

AN OVERVIEW OF PUMICE STONE AND ECO STONE IN DENIM WASHING INDUSTRY IN CASE OF SUSTAINABILITY

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Abstract: In denim washing industry pumice stone is a very popular material in enzyme or jumping process. Pumice stone is less costly and that's the only reason behind it's higher application. But pumice stone creates more sludge in ETP & requires more water in process which is not sustainable. Also for usage of pumice stone there is a higher possibility of damage issue in case of very light wash. In this study Eco Stone were used instead of Pumice stone to observe it's all kinds of outcome against Pumice stone with its sustainability. Because Eco stone require less water and create less sludge as its corrosion is lesser than Pumice stone. And for its smooth surface the possibility of physical damage of garments is lower.

Keywords: pumice stone, eco stone, enzyme wash, sustainable wash.

PREGLED UPOTREBE PLOVUĆCA I EKO KAMENA U INDUSTRIJI PRANJA DENIMA U SLUČAJU ODRŽIVOSTI

Apstrakt: U industriji pranja teksasa, plovućac je veoma popularan materijal u enzimskom procesu pranja zajedno ili samostalno. Plovućac je jeftiniji i to je jedini razlog njegove veće primene. Ali plovućac stvara više mulja u ETP-u i zahteva više vode u procesu koji nije održiv. Takođe kod upotrebe plovućca postoji veća mogućnost oštećenja u slučaju veoma laganog pranja. U ovoj studiji je korišćen eko kamen umesto kamena plovućca da bi se posmatrale sve vrste ishoda u odnosu na kamen plovućac sa aspekta njegove održivosti. Zato što eko kamen zahteva manje vode i stvara manje mulja jer je njegova korozija manja od plovućca. A zbog njegove glatke površine mogućnost fizičkog oštećenja odevnih predmeta je manja.

Ključne reči: plovućac, eko kamen, enzimsko pranje, održivo pranje.

1. INTRODUCTION

Denim garment is highly preferable by all kinds of fashion concern people all around the globe. Washing industries are playing a crucial role to meet with the higher demand in denim garment. Denim washing is a very popular finishing method which is widely used for creating fashionable & eye-catching products. Denim garment at its initial stage before washing is not wearable and comfortable as it has gone through process like weaving and dyeing. So it's consist of different kinds of sizing materials & impurities. In washing pro-

cess denim garment has to go through different process like enzyme wash, stone wash, bleach wash, acid wash, normal wash etc. After that a garment becomes more fashionable and comfortable for consumers [1–4].

Among all the washing techniques Enzyme process is well known in denim washing industry. Enzyme process is used to fade colour from all over the garments besides it polish the surface of garments. Which gives the garments distress and irregular look [5,6]. But enzymatic process sometimes fails to produce irregular effect where stone can produce easily and effectively. Pumice stone is used in stone washing method

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besides enzymes with garments, also sometimes without enzyme in case of jumping in industrial washing machine. Pumice stones are spun in washing machine with denim garments to create fashionable distress look on denim. But this process must be carried out carefully to avoid unwanted wear and tear issue [7-9].

Enzyme process with pumice stone exhibit a great difference in the physical and mechanical properties than the unwashed garments [10]. Also it is quite unsustainable and not environment and worker friendly. Pumice stone required more water in process and also required in mass amount as it's corrosive nature in process. Also after wash fabric damage issues are quite popular for light and long wash in case of pumice stone.

So instead of pumice stone alternative materials and methods had been introduced earlier for sustainability in process. Such as rubber sole had been used instead of pumice stone as an alternative material for enzyme, acid & Bleach wash [11]. Synthetic stones and peach kernels had shown better performance in low liquor ratio [12]. But water consumption analysis, effect on ETP, sludge % wasn't clear enough. Also as per buyer requirement same shade and outlook wasn't established by those alternatives before.

So this paper investigates the sustainability of Eco stone instead of Pumice stone with the same denim garment, enzyme and a standard recipe. Besides, the outlook of the garments should be as per the demand of consumer. Pumice stone was Just replaced with eco stone with less water, process timing and chemicals.

This study showed us these advantages of eco stone over pumice stone listed below:

- 1. Less water consumption
- 2. Less chemical consumption
- 3. Less sludge discharge
- 4. Cost effectiveness
- 5. Less time consumption
- 6. Quality improvement of Product [13].

