-} on spent tea leaves, water lettuce and coconut shell. The adsorption mixtures were uniformly and continuously agitated with a platform shaker at room temperature (25°C). At the end of the experiment, each mixture was filtered with a piece of filter paper into a clean conical flask. After which, 10^{-4} dm^3 of the filtrate was extracted using a 100 microlitre pipette and further diluted with 100cm^3 of distilled water. The diluted filtrate was then filtered with a micron filter into a small tube. The concentration of anions in the tube was determined using ion chromatography. The amount of anions adsorbed from the solution was calculated by taking the difference between initial and final concentrations.

2.3.1 Variation of sorbent mass

0.2 g of each adsorbent was first weighed into three 100 ml beakers containing the 80 cm^3 solution mixture of anions separately. The adsorption mixtures were continuously agitated at room temperature for 30 minutes after which the content of each beaker was filtered. The experimental setup was thereafter repeated for various sorbent mass of 0.2, 0.5 and 1.0g.

2.3.2 Variation of contact time

0.2 g of each adsorbent was first weighed into three 100 ml beakers containing the 80 cm^3 solution mixture of anions separately. The mixtures were first uniformly agitated for 30 minutes at room temperature before filtration. The experimental setup was thereafter repeated for various time intervals of 30, 150 and 1440 minutes.

III. RESULTS

3.1 Nitrite

Based on the results of ion chromatography, we can derive the percentage of each ions adsorbed by the sample by calculation. Generally, there is a decreasing trend observed, with the longer the time for the sample to be soaked, the lower the percentage of ions adsorbed. Water lettuce shows that it can remove the highest percentage of nitrite ion at 30 minutes and 1440 minutes for a fixed mass of sample of 0.2g. For 150 minutes, coconut husk is able to remove the highest percentage of nitrite ions (Annex 1, Figure 1). Both water lettuce and coconut are the most effective at mass of 0.2g (Annex 1, Figure 2)

3.2 Sulfate

Overall there is a decreasing trend between the percentage of sulfate ions adsorbed and the time taken. Water lettuce removes the highest percentage of sulfate ions at 30 minutes and 1440 minutes, while coconut removes the highest percentage of sulfate ions at 150 minutes (Annex 1, Figure 3). The most effective mass for both water lettuce and coconut is 0.2 grams (Annex 1, Figure 4).

3.3 Nitrate

There is also a general decreasing trend between the percentage adsorbed and the time taken. Water lettuce has the highest percentage of nitrate ion at 30 minutes and 150 minutes for a fixed mass of 0.2 grams. Meanwhile, spent tea leaves has the highest percentage of nitrate ion removal for 1440 minutes (Annex 1, Figure 5). The most effective mass for water lettuce is 0.2 grams and 1.0 gram for tea waste. (Annex 1, Figure 6).

IV. DISCUSSION

Oolong tea leaves were first prepared by soaking them in tap water at 90 °C for 10 min twice. After that, the tea leaves were recovered and were grounded to fine particles using mortar and pestle. After being grounded, the water lettuce was dried at 250°C for 20 minutes and then stored in a zip lock bag for future use[1].

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V. CONCLUSION AND FUTURE APPLICATION

From the experiment we can gather that the most effective condition for ion removal is to use 0.2 grams of water lettuce and soak it for 30 minutes. A possible commercialised device to be made out of this would be a tea bag as it is light, portable, and easily disposable. A future research possible would be to investigate the reusability of the water lettuce. This can be done by rinsing the water lettuce with de-ionised water and measure the effectiveness of the ion adsorption afterwards.

For a longer time period, spent tea leaves has proven to be prospective adsorbents at 0.2 grams for sulfate and nitrite while water lettuce showing the potential to adsorb nitrate well. These can be incorporated into a ball that can be thrown into a collective source of water that is able to adsorb the pollutants. It will be easily removed, thus making it environmentally friendly.

For further research, it is necessary to investigate the negative adsorption that takes place with nitrate and how it can be mitigated. It is important to continue this research as pollutants, no matter how insignificant they may seem, needs to be safely removed in order to create a sustainable water source for the future generation.

