Cost effectiveness analysis of bleach

Household bleach is a common commodity used by all income groups of India. This is mainly because of hot and humid climatic condition which left us with no other choice than white or light colour daily wear clothes. To maintain personal hygiene and attractive look within the available budget it is necessary to use bleaches. One question which bothered me quite often was, when so many bleach brands are accessible, which one is the best to buy and this gave me the idea to frame my research question “

“ Investigating the cost-effectiveness of various brands of chlorine-based bleaches containing sodium hypochlorite accessible in Indian Market”

Thus to determine the usefulness and effectiveness of the bleaches, it was worth calculating the concentration of free chlorine per rupee (Indian currency) spent.

The different bleaches were selected and the concentration of the free chlorine was calculated using iodometric titration. The cost per rupee was calculated and comparison was done using statistical tools.

After necessary calculations and comparison, it was concluded that the most cost-effective bleach is local bleach. Local bleach has maximum concentration of free chlorine per rupee spent. Although the moles of free chlorine in local bleach is just 0. 276mol/dm3 while in that of rin and robin are 0. 68mol/dm3 and 0. 588mol/dm3 respectively. But the local bleach is quite cheaper to other bleaches. It costs 30 rupees/dm3 while Robin costs 66 rupees/dm3 and Rin costs 80 rupees/dm3. The concentration of free chlorine per rupee spent on bleach is 0. 0092mol/dm3 while that of Rin bleach and Robin bleach is 0. 0085mol/dm3 and 0. 0089mol/dm3. Thus, I conclude that

Local Bleach brand is the most cost-effective brand among the three available in India.

INTRODUCTION:

1. 1 Background

As climate of India is hot and humid, people prefer to dress in light or white colour cloth. To keep them clean is a necessity for hygiene. Hence it requires daily washing and using bleach as the light colour fabric expose the stains more easily. When used in approved quantity and right way, bleach removes the nasty stains from white color fabric and brings back the brightness. Looking into Indian economy, it is not possible to buy dresses in large number by masses . Thus easy way out is the use of bleaches.

So when I started looking for a topic for my extended essay, my intensions were very clear. I was looking for an area for investigation which will help me to fulfill my requirement to do an essay for my diploma and give me the dual benefit to help my countrymen to choose a better and cost effective bleach which is affordable by them. I have collected the three bleaches which were having the maximum sale in the market , two were branded viz., Rin and Robin and one was a local brand usually purchased by lower income group people.

Bleach is a chemical that removes colors or whitens, often via oxidation. Common chemical bleaches include household chlorine bleach, a solution of approximately 3-6% sodium hypochlorite (NaClO), and oxygen bleach, which contains hydrogen peroxide or a peroxide-releasing compound such as sodium perborate, sodium percarbonate, sodium persulfate, tetrasodium

pyrophosphate, or urea peroxide together with catalysts and activators, e. g., tetraacetylethylenediamine and/or sodium nonanoyloxybenzenesulfonate. [1]

There are other types of bleaches as well for example bleaches which hare used for the bleaching of wood pulp, fats and oils, cellulose, flour, textiles, bee wax, skin etc. the commonly used bleach for this purpose is chlorine dioxide and in a number of other industries. In the food industry, some organic peroxides(benzoyl peroxide, etc.) and other agents (e. g., bromates) are used as flour bleaching and maturing agents. Peracetic acid and ozone are used in the manufacture of paper products, especially newsprint and white Kraft paper.[2]

But my investigation is related to household bleach used for removal of stains , which usually contain chlorine, though it often masquerades behind aliases such as “ sodium hypochlorite” or “ hypochlorite.”[3] Household bleach, used to whiten fabrics or remove mold from surfaces, is a 5% solution of a stabilized form of chlorine.[4]

