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Reducing Over-consumption of Acid during Skim Latex Coagulation in Cameroon's Rubber Processing Factories

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Abstract

Latex processing factories in Cameroon transform field latex to latex concentrate and skim latex is generated alongside, being poor in dry rubber content and high ammonia content, it is mostly coagulated as skim rubber, for use in rubber products. These factories face enormous problems with the overconsumption of acid during skim coagulation, which results to extra expenses and high acidic waste water production problems. Therefore the is a need to reduce the overconsumption of acid during skim coagulation. In order to solve this problem we started by identifying all possible causes of acid overconsumption at the factory using the ISHIKAWA diagram. We further hierarchized these causes using a Pareto diagram and sought out 3 main causes of great impact to be addressed which are: the low performance of the deammoniation process; poor practice of coagulation; negligence. We proposed solutions by optimising the deammoniation process at the tower i.e. controlling its skim and air flow rate inside the deammoniation tower to optimal values. Also we determine the optimal volume of acid needed for effective coagulation which when applied reduces acid consumption. Lastly we optimized by proposing a new mode of operations for the coagulation process. By implementing this new approach, we recorded an estimated total acid reduction of 28,924 L/month (347088L/ year) and this will enable the company to save money about 770,469 FCFA/month (21,245,639 FCFA/year). This approach can be adapted in any other rubber processing unit and will reduce acid overconsumption during skim latex coagulation.

Keywords: Skim latex; coagulation; acid overconsumption; rubber processing.

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1. Introduction

Natural Rubber is a poly isoprene within which the group isoprene C_5H_8 form a very long chains entangled within each other with no orientation. The latex plants are by nature much diversified in the plant kingdom but the most used quality of natural rubber is produced by the species Hevea Brasiliensis [1]. Latex is a milky fluid that flows out by bleeding the bark of the rubber tree, which is present in the form of a colloidal dispersion of rubber globules in a suspension of liquid called serum which is opaque white or yellow in colour depending on its origin or clear grey after an evolution or maturity of the product [2]. The production of usable rubber includes growing the trees, tapping them for their latex, and processing the latex to obtain raw natural rubber or latex concentrate. Which is further transformed to rubber based products like tires, condoms, gloves, and car parts etc. The composition of a Latex from Hevea B. plant are shown in table 1 below.

Table 1: Composition of Latex [2]

Constituents	Proportions (%)
Water	52 – 70
Rubber Particles	25 – 45
Proteins	1.5 - 2.8
Sugar	0.5 - 1.5
Ash	0.2 - 0.9
Lipids	1 - 1.7

Latex stability and mechanism of rubber coagulation is describe from its composition, in which rubber latex contains 5 – 10 g/L protein, about one-third of which occurs in the lutoid-body fraction, more than one-half (1 – 2 g/L) of the latter is Hevein an anionic protein [3]. When the negatively charge proteins binds to the cationic proteins of the lutoids as a result of the breakdown of the membrane, aggregation and thus coagulation of the rubber particle will occur [4] . The negative charges on the surfaces of the poly (cis-isoprene) results from the carboxylic groups of the adsorbed protein, reduction of pH will prevent the dissociation of the carboxyl groups resulting to coagulation [5] while increasing the pH will prevent coagulation. Therefore for coagulation to occur, the latex pH must be brought to those of the isoelectric point, proteins of the membrane supposed to have an isoelectric point close to 4.7 [6] but will however remain in suspension when the pH is out of the isoelectric pH range of 4.7 to 5.2. Coagulation can also result when there is microbial oxidation of the carbohydrates to volatile fatty acids such as formic, acetic and propionic acids [6]. Conventional method of coagulating natural rubber latex is by adding formic acid, acetic acid or sulphuric acid to the rubber latex. Also conventional way of preventing latex from coagulating is by adding ammonia (NH_3) to increase its pH away from the isoelectric pH. At the case study factory tapped latex which is liquid rubber is prevented from coagulating in the field by increasing the pH using base such as ammonia (NH_3).This is done by adding few drops of 10% NH_3 in the collection cup to slow down the coagulation process., also the collected latex is poured in a tank and ammonia is added and mixed to prevent the coagulation of the latex. At the Cameroon development cooperative (CDC), 1 liter of ammonia is added in 1000 liters of latex. This is done in the field after which it is transported to the factory in tankers driven by tractors and trucks. In the factory, after quality control and reception of the field latex, it is processed to either latex concentrate or coagulated to natural rubber grades. Generally latex concentrate is very expensive and highly solicited by industries for several applications and more difficult to produce than coagulated rubber and its production needs more quality control measures. According to company manual, the production latex concentrate starts by field latex control of parameters such as: pH should be ≥ 9, % NH_3 content in latex is $0.25 \geq NH_3 \leq 0.50$, dry rubber content ≥ 33%, magnesium, and volatile fatty acid. The latex is then filtered and adjusted by dilution to a dry rubber content of 33% before stocking in the bulking tank. Finally it is filtered again to remove coagulum present, then concentrated by centrifugation which yields a mixture of latex concentrate (>65 % dry rubber content (DRC) and skim latex (the lighter aqueous part of the mixture 2.5- 10% DRC) [7, 8]. The production of latex concentrate generates alongside skim latex which is poor in rubber and has a high pH ≥ 9 due to its high ammonia content. The skim which is poor in rubber particles can only be coagulated for use to produce skim rubber (block, crepe and coagulated latex) [9] , and this coagulation is done by adding acid such as formic acid, sulphuric acid into skim latex to reduce its pH to 4.7 – 5.2 for rubber coagulation to occur. The amount of acid used, however, depends on the concentration of ammonia containing in the skim latex. Generally most rubber processing factories face serious problems with the high consumption (overconsumption) of acid used to coagulate this skim latex, with heavy amount of acidic waste water generated [10, 11]. This necessitates additional treatment of the waste water before discharge to the environment in order to avoid pollution charges, thus skim rubber becomes very expensive to produce. In order to reduce the overconsumption of acid most factories engage in the process of deammoniation (a process of removal of NH_3 from latex skim and reduction of its pH before the coagulation process). This process of deammoniation is very important to reduce the ammonia content of latex to the lowest possible value. Thus reducing the quantity of acid needed to bring the skim latex to its isoelectric pH. Different methods of deammoniation have been reported in literature such as dialysis which involve the use of a membrane filter to trap the NH_3, mechanical agitation which involve stirring latex in an open tank and flowing latex through the horizontal open channel. However, these techniques can remove ammonia but they need long time and large area. In addition, ammonia evaporates as a pollutant to the environment [12], Bubbling technique was reported by [13] in which air bubbles at different sizes were used to remove ammonia in skim latex. The results showed that the concentration of ammonia decreases from 0.5% to 0.2% using bubbling technique and solved the environmental concerns of the previous techniques, but the process is slow and mostly used for low quantities of skim. Fast methods have increasingly been used in industrial processes to meet up with increasing daily skim production such methods are: Stripping which is the blowing of air in opposite flow direction through the skim latex to extract NH_3 present [14]; Deammoniation tower is a method which involve the infiltration of the skim latex through perforated plates while air is forced to flow through the skim on the opposite direction to wash out the NH_3 present in the skim [15]. This process is similar to stripping and it’s what is used in the case study factory for deammoniation. This technique has been reported to reduce the NH_3 content of a deammonified skim to 0.15% , but this value is never attained at the case study factory . therefore the skim latex coming out of the deammoniation tower in most rubber factories in Cameroon still contain high ammonia content than expected as such its coagulation demands high quantity of acid to bring skim to its isoelectric pH. This high quantity of acid consumed during coagulation possess a serious problem to most rubber factories handling skim latex. Presently the case study rubber factory faces serious problem with the overconsumption of acid during skim coagulation and needs to address this problem. Notwithstanding apart from the deammoniation process There are several other factors that can cause over consumption of acid during skim coagulation in an industrial process but most of these causes can only be identified onsite following an experimental design process and follow-up of existing practices. This causes range from unit operations to technicians and industrial practices put in place. A good understanding of the causes of overconsumption will enable the optimisation or reduction of the too much acid needed for skim coagulation. In this work our main aim is to identify the causes and to reduce the overconsumption of acid during skim coagulation. This will enable the company reduce its expenses in acid, reduce risk of handling acid and generate less acidic waste water to the surrounding.