ACKNOWLEDGMENT (HEADING 5)

The preferred spelling of the word "acknowledgment" in America is without an "e" after the "g". Avoid the stilted expression, "One of us (R. B. G.) thanks . . ." Instead, try "R. B. G. thanks". Put sponsor acknowledgments in the unnumbered footnote on the first page.

REFERENCES

[1] Antonio Zuorro, Roberto Lavecchia, Franco Medici, Luigi Piga. 2013. "Spent Tea Leaves as a Potential Low-cost Adsorbent for the Removal of Azo Dyes from Wastewater ." *The Italian Association of Chemical Engineering.*

[2] Cabi. 2014. *Invasive Species Compendium.* Accessed 3 April, 2015. http://www.cabi.org/isc/datasheet/41496.

[3] Devkota, Sudip. 2014. "Fruits in Nepal." *Academia.*

[4] Jaya Kumar Gurung, Hiroaki Ishiga, Mohan Singh Khadka and Nav Raj Shrestha. n.d. "Characterization of groundwater in the reference of arsenic and nitrate."

[5] Laowansiri, Sunantha. 2011. "Kinetic and Efficiency of Reactive Dye Sorption by Plant Biomass." *Medwell* (Medwell) 15-19.

[6] N.R. Khatiwada, S. Takizawa, T.V.N. Tran and M. Inoue. 2002. "Groundwater contamination assessment for sustainable." *Water Science and Technology* 147-154.

[7] P. C. Okafor, P. U. Okon, E. F. Daniel and E. E. Ebenso. 2012. "Adsorption Capacity of Coconut (Cocos nucifera L.) Shell for Lead, Copper, Cadmium and Arsenic from Aqueous Solutions." *International Journal of Electrochemical Science* 12354 - 12369.

[8] R.J.Bowell. 2003. "A Review of Sulfate Removal Options."

[9] Rosen, Diana. 2012. *Tea Muse.* Accessed 3 April, 2015. http://www.teamuse.com/article_111103.html.

[10] Salman, Mohammed Sadeq. 2009. "Removal of Sulfate from Waste Water by Activated Carbon." *Al-Khwarizmi Engineering Journal* 72-76.

[11] SEAM-N. 2008. "Annual report of River Water Quality Monitoring of Dharan –Biratnagar Corridor."

[12] Warner, Nathaniel R, Jonathan Levy, and Karen Harpp. 2008. "Drinking Water Quality in Nepal's Kathmandu Valley: A Survey and Assessment of Selected Controlling Site Characteristics ." *Hydrogeology Journal* 321–334.

[13] 2014. *We All Nepali.* Accessed 3 April, 2015. http://www.weallnepali.com/recipe/special-items/nepalitea.

[14] World Health Organisation. 2002. "Water treatment processes for reducing nitrate concentrations ."

[15] WWF. 2013. *Communities Come Together to Protect Wetland.* 25 January. Accessed 3 April, 2015. http://www.wwfnepal.org/?207351/Communities-come-together-to-protect-wetland.

