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AN APPROACH TO REDUCE LIME MUD WASTE IN RECOVERY PROCESS THROUGH SPLIT ADDITION OF LIME DURING CAUSTICIZATION FOR DESILICATION: EFFECT OF LIME RATIO AND LIME PURITY

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ABSTRACT:
In two stages causticizing, effect of lime purity and lime dosage plays an important role. At higher purity levels of lime, we are getting better silica removal efficiency during two stage causticizing process at same temperature and retention time. At higher dosage of lime in first stage during two stage causticizing process, silica removal efficiency is improved, however, we need to balance the dosage of lime at first stage depending on the inlet silica level and mud silica to feed in to lime kiln.

Keywords: causticizing, silica removal efficiency and lime purity.

INTRODUCTION:

Limestone is the most widely used mineral in the chemical industry and generally one of the by-products/ wastes from these chemical industries is a lime bearing sludge. The main sources of the lime sludge are sugar, paper, acetylene, fertilizer, sodium chromate and soda ash industries. It is estimated that approximately 4.5 million tonnes of these sludges are generated in the organised sectors of these industries. The sludges are disposed off wet in the form of slurry/ filter cake into lagoons/ settling tanks and are considered potential health and environmental hazards (1).Increasing environmental awareness and other issues have forced the industry to look for alternatives for the lime mud reburning. Lime mud reburning allows the conversion of solid waste into useful product. Although higher silica content of the lime mud prevents the conversion of $CaCO_3$ to available CaO. This may be due the formation of tricalcium silicate. It also induces uneven burning of the lime and increases furnace oil consumption. During lime mud reburning process, silica reacts with calcium oxide and form calcium silicate. This leads to a glass type dense coating layer over lime lumps which create problem in slaking reaction. The lime lumps do not react with water during slaking in weak wash liquor or water. The over-burnt or under-burnt lime is produced in case of high silica content. Silica is binding calcium oxide which results in less burnt lime purity. Thus a practice is followed to dispose off or purge some part of lime to keep silica content in acceptable level i.e. 4-5%. (2). The amount of lime mud which is to be purgedoff depends on silica input into the system.

The fibrous raw materials are the main sources of silica in the recovery system. However other sources are quality of lime stone, water and make up salt cake in kraft pulping process. It has been found by the researchers that the nonwood material generally have higher ash content than wood material. According to Zhong 2002, the bamboo ash content is 1-3%, wheat straw contains 3-5% and straw contains up to 15% (3).Rice straw contains higher amount of silica content where as wood based material contains traces only.(4-7)

Panda also studied that 70-80% silica comes from bamboo, 20% from lime and rest 5% from makeup salt cake. The silicon is the most important non process elements in the form of silica and silicates which creates problem in recovery system. (8-9).

In paper industry, The objective of causticizing process is to convert inactive sodium carbonate into active cooking chemical i.e. sodium hydroxide. This entire process can be divided into four parts : green liquor clarification, slaking, causticizing and white liquor clarification. The clarified green liquor is reacted with reburned lime which results white liquor production.(10-11)

In causticizing process slaking reaction takes place in which sodium carbonate reacts with calcium oxide to form sodium hydroxide and calcium carbonate. The final solution is called white liquor.

The slaking and causticizing reaction are expressed as below

$$CaO + H_2O \longrightarrow Ca(OH)_2 + Heat$$

$$Na_2CO_3 + Ca(OH)_2 \longrightarrow 2\ NaOH + CaCO_3$$

The slaking and causticizing process conditions play a major role for the separation of lime mud. The critical factor which affects the causticizing system is the quality of lime, lime dosage, green liquor concentration, temperature and stirring conditions in the reactors. (12-13).The variations in lime quality can cause problems during green liquor slaking, causticizing, and lime mud settling processes. (14-15)

The presence of silica in causticizing process is the most undesirable non process element. Lengyel (16) and Kulkarni (17) investigated the influence of silica on causticizing. Silica content increases the causticity slightly as a huge part of sodium silicate converted to sodium hydroxide. Moreover causticizing efficiency as well as sludge dryness decreases with increasing silica content.(18)

Non process elements in lime mud are widely acknowledged by the researchers in lime reburning process. The main NPE in the lime are magnesium (Mg), aluminum (Al), silicon (Si), phosphorus (P), iron (Fe), manganese (Mn), sulphur (S), sodium (Na), potassium (K), and chlorine (Cl). Silica is found the most crucial impuritiy in the lime reburning process. It presents in the form of calcium silicate in lime mud during the causticizing reaction. Lime mud containing silica has high alkali content and low solids (19) .As per Keitaanniemi and Virkola (8) the maximum acceptable level of silica in the lime is 4 wt. %, although this suggested amount seems to be high.

Lime mud as a byproduct of the recovery section is generally used as a land filling applications. Silica is the main culprit which restricts its usage in lime klin for reburning. The silica present in the green liquor reacts with calcium oxide and form calcium silicate that creates several problems in lime cycle. It has been found that the calcium silicate makes the lime mud harder to dewater which results lower dry content of the feed lime in lime klin. (19).