2. Materials and Methods

2.1. Materials

- Technical documents

Company technical bulletins, catalogues, technical daily data sheets of coagulation and acid consumption.

- Microsoft Visio was use for technical drawings, pH-meter, magnetic agitator and electric balance for measurements
- Reagents used are skim latex, 7,5% H_2SO_4 of 0,1N, distilled water, ammonia

2.2. Method

2.2.1. Analysis of existing state

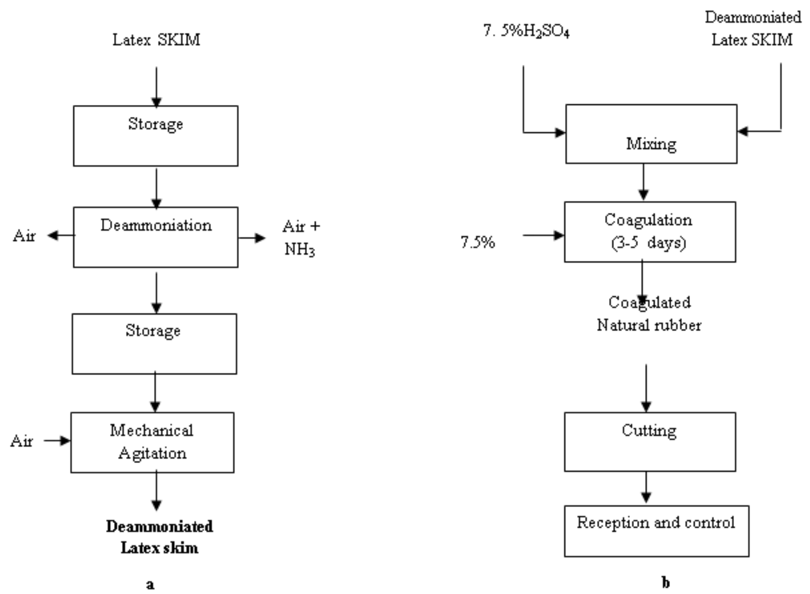


Figure 1: Procedure of deammoniation and coagulation of skim latex

We proceeded to study the existing practices at the rubber factory in which the procedure of deammoniation by understanding the mode of functioning of the de ammonification tower onsite and we did a follow-up of the acid consumption in coagulating the deammoniated latex skim. The process flow diagrams of the existing practice is shown in the figure below

From the figure above the procedure of deammoniation is shown in diagram (a) in which the latex skim is first stored in a tank after production, then the latex is then forwarded to the deammoniation tower at a control flow rate. The latex from the tower is mechanically agitated and stored as deammoniated latex. The coagulation process shown in (b) above involves the mixing of the deammoniated latex with sulphuric acid (7.5%) for 3-5 days to bring latex to its isoelectric pH, then coagulation occurs .the coagulated rubber undergo cutting and control before drying and storing for export.

- *Evaluating the extraction efficiency of NH_3, E_{NH3} by the deammoniation tower*

The extraction efficiency can be calculated using the formula below

$$\mathbf{E_{NH_3}} = \frac{(\%\mathbf{NH_{3I}} - \%\mathbf{NH_{3E}}) \times \mathbf{100}}{\%\mathbf{NH_{3I}}} \qquad (1)$$

Where, $\%NH_{3I}$: Inlet % of ammonia in skim at tower $\%NH_{3E}$: Exit % of ammonia in skim at from tower

- . ***Evaluating acid consumption during coagulation***

Based on data collected after different coagulation process, the acid consumption was evaluated using the following formula.

$$C_1 \times V_1 = C_2 \times V_2 \qquad (2)$$

Where, *C_1 : Concentration of NH_3 in SKIM,V_1 : Volume of SKIM,C_2 : Concentration of acid,V_2 : Volume of acid*

2.2.2. Identification and hierarchisation of causes of over consumption of acid

The ISHIKAWA diagram is used to identify the causes, which is a simple graphical representation of an outline that presents a chain of causes and effects. The end result is a diagram that lists all the possible causes of a problem with the appearance of a fish bone. The principal causes are often considered under the headings of the 5Ms' which stands for: Method, Materials, Machines, Man power and Milieu. The causes were hierarchized using the PARETO table and diagram.

