Parametric Effect of Sodium Hydroxide and Sodium Carbonate on the Potency of a Degreaser

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Abstract

Experimental and statistical analysis was carried out on the comparative effect of sodium hydroxide and sodium carbonate on the potency of a laboratory produced degreaser in this work. The materials used include; octadecyl benzene sulphonic acid, sodium hydroxide, sodium carbonate, sodium metasilicate, carboxyl methyl cellulose (C.M.C), formadelhyde, perfume, colourant and distilled water. Different samples of degreaser were produced with varying composition of sodium hydroxide and sodium carbonate respectively. Statistical significance through methods like analysis of variance (ANOVA) of some parameters on various concentrations of sodium hydroxide and sodium carbonate was investigated. The effect of the varying compositions of sodium hydroxide and sodium carbonate was also determined by using a gray scale (GS) test, and also subjecting surfaces heavily stained with crude oil to determine and characterize the cleansing action of the degreaser. It was found that as the concentration of sodium hydroxide increases, the cleansing ability also increases, whereas the increase in concentration of sodium carbonate had no effect on the cleansing ability. The work would enable production of effective, useful and property controlled degreasers at moderate cost.

Keywords: degreaser; gray scale; surfactant; crude oil; sodium hydroxide; sodium carbonate

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1. INTRODUCTION

Over the years the growth of detergent manufacture has passed through series of development. More complex and less toxic detergent such as the linear alkyl benzene sulphonate, which is easily biodegradable and has less potential for polluting the environment, have emerged over the years. These improvements were due to the fact that conventional soaps and detergents were limited, as they could not be used to remove very stubborn stains like grease, oil and other dirt from plant floors, turbine surfaces and barges [1].

The detergent industry seems to have two environmental challenges that are been addressed. For instance, environmentalists were concerned with one of the raw materials phosphate, which is a builder. Phelps (2003) reportedly added large amounts of phosphorous compounds to the nation’s waterways. As a fertilizer, the phosphorous stimulated the growth of algae and those large crops of algae significantly depleted the amount of dissolved oxygen in water. This decrease in free oxygen harms other marine life, which in turn could be threatening to normal ecological patterns [2].

Through efforts, the formerly used surfactant alkyl benzene sulphonate (ABS) had almost being replaced with linear alkyl benzene Sulphonate (LABS) due to the latter’s ability to easily biodegrade [3,4]. Depending on the type of surfactant, degreasers are usually classified as heavy or light duty. Heavy duty degreasers are useful in areas where high detergency power is needed and a considerable amount of sequestering agent such as sodium octadecyl benzene sulphonate is often added. According to James (2006), surfactants have been classified as anionic surfactants (with negative charge), non-ionic surfactants (no charge), cationic surfactants (with positive charge), amphoteric surfactants (with both positive and negative group), according to the electrical charge in the chain-carrying portion of the molecule after dissociation in aqueous solution [5].

The basic raw materials as well as additives in the formulation of liquid detergent usually include sodium hydroxide (a neutralizing alkali), sulphonic acid (a foaming agent), water, sodium carbonate (a water softener), carboxyl methyl cellulose (CMC) as a chemical builder, perfume, formaldehyde (a preservative), colourant / dye, as well as sodium metasilicate (a corrosion inhibitor) to varying degrees and/or proportions depending on the end use. These components have their own specific and or combined role in liquid detergent formulation.

As part of a continual effort for improvement in the industry, Ernenwein et al. (2012) successfully degreased solid model hard-surfaces with alkylpolypentosides (APPs) based surfactants and established their effectiveness compared to some other sugar - based surfactants. Khan (2013) has reviewed the importance of proteases in detergent and leather industries, establishing their efficacy. In another related development, the degreasing action of secondary butyl ether and formulation (solvent and emulsifier) in comparison with a commercial degreasing product revealed an improved degreasing action Kirubanandan et al. (2012) [5,6,7].

In this work the effect of varying proportion of sodium hydroxide and sodium carbonate on the physical properties and potency of a degreaser is being investigated, with a view to characterize their effect statistically and with recognized standards in the industry.