It is particularly effective on cotton fiber, which stains easily but bleaches well. Usually 50 to 250 ml of bleach per load is recommended for a standard-size washer. The properties of household bleach that make it effective for removing stains also result in cumulative damage to organic fibers such as cotton, and the useful lifespan of these materials will be shortened with regular bleaching. The sodium hydroxide (NaOH) that is also found in household bleach (as noted later) causes fiber degradation as well. It is not volatile, and residual amounts of NaOH not rinsed out will continue slowly

degrading organic fibers in the presence of humidity. For these reasons, if stains are localized, spot treatments should be considered whenever possible. With safety precautions, post-treatment with weak organic acids such as acetic acid (vinegar) will neutralize the NaOH, and volatilize the chlorine from residual hypochlorite. Old t-shirts and cotton sheets that rip easily demonstrate the costs of laundering with household bleach. Hot water increases the activity of the bleach, owing to the thermal decomposition of hypochlorite which ultimately generates environmentally-undesirable chlorate.[5]

Color in most dyes and pigments are produced by molecules, such as beta carotene, which contain chromophores. Chemical bleaches work in one of two ways:

An 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.

Reducing bleach works by converting double bonds in the chromophore into single bonds. This eliminates the ability of the chromophore to absorb visible light.[6]

The chlorine based bleaches are oxidized bleach. These bleaches have an edge over reducing bleaches because they act as disinfectant as well.

The process of bleaching can be summarized in the following set of chemical reactions:

Cl2(aq) + H2O(l) H+(aq) + Cl-(aq) + HClO(aq)

The H+ ion of the hypochlorous acid then dissolves into solution, and so the final result is effectively:

Cl2 (aq) + H2O (l) 2H+ (aq) + Cl-(aq) + ClO-(aq)

Hypochlorite tends to decompose into chloride and a highly reactive form of oxygen:

ClO- Cl- +1/2 O2

This oxygen then reacts with organic substances to produce bleaching or antiseptic effects.[7]

To begin my investigation I gathered information about brands of chlorine based bleach, its uses and its contents. From the information collected I found out that sodium hypochlorite is an active ingredient in bleaches. Sodium hypochlorite is the magical ingredient which removes stains from the clothes. So if I find out which bleach has the more concentration of sodium hypochlorite and is cheaper than other bleaches will be considered as the best bleach for Indian people. This observation led to my precise topic selection that is “ Investigating the cost-effectiveness of various brands of chlorine-based bleaches containing sodium hypochlorite accessible in Indian Market”

After selection of topic next obvious step was to find various methods available in literature and select for an appropriate method for the estimation of the sodium hypochlorite in the bleaches. Various methods

available are discussed in the methodology section of my essay. The one I have selected is based on the fact that it is easy to do and also gives a fair estimation of the concentration of hypochlorite in the available laboratory conditions.

1. 2 Methods to judge the cost effectiveness of Bleach

Some of the methods available in literature for the estimation of concentration of sodium hypochlorite are discussed below:

Method 1:

One of the common methods is to add excess hydrogen peroxide to a measured amount of bleach. This will result in the formation of oxygen gas. The volume of the gas is collected over water and measured. This is then used to calculate the concentration of sodium hypochlorite in a house hold bleach sample.

A few commercial bleaches in their containers, with prices, can be placed on a suitable tray, each with a 10 cm3 syringe and 250 cm3 beaker, both labeled, into which small samples of the bleach can be placed. Measure 5 cm3 of each bleach into their side-arm flask for each experiment. Small samples of the hydrogen peroxide solution could be collected in a 100 cm3 beaker. Bleaches liberate toxic chlorine gas on contact with acids.

The chemical reaction involved is

H2O2(aq) + NaOCl(aq) â†’ H2O(l) + NaCl(aq) + O2(g)

Direct comparison of volume of oxygen collected in the measuring cylinder can be used to compare the effectiveness of the bleach.[8]

Method 2:

Spectophotometric method has also been employed for the quantitative estimation of sodium hypochlorite in commercially available bleach solution. The method is based directly on the absorbance of hypochlorite in alkaline aqueous media. The other method takes advantage of the quantitative reaction of hypochlorite and ammonia in alkaline solution to form chloramine, which has a higher molar absorptivity.[9]

Method 3:

Another most common laboratory method is IODOMETRIC TITRATION.