2.2.3. Optimisation by experimental assessment and design

- 100 ml Samples of the different batch of deammoniated skim latex were collected and all parameters measured (pH, NH_3 content, air flow rate and skim flow rate).
- 50ml of different days of deammonified skim latex after dilution were titrated against 7.5% H_2SO_4 and allowed to coagulate. From which the volume of acid used for coagulation was measured and the minimum amount of acid sufficient for coagulation was also recorded.

3. Results and discussion

3.1. Evaluating the existing state

3.1.1. Characterization of skim latex before deammoniation

Some key characteristic of skim latex measured at the case study factory the quantity of skim, pH and ammonia content are shown in the table below

- % NH_3 content in skim latex

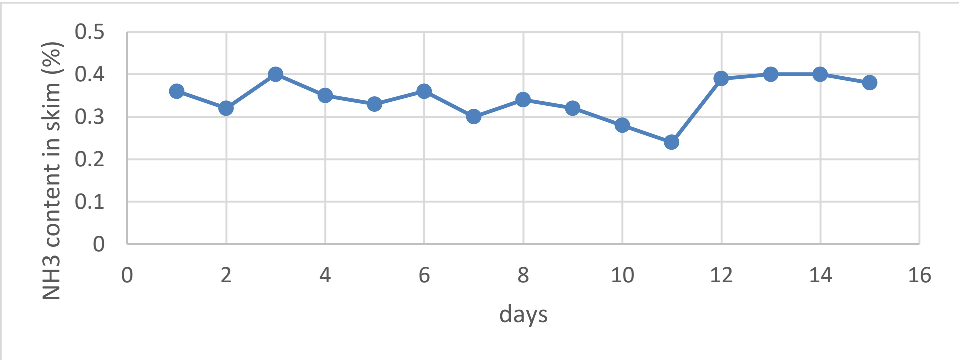


Figure 2: variation of % ammonia in skim latex produced

From the figure we see that the ammonium content in skim latex is typically between 0.25% and 0.4% with the highest percentage recorded of 0.4%, from this percentage ammonia in skim we can now we can see the need for high amount of acid during coagulation therefore the deammoniation tower has remove ammonia from skim to reduce to a lower value of about 0.15 for ideal deammoniation.

- pH of skim latex

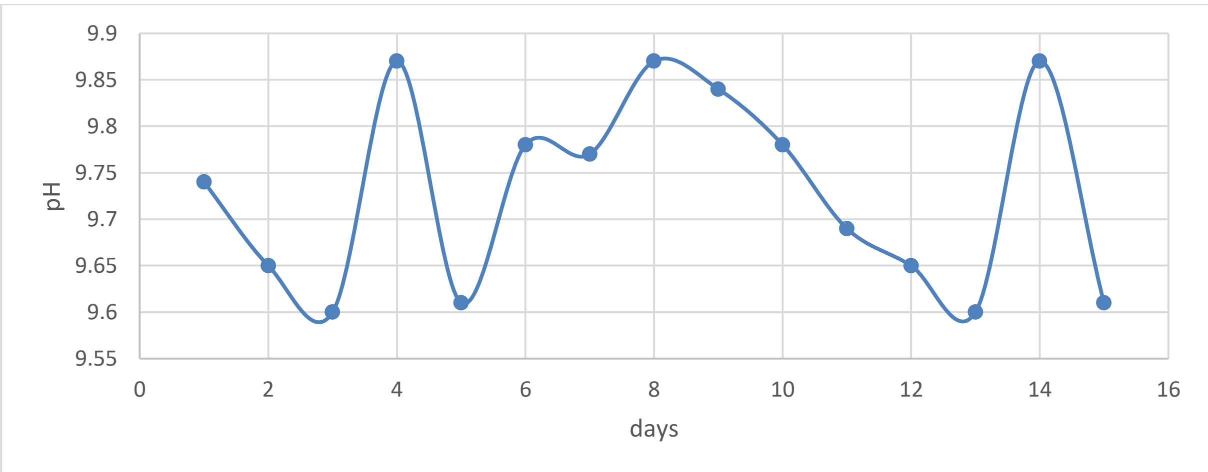


Figure 3: variation of pH in skim latex produced

The pH of skim varies with the ammonium content in skim the higher the ammonium content the higher the pH. Generally from the figure we realize that skim pH is always basic and most days recorded it was >9, with a variation from 9.6 - 9.88. For coagulation to occur this pH has to be reduce to the isoelectric pH of latex between 4.7 to 5.2 by adding acid. Thus the higher the pH of latex the greater the amount of acid needed to coagulate latex