ANNEX

<u>Annex 1</u>

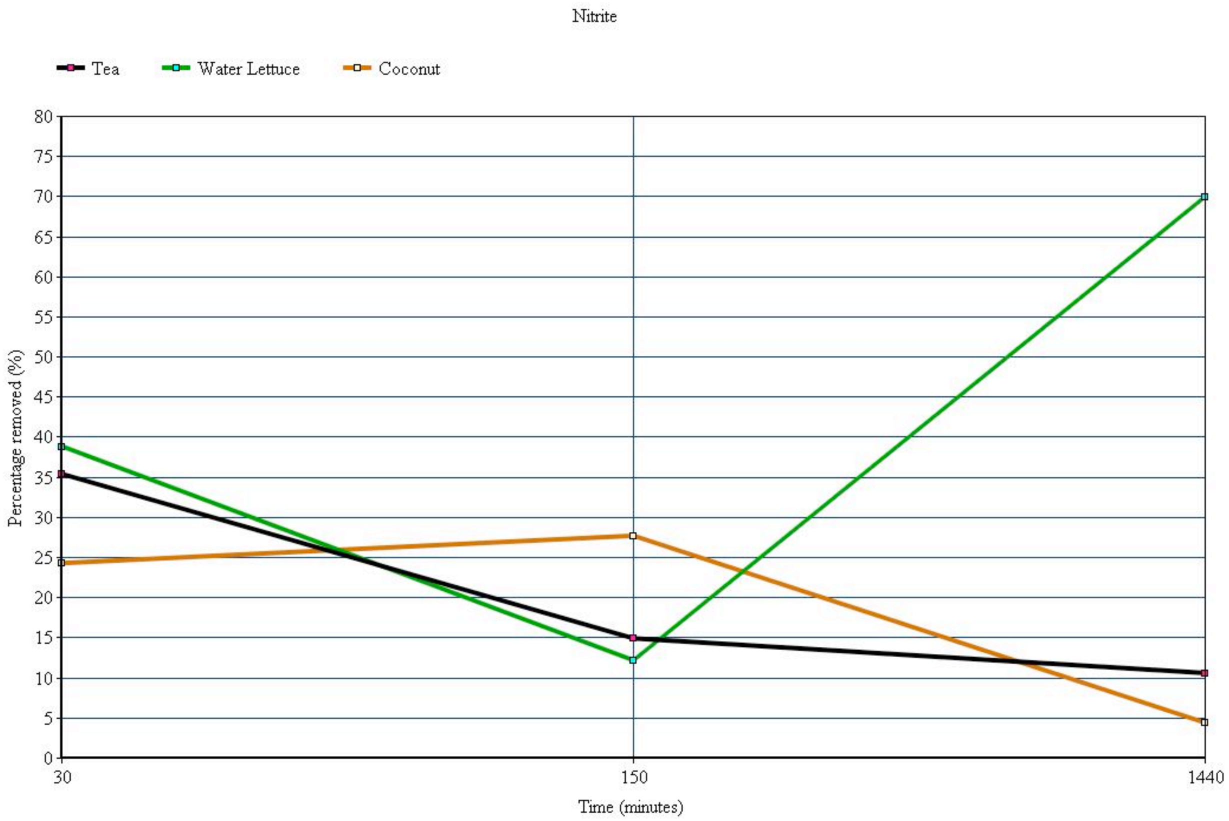