It is well known that 1% of silicon reduces lime availability by 6%. This is because the formation of calcium silicates (20). Silica concentration in the system reduces the lime reactivity significantly. It was studied by the researchers that available calcium carbonate for decomposition was reduced from 98 to 69% on increasing silicon content from 0 to 5.5 % (21). Besides calcium silicate, silicon also reacts in the formation of various other impurities such sodium aluminosilicates.(22-26)

Mostly the lime mud is used as land filling application which is inappropriate disposal method and creates lots of problem. Before disposing the mud in land filling it should be fulfilled certain criteria like limits of metal ions which depend on the location and present regulations. The lime mud has the potential in several uses such as in soil conditioning, fertilizing or as a catalyst in hydrogen production. (27-28)

The present study was carried out by splitting the dosage of lime into two stages. The hypothesis behind this is the removal of bulk silica in first stage causticizing process. As following two reactions takes place during causticizing process and the 1st stage lime addition preferentially reacts with the silica in green liquor (reaction 2) and precipitated silica sludge is removed by settling and supernatant liquid is taken for further recausticizing (reaction 1). Lime mud generated in 2nd stage has less silica which may be recycled in the system after reburning in lime kiln.

$Na_2CO_3 + Ca(OH)_2 \longrightarrow 2\ NaOH + CaCO_3$........................ (1)

$Na_2SiO_3 + Ca(OH)_2 \longrightarrow 2\ NaOH + CaSiO_3$........................ (2)

The effect of lime ratio as well as lime purity was also studied.

Spider silk one of the Biomaterials is one of the outstanding fibrous biomaterial which consists almost entirely of large proteins. Silk fibers have tensile strengths comparable to steel and some silks are nearly as elastic as rubber. In combining these two properties, silks reveal a toughness that is two to three times that of synthetic fibers like Nylon or Kevlar. Spider silk is also antimicrobial, hypoallergenic and completely biodegradable. Apart from medical applications spider silk has many other non- medical applications. Thus from the above study it is concluded that spider silk cannot be produced on large scale like that of the silkworm but the spider silk has tremendous application in medical terms as the spider silk is much more tougher and elastic in nature.

We have taken greed liquor for the experimentation purpose from a reputed integrated pulp and paper industry with all details.

Pulping conditions:

The fibrous raw materials used for the pulping were mixed hard wood chips and bamboo. The hard wood and bamboo chips were mixed in the proportion of the white liquor was charged 17% on the od weight of fibrous raw material. The cooking was performed in batch digester maintaining 165 ^{0}C temperature and 6.5 kg/cm^2 pressure. After pulping the pulp was transferred to washing stage to remove black liquor and sent to Recovery process for further

Recovery operations

The black liquor received from washing plant was sent to recovery section to recover the cooking chemicals. The recovery of chemicals includes various unit operations like evaporation of black liquor, combustion of black liquor in recovery boiler, causticization of sodium carbonate to sodium hydroxide and the regeneration of active lime in a lime klin. Weak black liquor of 15-20% concentration from brown stock washing was concentrated in multi effect evaporator upto 65-70% solids level so that it could be burned effectively in recovery boiler. The strong black liquor then combusted in boiler and converted into smelt bed consisting mostly Na_2S and Na_2CO_3. The smelt is discharged into a dissolving tank to form green liquor.

Then the lab scale studies were performed with the green liquor collected from plants for causticizing reactions. Figure shows the major unit operations in the chemical recovery cycle of the Kraft process.

Causticizing :

Causticizing experiments were carried out laboratory in stainless steel container using a geared stirrer paddle at 150 rpm at 90°C in constant temperature water bath for 30 min. After the reaction, the mixture was settled for 30 min in an oven at 80°C. The supernatant liquid was thereafter decanted. The remaining mud slurry was then filtered through leaf filter and mud cake formed on the leaf filter was subsequently washed with hot water. Filtration and washing were carried out under vacuum of 360 mm of Hg. Leaf filter was used to simulate the plant condition with the drum filter at the rate of 2 rpm. (Leaf filter was immersed in the mud slurry for 10 sec, drained for 3 sec and after that, dipped in hot water for 7 sec and again drained for 3 sec.)

Hot water (80°C) was used for the washing of mud cake to get displacement ratio of 1.2 during washing through the leaf filter.

In laboratory desilication study, the first stage causticizing experiments were carried out with clarified green liquor. Experiments were carried out with lime at different purity levels.

First stage lime addition was carried out at two different levels i.e. 25 & 30 % of total lime required for the 80 % causticizing efficiency. In the laboratory, the experimental conditions were maintained as in Table-3a and b.

Lime Quality Used

Lime used for the desilication experiments was analyzed for the available CaO and silica. Detailed analysis is given in Table-2. All experiments were carried out using same quality of lime. The whole lime (composite) was crushed to coarse powder, -10 mesh, and added.Lime was at room temperature at the time of adding to hot green liquor.

The analysis of clarified green liquor and mud carried out and the details are given in the Tables.

RESULT AND DISCUSSION:

In two stage desilication, about 30 to 40% lime addition in first stage out of total lime required for total causticization, gives better desilication efficiency. The lime purity has important role as it improves desilication efficiency in first stage. To ge the better and efficient silica removal, higher purity of lime gives good silica remove efficiency which will help in reducing the overall solid waste to be purged from the system with higher silica levels. This is mostly used by cement industries wherein silica is helpful for cement manufacturing.