- Skim latex flow rate

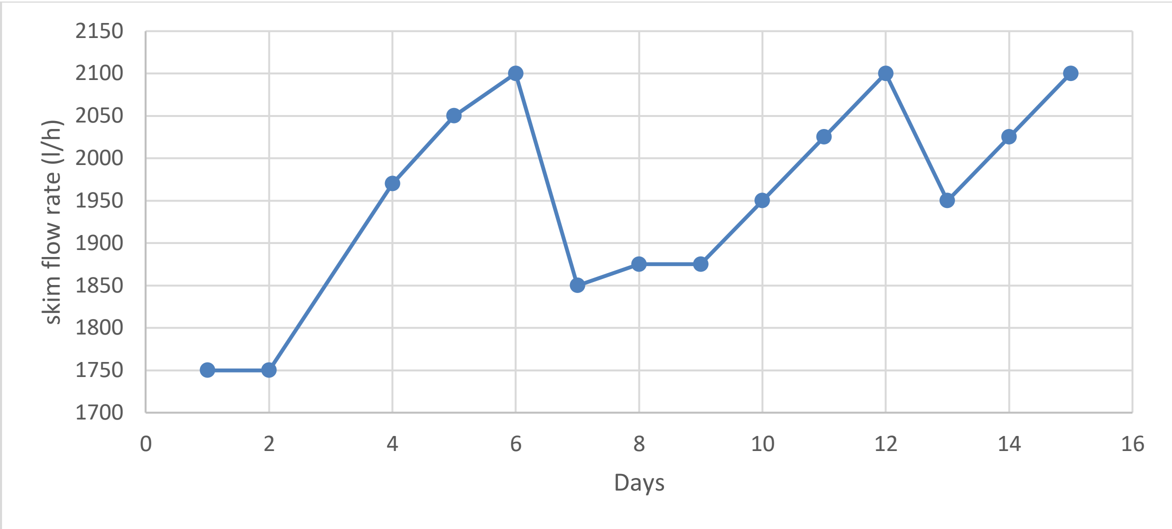


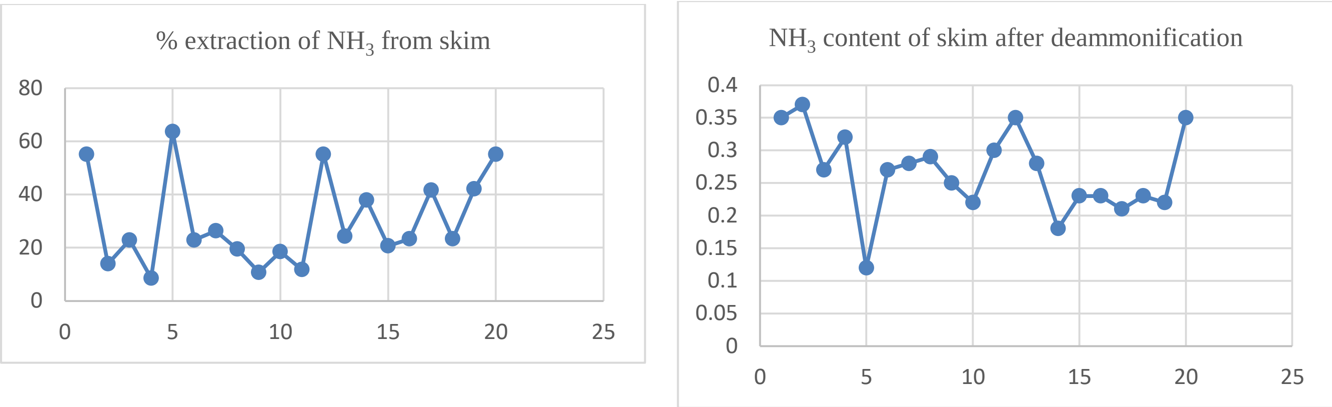
Figure 4: variation of skim latex flow rate to the deammoniation tower

In other to produce coagulated skim rubber the skim latex needs to be deammoniated to reduce the % NH_3 present in other to reduce the amount of acid needed to reduce the pH to its isoelectric pH. Generally at the case study factory the quantity of acid varies daily depending on the quantity of latex concentrate produce. And skim flow rate varies from 1750-2100 L/h with an average hourly flow rate is 1950 L/h.

3.1.2. Evaluation of deammoniation rate and quantity of acid consumption rate

We calculated the % of extraction of NH_3 at the deammoniation tower and the quantity of acid used during different coagulation days

- Efficiency of extraction of ammonia by the deammoniation tower



a

b

Figure 5: a) % extraction of NH3 from skim by deammoniation tower b) NH_3 content of deammoniated skim

Following the present practice a standard deammoniation tower has the ability to reduce NH_3 content of deammoniated skim latex to < 0.15% but from the figure b above a great majority of the deammoniated skim latex had NH_3 content > 0.2 this shows a < 50% extraction ability of the tower therefore this obviously will lead to overconsumption of acid.

- ***Evaluation of acid consumption during coagulation of deammoniated latex***

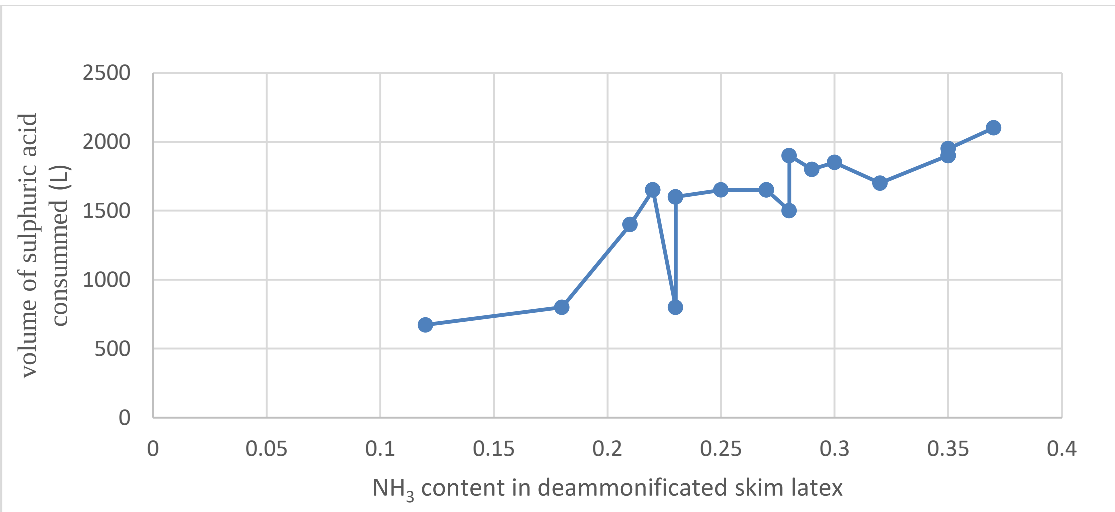


Figure 6: variations of volume of acid consumed to coagulate deammoniated latex from tower

The quantity of acid consumed varies with different ammonia content in skim latex as shown in the figure above this is due to the fact that high amount of acid is needed to bring a more basic skim latex to its isoelectric pH. Therefore the deammoniation of skim latex is very important to reduce the ammonia content to as minimum as possible in other to reduce acid consumed.

3.2. Identification and hierarchisation of causes of over consumption of acid

- ***ISHIKAWA diagram***

We started with a questionnaire to sort out the various factors that can cause over consumption of acid during coagulation of skim the various causes are represented in the ISHIKAWA diagram below.

