

Candidates must complete this page and then give this cover and their final version of the extended essay to their supervisor.

Candidate session number

Candidate name

School number

School name

Examination session (May or November)

MAY

Year

2012

Diploma Programme subject in which this extended essay is registered: CHEMISTRY

(For an extended essay in the area of languages, state the language and whether it is group 1 or group 2.)

Title of the extended essay: Environmental friendly paper bleaches**Candidate's declaration**

*This declaration must be signed by the candidate; otherwise a grade may not be issued.*

The extended essay I am submitting is my own work (apart from guidance allowed by the International Baccalaureate).

I have acknowledged each use of the words, graphics or ideas of another person, whether written, oral or visual.

I am aware that the word limit for all extended essays is 4000 words and that examiners are not required to read beyond this limit.

This is the final version of my extended essay.

Candidate's signature: \_\_\_\_\_

Date: 8/03/12

### Supervisor's report and declaration

The supervisor must complete this report, sign the declaration and then give the final version of the extended essay, with this cover attached, to the Diploma Programme coordinator.

Name of supervisor (CAPITAL letters) \_\_\_\_\_

Please comment, as appropriate, on the candidate's performance, the context in which the candidate undertook the research for the extended essay, any difficulties encountered and how these were overcome (see page 13 of the extended essay guide). The concluding interview (viva voce) may provide useful information. These comments can help the examiner award a level for criterion K (holistic judgment). Do not comment on any adverse personal circumstances that may have affected the candidate. If the amount of time spent with the candidate was zero, you must explain this, in particular how it was then possible to authenticate the essay as the candidate's own work. You may attach an additional sheet if there is insufficient space here.

*Not helpful.*

This declaration must be signed by the supervisor; otherwise a grade may not be issued.

I have read the final version of the extended essay that will be submitted to the examiner.

To the best of my knowledge, the extended essay is the authentic work of the candidate.

I spent  hours with the candidate discussing the progress of the extended essay.

Supervisor's signature: \_\_\_\_\_

Date: 8-03-2012

**Assessment form (for examiner use only)**

Candidate session number

**Achievement level**

Criteria	Examiner 1	maximum	Examiner 2	maximum	Examiner 3
A research question	2 ✓	2	1 ✓	2	
B introduction	1 ✓	2	1 ✓	2	
C investigation	2 ✓	4	3 ✓	4	
D knowledge and understanding	2 ✓	4	1 ✓	4	
E reasoned argument	1 ✓	4	1 ✓	4	
F analysis and evaluation	1 ✓	4	1 ✓	4	
G use of subject language	2 ✓	4	2 ✓	4	
H conclusion	1 ✓	2	1 ✓	2	
I formal presentation	2 ✓	4	2 ✓	4	
J abstract	2 ✓	2	2 ✓	2	
K holistic judgment	2 ✓	4	2 ✓	4	
Total out of 36	18 ✓		17 ✓		

*NB This appeared on the sample on IBIS as 16 not 18*

Name of examiner 1: \_\_\_\_\_ Examiner number: \_\_\_\_\_  
 (CAPITAL letters)

Name of examiner 2: \_\_\_\_\_ Examiner number: \_\_\_\_\_  
 (CAPITAL letters)

Name of examiner 3: \_\_\_\_\_ Examiner number: \_\_\_\_\_  
 (CAPITAL letters)

IB Cardiff use only: B: ✓

IB Cardiff use only: A: 105150

Date: 9/5

# Environmental friendly paper bleaches

Candidate name:

Candidate Number:

Subject: Chemistry

Word count: 3315 ✓

May 2012

**Abstract:**

With nowadays concerns about the planet and its conservation, many people have chosen a new practice: recycling paper. In its process, bleach is used to whiten the paper. The aim of this investigation is to study if it is more useful the use of sodium hypochlorite or hydrogen peroxide for bleaching paper with pink marker ink and black pen ink, commonly used by students at school. Later evaluate how long it is convenient to have the paper soaked in the bleach solution for each type of ink. RQ ✓

To assess this, 40 papers of equal size and material where placed in 40 test tubes. 20 painted with black ball pen, 20 with pink microfiber. Of each type of ink, half where set with hydrogen peroxide and half with sodium hypochlorite. Using a colorimeter, absorbance values were taken for each type of ink and bleach every 1.50 hours. Results showed that for black ball pen sodium hypochlorite gave more effective values; as the difference between bleaches was small, taking into account environmental issues, hydrogen peroxide is recommended to be used. ✓

For whitening pink microfiber hydrogen peroxide is also recommended as results where more effective and it produces less harm to the environment. Hydrogen peroxide is among the most versatile, effective and environmentally friendly oxidizing agents.

