Cleaning of clogging central tube in juice clarifiers

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Abstract

This research aims to remove the solid sediments that completely blocked the central distribution pipe in the juice clarifiers. These sediments can't be removed by traditional methods such as crushing or heating, due to the special condition of the pipe inside the clarifier, its narrow diameter and vertical position. Therefore, chemical methods were used to solve this problem. A new technique was used in this process through a mixture of sodium hydroxide and hydrogen peroxide solution. There are many experiments and attempts to find the most suitable way of addition and also the final required concentrations of 1:1 dilution for both solutions and the diluted sodium hydroxide solution (48%) was added firstly and after 24 hours a solution of hydrogen peroxide was added with twice the amount of sodium hydroxide. This work was based on the fact that the decomposition of hydrogen peroxide in the alkaline medium is accompanied by the release of oxygen, the occurrence of effervescence and the rise of impurities up to the surface of the solution in an exothermic reaction. This method which has been succeeded in removing sediments from the pipe of lengths up to 7 meters, can be considered a new addition in the field of chemical removal of sediments.

Introduction

Clarification of juice in sugar cane industry is a process at which the hot treated juice allowed to undergo sedimentation in a special equipment known as clarifiers.

The mean purpose of clarification process are [1]:

1) Maximum elimination of non-sugars
2) Maximum elimination of colloids
3) Maximum rate of settling
4) Minimum colour formation
5) Minimum volume of mud

6) Minimum calcium content of juice
7) Low turbidity of the juice
8) Suitable pH of juice to avoid inversion of sucrose

Before clarification treatment of raw cane juice with lime, sulpher dioxide and orthophosphoric acid yielded essentially a precipitated calcium phosphate microfloc particles which act as sweep flocculants in the clarifier, removing suspended matter from the juice and adsorbing dissolved molecules and ions but calcium phosphate alone don't give the perfect clarification.

So, increasing the settling rate of the calcium phosphate microfloc particles and improve the efficiency of separation of the liquid-solid system, through addition of a high molecular weight copolymer of acrylamide (AAm) and sodium acrylate to the juice [(2, 3)]. The commercial type used in Egyptian sugar industry known Sabaran. The clarified juice is collected from the top of the clarifier and sent to the evaporator station for concentration.

The sediments result from clarification process known as mud juice which removed also continuously from clarifiers undergo filtration to produce filtrated juice and pressmud which are later used as fertilizer. If a problem had occurred in the system of effluence from the clarifiers that may cause a collection of this sediments and big troubles in the clarification process beside the ability of clogging pipes inside clarifiers. In this case the composition of sediments at which cause the clogging like essentially the composition of pressmud [(4, 5)].

The past methods of cleaning of the clogging pipes depending up essentially on the availability to isolate the clogging pipes from its location to remove sediments from it like that the pipe is heated to a high degree with an external flame and then the knocking is taken from the skyscraper and the sediment inside the pipe then easily isolated.