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Table: 1 Green liquor analysis

Description	**Unit**	**Values**
Green liquor volume	lt	6.00
Na_2S	gpl as Na_2O	25.60
NaOH	gpl as Na_2O	17.20
Na_2CO_3	gpl as Na_2O	68.40
TTA	gpl as Na_2O	111.20
Silica	gpl as SiO_2	3.28
CausticisingEffeciency	%	80.00

Table: 2 Analysis of lime

Description	**Unit**	**Values**
Available CaO	%	63.40
Silica	%	4.70
Burnt lime required	g	438.34

Table: 3 Total CaO requirement

Description	**Unit**	**Values**
Green liquor volume	lt	6.00
Silica in green liquor	g	19.68
Total CaO requirement	g	277.90

Table: 3A Requirement of lime dosage at first and second stage causticizing process

Time	min	10							
Temperature	°C	80							
Lime purity	%	63.4							
Causticising stage		I	II	I	II	I	II	I	II
Lime added	%	10	90	20	80	30	70	40	60
	g	43.83	394.5	87.67	350.66	131.50	306.83	175.33	262.1
Silica in lime	g	2.06	18.54	4.12	16.48	6.18	14.42	8.24	12.32

Total silica qty in Ist stage	g	21.74	38.22	23.8	36.16	25.86	34.1	27.92	32.0

Table: 4 Effect on white liquor properties with split addition of lime in the ratio of 10:90

Description	Unit	Single stage	First stage	Second stage
Lime addition	%	100	10	90
Silica in causticized liquor	gpl	0.5	2.2	0.45
Causticized liquor TTA	gpl as Na_2O	117.6	118.7	122.4
NaOH	gpl as Na_2O	82.2	33.2	83.5
Na_2S	gpl as Na_2O	18.5	25.3	19.5
Na_2CO_3	gpl as Na_2O	16.9	60.2	19.4
Causticizing efficiency	%	82.9	35.5	81.1
Desilication	%	84.6	32.9	86.3

Table: 5 Effect on weak white liquor properties with split addition of lime in the ratio of 10:90

Description	Unit	Single stage	First stage	Second stage
Lime addition	%	100	10	90
Weak green liquor volume	lt	6	2	6
Silica in weak liquor	gpl	0.17	0.5	0.11
	g	1.02	1	0.66
Weak green liquor TTA	gpl as Na_2O	25.2	21	30.2

Table: 6 Effect on lime mud properties with split addition of lime in the ratio of 10:90

Description	Unit	Single stage	First stage	Second stage
Lime addition	%	100	10	90
$CaCO_3$ formed	G	433.66	36.92	399.2
$CaSiO_3$ formed	G	72.61	10.1	61.5
Other inerts in lime	G	120.60	10.86	107.8
Total lime mud qty	G	729.63	67.9	664.2
Silica in lime mud	%	5.098	5.56	4.45
Cake consistency	%			

Table: 7 Effect on white liquor properties with split addition of lime in the ratio of 20:80

Description	Unit	Single stage	First stage	Second stage
Lime addition	%	100	20	80
Silica in desilicated green liquor	gpl	0.5	1.6	0.35
Disilicated green liquor TTA	gpl as Na_2O	117.6	116.1	124.1
NaOH	gpl as Na_2O	82.2	33.9	85.8
Na_2S	gpl as Na_2O	18.5	25	19.3
Na_2CO_3	gpl as Na_2O	16.9	57.2	19
Causticizing efficiency	%	82.9	37.2	81.9
Desilication	%	84.6	51.2	89.3

Table: 8 Effect on weak white liquor properties with split addition of lime in the ratio of 20:80

Description	Unit	Single stage	First stage	Second stage
Lime addition	%	100	20	80
Weak green liquor volume	lt	6	2.1	6
Silica in weak liquor	gpl	0.17	0.53	0.08
	g	1.02	1.12	0.48
Weak green liquor TTA	gpl as Na_2O	25.2	21.5	29.1

Table: 9 Effect on lime mud properties with split addition of lime in the ratio of 20:80

Description	Unit	Single stage	First stage	Second stage
Lime addition	%	100	20	80
$CaCO_3$ formed	G	433.66	74.1	358.2
$CaSiO_3$ formed	G	72.61	22.3	49.2
Other inerts in lime	G	120.60	21.8	97.1
Total lime mud qty	G	729.63	136.95	593.1
Silica in lime mud	%	5.098	7.3	3.91

Table: 10 Effect on white liquor properties with split addition of lime in the ratio of 30:70

Description	Unit	Single stage	First stage	Second stage
Lime addition	%	100	30	70
Desilicated green liquor volume	lt	4.11	5.21	3.58
Silica in desilicated green liquor	gpl	0.5	1.06	0.18
Disilicated green liquor TTA	gpl as Na_2O	117.6	116	124.8
NaOH	gpl as Na_2O	82.2	34.8	87
Na_2S	gpl as Na_2O	18.5	24.8	19
Na_2CO_3	gpl as Na_2O	16.9	56.4	18.8
Causticizing efficiency	%	82.9	38.2	82.2
Desilication	%	84.6	67.7	94.5

Table: 11 Effect on weak white liquor properties with split addition of lime in the ratio of 30:70

Description	Unit	Single stage	First stage	Second stage
Lime addition	%	100	30	70
Weak green liquor volume	lt	6	1.7	6
Silica in weak liquor	gpl	0.17	0.63	0.06
	g	1	1.07	0.36
Weak green liquor TTA	gpl as Na_2O	25.2	22.8	28.4

Table: 12 Effect on lime mud properties with split addition of lime in the ratio of 30:70

Description	Unit	Single stage	First stage	Second stage
Lime addition		100	30	70
$CaCO_3$ formed	G	433.66	117.3	314.5
$CaSiO_3$ formed	G	72.61	29.58	41.43
Other inerts in lime	G	120.60	33.96	85.43
Total lime mud qty	G	729.63	207.9	520.8
Silica in lime mud	%	5.098	9.4	3.64
Cake consistency	%	47	48.6	48.2

Table: 13 Effect on white liquor properties with split addition of lime in the ratio of 40:60