For hydrogen peroxide 6 hours seemed enough to whiten the paper and maintain the paper unbroken and for sodium hypochlorite 4.30 hours are enough to whiten; it is convenient not to leave it for too much longer as it breaks down the paper. ✓

Word count: 256

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*brief*

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**Research Question:**

Is it more useful the use of sodium hypochlorite or hydrogen peroxide in the process of bleaching paper with pink marker ink and black pen ink? How long is it convenient to have the paper soaked in the bleach solution for each type of ink?

*in what way?*

*needs to be sharpened.*

**Introduction:**

Is it more useful to use of sodium hypochlorite or hydrogen peroxide in the process of bleaching paper with pink marker ink and black pen ink?

With nowadays concerns about the planet and its conservation, many people have chosen a new practice: recycling. "The United States Environmental Protection Agency (EPA) has found that recycling causes 35% less water pollution and 74% less air pollution than making virgin paper."<sup>1</sup> These percentages are very catchy, still there is a small issue related to the bleach used when recycling paper. Sodium hypochlorite is a contaminant solution as it contains Bromate, which is a "man made chemical that does not occur naturally"<sup>2</sup>, and for many years this has been the mainly used bleach. On the other hand hydrogen peroxide is among the most versatile, effective and environmentally friendly oxidizing agents. It is used to treat a large number of pollutants<sup>3</sup>. That is why I choose to investigate if using hydrogen peroxide is a good solution to pollution concerns.

"Bleach refers to a number of Chemicals that remove colour, whiten, or disinfect, often via oxidation. Common chemical bleaches include household chlorine bleach (a solution of approximately 3-6% sodium hypochlorite, NaCl), oxygen bleach (which contains either hydrogen peroxide or a peroxide-releasing compound)."<sup>4</sup>

Colour in most dyes and pigments are produced by molecules which contain chromophores. "Oxidizing bleach works by breaking the chemical bonds that make up the chromophore. This changes the molecule into a different substance that either does not contain a chromophore or contains a chromophore that does not absorb visible light."<sup>5</sup>

<sup>1</sup> [http://en.wikipedia.org/wiki/Paper\\_recycling](http://en.wikipedia.org/wiki/Paper_recycling)

<sup>2</sup> <http://www.groundwateruk.org/groundwater-projects-bromate-pollution.aspx>

<sup>3</sup> [http://www.brightenyourfuture.com/pdf/en/brochure\\_H2O2\\_environment\\_EN.pdf](http://www.brightenyourfuture.com/pdf/en/brochure_H2O2_environment_EN.pdf)

<sup>4</sup> <http://en.wikipedia.org/wiki/Bleach>

<sup>5</sup> <http://en.wikipedia.org/wiki/Bleach>

*reliability of these sources?*

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It is known that sodium hypochlorite is very effective in short time, reason why it is used for whitening cloth and fiber, although "it causes some fiber degradation as it is not volatile; and leaving the paper soaked in the solution for too long will break it down."<sup>6</sup>

I will test the rate of bleaching for the two substances using in each case two types of ink and the same paper for all. The reason I choose these variables is because I thought of the materials most used at my school, where a new campaign of recycling is starting. So I will use black ball pen and pink microfiber, keeping the type of paper constant as this extended essay is focused on the type of ink.

So as independent variables I chose sodium hypochlorite and hydrogen peroxide; the degree of whitening as the amount of ink released by the paper as dependent variable. The amount of ink released will be measured in a solution with the bleach by using a spectrophotometer; this is a "photometer (a device for measuring light intensity) that can measure intensity as a function of the light source wavelength"<sup>7</sup>.