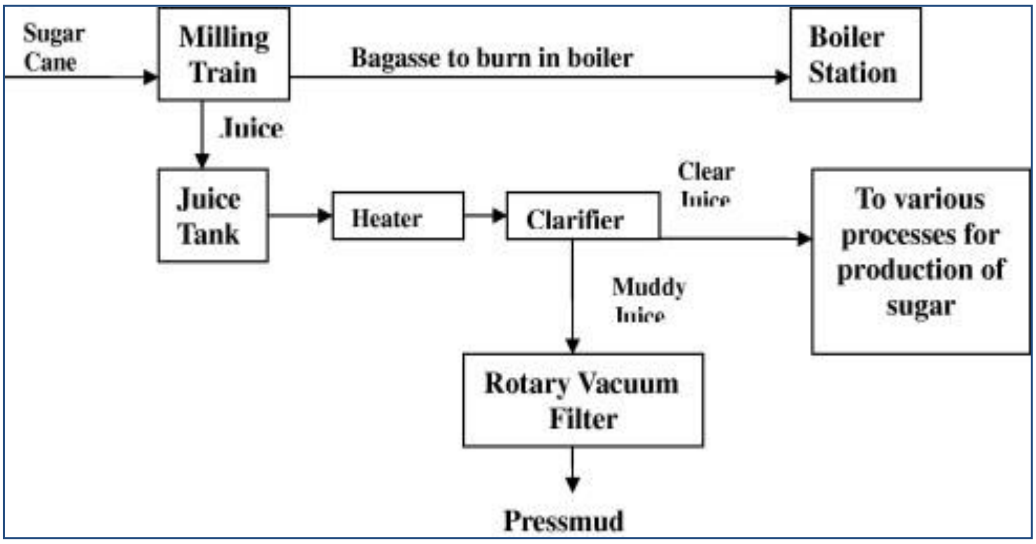


Fig. 1. A schematic diagram of formation of pressmud waste in sugar mill.

Composition of pressmud

Composition	% wet basis
Sugar	2.1
Moisture	78.2
Wax	2
Fat	1.6
Nitrogen	0.4
P_2O_5	0.4
K_2O	0.2
CaO	0.8
Fiber	4.3

Table 1: General composition of wetted pressmud (expressed % wet basis)(4).

Composition	Amount Present
Sugar	5–15%
Fiber	15–30%
Crude wax	5–14%
Crude protein	5–15%
SiO	4–10%
CaO	1–4%
MgO	0.5–1.5%
PO	1–3%
Total ash	9–10%

Table 2: General composition of pressmud (expressed % dry matter)(4)(5)

Description of Dorr-Oliver clarifier (6) (7)

Clarifiers are normally preceded by a flash tank. This is a simple cylindrical tank located just above and ahead of the clarifier, with a flue open to the atmosphere. The juice from the heaters discharges tangentially into this tank; since the juice has been brought to 101.5 - 104.5 °C partially flashes into vapour when discharged into this vessel at atmospheric pressure. This flashing removes the air bubbles attached to the suspended particles, if not removed, it would prevent particles of baggass from settling during the clarification process.

Clarifiers are generally divided into five compartments. Fed separately by a rotating central tube by means of openings situated in the upper part of the compartment

Clarifier is provided with a central hollow shaft with rotating very slowly and carries scrapers of sheet metal which slowly brush the bottom of each compartment. The clear supernatant juice is withdrawn from each compartment by a circumferential internal pipe with several openings which withdraw the juice close to the roof of the compartment. The juice then passes through an overflow box, by vertical pipes fitted with sliding.

The mud deposited on the bottom plate of compartment are moved by scrapers mounted to the bottom of the clarifier (collecting mud) and then withdrawn from the bottom of the clarifier to filtration process .

volume of clarifier (capacity)	**475 m^2**
Surface area	**355 m^2**
Diameter	**9.5 m**
Height	**9.5 m**
Number of compartment	**5**
Distance between tow compartments	**1.33 m**
Compartment Surface area	**71 m^2**
Central tube lengths	**7.23 m**
Central tube diameter	**368 mm**