	Unit	**Single stage**	**First stage**	**Second stage**
Lime addition	%	100	40	60
Silica in desilicated green liquor	gpl	0.506	1.0	0.17
Disilicated green liquor TTA	gpl as Na_2O	117.6	114.8	125.2
NaOH	gpl as Na_2O	82.2	35	88.2
Na_2S	gpl as Na_2O	18.5	24.5	18.8
Na_2CO_3	gpl as Na_2O	16.9	55.3	18.2
Causticizing efficiency	%	82.9	38.8	82.9
Desilication	%	84.6	68.3	94.8

Table: 14 Effect on weak white liquor properties with split addition of lime in the ratio of 40:60

Description	**Unit**	**Single stage**	**First stage**	**Second stage**
Lime addition		100	40	60
Weak green liquor volume	Lt	6	2.5	6
Silica in weak liquor	gpl	0.17	0.5	0.055
	G	1	1.25	0.33
Weak green liquor TTA	gpl as Na_2O	25.2	22.9	28.1

Table: 15 Effect on lime mud properties with split addition of lime in the ratio of 40:60

Description	**Unit**	**Single stage**	**First stage**	**Second stage**
Lime addition		100	40	60
$CaCO_3$ formed	g	433.66	156.2	275.85
$CaSiO_3$ formed	g	72.61	37.05	35.62
Other inerts in lime	g	120.60	46.2	74.23
Total lime mud qty (measured)	g	729.63	279.5	449.3
Silica in lime mud (Measured)	%	5.098	9.5	3.65

Table: 16 A comparative study to see the effect of lime addition in different proportions on green liquor desilication and silica content in lime mud

Stages	Single	I	II	I	II	I	II	I	II
Lime addition	100	10	90	20	80	30	70	40	60
Desilication effic	84.6	32.9	86.3	51.2	89.3	67.7	94.5	68.3	94.8
Silica in lime mud	5.098	5.56	4.45	7.3	3.91	9.4	3.64	9.5	3.65

Table: 17 Details of experiment plan to see the effect of purity level on silica removal

Time		**10 min**																	
Temp	**°C**	**80**																	
Lime purity	**%**	**63.4**						**70**						**80**					
Stage Ca		I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II
Lime added	%	20	80	30	70	40	60	20	80	30	70	40	60	20	80	30	70	40	60

Table: 18 Green liquor analysis

Description	**Unit**	**Values**
Na2S	gpl as Na_2O	20.8
NaOH	gpl as Na_2O	21.2
Na2CO3	gpl as Na_2O	69.7
TTA	gpl as Na_2O	111.7
Silica	gpl as SiO_2	4.6
CausticizingEfficiency	%	

Table: 19 Effect of lime purity i.e. 63.4% on white liquor properties with split addition of lime in the ratio of 20:80

Description	**Unit**	**Single stage**	**First stage**	**Second stage**
Lime addition	%	100	20	80
Silica in desilicated green liquor	gpl	0.75	3.14	0.60
Disilicated green liquor TTA	gpl as Na_2O	110.8	111.9	111.4
NaOH	gpl as Na_2O	72.9	31.2	73.8
Na_2S	gpl as Na_2O	17.9	18.2	18.1
Na_2CO_3	gpl as Na_2O	18.5	62.5	19.5

Causticizing efficiency	%	79.8	33.3	79.1
Desilication	%	83.7	31.71	86.96

Table: 20 Effect of lime purity i.e. 63.4% on white liquor properties with split addition of lime in the ratio of 30:70

Description	**Unit**	**Single stage**	**First stage**	**Second stage**
Lime addition	%	100	30	70
Silica in desilicated green liquor	gpl	0.75	2.59	0.50
Disilicated green liquor TTA	gpl as Na_2O	110.8	111.6	110.9
NaOH	gpl as Na_2O	72.9	35.6	73.4
Na_2S	gpl as Na_2O	17.9	18.2	18.6
Na_2CO_3	gpl as Na_2O	18.5	57.8	18.9
Causticizing efficiency	%	79.8	38.1	79.5
Desilication	%	83.7	43.67	89.13

Table: 21 Effect of lime purity i.e. 63.4% on white liquor properties with split addition of lime in the ratio of 40:60

Description	**Unit**	**Single stage**	**First stage**	**Second stage**
Lime addition	%	100	40	60
Silica in desilicated green liquor	gpl	0.75	2.58	0.49
Disilicated green liquor TTA	gpl as Na_2O	110.8	112.4	111.3
NaOH	gpl as Na_2O	72.9	41.2	73.5
Na_2S	gpl as Na_2O	17.9	18.7	19.0
Na_2CO_3	gpl as Na_2O	18.5	52.5	18.8
Causticizing efficiency	%	79.8	44.0	79.6
Desilication	%	83.7	43.89	89.35

Table: 22 Effect of lime purity i.e. 70.0% on white liquor properties with split addition of lime in the ratio of 20:80

Description	**Unit**	**Single stage**	**First stage**	**Second stage**
Lime addition	%	100	20	80
Silica in desilicated green liquor	gpl	0.69	2.94	0.54
Disilicated green liquor TTA	gpl as Na_2O	109.0	111.5	111.1
NaOH	gpl as Na_2O	72.3	30.4	73.4
Na_2S	gpl as Na_2O	18.5	18.9	18.7
Na_2CO_3	gpl as Na_2O	18.2	62.1	19.1
Causticizing efficiency	%	79.9	32.9	79.4
Desilication	%	85.0	36.16	88.26

Table: 23 Effect of lime purity i.e. 70.0% on white liquor properties with split addition of lime in the ratio of 30:70