Figure 1

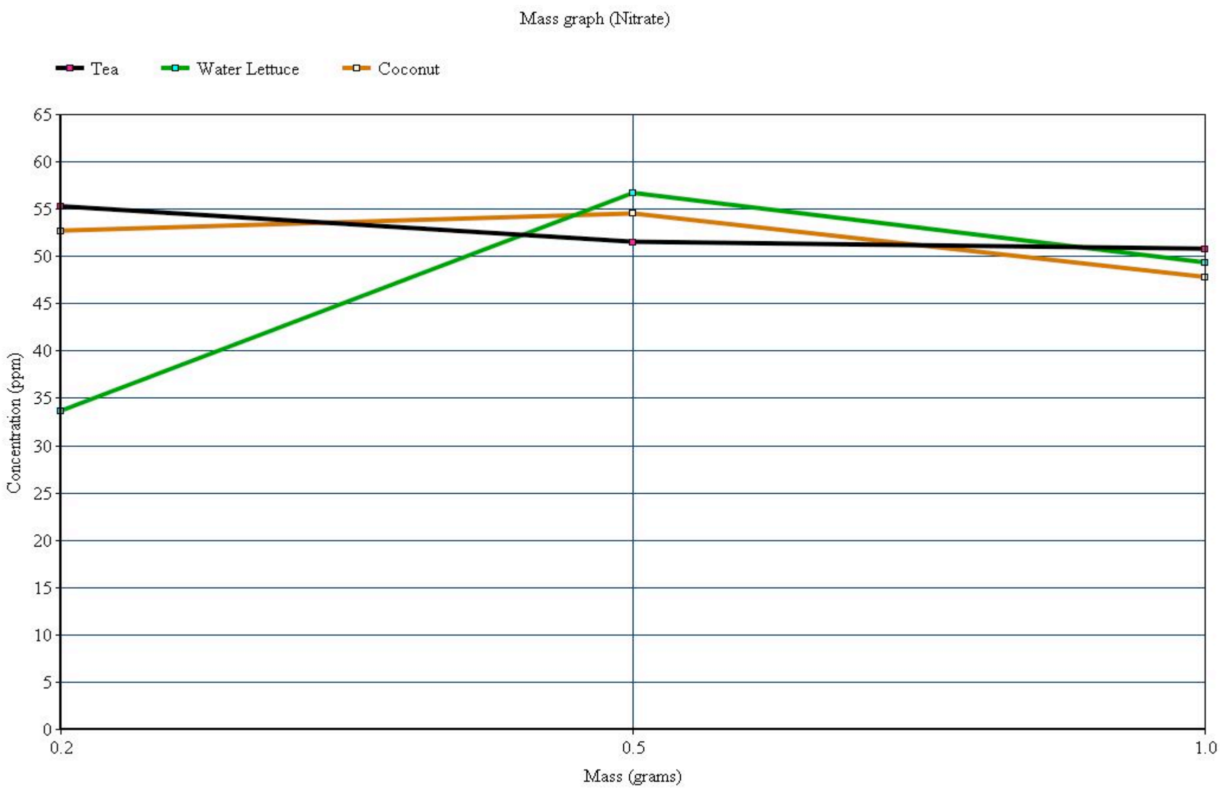