Table 3: Specifications of Armant clarifiers

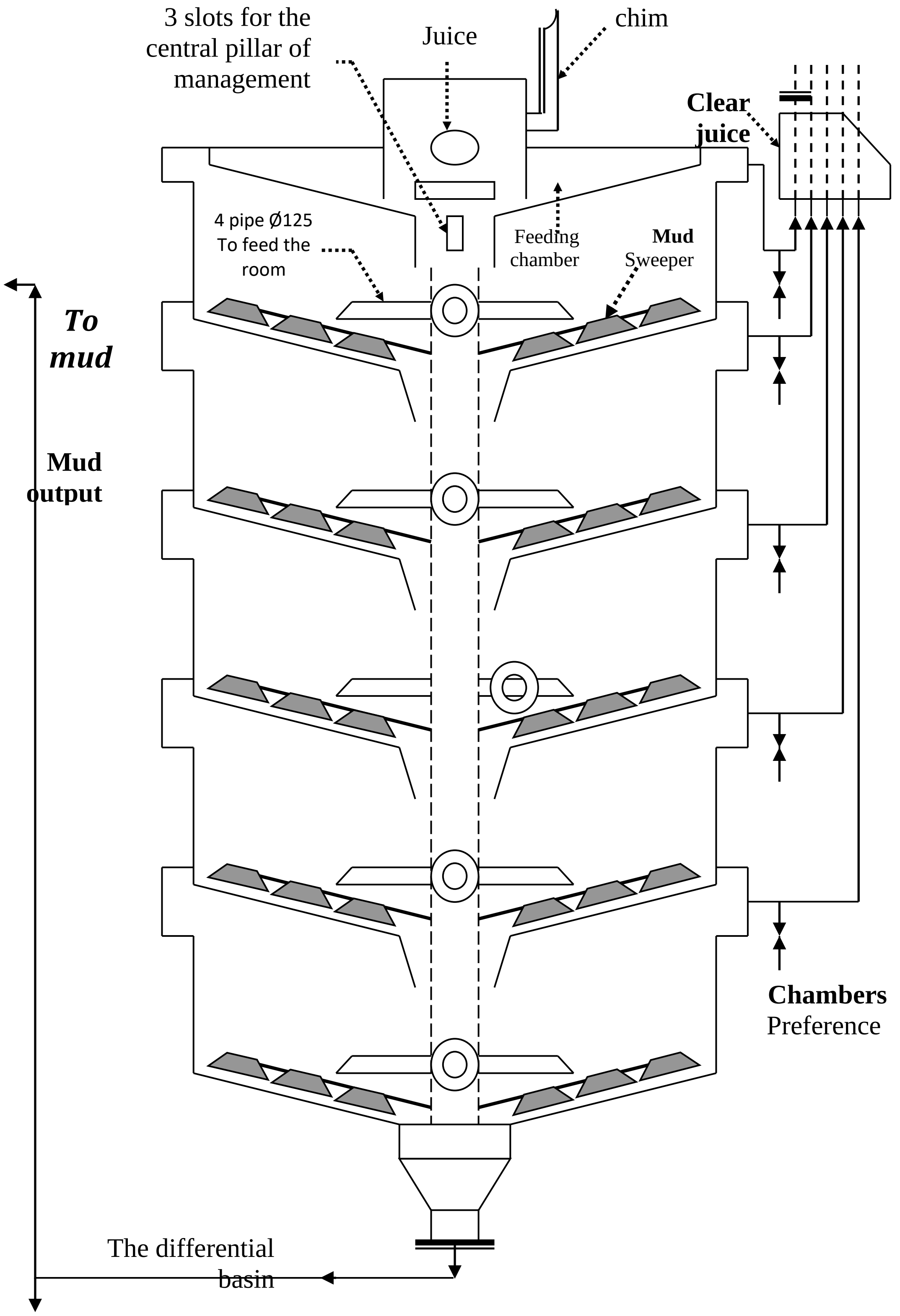


Fig. 2. Clarifier Structural Form

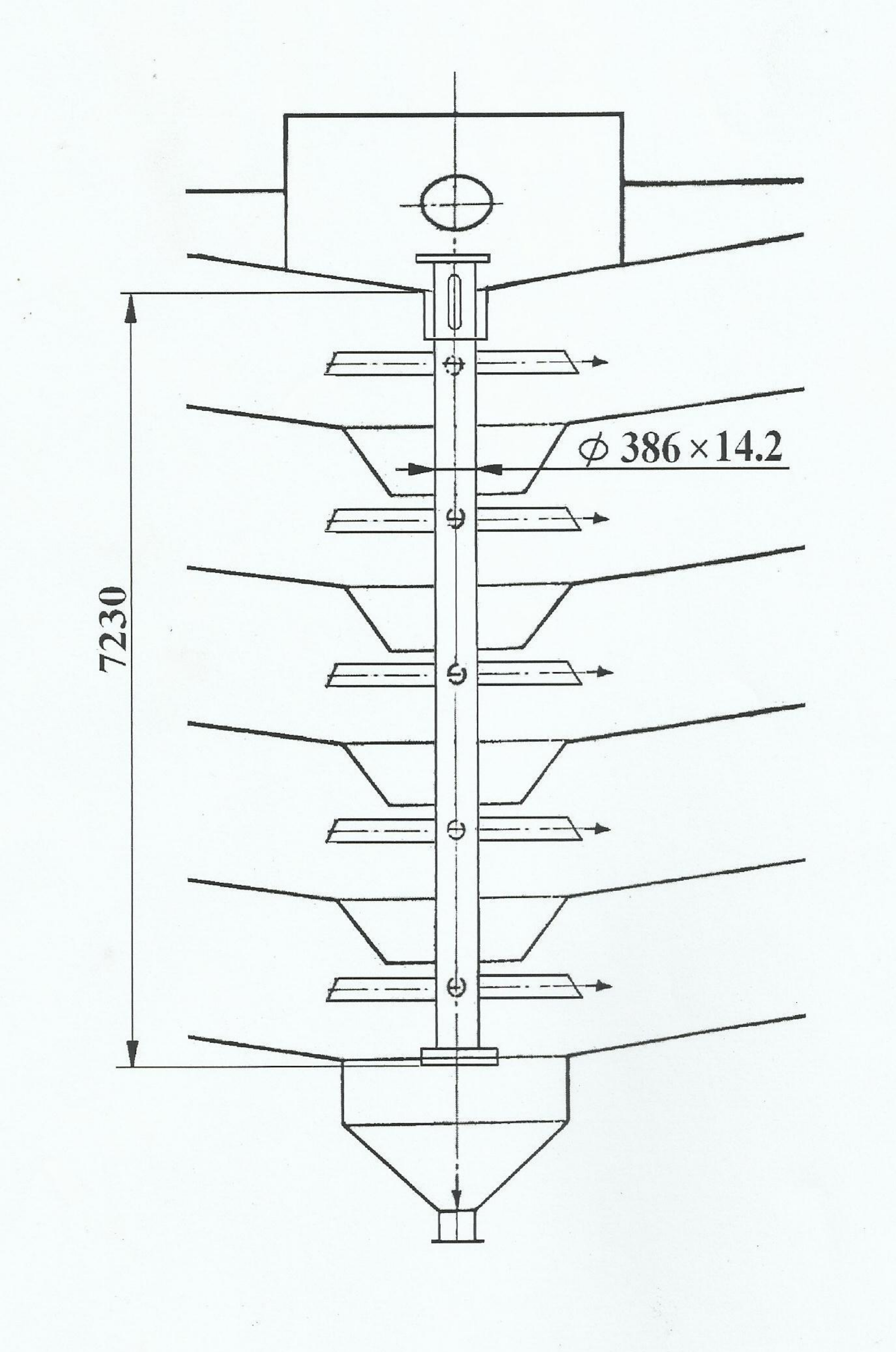


Fig. 3. Clarifier Central Tube Structural Form The above two figures was done by the Armant Engineering Drawing Office

Experimental

Reagents

Dilute solution (1:1) of sodium hydroxide 48%

Dilute solution (1:1) of hydrogen peroxide (food grade) 50%

Procedure

Laboratory tests:-

A sample of the sediments was subjected to simple analysis in the factory laboratory like moisture, soluble matter, combustion analysis and insoluble matter

Factory trials:-

1- At the first compartment of the clarifier, a mechanical hole is occurred in the central tube at the beginning of the room with a height of 40 and 25 cm width to be used in the addition of a mixture of chemicals used.

2- The sediments beside the opening hole are cleaned mechanically .

3- A sample of the removed scales was undergo simple analysis in the factory laboratory like moisture, soluble matter, combustion analysis and insoluble matter (as we mentioned earlier)

4- Several experiments have been conducted to determine the most appropriate concentration of chemicals used as well as determine the best method of addition

5- A solution (1:1) of sodium hydroxide was added from the hole tell feel the hole space and let it for 24 hours

6- After 24 hours from the addition of sodium hydroxide solution of (1:1), hydrogen peroxide was added to mixed with soda solution and allow the reaction between them to occur the quantity of hydrogen peroxide solution was doublet of the sodium hydroxide solution

7- Evolution a lot of fumes from the hole at the tube was recognized after the addition of hydrogen peroxide solution to the soaked sodium hydroxide solution

8- After ending of reaction between sodium hydroxide and hydrogen peroxide which indicated through stopping the gasses evolution it was recognized that a longitudinal distance in the tube below the opening hole contain a fragile sediments this distance about 30 – 40 cm at which easily separated from the tube ,collected and removed it out the clarifier

9- Repeating the last steps 5-8 times until all the available space of the tube inside the compartment was removed and this part of the tube was completely cleaned