2. MATERIALS AND METHODE

2.1. Materials

Five hundred pieces same shaded dark blue colour raw garments were collected from the inventory of a well known washing plant of Bangladesh. The raw garmets were kept there for washing purpose for an european buyer. The fabric of that garments were 100% pure cotton. GSM (Gram per Square Meter) of that fabric was 450, and the fabric was 3/1 warp faced Z- twill constructed. Modern machineries like Washing Machine Model- YILMAK RAINFOREST RF500, Hydro Machine Model - YILMAK-HG200, Dryer Machine Model - YILMAK HNS 6000 were used for the trial. Two batch of garments and each batch contained 250 pieces were trialled with a standard recipe but once with regular pumice stone of size 2cm-3cm (Origin-Turkey) & again with eco stone of size 2cm-3cm (Origin-Turkey) [14,15]. The technical specifications of used machineries with picture described below:

Table 1: Washing Machine Technical Specification

Parameters	Specifications
Country of Origin	Turkey
Company Name	Yilmak
Drum Volume	5020 liters
Drum Diameter	1820 mm
Drum Depth	1930 mm
Variable Speed	1-100 RPM
Installed Power	21 kW
Height	2900 mm
Width	2300 mm
Depth	3300 mm



Figure 1: Front Loading Washing Machine (a) Hydro Extracting Machine (b) Dryer (c)

Table 2: Hydro Extracting Machine Technical Specification

Parameters	Specifications
Country of Origin	Turkey
Company Name	Yilmak
Drum Volume	1057 litres
Drum Diameter	1502 mm
Drum Depth	598 mm
Variable Speed	1-700 RPM
Installed Power	30 kW
Height	1350 mm
Width	1800 mm
Depth	2150 mm

Table 3: Dryer Technical Specification

Parameters	Specifications
Country of Origin	Turkey
Company Name	Yilmak
Drum Volume	5950 litres
Drum Diameter	1750 mm
Drum Depth	2475 mm
Installed Power	23 kW
Steam Consumption	575 kg/h
Natural Gas Consumption	26-31 m3
Height	2900 mm
Width	3050 mm
Depth	3000 mm



a)



b)

Figure 2: Picture of Eco Stone(a) Picture of Pumice Stone (b)



Figure 3: Eco stone & Pumice Stone Before & after use

2.2. Method

The washing machine capacity was 140 kg. 250 pieces garments were taken for each trial batch which was weighted, the total weight of batch was 127.5 kg (garments average weight was 510 g) . That mean 91.1% of the machine capacity were used for each batch.

As per buyer required standard two standard recipe were set up for both eco and Pumice stone trial. For both trial ultimate goal was to gain the buyer's desired outlook.The followed recipe flow chart described below:

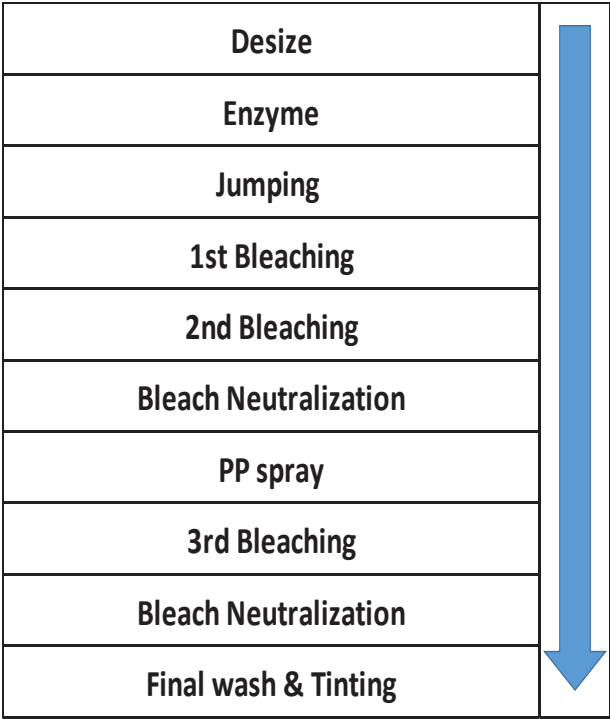


Figure 4: Required Process flow for Final Finished Denim Jacket

First of all desizing was done for 10 minutes for both trial with same liquor ratio 1:5 that mean 600 litres water was taken in machine, and temperature was 50°C. Desizing was done by taking 1000 g (Gram) Soda ash (Na_2CO_3) and 300 g antiback-staining Agent. So Dosing for Soda ash (Na_2CO_3) was 1.67 g/l(Gram per litre) and for antiback-staining agent was 0.50 g/l.

After that a 5 minutes rinse was given in room temperature with 1:6 liquor ratio That mean 800 litre water was taken in machine for rinse. For both trial same type of rinse was given after desizing.

Next the enzyme process was done for 40 minutes for both trial with same liquor ratio 1:3.That mean 400 litres of water were taken in machine and the temperature was 45°C. Enzyme was done by same amount of neutral powder enzyme (Lava Cell NHC

Cold) 700 g and antiback-staining agent 300 g. So dosing for enzyme was 1.75 g/l and antiback-staining agent was 0.75 g/l. But for eco stone trial 4 bag new eco stone were taken each bag contained 20kg of eco stone That mean 80,000 g eco stone was taken. On the other hand for pumice stone trial total 5 bags were taken. 3 of them were new bag and the other two were old used pumice stone. So 100000 g pumice stone were taken for pumice stone trial.