We can determine the OCl- ion content of a bleaching solution by reacting a known mass or volume of the solution with excess reducing agent, such as iodide ion (I-) in an acidic solution.

OCl- (aq, colorless) + 2I-(aq, colorless) + 2H3O+(aq) —-> I2(aq, brown) + Cl-(aq, colorless) + 3H2O(l)

The reaction above proceeds to completion. Visible evidence of reaction is the change in the appearance of the solution from colorless to brown, due to the formation of iodine (I2). In the presence of excess I- ion, the amount of I2 formed is a measure of the amount of OCl- ion reacting.

Then we determine the amount of I2 formed by titrating the I2 with a standard sodium thiosulfate solution (Na2S2O3). The titration reaction for this experiment is shown in the equation below.

I2 (aq, brown) + 2 S2O3-2(aq, colorless) —> 2I- + 2S4O3-2(aq, colorless)

Thiosulfate ion is a reducing agent that reacts quantitatively with I2. The titration reaction is complete when the I2 formed from the reaction of OCl- ion with I- ion is reconverted to I- ion by S2O3-2 ion.

As the titration proceeds, the I2 concentration in the solution decreases. This causes the solution color to change from brown to pale yellow near the end of titration. The end point occurs when all the I2 has reacted and the solution is colorless. Because the change from yellow to colorless is not very distinct, establishing the end point of this final color change is difficult. We can make the end point more distinct by adding a small amount of starch solution to the titration mixture when the solution turns pale yellow. The unreacted I2 combines with the starch, forming a deep blue complex. The starch molecules tend to curl up into spirals and the hole formed is just the right size for the iodine molecules to fit in. Additional S2O3-2 ion reacts with the complex I2, causing a breakdown of the complex. Disappearance of the blue color signals the end point.[10]

We can determine the concentration of OCl- ion in the solution. The moles of iodine in the solution are equal to moles of sodium hypochlorite. So then we can find out the concentration of OCl-.

I have used the iodometric titration for my investigation because

It is easy to carry it out in school laboratory conditions.

Gas volume measurement often leads to more random errors in the measurements which ultimately affect the concentration calculations.

Spectrophotometric methods are most reliable method but due to non availability of the instrument, I took the decision to stick to iodometric titration.

2. METHODOLOGY:

2. 1 Hypothesis

More the sodium thiosulfate used to titrate the solution more effective is the bleach at removing the stains.

The bleach which has high concentration of sodium hypochlorite is better at removing stains then the bleach with less concentration of sodium hypochlorite.

Based on Indian mentality, the expensive the bleach the better is it at removing the stains.

The expensive brand should be more cost effective.

2. 2 Selection of bleaches

3 different chlorine-based bleaches containing sodium hypochlorite which are easily available in Indian market. The first one is rin bleach which is thought to be the best bleach because it is expensive of all bleaches available in the market. It costs 40 Rs for 500 ml. The second bleach which I have taken is robin which costs 33 Rs for 500ml, a great competitor to RIN. And the third bleach which I have taken is bleach from a local brand which costs only 15Rs for 500ml.

2. 3 Experiment 1

Make a soya bean solution using 17 grams of soyabean and dissolved up to 100 cm3 mark. Put three drops of the solution on a piece of cloth and using a syringe the amount of bleach required to remove the stain should be noted down.

2. 4 Experiment 2

As told earlier I will be using titration with sodium thiosulfate for calculating the concentration of sodium thiosulfate in the bleaches. The method involves two main steps.

Step 1: Standardizing the solution of sodium thiosulfate solution

As sodium thiosulfate is not a primary standard, so it was standardized using a known concentration of potassium iodate KIO3 and the exact concentration of sodium thiosulfate was calculated.