Absorbance is a "measure of the amount of light absorbed (at particular wavelength) as the light passes through a sample or substance."<sup>8</sup> The particular wavelength for the samples will be found out in the initial test. The initial test will be to determine the wavelength to use to measure the absorbance that is proportional to the colour concentration where the independent variable is the wavelength and the dependent variable is the absorbance of the different solutions. ✓

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<sup>6</sup> [http://en.wikipedia.org/wiki/Sodium\\_hypochlorite](http://en.wikipedia.org/wiki/Sodium_hypochlorite)

<sup>7</sup> <http://en.wikipedia.org/wiki/Spectrophotometer>

<sup>8</sup> <http://www.biology-online.org/dictionary/Absorbance>

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### Initial Test

This was carried out in order to test if the experiment of the extended essay would have any efficient and evidential result and to choose correctly the variables and parameters.

### Part 1

#### Materials:

4 test tubes (13x100 mm), 4 equal pieces of paper ("Estrada" made in Argentina ), 20 ml de of sodium hypochlorite (solution that contains 4-6%) and 20 ml of hydrogen peroxide, (solution that contains 3%) black ball pen (Brand: Bic, made in Mexico) and pink microfiber(Brand: Stabilo, point 88, fine 0,4; made in Germany).

#### Procedure:

Paint equally two papers with the black ball pen and two papers with pink microfiber.

Place one paper into each test tube.

Pour 10 ml of hydrogen peroxide into the test tube with the paper painted black and 10 ml to the test tube with the paper painted pink.

Pour 10 ml of sodium hypochlorite to each of the other test tubes.

Leave it rest for one week.

#### Results:

The test tube with the paper painted black and hydrogen peroxide suffered no effect at all.

The paper painted black that was in sodium hypochlorite was completely white.

The paper painted pink in hydrogen peroxide was also white.

The paper painted pink that was with sodium hypochlorite was White but also the paper was all broken down.

#### Conclusion:

Evidently sodium hypochlorite was very effective, but as mentioned in the introduction, it was left too much time and has broken down the paper. On the other hand hydrogen peroxide successfully whitened one of the inks (paper painted pink) but had no effect on the other one (paper painted black). This must be taken into account for the main experiments of the extended essay. It must be considered the proportions of solution and paper and amount of ink in order to have more effective results.

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## Part 2

Determine the wavelength ideal for the experiment of the extended essay.

As the bleach whitens the paper, ink will detach from the paper and dissolve in the solution, causing a change in absorbance of the bleach used. "The extent to which a sample absorbs light depends strongly upon the wavelength of the light"<sup>9</sup>. In this way we will be able to see the rate of whitening and make kinetics of the absorbance in time for each sample.

### Materials:

Sodium hypochlorite and hydrogen peroxide from the test tubes of the first part of the experiment, colorimeter, clean sodium hypochlorite (solution that contains 4-6%) and hydrogen peroxide (solution that contains 3%).

### Procedure:

Take a sample of clean sodium hypochlorite and set the blank in the colorimeter for wavelength 450 nm.

Take out the sample and empty the tube.

Pour into the tube the sodium hypochlorite that was used to bleach the paper painted Pink and place it into the apparatus.

Try and see if there is any detection for absorbance with the wavelengths (nm): 450, 500, 550, 600, 650, 700. Take note of the wavelength that detects more absorbance.

Once the most convenient and useful wavelength for the solutions is perceived, withdraw the sample and again place a test tube with clean sodium hypochlorite and mark the "zero" in that wavelength.

Withdraw the sodium hypochlorite and place the former sample to take note of the absorbance.

Do the same for hydrogen peroxide.

### Results:

Absorbance was better detected in each of the cases for the wavelength of 550 nanometers.

Absorbance of sodium hypochlorite in black ink: 0.277

Absorbance of hydrogen peroxide with pink ink: 0.606

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<http://www.chm.davidson.edu/vce/spectrophotometry/absorbancespectrum.html>

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Results of absorbance for wavelengths from 450 to 700 nm for both bleaches:

Wavelength (nm)	Absorbance (AU $\pm 0.001$ ) sodium hypochlorite with black ink	Absorbance (AU $\pm 0.001$ ) hydrogen peroxide with pink ink
450	0,000	0,000
500	0,000	0,000
550	0,277	0,606
600	0,000	0,097
650	0,000	0,000
700	0,000	0,000

Table 1: Shows the values for absorbance for sodium hypochlorite with black ink and hydrogen peroxide with pink ink. These values show that there is most detection of absorbance for both cases at wavelength = 550 nm.