2. MATERIALS AND METHODS

The formulation adopted was proposed by Akas (2001).

2.1 Reagents

Octadecyl benzene sulphonic acid, sodium hydroxide, sodium carbonate, sodium metasilicate, carboxyl methyl cellulose (C.M.C), sodium chloride, perfume (lavender), colourant, distilled water.

2.2 Apparatus

Measuring cylinder (250ml), electronic stirrer, beakers (pyrex), electronic weighing balance, pH meter (Mettler Toledo), viscometer, density bottle (50ml), spatula, nose mask, hand gloves, eye goggle.

2.3 Experimental Procedure

(a) NaOH concentration was kept constant, while varying Na_2CO_3 concentration. Sample 1 (5g of NaOH, 1g of Na_2CO_3)

The beaker used as the mixing vessel was properly cleaned and 300 ml of distilled water was poured into it. Fifty milliliters (50 ml) of sulphonic acid was poured into the mixing vessel too and mixed vigioriously for 5 mins at 250 rpm. Five grams (5 g) of sodium hydroxide was dissolved in 50 ml of distilled water which was added to neutralise the acidic solution, and also stirred vigorously for 5mins at 250 rpm. Three grams (3 g) of C.M.C that was hydrolyzed with 50 ml of distilled water was added into the mixing vessel containing the homogenous solution and it was seen that it made the solution viscous and the speed was increased to 500 rpm for another 5mins. One gram (1 g) of sodium carbonate dissolved in 50 ml of distilled water was added to the solution and stirring occurred for 5 mins at the same speed of 500 rpm. Five milliliters (5 ml) of sodium silicate was added to the solution and stirred for 5mins, maintaining the speed of 500 rpm. Five milliliters (5 ml) of formaldeyde was added to the solution, stirred for 5 mins at a speed of 500 rpm. Five milliliters (5 ml) of perfume was added to the solution, stirred at same speed for a 5 mins. Lastly, blue colorant was added and stirring continued for 5 mins at 500 rpm. The solution was allowed to settle for a while before pouring into a pet bottle.

The experimental procedure for sample 1 above was also repeated for samples 2, 3, 4 and 5 using sodium carbonate concentrations of 3 g, 5 g, 7 g and 9 g respectively. For all the samples, insoluble matter was not detected, texture was smooth to feel, specific gravity were determined at 25 ^oC, lather was sustained and soluble samples were obtained.

(b) Na_2CO_3 concentration was kept constant, while varying NaOH Concentration. Sample 1 (5g of Na_2CO_3, 1g of NaOH)

The beaker used as the mixing vessel was properly cleaned and 300 ml of distilled water was poured into it. Fifty milliliters (50 ml) of sulphonic acid was poured into the mixing vessel too and mixed vigorously for 5 mins at 250 rpm. One gram (1 g) of sodium hydroxide dissolved in 50 ml of distilled water was added to neutralise the acidic solution, and also stirred vigorously for 5 mins at 250 rpm. Three grams (3 g) of C.M.C that was hydrolyzed with 50 ml of distilled water was added into the mixing vessel containing the homogenous solution and it was seen that it made the solution viscous and the speed was increased to 500 rpm for another 5 mins. Five grams (5 g) of sodium carbonate dissolved in 50 ml of distilled water was added to the solution and stirring occurred for 5mins at the same speed of 500 rpm. Five milliliters (5 ml) of sodium silicate was added to the solution and stirred for 5 mins, maintaining the speed of 500 rpm. Five milliliters (5 ml) of formaldehyde was added to the solution, stirred for 5 mins at a speed of 500 rpm. Five milliliters (5 ml) of perfume was added to the solution, and stirred at same speed for 5 mins. Lastly, yellow colorant was added and stirring continued for 5 mins at 500 rpm. The solution was allowed to settle for a while before pouring into a pet bottle.