Description	**Unit**	**Single stage**	**First stage**	**Second stage**
Lime addition	%	100	30	70
Silica in desilicated green liquor	gpl	0.69	2.43	0.47
Disilicated green liquor TTA	gpl as Na_2O	109.0	111.1	110.9
NaOH	gpl as Na_2O	72.3	35.0	72.9
Na_2S	gpl as Na_2O	18.5	18.9	19.2
Na_2CO_3	gpl as Na_2O	18.2	57.2	18.7
Causticizing efficiency	%	79.9	37.9	79.6
Desilication	%	85.0	47.26	89.78

Table: 24 Effect of lime purity i.e. 70.0% on white liquor properties with split addition of lime in the ratio of 40:60

Description	**Unit**	**Single stage**	**First stage**	**Second stage**
Lime addition	%	100	40	60
Silica in desilicated green liquor	gpl	0.69	2.40	0.47
Disilicated green liquor TTA	gpl as Na_2O	109.0	111.5	110.5
NaOH	gpl as Na_2O	72.3	40.7	72.9

Na_2S	gpl as Na_2O	18.5	18.9	19.5
Na_2CO_3	gpl as Na_2O	18.2	51.8	18.0
Causticizing efficiency	%	79.9	44.0	80.2
Desilication	%	85.0	47.8	89.78

Table: 25 Effect of lime purity i.e. 80.0% on white liquor properties with split addition of lime in the ratio of 20:80

Description	**Unit**	**Single stage**	**First stage**	**Second stage**
Lime addition	%	100	20	80
Silica in desilicated green liquor	gpl	0.63	2.7	0.5
Disilicated green liquor TTA	gpl as Na_2O	108.1	109.2	110.2
NaOH	gpl as Na_2O	70.2	28.3	70.9
Na_2S	gpl as Na_2O	20.1	19.1	20.7
Na_2CO_3	gpl as Na_2O	17.8	61.8	18.5
Causticizing efficiency	%	79.8	31.4	79.3
Desilication	%	86.3	41.2	89.1

Table: 26 Effect of lime purity i.e. 80.0% on white liquor properties with split addition of lime in the ratio of 30:70

Description	Unit	Single stage	First stage	Second stage
Lime addition	%	100	30	70
Silica in desilicated green liquor	gpl	0.63	2.2	0.43
Disilicated green liquor TTA	gpl as Na_2O	108.1	110.0	111.2
NaOH	gpl as Na_2O	70.2	34.3	72.5
Na_2S	gpl as Na_2O	20.1	19.9	20.7
Na_2CO_3	gpl as Na_2O	17.8	55.8	17.9
Causticizing efficiency	%	79.8	38.1	80.2
Desilication	%	86.3	52.2	90.7

Table: 27 Effect of lime purity i.e. 80.0% on white liquor properties with split addition of lime in the ratio of 40:60

Description	**Unit**	**Single stage**	**First stage**	**Second s**
Lime addition	%	100	40	60
Silica in desilicated green liquor	gpl	0.63	2.17	0.44
Disilicated green liquor TTA	gpl as Na_2O	108.1	110.8	111.6
NaOH	gpl as Na_2O	70.2	39.5	73.3
Na_2S	gpl as Na_2O	20.1	19.1	20.7
Na_2CO_3	gpl as Na_2O	17.8	52.2	17.5
Causticizing efficiency	%	79.8	43.0	80.7
Desilication	%	86.3	52.8	90.4

Table: 28 comparative study to see the effect of lime purity at different split addition of lime on green liquor desilication and silica content in lime mud

Lime purity	**60**							**70**							**80**						
Stages	Single stage	I	II	I	II	I	II	Single stag	I	II	I	II	I	II	Single stag	I	II	I	II	I	II
Lime addition	100	20	80	30	70	40	60		20	80	30	70	40	60		20	80	30	70	40	60
Desilication eff. of caus. liquor	83.7	31.7	86.9	43.7	89.1	43.9	89.3	85.0	36.2	88.3	47.3	89.8	47.8	89.8	86.3	41.2	89.1	52.2	90.7	52.8	90.4
Silica in lime mud	5.1	8.5	4.1	10.0	3.7	10.2	3.67	4.9	8.1	3.9	9.4	3.5	9.5	3.5	4.6	7.9	3.7	9.1	3.2	9.0	3.0

Fig: 1Effect of lime addition on desilication efficiency of causticized liquor after first stage