Conclusion:

1. The wavelength of 550 nm will be used as it has best detected absorbance for each sample.
2. In order to perceive and observe better results and differences between the two bleaches, a smaller amount of bleach must be used. This must show better and clearer results in absorbance as the solution will be more concentrated.

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**Experiment:**

Variables: See introduction.

Materials:

40 test tubes(13x100 mm), 100 ml of hydrogen peroxide ( $H_2O_2$ ) (solution that contains 3%), 100 ml of sodium hypochlorite (NaClO) (solution that contains 4-6%), test tube rack, black permanent marker, two equal sheets of paper("Estrada" made in Argentina ), black ball pen (Brand: Bic, made in Mexico), pink microfiber(Brand: Stabilo, point 88, fine 0,4; made in Germany) , colorimeter.

Procedure:

- Cut 40 papers of equal size.
- Paint 20 of those papers with black pen ink as even as possible and making sure the pressure at which it is painted is kept constant.
- Each paper must have the same amount of ink, it is recommended that you mark the space area to be painted and maintain it the same for all the papers.
- Put the 20 papers with black pen ink into separate test tubes. Make sure that the side of the paper that is painted is facing inwards. In this way the ink is not in touch with the test tube walls and does not lose surface area, which could affect the rate of whitening, as less ink would be in touch with the bleach. Label all test tubes.
- Take the other 20 papers and paint them with the pink microfiber ink the same way as it was done with the black ball pen.
- Place the papers in 20 different test tubes the way it was done with the others and label them.
- Place the test tubes in two racks so that all the test tubes with black papers remain in one and the test tube with pink papers in another rack.
- Of the 20 test tubes of each paper, 10 will be labelled " $H_2O_2$ " and 10 "NaClO"
- Pour 5 ml of hydrogen peroxide to the corresponding test tubes and 5 ml of sodium hypochlorite to the corresponding test tubes.
- Take two initial samples for each colour paper and bleach (eight in total) and remove the paper.
- Repeat the procedure every 1.50 hours till all the test tubes are empty. You will have two samples for each hour for each colour paper and bleach.

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- Measure the absorbance for each sample and take note of the results.
- Make a kinetic to show the rate of whitening for each bleach and ink.

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**Results:**

"Although absorbance does not have true units, it is quite often reported in "Absorbance Units" or AU"<sup>10</sup>

Absorbance values for different bleaches for pink ink:

Pink: Incubation time / hours ( $\pm 0,01$ h)	Absorbance (AU $\pm 0.001$ ) sodium hypochlorite		Absorbance (AU $\pm 0.001$ ) hydrogen peroxide	
	Trial 1	Trial 2	Trial 1	Trial 2
0,00	0.006	0.003	0.055	0.045
1,50	0.016	0.013	0.101	0.119
3,00	0.025	0.023	0.102	0.122
4,50	0.076	0.030	0.137	0.220
6,00	0.091	0.068	0.218	0.242

Table 2: Shows the absorbance (AU) for the two different bleaches for the pink microfiber. Samples were all set at the same time, and every 1.50 hours two samples for each type of bleach were removed. This process is to show the evolution of whitening over time. The wavelength used to obtain these results is 550 nm.

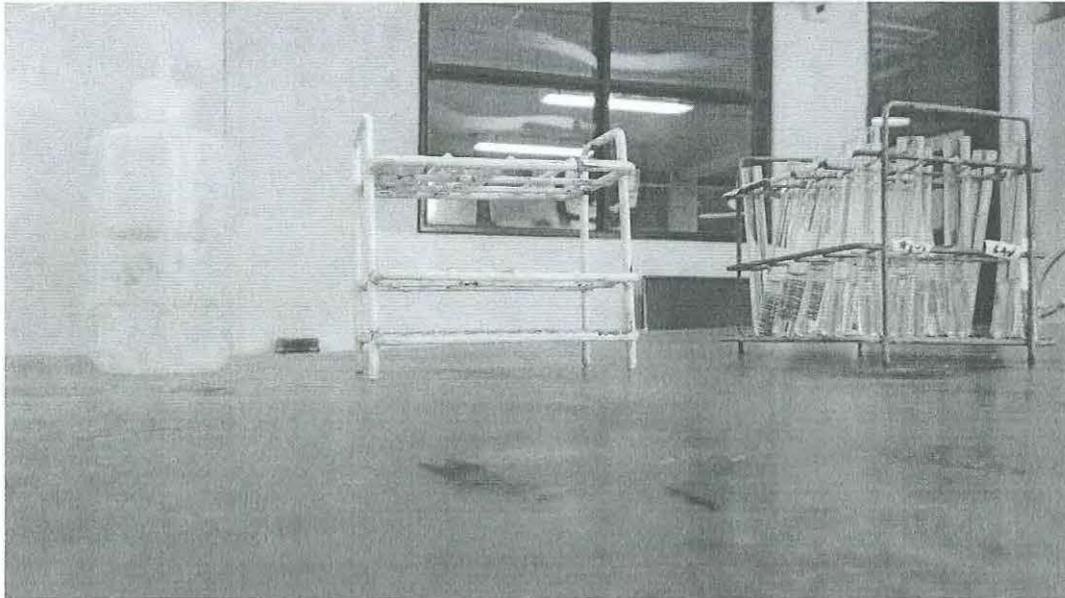
Absorbance values for different bleaches for black ink:

Black: Incubation time / hours ( $\pm 0,01$ h)	Absorbance (AU $\pm 0.001$ ) sodium hypochlorite		Absorbance (AU $\pm 0.001$ ) hydrogen peroxide	
	Trial 1	Trial 2	Trial 1	Trial 2
0,00	0.007	0.013	0.029	0.031
1,50	0.026	0.040	0.083	0.062
3,00	0.050	0.077	0.084	0.096
4,50	0.342	0.339	0.127	0.188
6,00	0.506	0.543	0.255	0.279

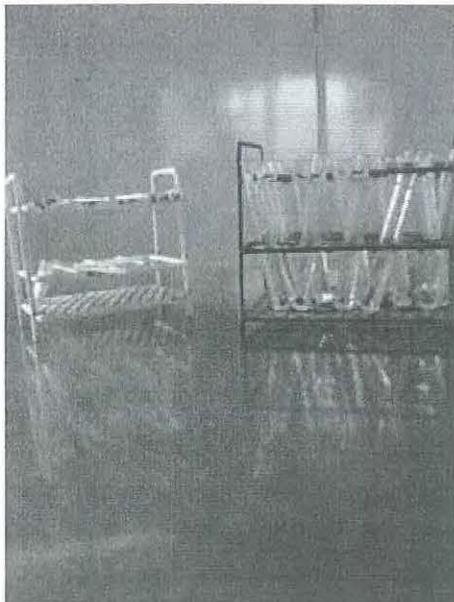
Table 3: Shows the absorbance (AU) for the two different bleaches for the black ball pen. Samples were all set at the same time, and every 1.50 hours two samples for each type of bleach were removed. This process is to show the evolution of whitening over time. The wavelength used to obtain these results is 550 nm.

<sup>10</sup> <http://en.wikipedia.org/wiki/Absorbance>

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This picture above shows 20 test tubes with paper painted with black ball pen, on the right soaked in sodium hypochlorite and on the left in hydrogen peroxide when the experiment was just about to begin. The empty rack is to hold papers as they are taken from the test tubes every hour and a half.



The picture above shows the 20 test tubes with paper painted with black ball pen as the first picture but at the end of the experiment. All papers that have been removed from test tubes are now all on the rack at the left.

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**Processing the data:**

**Black ball pen:**

Values to be used in plotting the rate of whitening for sodium hypochlorite and black ink:

Average absorbance (AU $\pm$ 0.001) for sodium hypochlorite	Incubation time / hours ( $\pm$ 0,01 h)
0,010	0,0
0,033	1,5
0,064	3,0
0,341	4,5
0,525	6,0

Table 4: Shows the adapted values that will be used for plotting the graph. The absorbance values for sodium hypochlorite are an average of the two values obtained in each case from the experiment. The time represents how long the papers have been whitened in test tube with the bleach, a half hour is represented by 0,5.