Approximately 8. 00±0. 01 grams of sodium thiosulfate (Na2S2O3 5H2O) was taken a 100 cm3 beaker and dissolved by adding small amount of double distilled water. It was stirred using a glass rod till it was completely dissolved.

Solution was transferred to 250 cm3 of standard flask carefully using a funnel.

Solution was made up to the mark and mixed well by tilting the flask three times.

A solution of potassium iodate, KIO3 (0. 2 Mole/dm3) was prepared by dissolving 10. 7±0. 01 grams of KIO3 in 100 cm3 beaker and dissolving it in

minimum amount of water and making the solution in 250 cm3 standard flask.

Further 25. 0±0. 06 cm3 of KIO3 solution is pipette out using a 25. 0±0. 06 cm3 pipette and a pipette filler and poured in standard measuring flask and solution was made 250 cm3 using distilled water.

Preparation of 1 mol/dm3 of sulfuric acid

Take 55cm3 of 98% pure sulphuric acid in 100cm3 measuring flask.

Now slowly pour this acid into 500cm3 of constantly stirred water in a beaker

Now transfer this solution into 1dm3 conical flask and add water till the 1dm3 mark.

Preparation of 10% potassium iodide

Take 10grams of potassium iodide

Dissolve it in 100cm3 solution

Preparation of 2%starch indicator

Take 2grams of starch

Add little bit of cold water until a smooth paste is obtained

Add 100cm3 of boiling water and stir

Heat the solution until the solution is clear

25. 0±0. 06 cm3 of KIO3 solution is pipette out using a 25. 0±0. 06 cm3 pipette and a pipette filler and poured in conical flask.

10. 00±0. 05 cm3 of potassium iodide (10% w/v) is added to the flask using a measuring cylinder.

To this solution 10 . 00±0. 05 cm3 of sulfuric acid (1 mol/dm3) is added to the flask using another measuring cylinder.

Sodium thiosulfate is filled in 50. 00±0. 05 cm3 burette and added to the conical flask containing KIO3, KI and H2SO4solution till the solution in the conical flask turned pale yellow.

2 to 3 drops of starch solution (1% w/v) was added to the conical flask.

The solution turned blue black.

More sodium thiosulfate was added to the conical flask with constant swirling till the solution turned colorless.

The final volume of thiosulfate solution added is recorded

Three concordant readings are taken to have consistency in the recorded data

Step 2: Titration of the different brands of bleaches using standardized solution of sodium thiosulfate. Thus calculating the concentration of sodium hypochlorite present in different brands of bleaches.

Procedure:

I have taken 25. 0±0. 06cm3 of Rin bleach using a pipette and pipette filler into 250cm3 graduated flask.

To this water was added to make the solution up to 250cm3 mark.

25. 0±0. 06cm3 of the solution poured with the help of pipette into a conical flask and the same procedure as given above was repeated with RIN bleach followed by the other two bleaches, Robin and local brand.

3. Data collection and processing:

3. 1 Finding out the concentration of Sodium Thiosulfate

Standardization of sodium thiosulfate:

Volume of potassium iodate taken in conical flask = 25. 0±0. 06 cm3

final burette reading / cm3±0. 05cm3

20. 10

19. 90

20. 00

initial burette reading / cm3±0. 05cm3

0. 00

0. 00

0. 00

volume of sodium thiosulfate used / cm3±0. 1cm3

20. 10

19. 90

20. 00

Average volume of sodium thiosulfate used = 20. 00 cm3

Calculations:

25. 0 cm3 of KIO3 solution required 20. 00 cm3 of Sodium thiosulfate.