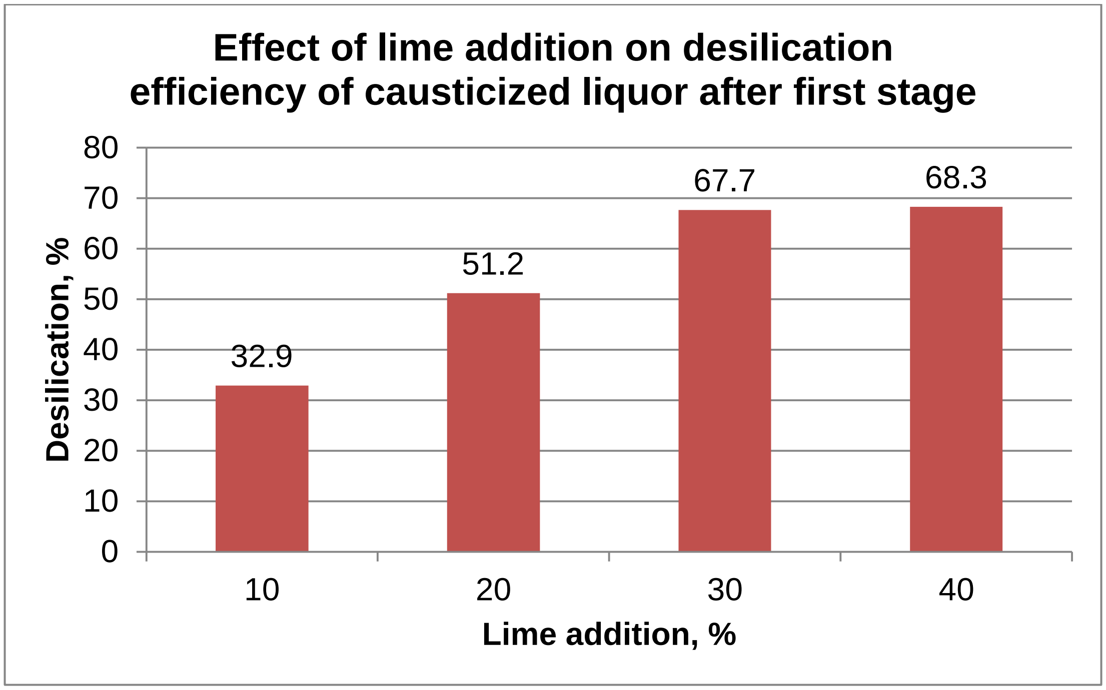

Fig: 2 Silica in lime mud after first stage (effect of lime addition)

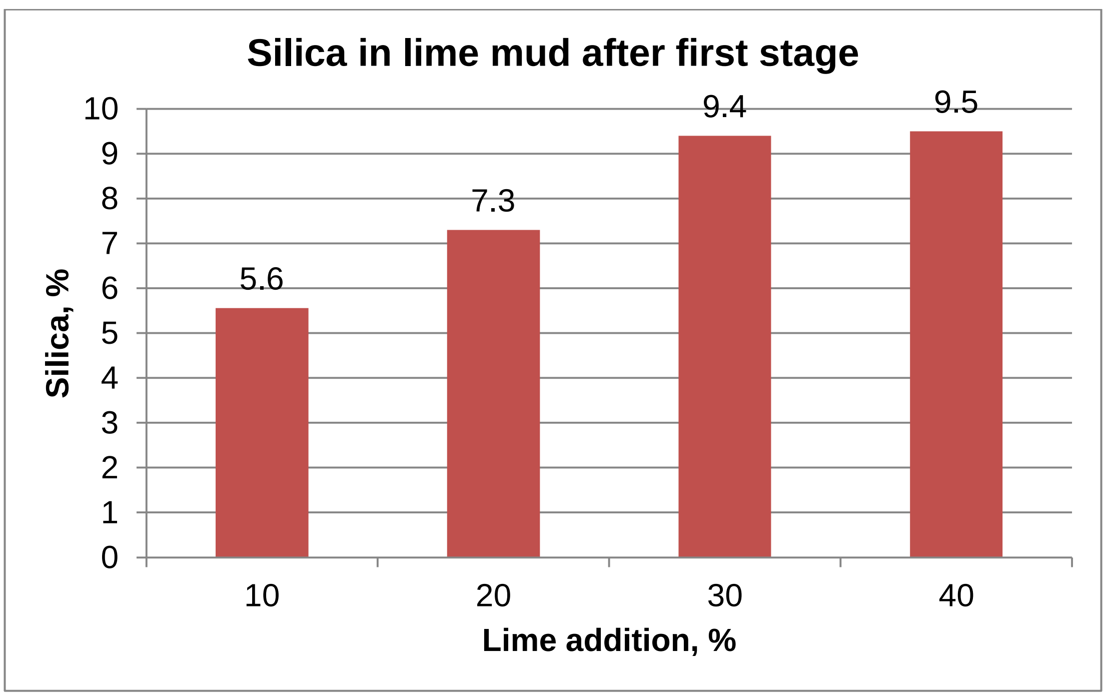

Fig: 3 Effect of lime addition on desilication efficiency of causticized liquor after second stage

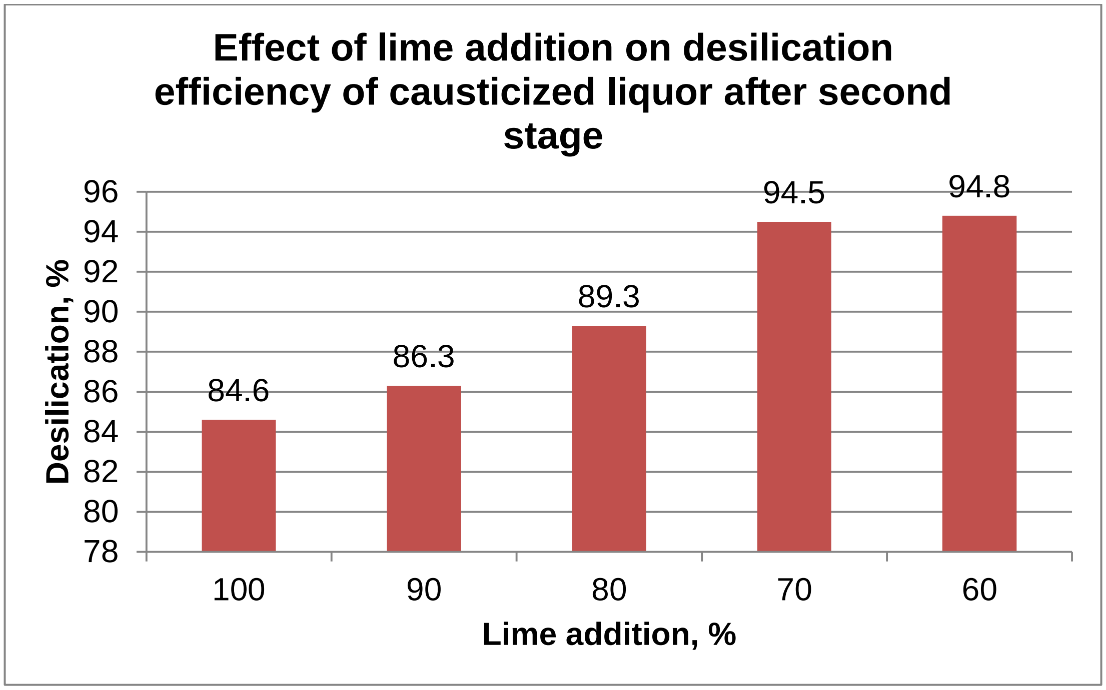

Fig: 4 Silica in lime mud after second stage (effect of lime addition)