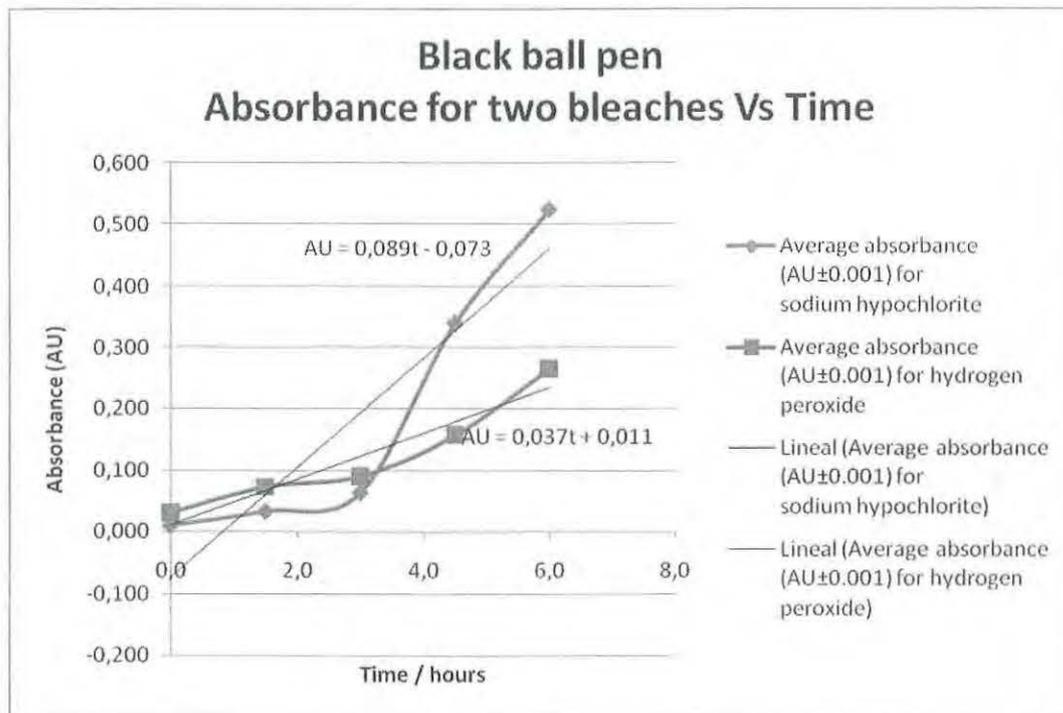
Values to be used in plotting the rate of whitening for hydrogen peroxide and black ink:

Average absorbance (AU $\pm$ 0.001) for hydrogen peroxide	Incubation time / hours ( $\pm$ 0,01 h)
0,030	0,0
0,073	1,5
0,090	3,0
0,158	4,5
0,267	6,0

Table 5: Shows the adapted values that will be used for plotting the graph. The absorbance values for hydrogen peroxide are an average of the two values obtained in each case from the experiment. The time represents how long the papers have been whitened in test tube with the bleach, a half hour is represented by 0,5.

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Graph showing rate of whitening for black ink and for bleaches:



Graph 1: Shows how the absorbance (AU) for sodium hypochlorite (Blue line) evolves as time passes. Samples have been taken every 1.50 hours and results have been plotted to show the rates. Results for hydrogen peroxide bleach (Pink line) have been plotted to compare the rate between the two bleaches for the same type of ink, this graph shows the black ball pen. In general absorbance values increase when samples are left for more time for the bleach to react with the ink. Sodium hypochlorite shows an abrupt positive slope between hours 3.00 and 6.00. The mean gradient for the line representing the whitening with sodium hypochlorite is 0.089; this is a gradient 2.405 times larger than the one of hydrogen peroxide, which is 0.037. With these values it can clearly be seen that sodium hypochlorite has a much faster rate, at first the whitening is quite constant and after 3 hours there is a noticeable increase whilst the hydrogen peroxide maintains a constant increase over the 6 hours. Last recording of absorbance for sodium hypochlorite is 0.525 and for hydrogen peroxide it is 0.267.

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**Pink microfiber:**

Values to be used in plotting the rate of whitening for sodium hypochlorite and pink ink:

Average absorbance (AU±0.001) for sodium hypochlorite	Incubation time / hours (±0,01 h)
0,005	0,0
0,015	1,5
0,024	3,0
0,053	4,5
0,080	6,0

Table 6: Shows the adapted values that will be used for plotting the graph. The absorbance values for sodium hypochlorite are an average of the two values obtained in each case from the experiment. The time represents how long the papers have been whitened in test tube with the bleach, a half hour is represented by 0,5.