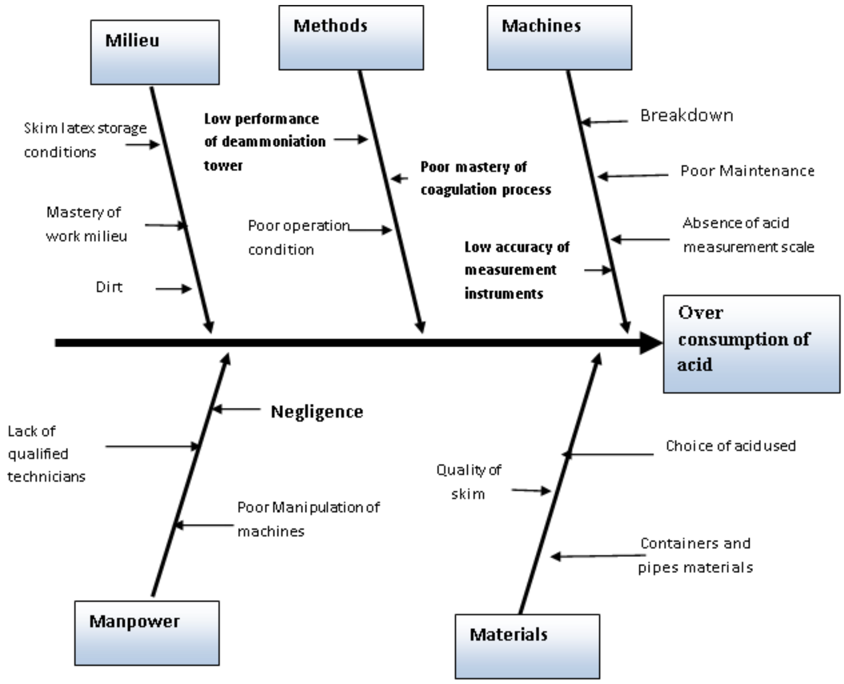


Figure 7: ISHIKAWA diagram expresses the various possible causes of acid overconsumption during skim latex coagulation.

The Ishikawa diagrams represent the totality of causes to effects. In other for us to streamline to the main causes, a failure mode analysis was carried out from which criticality analysis was done for each effect

- ***Hierarchisation using Pareto diagram***

Hierarchisation of the causes of over consumption was done using the method of 80-20 by Pareto which gives the result presented in the table below

The table above ranks the various causes of overconsumption of acid during skim coagulation based on their criticity and frequency of occurrence during deammoniation and coagulation process. The most ranked causes are main causes that needs to be addressed, in other to classify this main causes, from the table we then further represented all causes on a Pareto chart shown below to be able to have a better view of the main causes of the over consumption.

Table 2: Pareto table hierarchising the different causes identified

CAUSES OF OVER CONSUMPTION	RANKING CRITICITY	FREQUENCY (%)	CUMULAIVE FREQUENCY (%)
Low performance of the deammoniation tower	75	33.185	33.185
Poor mastery of coagulation process and Absence of an acid mesuring scale	65	28.76	61.945
Negligence	40	17.70	79.645
Low accuracy of measurement instrument	25	11.06	90.705
Lack of qualified technicians	10	4.42	95.125
breakdown	8	3.54	98.665
Cleaning of equipement	1	0.44	99.105
Quality of SKIM	1	0.44	99.545
Storage condition	1	0.44	100
TOTAL	226	100	

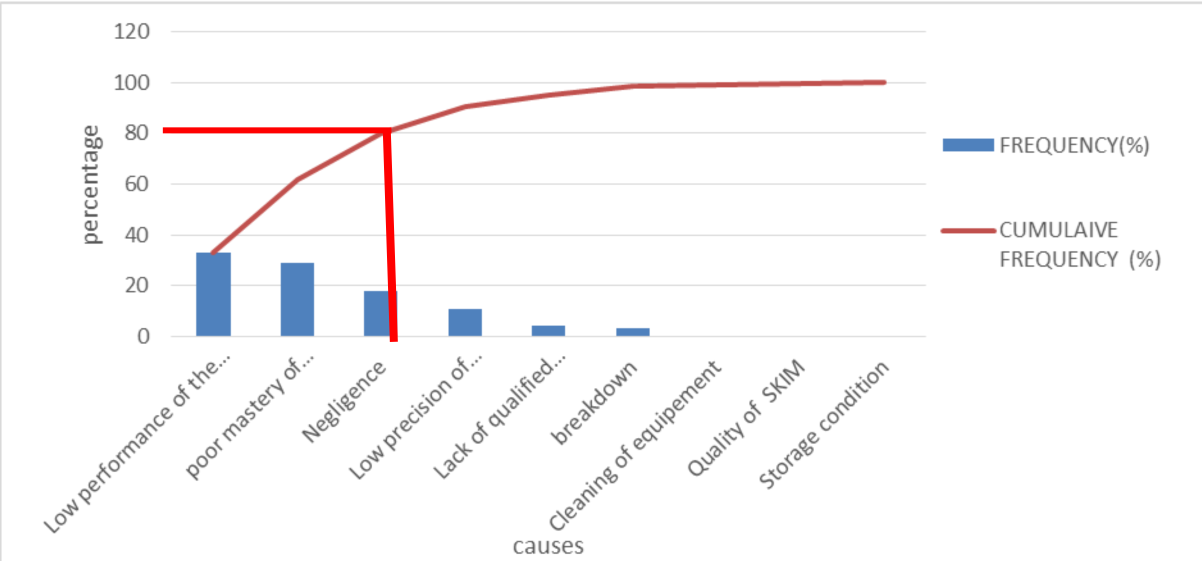


Figure 8: Pareto chat showing causes of 80% of the problems of overconsumption of acid during coagulation

The Pareto chart above shows us the causes which are responsible for 80% of the problems link to overconsumption of acid at the skim coagulation unit. From the chart, extrapolating causes of 80% overconsumption of acid were identified. The three main causes are: low performance of the deammoniation tower; poor mastery of coagulation process and absence of an acid measuring scale; negligence. Therefore these causes needs to be addressed by optimising the process to reduce over consumption of acid during coagulation.