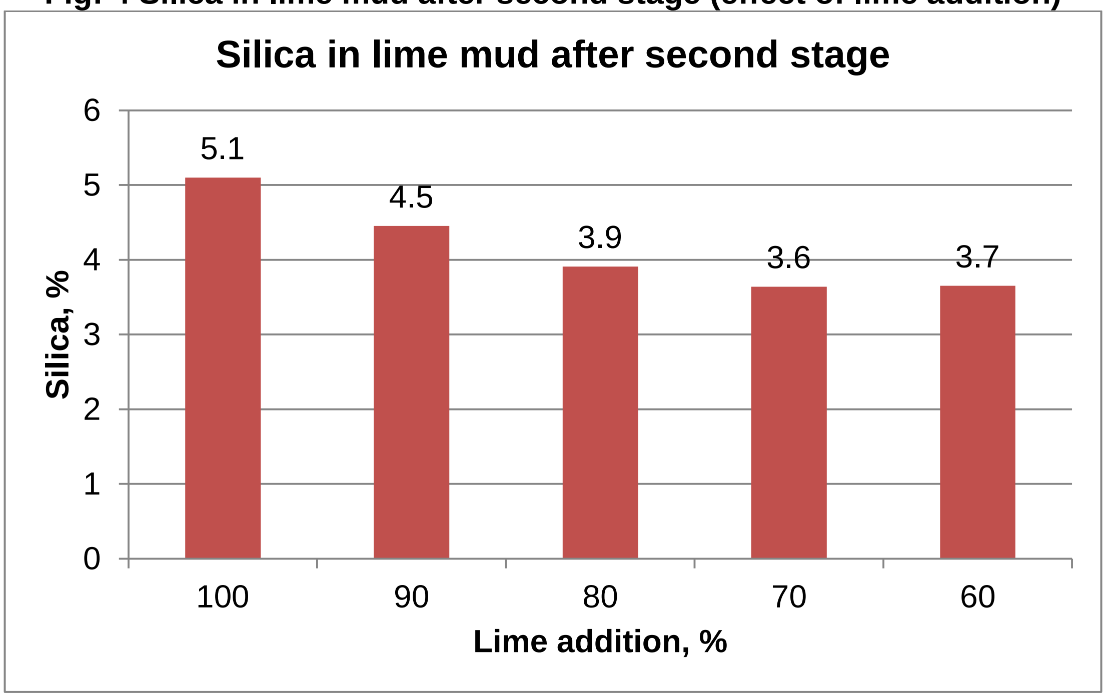

Fig: 5 Effect of lime purity on desilication efficiency of causticized liquor after first stage

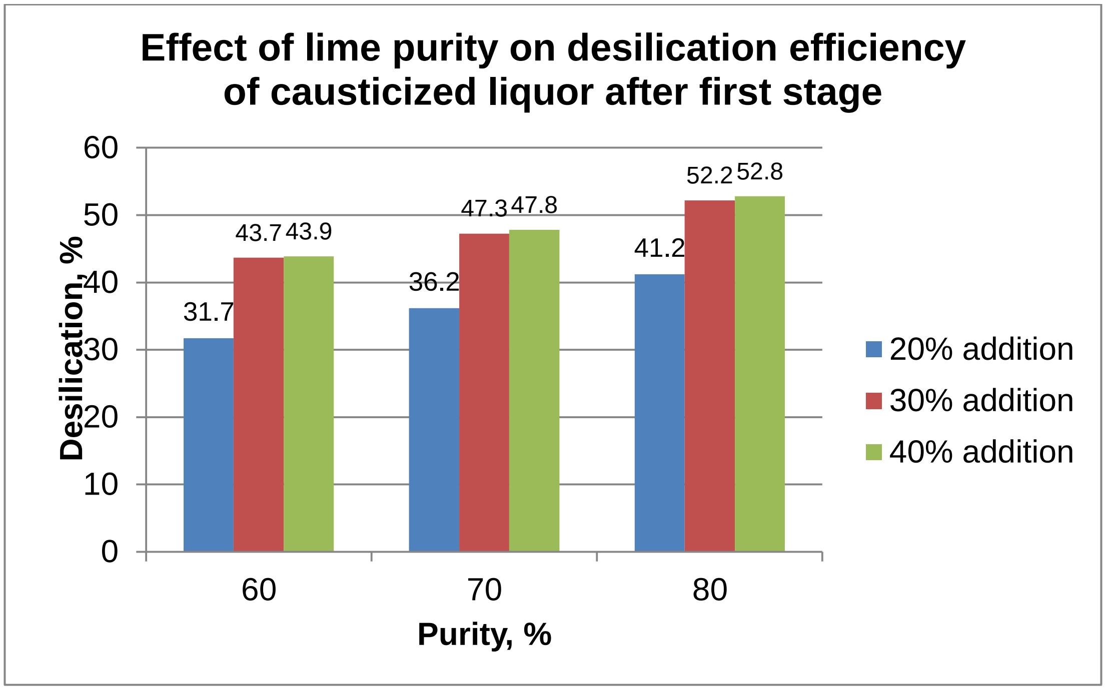

Fig: 6 Silica in lime mud after first stage (effect of lime purity)