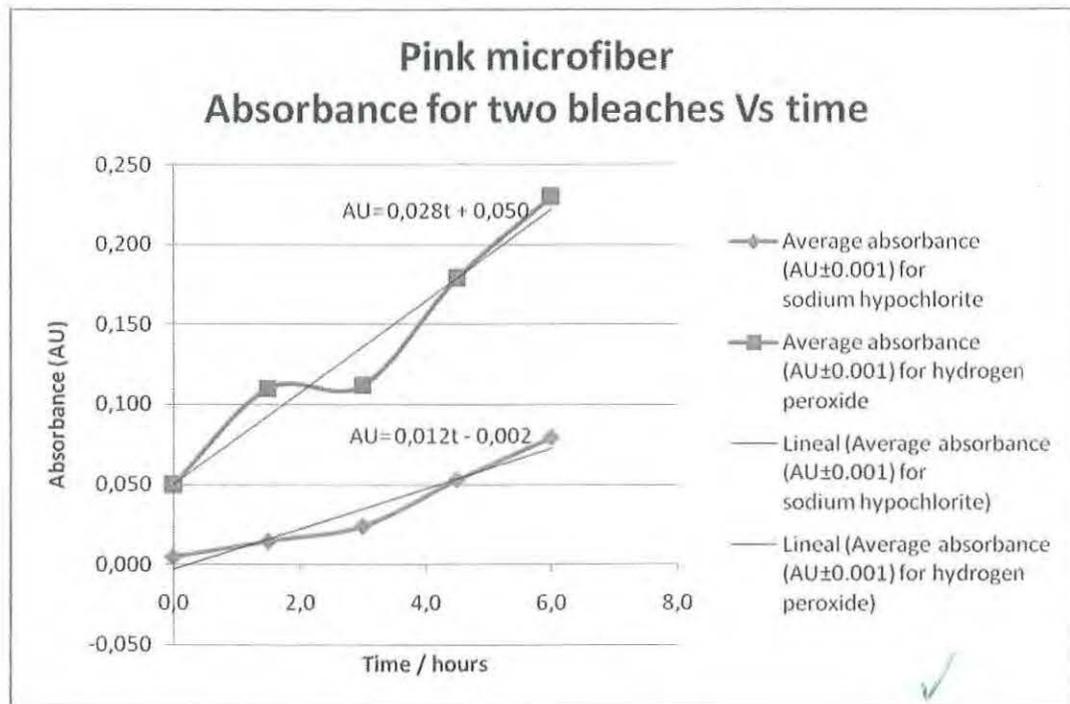
Values to be used in plotting the rate of whitening for hydrogen peroxide and pink ink:

Average absorbance (AU±0.001) for hydrogen peroxide	Incubation time / hours (±0,01 h)
0,050	0,0
0,110	1,5
0,112	3,0
0,179	4,5
0,230	6,0

Table 7: Shows the values that will be used for plotting the graph. The absorbance values for hydrogen peroxide are an average of the two values obtained in each case from the experiment. The time represents how long the papers have been whitened in test tube with the bleach, a half hour is represented by 0,5.

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Graph showing rate of whitening for pink ink and for bleaches:



Graph 2: Shows how the absorbance (AU) for sodium hypochlorite (Blue line) evolves as time passes. Samples have been taken every 1.50 hours and results have been plotted to show the rate. Results for hydrogen peroxide bleach (Pink line) have been plotted to compare the rate between the two bleaches for the same type of ink, this graph shows the pink microfiber. As from the initial value there is a noticeable difference in absorbance. The mean gradient for the line representing the whitening with hydrogen peroxide is 0.028; this is a gradient 2.334 times larger than the one of sodium hypochlorite, which is 0.012. With these values it can clearly be seen that hydrogen peroxide has a much faster rate. Last recording of absorbance for sodium hypochlorite is 0,080 and for hydrogen peroxide it is 0,230, the difference considerable.

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**Conclusion:**

According to the results of the experiments it can be stated that for whitening paper with black ball pen it is most convenient to use hydrogen peroxide. Sodium hypochlorite samples showed higher values of absorbance, but so did the hydrogen peroxide samples and the difference at the end of the experiment is relatively small. It is also taken into account that sodium hypochlorite is very contaminant compared to the hydrogen peroxide. When results differ but so little (Last absorbance (AU) of sodium hypochlorite: 0,525; Last absorbance (AU) of hydrogen peroxide: 0,267) the better option must be the one that produces less harm to the environment, as the objective is to try to preserve nature and recourses for a better future.