10- In all previous steps, safety instructions were strictly followed

11- After finishing the cleaning of first compartments we was repeated the last work in the other compartment until the complete cleaning of the tube through all the clarifier

12- A daily cleaning of 30-40 cm of the height of the sediments at the tube

13- The problem was completely resolved - by the armature thanks to God - within 15 days of the beginning of the experiment

Results and dissection

Testes	Results % gram
Moisture	2.93
Losses by combustion	12.49
Insoluble matter	52.48
Soluble matter	47.52

Table 4: Analysis of sediments sample

The last analysis indicate a very low humidity of these deposits as well as a high levels of non-soluble substances

Causes of the problem (Sediment Collection Mechanism):-

In the end of the juics season clarifiers were completely discharge from clear and mud juices but a remaining amount of mud juice still inside clarifier which need a repeated water washing by pushing a water stream from the top of the pipe to extract the sediment inside it through the distribution branches connected to it in all its compartment.

In this case – Armant sugar factory (one of the ESIIC factories) at season 2012- no water stream was pushed inside the central tube and therefore the sediment remained inside the tube and was not disbursed ,and the problem became difficult due to the vertical position of the pipe in the middle of the clarifier and its narrow width 36.8 cm and long height 723 cm.

So we can say that the sediment under study was essentially contents of dry matters of mud juice , bagasse, sugars, waxes, nitrogen compounds, SiO, CaO, MgO, P_2O_5 and ash .The remaining matters in the presence of coagulant materials causes a strong accumulation of insoluble matters and over time, the temperature of the weather are rising which cause self-evaporation for water inside clarifier that leads to concentration of soluble solid materials, this kind of sedimentation is known as zone sedimentation(8) .

Taking into consideration the presence of fine bagasses particles and their role in binding the non-dissolved materials with the sediments formed by self-evaporation, this eventually results in the formation of solid deposits with a cohesive vacuum structure that fills the inner space of the central clarifier tube

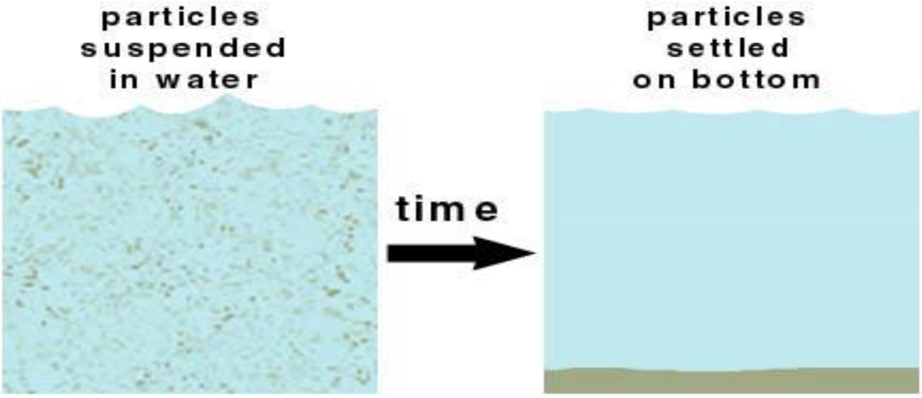


Fig 4 Sedimentation process[9] .

The nature and composition of sediments

By checking the input and output of the clarification process, we found that the sediment caused by the central tube blockage is only the remainder of the mud juice which with time converted to a dewatering pressmud which is evident from moisture analysis of the sample of 2.93% compared to 78.2% for wetted pressmud. So, we consider that the composition of the sediments under study is the same of pressmud as in Tables 1and 2

The approach of problem solving

At the ends we can say that these sediments are composed of of different chemical groups and the link between them is the result of sedimentation method, so any removal of any of these components will necessarily lead to the lack of geometric structure of the deposited sediments and this leads to the disintegration of link between them. The ease of disintegration and removal. Therefore, the emphasis was placed on the components with high ratios in the composition of sediments, which is fiber because of its important role in linking the components of the sediments together, as well as being the largest component of the amount of sediments. Achieving this goal was first treated with waxes and fats in the sediments through a solution of sodium hydroxide soaked for 24 hour and then add a solution of hydrogen peroxide on it, which worked to get rid of the lignin in the fiber, the lack of engineering structure of the deposits and the ease of penetration to repeat the experiment to the end