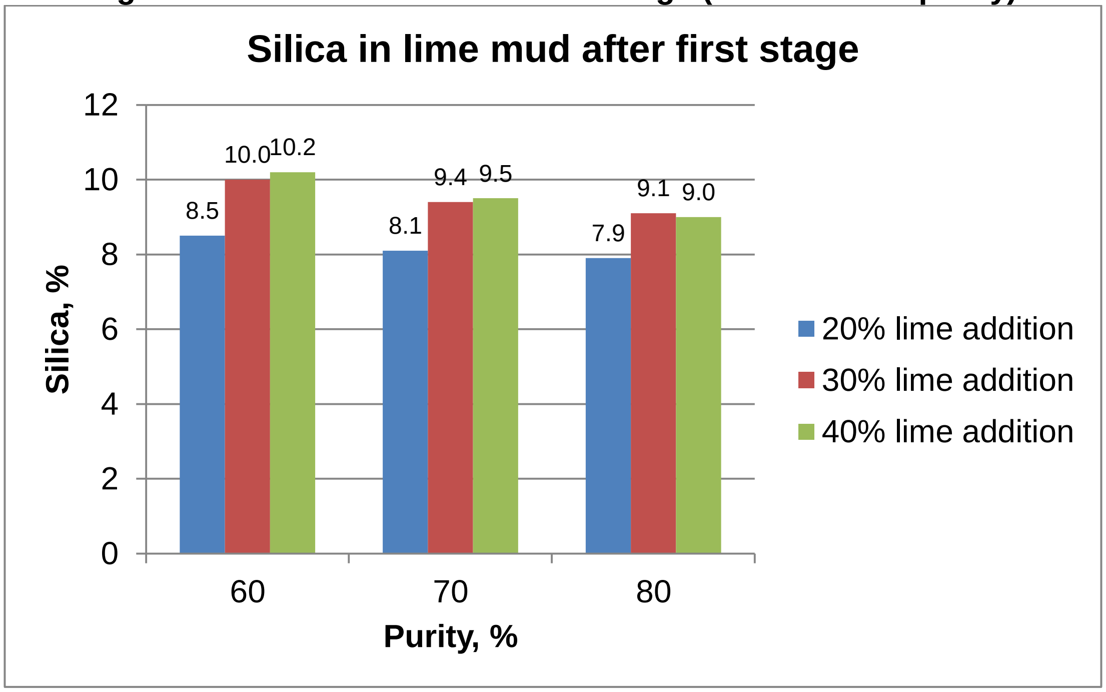

Fig: 8 Effect of lime purity on desilication efficiency of causticized liquor after second stage

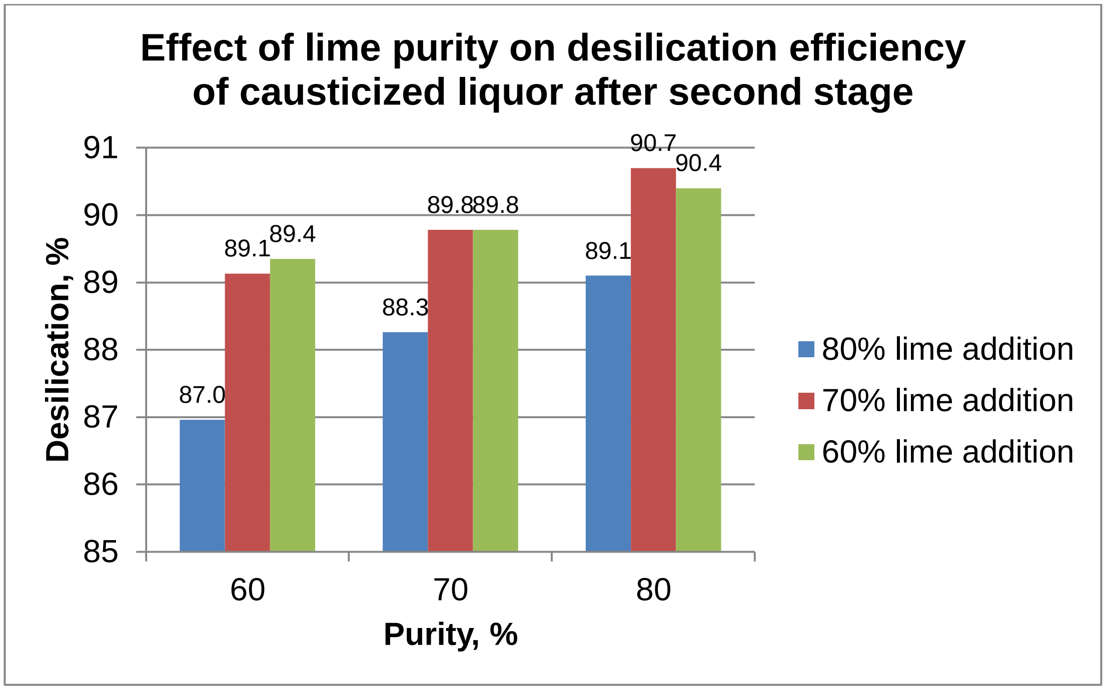

Fig: 9 Silica in lime mud after second stage (effect of lime purity)