The experimental procedure for sample 1 above was also repeated for samples 2, 3, 4 and 5 using sodium hydroxide concentrations of 3 g, 5 g, 7 g and 9 g respectively. For all the samples, insoluble matter was not detected, texture was smooth to feel, specific gravity were determined at 25 ^oC, lather was sustained and soluble samples were obtained.

3. RESULTS AND DISCUSSIONS

Ten samples of degreasers were produced, for which some results were obtained and analyzed as described below:

Table 1: Properties of degreaser at various weights of NaOH

Weight of NaOH (g)	pH	Viscosity (cP)	Weight of product (g)	Density (g/ml)
1	10.30	33.85	49.88	0.9976
3	10.61	47.92	51.48	1.0296
5	10.72	55.78	51.63	1.0326
7	11.59	60.31	51.75	1.0350
9	11.64	66.38	51.90	1.0380

Table 2: Mean and standard deviations of parameters for various weights of NaOH

Name of parameter	Count	Mean	Standard deviation
Weight of NaOH (g)	5	5.000000	3.162278
pH	5	10.972000	0.607100
Viscosity (cP)	5	52.848000	12.575793
Weight of product (g)	5	51.328000	0.824057
Density (g/ml)	5	1.026560	0.016481

Table 3: Analysis of Variance for various weights of NaOH

Statistical test range	Sum of squares	Degrees of freedom
Between groups	13186.2925	4
Within groups	676.7939	20
Fisher's F = 97.4173		
Probability factor, P < 8.0843E-13		

Table 4: Bonferroni-Holm Posthoc parametric test for various weights of NaOH

Group 1	Group 2	Critical	P	Significance
Weight of product (g)	Density (g/ml)	0.005000	9.30E-15	Significant
pH	Weight of product (g)	0.005556	3.06E-13	Significant
pH	Density (g/ml)	0.006250	3.39E-10	Significant
Weight of NaOH (g)	Weight of product (g)	0.007143	1.07E-09	Significant
Viscosity (cP)	Density (g/ml)	0.008333	1.56E-05	Significant
Weight of NaOH (g)	Viscosity (cP)	0.010000	3.49E-05	Significant
pH	Viscosity (cP)	0.012500	7.35E-05	Significant
Weight of NaOH (g)	Ph	0.016667	3.22E-03	Significant
Weight of NaOH (g)	Density (g/ml)	0.025000	2.29E-02	Significant
Viscosity (cP)	Weight of product (g)	0.050000	7.94E-01	Not significant

Table 5: Properties of degreaser at various weights of Na_2CO_3

Weight of Na_2CO_3 (g)	pH	Viscosity (cP)	Weight of Product (g)	Density (g/ml)
1	9.43	24.43	51.36	1.0272
3	10.21	29.67	51.01	1.0202
5	10.61	32.46	50.60	1.0120
7	10.75	49.14	49.02	0.9804
9	10.83	53.88	48.25	0.9650

Table 6: Mean and standard deviations of parameters for various weights of Na_2CO_3

Name of parameter	Count	Mean	Standard deviation
Weight of Na_2CO_3 (g)	5	5.000000	3.162278
pH	5	10.366000	0.575048
Viscosity (cP)	5	37.916000	12.849748
Weight of product (g)	5	50.048000	1.345463
Density(g/ml)	5	1.000960	0.026909

Table 7: Analysis of Variance for various weights of Na_2CO_3

Statistical test range	Sum of squares	Degrees of freedom
Between group	9494.456970	4
Within group	709.030816	20
Fisher's F = 66.953768		
Probability factor, P < 2.70531E-11		

Table 8: Bonferroni-Holm Posthoc parametric test for various weights of Na_2CO_3

Group 1	Group 2	Critical	P	Significance
Weight of product (g)	Density (g/ml)	0.005000	5.73E-13	Significant
pH	Weight of product (g)	0.005556	6.08E-12	Significant
pH	Density (g/ml)	0.006250	3.57E-10	Significant
Weight of Na_2CO_3 (g)	Weight of product (g)	0.007143	1.99E-09	Significant
Viscosity (cP)	Density (g/ml)	0.008333	2.04E-04	Significant
Weight of Na_2CO_3 (g)	Viscosity (cP)	0.010000	5.33E-04	Significant
pH	Viscosity (cP)	0.012500	1.37E-03	Significant
Weight of Na_2CO_3 (g)	pH	0.016667	5.76E-03	Significant
Weight of Na_2CO_3 (g)	Density (g/ml)	0.025000	2.22E-02	Significant
Viscosity (cP)	Weight of product (g)	0.050000	6.90E-02	Not significant