The ionic equation related to the titration is

IO3-1 + 5I-1 + 6H+ ® 3I2 + 3H2O

The I2 produced by the reaction between iodate ion and iodide ion is related stoichiometrically to thiosulfate ion as follows

I2 + 2S2O32- ® S4O62- + 2I-1

Moles of KIO3 (0. 1 Mol/dm3) in diluted solution = 0. 01 mol/dm3

Moles of 0. 01 mol/dm3 KIO3 in 25 cm3 of solution = 0. 01 x 25 x 10-3

= 0. 25 x10-3

Ratio of moles of KIO3: I2

1 : 5

So moles of I2 in solution = 5 x 1 x 0. 25 x10-3

= 1. 25 x10-3

Ratio of moles of I2 : S2O32-

1 : 2

Therefore moles of thiosulfate = 2 x 1 x 1. 25 x10-3

= 2. 50 x 10-3

20. 00 cm3 of thiosulfate solution has 2. 50 x 10-3 moles

Therefore the concentration of thiosulfate solution = 2. 50 x 10-3 x 103/20. 00

= 0. 125 mol/dm3

3. 2 collection

T value for the t- test between RIN and ROBIN is 36. 83644

This value is a lot higher than the cut off value (2. 31. using degrees of freedom= [n1-1] + [n2-1] = 8) at a 5% significance level. This implies that there is lot lesser than . 1% chance that the 2sets of readings belong to one population or the difference is just difference is insignificant.

3. 3 Calculation

25. 0 cm3 of diluted Rin brand bleach solution required 27. 8 cm3 of Sodium thiosulfate.

Moles of sodium thiosulphate=

Moles of iodine, I2, were present in the conical flask after the bleach reacted with an excess of iodide ions

2S2O32-(aq) + I2(aq) S4O62-(aq) + 2I-(aq)

Moles of I2 = moles of sodium thiosulphate ÷ 2

Moles of I2 = 0. 00348 ÷ 2

Moles of I2 = 0. 0017 moles

- 1 mol of iodine is displaced by 1 mol of ‘ free chlorine’.

Cl 2(aq) + 2I-(aq) 2Cl-(aq) + I2 (aq)

The ‘ free chlorine’ concentration, in mol dm-3, of the bleach ‘ RIN’

1 mole iodine = 1 mole of free chlorine

âˆ´25cm3 of diluted bleach solution contains 0. 0017 moles of chlorine

Therefore the undiluted bleach solution of 25 cm3 would contain . 017 moles

Concentration of iodine in 500 cm3 of RIN bleach solution is

Therefore the concentration is 0. 34mol/500cm3 of RIN bleach.

Therefore the concentration is 0. 68mol/dm3.

25. 0 cm3 of diluted Robin brand bleach solution required 23. 53 cm3 of Sodium thiosulfate.

Moles of sodium thiosulphate=

Moles of iodine, I2, were present in the conical flask after the bleach reacted with an excess of iodide ions

2S2O32-(aq) + I2(aq) S4O62-(aq) + 2I-(aq)

Moles of I2 = moles of sodium thiosulphate ÷ 2

Moles of I2 = 0. 00294 ÷ 2

Moles of I2 = 0. 00147 moles

- 1 mol of iodine is displaced by 1 mol of ‘ free chlorine’.

Cl 2(aq) + 2I-(aq) 2Cl-(aq) + I2 (aq)

The ‘ free chlorine’ concentration, in mol dm-3, of the bleach ‘ RIN’

1 mole iodine = 1 mole of free chlorine

âˆ´25cm3 of dilute bleach solution contains 0. 00147 moles of chlorine

Concentration of iodine in 500 cm3 of Robin bleach solution is

Therefore the concentration is 0. 294 mol/500cm3 of Robin bleach.

Therefore the concentration is 0. 588mol/dm3.

25. 0 cm3 of diluted LOCAL brand bleach solution required 11. 07 cm3 of Sodium thiosulfate.