3.3. Optimization of the process to reduce overconsumption of acid

- Optimizing the deammoniation process

At the deammoniation tower we realized two key factors that influenced the deammoniation of latex skim at the tower: The flow rate of skim latex feed into the deammoniation tower; the flow rate of air in the tower. The deammoniation tower used at the case study factory is shown below

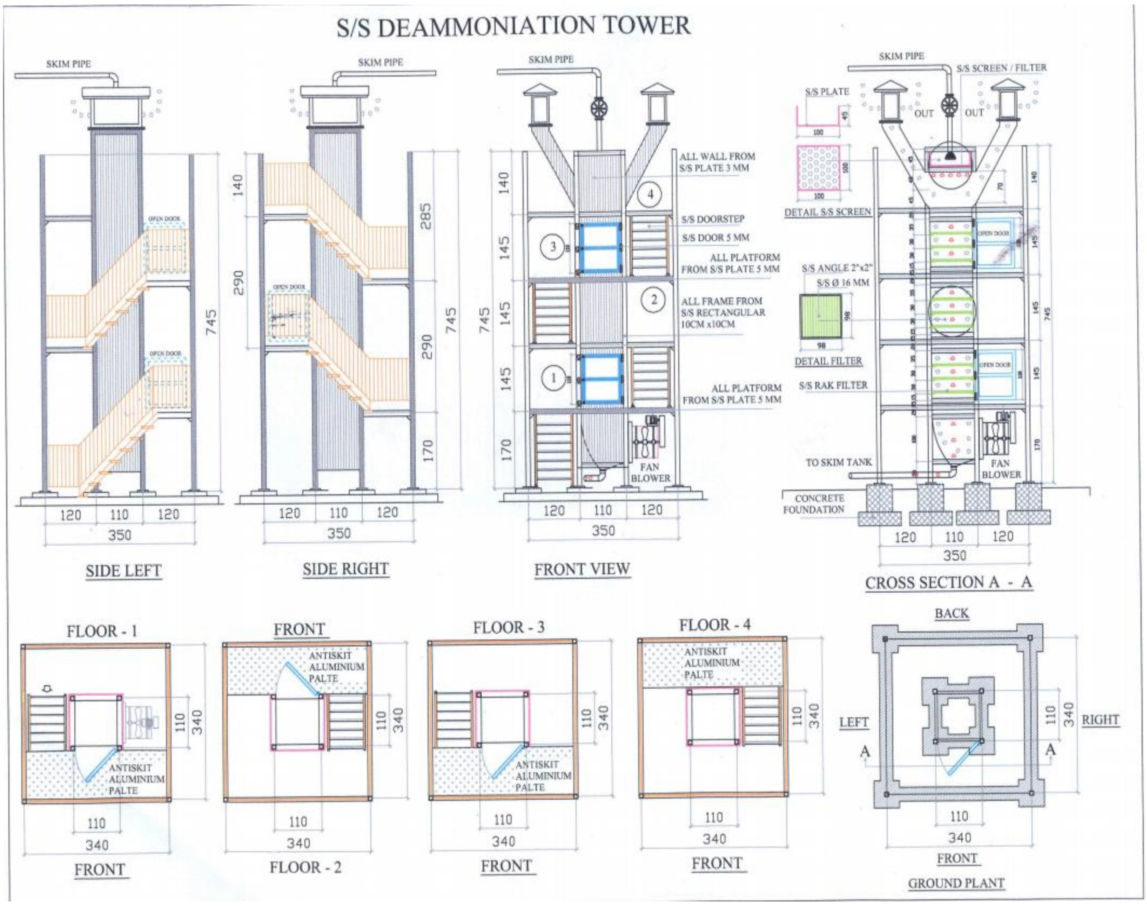


Figure 9: Standard deammoniation tower (company technical document)

This two factors varied in different batch days of deammoniation and thus are the main factors that influenced the rate of extraction of ammonia from skim latex at the tower. The variations of skim and air flow rate are shown in the table below.

Table 3: variations of skim and air flow rate at the during deammoniation at the factory

	Low feed rate	**Intermediat feed rate**			**High feed rate**
Skim latex flow rate (L/h)	1750	1850	1970	2050	2100
Air rate (m^3/h)	500	750	1000	750	1500

We engaged in an experimental follow up and recording operational data for several days of deammoniation batch operations in other to determine and optimal skim and air flow rate for maximum deammoniation by the tower. We control these two key parameters over a period of 30 production days, by monitoring the resultant effect of changes in this parameters on the ammonia content of the resultant latex skim after deammoniation. The results are shown in the figure below.

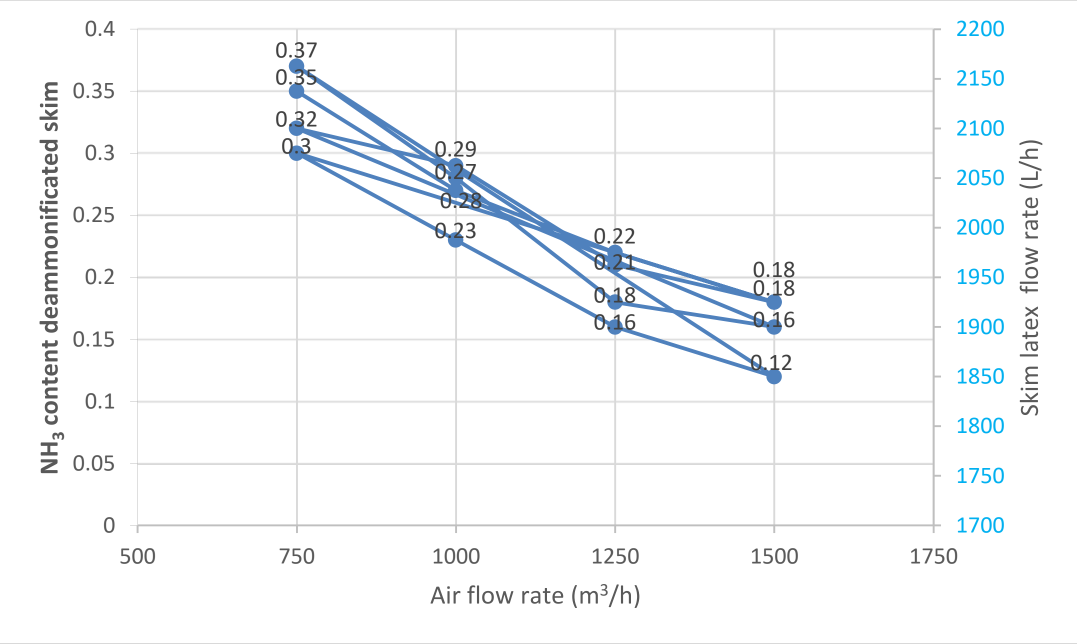


Figure 10: variation of NH3 content of skim with changes in skim and air flow rate in the deammoniation tower