It can be seen from Table 1 that as the weight proportion of sodium hydroxide increased, the pH, viscosity, density and weight of the product (degreaser) also increased. This showed that the degreaser becomes more basic. All the statistical computation presented in this work were carried out with the aid of Daniel's XL Toolbox Version 5.09 © 2008 - 2013 software. Table 2 showed the count, mean and standard deviations of the parameters investigated, with the density and viscosity showing the smallest and largest standard deviations respectively. In Table 3, the analysis of variance (ANOVA) of the various group of parameters investigated showed that the sum of squares within the groups is smaller than the sum of squares between the groups. There seems to be a statistically wide variation between the individually investigated degreaser parameters and the five different weight groups at the 95% confidence interval, as $F(4, 20) = 97.4173$ and $P < 8.0843E-13$. Fisher's F is a ratio of the variance between groups to the variance within groups and P is a probability factor that must be less than 0.05 in the ANOVA analysis. The degree of freedom between the groups is 4, while the degree of freedom within the groups is 20. The F and P values implied a strong dependence of pH, viscosity, density and weight of the product (degreaser) on the various weights of NaOH considered. In Table 4, the Bonferroni-Holm Posthoc parametric test for various weights of NaOH is presented. All the parameters investigated showed a strong dependence or significance on each other except for the relationship between viscosity and weight of product degreaser with a P value of 0.794 which is greater than 0.05 in the 95% confidence interval.

As shown in Table 5, as the weight proportion of sodium carbonate increased, the pH and viscosity of increased, while the density and weight of the product (degreaser) decreased. This showed that the degreaser becomes more basic and lighter as the proportion of Na_2CO_3 increased with constant NaOH weight. Table 6 showed the count, mean and standard deviations of the parameters investigated, with the density and viscosity showing the smallest and largest standard deviations respectively. As presented in Table 7, the analysis of variance (ANOVA) of the various group of parameters investigated showed that the sum of squares within the groups is smaller than the sum of squares between the groups. There seems to be a statistically wide variation between the individually investigated degreaser parameters and the five different weight groups at the 95% confidence interval, as $F (4, 20) = 66.953768$ and $P < 2.70531E-11$. Fisher's F also represented a ratio of the variance between groups to the variance within groups and P denotes a probability factor that must be less than 0.05 in the ANOVA analysis. The degree of freedom between the groups is also 4, while the degree of freedom within the groups is still 20. The F and P values implied a strong dependence of pH, viscosity, density and weight of the product (degreaser) on the various weights of Na_2CO_3 considered. In Table 8, the Bonferroni-Holm Posthoc parametric test for various weights of Na_2CO_3 is presented. All the parameters investigated showed a strong dependence or significance on each other except for the relationship between viscosity and weight of product degreaser with a P value of 0.069 which is greater than 0.05 in the 95% confidence interval selected.

Comparatively on the overall, various weights of NaOH seems to have a stronger significance on the degreaser properties than those of Na_2CO_3 considering the relative smallness of the P values of Table 4 to Table 8, except for the last two cases investigated, where the P values in Tables 8 are smaller relatively to those in Table 4.

The different Samples of Degreasers produced were tested on different surfaces. The surfaces that were subjected to test with the degreasers produced were stained with crude oil. It was observed that the crude oil stain on metal surface was effectively emulsified as the concentration of sodium hydroxide was increased. Also a washing test was done on white handkerchiefs that were equally stained with equal quantity of crude oil (10ml) and 50ml of the different samples of degreasers produced was used to wash these handkerchiefs that were all soaked separately in 100ml of water and a washer set at a speed of 250rpm was used to wash these handkerchiefs for 20mins each, and they were allowed to dry. It was seen that the ten different handkerchiefs had different degree of color change from a fresh handkerchief that was serving as a standard control.