Moles of sodium thiosulphate=

Moles of iodine, I2, were present in the conical flask after the bleach reacted with an excess of iodide ions

2S2O32-(aq) + I2(aq) S4O62-(aq) + 2I-(aq)

Moles of I2 = moles of sodium thiosulphate ÷ 2

Moles of I2 = ÷ 2

Moles of I2 = 0. 00069 moles

- 1 mol of iodine is displaced by 1 mol of ‘ free chlorine’.

Cl 2(aq) + 2I-(aq) 2Cl-(aq) + I2 (aq)

The ‘ free chlorine’ concentration, in mol dm-3, of the bleach ‘ RIN’

1 mole iodine = 1 mole of free chlorine

âˆ´25cm3 of diluted bleach solution contains 0. 00069 moles of chlorine

Concentration of iodine in 500 cm3 of Local bleach solution is

Therefore the concentration is 0. 138mol/500cm3 of RIN bleach.

Therefore the concentration is 0. 276mol/dm3.

3. 4 analysis and interpretation

Calculating the cost-effectiveness

- BRAND
- RIN
- ROBIN
- LOCAL

Concentration of free chlorine (mol/dm3)

- 0. 68
- 0. 588

- 0. 276

Price of 500cm3 bleach in rupees

- 40
- 33
- 15

Price of 1dm3 bleach (= price of 500cm3Ã-2) in rupees

- 80
- 66
- 30

Concentration of free chlorine per rupee spent on bleach (= concentration of free chlorine in 1dm3 bleach/price of 1 dm3 bleach)

- 0. 0085
- 0. 0089
- 0. 0092

Matrix 1

It can be seen from the experiment 1 higher amounts of bleach is used to remove the stain as we move from RIN to ROBIN to the local brand. And as it can also be seen from the histogram above (graph 1) that the free chlorine concentration decreases as we move from RIN to ROBIN to the local brand it can be inferred that higher the concentration lesser is the amount of bleach required. How so ever the amount of free chlorine required is nearly the same

4. Conclusion:

4. 1 Results

The free chlorine concentration per rupee spent is maximum of local brand bleach. Therefore the local bleach is most cost-effective bleach. The local brand bleach over takes other branded bleaches like RIN and Robin which are very famous in Indian market. There is a very small difference between each of them when we calculate the concentration of free chlorine per rupee spent. But when we see the concentration of free chlorine in rin and robin they are quite higher then local brand. Local brand has very less moles of sodium hypochlorite per dm3 of the bleach. So the volume required to remove a stain by local brand bleach would be quite large then the volume required of rin or robin brand bleach. This can give a wrong impression that the other brands are better or more efficient at removing stain. But we know that it isn’t so. Only if higher amounts of the local brands were used the same stain would take lesser money to be removed. This proves the Indian mentality.

Resolved questions

- Is the amount of sodium thiosulfate used proportional to the amount of free chlorine atoms-

Yes very much. It can be inferred by comparing graph 1 (or matrix 1) and graph 2

- Does the concentration of sodium hypochlorite affect the effectiveness of the bleach-

Higher the concentration of sodium hypochlorite more is the effectiveness of the bleach. Inferred from graph 1 (or matrix 1) and table 1

- Checking the Indian mentality-

It depends on the amount of bleach used. But it can easily be inferred that the local brand is a lot more cost efficient

- Deriving the cost effectiveness of different brands of bleach

Hypothesis 1 and 2 were confirmed to be true via experimentation while the other two hypotheses (namely 3 and 4) are proved to be wrong.

Evaluation

Weaknesses

- It isn’t very easy to note down the point of the end of the titration.
- Accuracy can tend to pose a problem
- The distil water can have other salts present

Improvements

- Colorimetry should be used for knowing the end point
- More accurate burettes can be used
- Ultra pure water should be used rather than distilled water

4. 2 Extension

- The other method should be used.
- A more number of brands should be used.
- Other active ingredients should be tested for. Biologically active organisms like bacterias should also be considered.
- The activity of the other active substances should be tested.

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