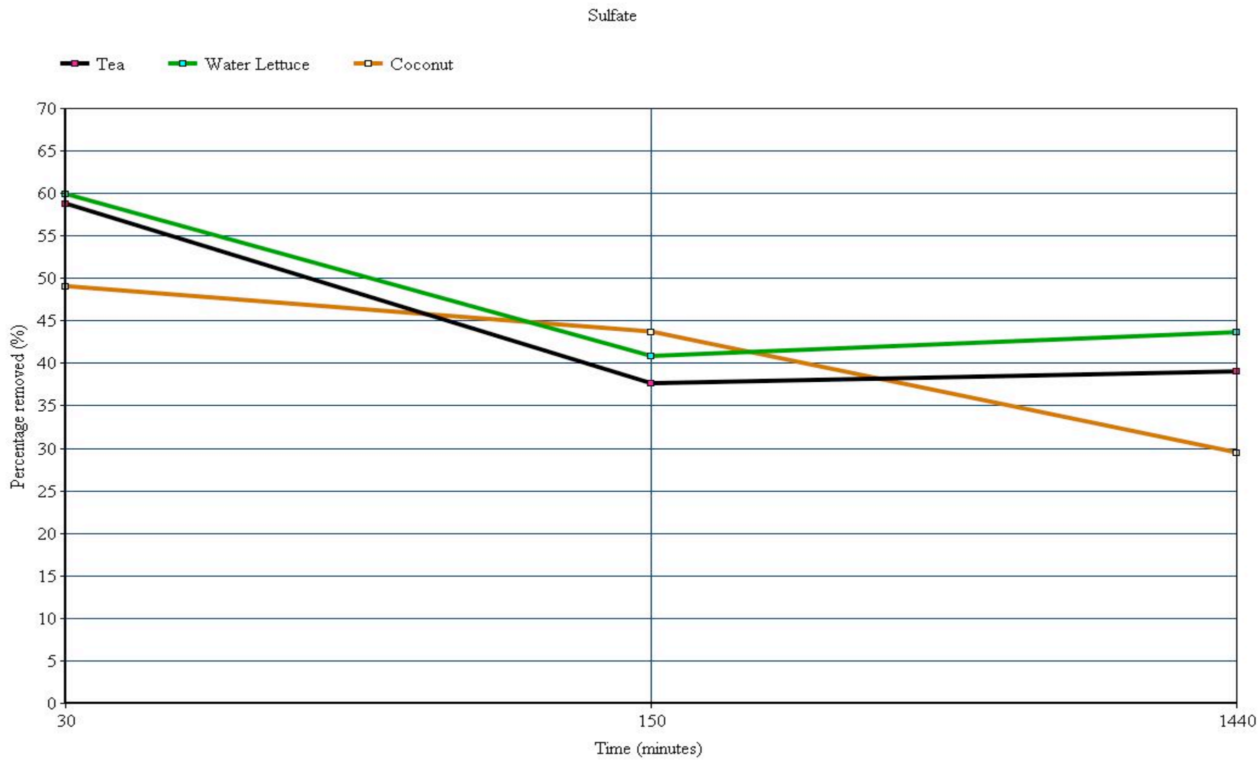
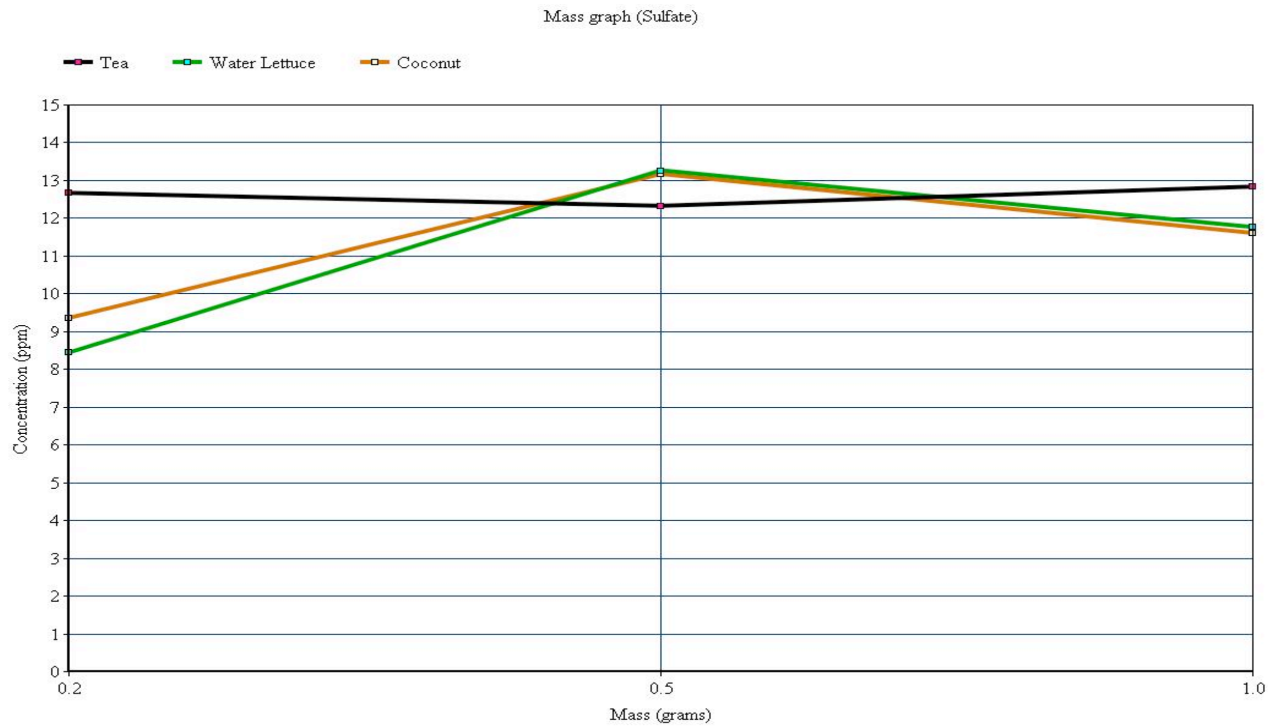