To test for the degree of whiteness a gray scale (GS) test was carried out using a gray scale. It is applicable to textiles made from all fibers in the form of yarn or fabric whether dyed, printed or otherwise. This is a standard test by Nigerian Industrial Standards (NIS).

Briefly, the grey scale is for assessing the degree of staining caused by a dyed textile or yarn in a color fastness tests. The scale consists of nine pairs of gray color chips each representing a visual difference and contrast. The fastness rating goes step-wise from:
Note 5 = no visual change (best rating) to Note 1 = a large visual change (worst rating).

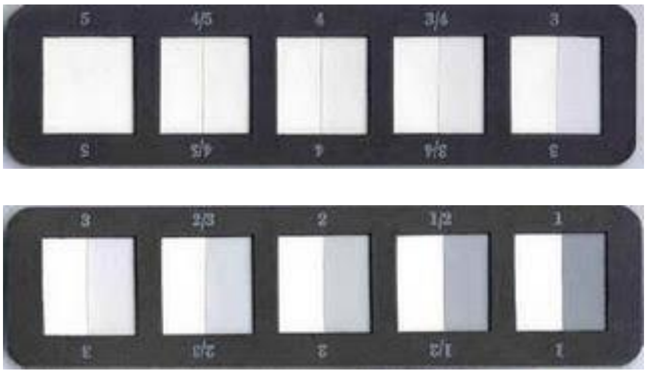

Figure 1: Picture of a gray scale.

The grey scale has the nine (9) possible values: 5, 4-5, 4, 3-4, 3, 2-3, 2, 1-2, 1.
1 = very poor, 2 = poor, 3 = average, 4 = very good, 5 = excellent.

The first half of each pair shows the starting colour, which is the colour of the control, while the second half of each pair shows the colour of the treated fabric as shown in Figure 1.

Results obtained after using the gray scale are as follows:

Table 9: Showing gray scale results for varying sodium hydroxide concentration.

Weight of NaOH (g)	GS Results	Comments
1	2 - 3	Poor - average
3	3	Average
5	3 - 4	Average - very good
7	4	Very good
9	4 - 5	Very good - excellent

Table 10: Showing gray scale results for varying sodium carbonate concentration.

Weight of Na_2CO_3 (g)	GS Results	Comments
1	2	Poor
3	2 - 3	Poor - average
5	2 - 3	Poor - average
7	2 - 3	Poor - average
9	2 - 3	Poor - average

As observed in Table 9, the grey scale test indicated that higher proportion of sodium hydroxide resulted in better cleaning action with the best value obtained at a sodium hydroxide concentration of 9 g. On the other hand, as shown in Table 10, higher proportion of sodium carbonate seems to have no improved effect on the cleaning action of the degreaser.

4. CONCLUSION

From the experiment and statistical analysis, there seems to be a statistically wide variation between the individually investigated degreaser parameters with various weights of NaOH and Na_2CO_3. In addition to the strong dependence of degreaser properties on various weights of NaOH and Na_2CO_3, various weights of NaOH seem to have a stronger significance on the degreaser properties than those of Na_2CO_3. It was seen that as the concentration of sodium hydroxide was increased, the cleansing efficiency also increased. The increase in concentration of sodium carbonate did not have any significant effect on the cleansing effectiveness. Furthermore, as the weight of sodium hydroxide alone was increased, the pH was also increased, while as the weight of sodium carbonate alone was increased, the produced degreaser exhibited lighter density. In conclusion the presence of sodium carbonate has nothing to do with the cleaning ability of degreasers, but sodium hydroxide does, as depicted by the gray scale test. This indicated that the cleansing action depended greatly on the chemical species present in the reacting cleansing media rather than physical properties variations alone. The outcome of the work would assist producers of degreasers to produce effective, useful and property controlled product at moderate cost.

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