Roles of sodium hydroxide in this method

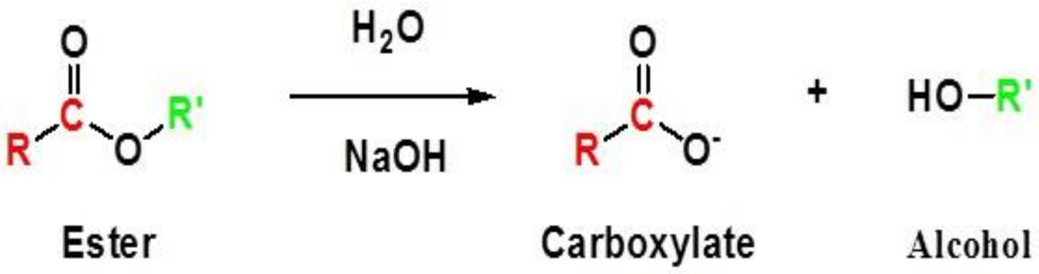
Caustic soda is the most famous cleaning agent beside hydrochloric, phosphoric, sulphamic, formic, citric and sulphuric acids also molasses ferment and alumina-ferric solution are used as a chemical cleaning agents. Also it plays an important role in this way by adding it separately at the beginning for 24 hours in so-called soaking process and is mainly aimed to:

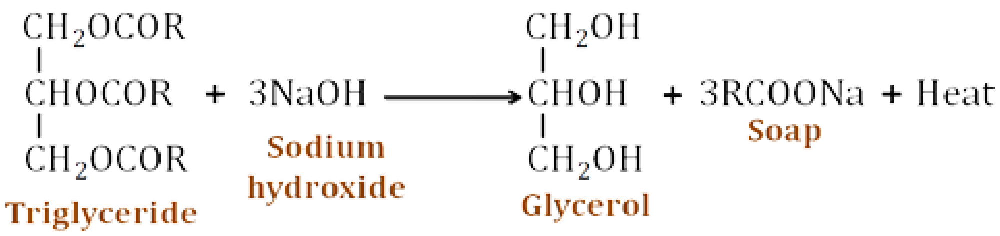
- Make an aqueous media to allow any precipitated soluble matter to be dissolved

- Get rid of waxes and fatty substances on the surface of the sediment through its interaction with waxes and fat as follows(10):

When triglycerides in fat/oil react with aqueous NaOH, they are converted into soap and glycerol. This is called alkaline hydrolysis of esters. Since this reaction leads to the formation of soap, it is called a saponification process.

General reaction





Both of waxes and fats are esters of fatty acids

1- **Causing alkaline hydrolyses for proteins to produce sodium salt of the carboxylic acid group and an amine.**

$$R\text{-}CO\text{-}NH\text{-}R + NaOH \dashrightarrow RCOO^{-}Na^{+} + RNH_2$$

Role of hydrogen peroxide in this method(11)

Hydrogen peroxide plays a bult up interesting in multifieldes because of its different chemical properties coming from its dissociation .

Hydrogen peroxide is a weak oxidant, however, it have both electrophilic and nucleophilic properties.

The electrophilic character arises from the -O-O- bond is easily polarized

$$\mathbf{H_2O_2 \Longleftrightarrow OH^{\delta-} + OH^{\delta+}}$$

Hence, **H_2O_2** will oxidise electron-rich nitrogen and sulpher centers such as aliphatic tertiary amines and sulphides.

Also, H_2O_2 can act as a nucleophile when readily adds to many carbonyl groups giving hydroxyl hydroperoxides. The behavior of H_2O_2 is detected through the type of active species produced from H_2O_2 dissociation Hydrogen peroxide

dissociation produces perhydroxyl anion HO_2 alkaline medium as follow:-

$$\mathbf{H_2O_2 \rightleftharpoons HO_2^- + H^+ \quad pka\ 11.6}$$

It acts a powerful nucleophile and attacks electron deficient olefins, ketones and aldehydes which plays the main role in bleaching and product purification particularly of natural materials

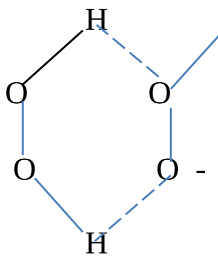
Mixing hydrogen peroxide with sodium hydroxide as a cleaning agent(12)(13)

Reaction of sodium hydroxide with hydrogen peroxide gave sodium hydroperoxide and water.