Figure 2


Sulfate
Tea
Water Lettuce
Coconut
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
Percentage removed (%)
30
150
1440
Time (minutes)


Mass graph (Sulfate)
Tea
Water Lettuce
Coconut
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
Concentration (ppm)
0.2
0.5
1.0
Mass (grams)

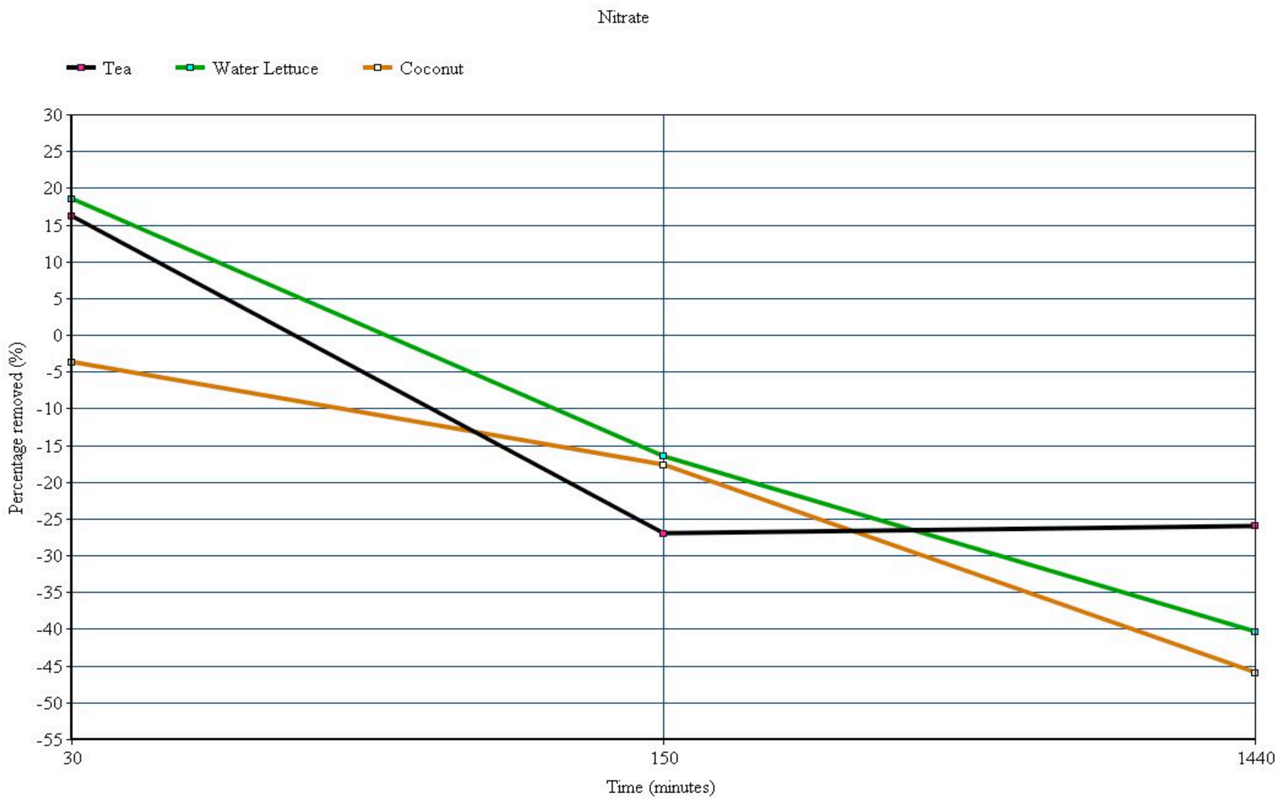


Figure 5

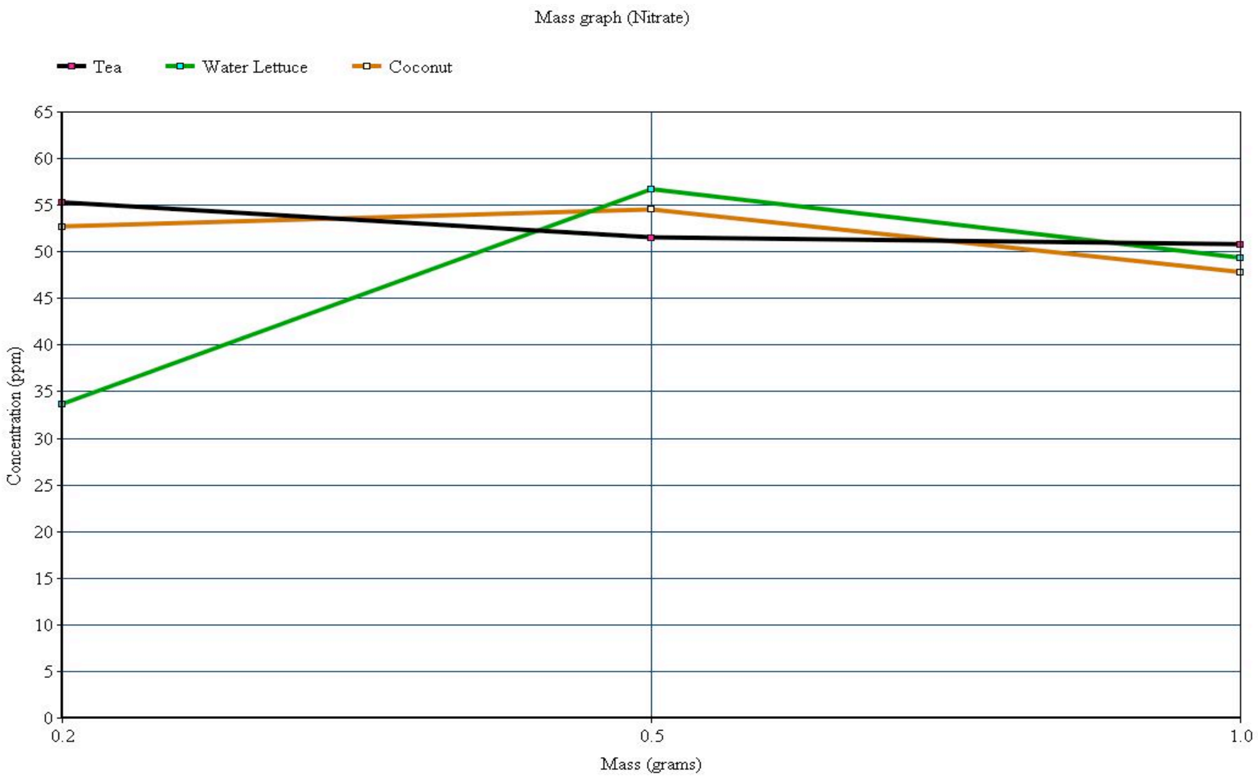


Figure 6

Annex 2

Table showing the results of all samples

Sample	Nitrite/moldm^{-3}	nitrate /moldm^{-3}	Sulfate/ moldm^{-3}
0.2g tea	0.126304348	0.89116129	0.131875
0.2g water lettuce	0.07423913	0.542532258	0.087864583
0.2g coconut	0.045152174	0.849548387	0.09740625
0.5g tea	0.128956522	0.830677419	0.128302083
0.5g water lettuce	0.127065217	0.913983871	0.138104167
0.5g coconut	0.121869565	0.878887097	0.13709375
1.0g tea	0.105913043	0.818790323	0.133604167
1.0g water lettuce	0.106065217	0.795322581	0.122447917
1.0g coconut husks	0.116173913	0.770596774	0.1208125
30 minutes tea	0.0905	0.596080645	0.091135417
30 minutes water lettuce	0.085673913	0.579290323	0.088635417
30 minutes coconut	0.106065217	0.737177419	0.112625
150 minutes tea	0.119195652	0.902919355	0.137885417
150 minutes water lettuce	0.123021739	0.828387097	0.130791667
150 minutes coconut	0.101282609	0.836532258	0.1244375
1440 minutes tea	0.12523913	0.895919355	0.134802083
1440 minutes water lettuce	0.042108696	0.998016129	0.124604167
1440 minutes coconut	0.133913043	1.037451613	0.155885417

Calculated original concentration used (in mol/dm^3)

Ions	Concentration/ moldm^{-3}
Nitrite	0.140065217
Nitrate	0.71116129

Sulfate	0.221875