According to company documents a standard deammoniation tower has to generate skim latex having ammonia content ranging from 0.13 to 0.17% .Therefore from the figure above the ammonia content in skim latex is reduces with decrease skim flow rate (<1950 L/h) and increase air flow rate (>1250 m3/h). We also observed that optimal deammoniation was obtained at an air flow rate of 1500m^3/h and the skim flow rate between 1850-1930L/h, this yielded a deammoniated skim latex of lowest ammonia content. (0.12- 0.18).Therefore at the level of the deammoniation tower this parameters have to be considered with keen attention because the influence the residence time of the skim in the tower. To be able to optimize the deammoniation process maintaining these two parameters at optimal values lead to a reduction of acid consumption as shown in figure 11 below

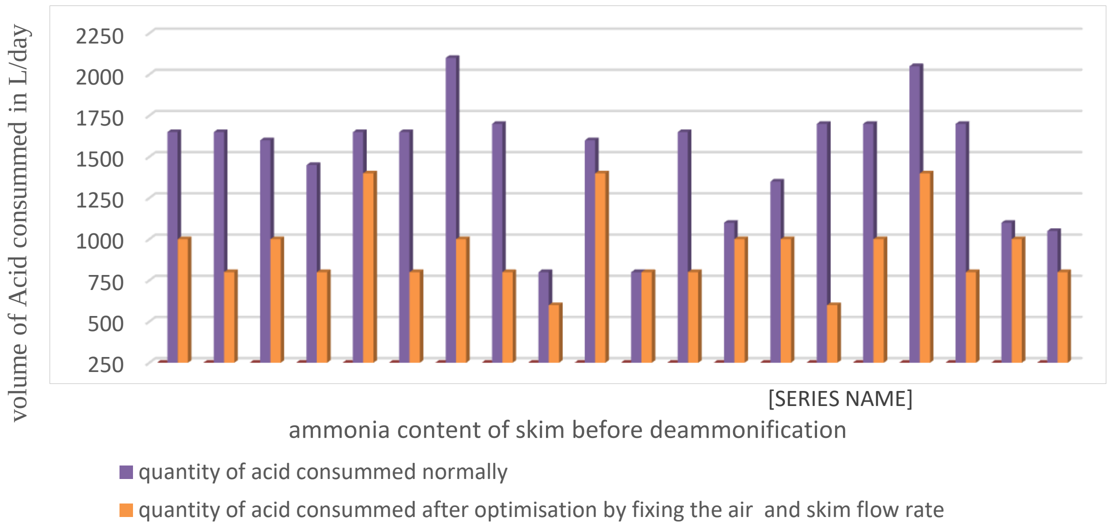


Figure 11: Reduction of acid consumption by controlling skim and air flow rate at the deammoniation tower

the average consumption per hour maintaining an air flow rate >1500m3/h and a skim flow rate between 1850-1950 l/h was estimated at 940 L/day which is far lower than the 1503L/day that was consumed normally without taking in to consideration the precision of key deammoniation parameters like air and skim flow rate. This is about 37% reduction of the acid consumption if deammoniation is well done. The monthly acid consumption is estimated at 36406L, but applying the proposed optimisation method we recorded a reduction to 24440L a month a reduction of 11963 L (143592L/ year) and this will enable the company to save 732,373 FCFA/month(8,788,480 FCFA/year) this is money which will be recovered optimizing the skim coagulation process.

- ***Poor mastery of coagulation process and absence of an acid measurement scale***

We realized that the process of coagulation was poorly done at the factory, we engaged in measuring the minimum amount of acid needed for effective coagulation as such by titrating sulphuric acid against 100ml of deammoniated skim each day after deammoniation process and results projected to the actual volume coagulated at the factory were compared. The results are shown below

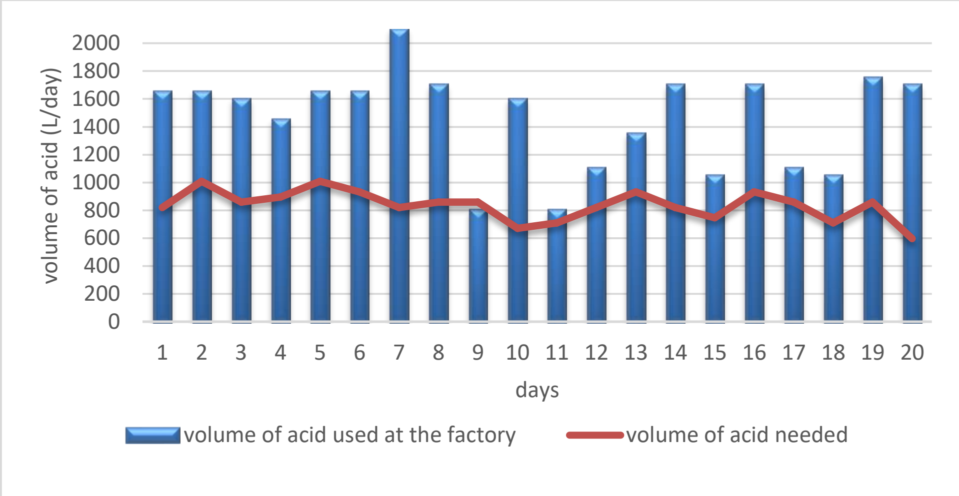


Figure 12: reduction of acid consumption by accurate measurements and good mastery of coagulation process

From the figure we realized that too much acid was been used at the factory than what is actually needed for effective coagulation. The optimum daily coagulation is highlighted in the graph and with the control of this parameter by measurement before each coagulation process we recorded a reduction to 16961L/ month a (203533L/ year) and we extrapolated that 60% of this excessive use of acid is due to poor mastery of coagulation and measurements and 40 % is due to negligence. Therefore 60% yield a reduction rate of 122119 L/year, this will enable the company to save 622,857FCFA/month (7,474,291 FCFA/year) this is money which will be recovered with good mastery of coagulation process and measurements.