$NaOH + H_2O_2 = NaHO_2 + H_2O$

$$\mathbf{H_2O_2 + OH^- \longrightarrow HO_2^- + H_2O}$$

$$\mathbf{H_2O_2 + HO_2^- \longrightarrow}$$



$$\mathbf{\longrightarrow H_2O + O_2 + OH^-}$$

It is clear that the rate will go through a maximum when the peroxide is 50% ionized, that is $[H_2O_2]=[HO_2^-]$

So, OH- catalyzes decomposition of peroxide, but a maximum is reached when the amount of hydroxide added is half the amount of peroxide. If more hydroxide than peroxide is added, the catalytic effect is lost.

Also, reaction between hydrogen peroxide and sodium hydroxide is exothermic reaction and the reaction rate constant depended on decomposition temperature and solution pH.

Moreover many of the previous studies in the field of this paper, wood and biofuel industry have been done to treat fiber with a mixture of hydrogen peroxide and sodium hydroxide to remove lignin (14) (15) (16) (17)

It plays an important role as a pre-treatment of bio-mass (Karagöz et al., 2012)(18). This process is also known as alkaline peroxide oxidation (APO) and promotes the depolymerization of lignin via reacting lignin and related phenolics (Gould, 1984) (19). This pre-treatment has been successfully applied to corn stower (Selig et al., 2009) (20), cashew apple bagasse (Correia et al., 2013) (21),

In the last (APO) hydrogen peroxide concentration (0%-1.25% and 2.5%) combined with 1% NaOH and temperature (30°C, 45°C and 60°C)

Reaction between hydrogen peroxide and sodium hydroxide is considered a dangerous reaction at high concentrations, so when conducting such reactions it must be taken care the use of dilute solutions and also taking into account all precautions for safety

Conclusion

Using a mixture of dilute solution of hydrogen peroxide 50% and a dilute solution (of sodium hydroxide 48% with ratio 2:1 was succeeded in the removing of the bulk sediments inside the closed central clarifier tube, through determine the nature of sediment and the mechanism of sedimentation.

Acknowledgment

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الملخص العربي

إزالة الرواسب من الماسورة المركزية المسدودة بمروقات العصير

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يهدف البحث الي ازالة الرواسب الصلدة التي تترسب بمواسير التوزيع المركزية بأحواض الترويق بمصانع السكر والتي لا يمكن ازالتها بالطرق التقليدية مثل الكرش او التسخين وذلك نظرا للوضع الخاص للماسورة داخل الحوض وضيق قطرها وكذلك وضعها الراسي .

ولهذا تمت الاستعانة بالطرق الكيميائية لحل المشكلة وفيها تم استخدام تقنيه جديده في عملية الإزالة بمخلوط من محلولي هيدروكسيد الصوديوم وفوق اكسيد الهيدروجين ولقد اجريت العديد من التجارب والمحاولات للوقوف علي انسب طريقه للإضافة وكذلك التركيز المطلوب وكانت النتيجة هي استخدام تخفيف بنسبة1:1 لكلا المحلولين مع اضافة محلول هيدروكسيد الصوديوم المخفف (48%) اولا وبعد 24 ساعة كانت تتم اضافة محلول فوق اكسيد الهيدروجين مع مراعاة ان تكون كمية فوق اكسيد الهيدروجين المضافة ضعف كمية هيدروكسيد الصوديوم حيث ان فوق اكسيد الهيدروجين يتحلل في الوسط القلوي مصحوبا بإطلاق للأكسجين وحدوث فوران وتصاعد للشوائب لسطح المحلول وهو تفاعل طارد للحرارة.

هذا وقد نجحت هذه الطريقة في ازالة الرواسب من طول الماسورة الذي تجاوز 7 متر فيما يعد إضافة جديده في مجال ازالة الرواسب بالطرق الكيميائية.