On the other hand, when whitening paper with pink microfiber, hydrogen peroxide showed to be much more effective than sodium hypochlorite. After the 6 hours had passed, the difference in absorbance values were important (Last absorbance (AU) of sodium hypochlorite: 0,080; Last absorbance (AU) of hydrogen peroxide: 0,230). In the period of time tested it is evident hydrogen peroxide is most effective. This result is very positive for it means that is much efficient, and at the same time less harmful to the environment; knowing that contaminating sodium hypochlorite could be switched to hydrogen peroxide and not only pollute less but have even better results.

According to the time convenient to leave the paper in the bleaches, for hydrogen peroxide 6 hours seemed enough to whiten the paper and maintain the paper unbroken. On the other hand for sodium hypochlorite for the black ball pen 4.50 hours are enough to whiten, for pink microfiber effect would be less but as it has just been discussed, this option is not recommended. But if it is eventually used it is convenient not to leave it for too longer as it breaks down the paper and dissolves it.

It would be highly recommended for a school institution that has a recycling campaign or recycles paper for students to use microfibers as the pink one used in the experiments and avoid using the black ball pen used. It would be ideal to eventually test and find the one ball pen that can easily be whitened during the recycling process with hydrogen peroxide.

To have more accurate results it would be a good idea to try not only with more types of ink, but with different types of paper and also try leaving the samples with hydrogen peroxide for a longer period of time to see if it actually reaches similar results as sodium hypochlorite.

Another aspect that could have altered the results is the fact that absorbance values were all measured at the end of the experiment, that is to say, after the 6 hours have passed and all the papers have been taken from the test tube with bleach. Bleaches work on the molecules in the solution, "breaking the chemical bonds that make up the chromophore. This

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changes the molecule into a different substance that either does not contain a chromophore, or contains a chromophore that does not absorb visible light.”<sup>11</sup> This chromophore is the component of the molecule responsible for its colour. So it may have occurred that the bleach continued acting on the ink dissolved changing the absorbance values and giving inexact results.

*Contains very little 'hard' chemistry.*

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<sup>11</sup> <http://en.wikipedia.org/wiki/Bleach>

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Brighten your future,  
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Date: 15/12/11 Time: 14:56

Chemical land 21,  
<http://www.chemicalland21.com/industrialchem/inorganic/SODIUM%20HYPOCHLORITE.htm>  
Date: 07/03/12 Time: 8:52

Espectrometría, [http://www.uco.es/organiza/departamentos/bioquimica-biolmol/pdfs/08\\_ESPECTROFOTOMETR%C3%8DA.pdf](http://www.uco.es/organiza/departamentos/bioquimica-biolmol/pdfs/08_ESPECTROFOTOMETR%C3%8DA.pdf) Date: 23/11/11 Time: 18:23

Espectrometría UBA, <http://materias.fi.uba.ar/6305/download/Espectrofotometria.pdf> Date: 29/11/11 Time: 23:43

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<http://www.chm.davidson.edu/vce/spectrophotometry/absorbancespectrum.html>

Date: 13/12/11 Time: 20:45 Wikipedia, [http://en.wikipedia.org/wiki/Paper\\_recycling](http://en.wikipedia.org/wiki/Paper_recycling) Date: 15/12/11 Time: 15:34

Wikipedia, <http://en.wikipedia.org/wiki/Bleach> Date: 15/12/11 Time: 15:48

Wikipedia, [http://en.wikipedia.org/wiki/Sodium\\_hypochlorite](http://en.wikipedia.org/wiki/Sodium_hypochlorite) Date: 15/12/11 Time: 16:08

Wikipedia, <http://en.wikipedia.org/wiki/Absorbance> Date: 6/12/11 Time: 11:12

<http://www.groundwateruk.org/groundwater-projects-bromate-pollution.aspx> Date: 4/03/12 Time: 16:03

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UK Ground water forum, <http://www.groundwateruk.org/groundwater-projects-bromate-pollution.aspx> Date: 07/03/12 Time: 9:17

*A text book (or two) would have been helpful. No analysis of reliability of sources*