- ***Negligence***

Poor mastery of the working environment and key control parameters since the present technology is new in the factory as shown the process flow diagram in figure 1 above, as such we design a new work plan indicating key control areas of interest that will help in the reduction of overconsumption in selected unit operations as shown

Due to negligence there is overconsumption of acid during skim coagulation, this is due to the fact that most measurements are not done before the coagulation process, this causes 40% of the overconsumption recorded in figure 12 above. The process flow above shows key control parameters which are usually neglected at the factory, this parameters needs to be properly controlled at each stage of the deammoniation and coagulation process as shown in figure 13 above. With the use of this proposed process flow with appropriate control at each stage of skim coagulation, the factory will be able to reduce 6784 L/month (81412 L/year) in which the company will save 4982868 FCFA/year as calculated from figure 12 above.

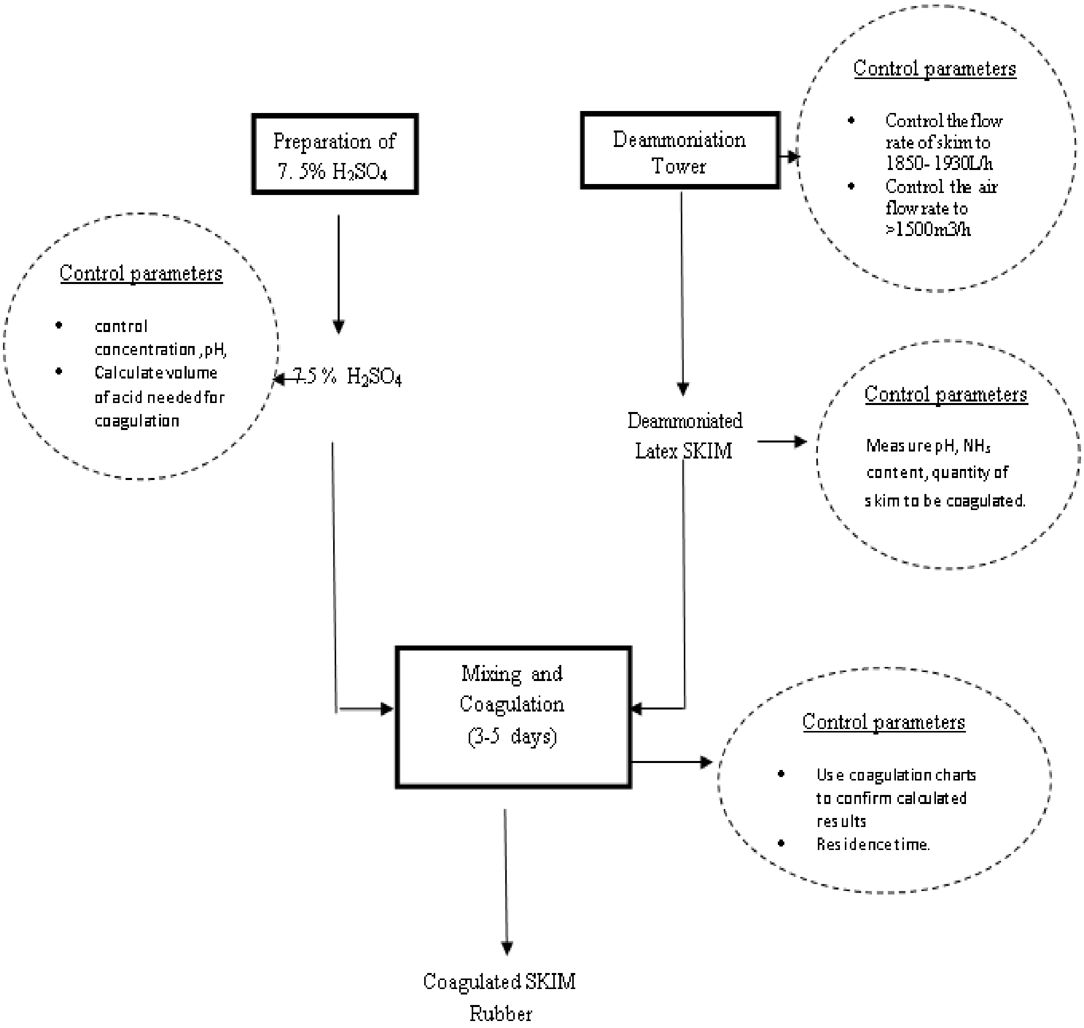


Figure 13: Proposed process flow diagram to enable control of key parameters neglected that influence acid consumption during skim coagulation

4. Conclusion

The main objective of this work was to identify and propose solutions to the over consumption of sulphuric acid used in the coagulation of skim latex in Cameroon rubber factories. We use the ISHIKAWA diagram to identify all possible causes of overconsumption and we further hierarchized this causes using a Pareto diagram. From which 3 main causes were of great importance to be addressed which are the low performance of the deammoniation tower, poor practice of coagulation and measurements of acid used and negligence. We obtained an estimated reduction of 28,924 L/month (347088L/ year) and this will enable the company to save about 770,469 FCFA/month (21,245,639 FCFA/year) This work will help most rubber factories to pay more attention to the importance of reducing overconsumption and save more finances over the years.

5. Recommendations

We recommend that a maintenance check list be put in place at the end of each production week, this will help solve the problem of breakdown and cleaning of equipment. Also we recommend training of technicians involve in the unit of deammonification and coagulation, this will help improve the skills of the workers.

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