Then check time were allocated for 5 minutes for both trial recipe. After that a rinse was given for 5 minutes same as previous rinse in Room temperature.

Then without water garments were spun only with stone in washing machine for ten minutes for both trial. This process is called jumping in washing industry. In pumic stone trial extra 2 bags pumic stone were required for jumping but in eco stone trial no new stone required.

After jumping stone was removed then 5 minutes rinse was given.But in case of pumice stone extra one rinse in room temperature required for 5 minutes before jumping as there were a lots of stone broken pieces were in batch.

Then first and second bleaching was done for both trial with 35% calcium hypochlorite ($\text{Ca}(\text{OCl})\text{Cl}$) with same liquor ratio for both. The liquor ratio for first and second bleaching process was 1:5 that mean 600 litres water was taken in machine. And dosing was 16.67 g/l for first and 8.33 g/l for second bleaching process.That mean first time 10kg and second time 5 kg bleach were taken for both trial. First time bleaching was done for 15 minutes and second one was only for 10 minutes.

Then one hot rinse at 50 °c was given for 5 minutes and another 5 minutes rinse was given in room temperature for both trial.Then sequentially neutralization clean up and acid rinse process was done for both trial in same manner.

Neutralization was done for 10 minutes on 1:4 liquor ratio with 500 litres of water and by dosing 2.00 g/l sodium thiosulfite ($\text{Na}_2\text{S}_2\text{O}_3$) by taking 1000 g of it.Then clean up process was completed by dosing 2.00 g/l of hydrogen peroxide (H_2O_2) and 0.60 g/l of antiback-staining agent. The liquor ratio was 1:4 for this process. 500 litres of water 1000 g of hydrogen peroxide (H_2O_2) and 300 g antiback-staining agent were taken for this clean up process for both trial.And the clean up process was done for 10 minutes.

After that acid rinse was done for 3 minutes with 1:4 liquor ratio by taking 500 litres of water and by dosing 0.6 g/l citric acid by taking 300 g of it.Both neutralization and Clean up process were done at

50°C temperature but acid rinse was done at room temperature.

Then the garments shade was checked by quality controllers and send for hydro and dryer. After that Potassium permanganate (KMnO₄) spray was sprayed on some areas of garments as per buyer's requirement.

After PP spray for pumic stone trial another second enzyme process was required but not required for eco stone trial. Because for eco stone the buyer required outlook were gained on first enzyme process. This second enzyme process for pumice stone trial was same as before just dosing was slightly changed. Only 1.5 g/l neutral powder enzyme and only 0.5 g/l antiback-staining agent were dosed and took 15 minutes for completion. After that 5 minutes rinse in Room temperature was given.

Then Third time bleaching was done for both trial same as second bleaching process but dosing was 3.33g/l for eco stone process and 5.00 g/l for pumice stone process. Because in eco stone trial shade was little bit light so less amount of bleaching agent required. Then another 5 minutes check time were allocated for both trial recipe.

Then a normal room temperature rinse was given for 5 minutes for both trial. And another neutralization was required then after the third bleaching process. But this time for neutralizations 450 litres of water was taken and 2.22 g/l sodium metabisulfite (Na₂S₂O₅) were dosed for eco stone trial by taking 1000 g of it. On the other hand for pumice stone trial 3.33 g/l sodium metabisulfite(Na₂S₂O₅)were dosed by taking 1500 g of it. In case of pumic stone 0.67 g/l antiback-staining agent were dosed by taking 300 g of it. But for eco stone trial no antiback-staining agent required for neutralization process. After that another clean up process required at 45° c temperature but instead of hydrogen peroxide (H₂O₂) Soda ash (Na₂CO₃) was used and water was taken only 450 litres. That mean the dosing for Soda ash (Na₂CO₃) was 2.22 g/l and for antiback-staining agent was 0.67 g/l. Then a rinse for 5 minutes was given in room temperature.

Finally tinting process was done for both trial in same way. For tinting 400 litres water was taken with 1:3 liquor ratio and 7g of Direct dye brown colour,0.50 g of direct dye red colour,1000 g common salt, 200 g citric acid and 100 softner were taken.Dosing was respectively 0.018 g/l for brown Colour, 0.001 g/l for red colour, 2.5 g/l for common salt, 0.5 g/l for citric acid and 0.250 g/l for softner.

Trial with Pumice stone took total 228 minutes for completeing the wash. And the trial with eco stone took 25 minutes less That mean 203 minutes for com-

pleteing the wash. Time were counted without hydro extracting & drying time.

For both trial with eco & Pumice stone the process flow was almost same but in case of Pumice stone second enzyme process is required after PP (Potassium permanganate (KMnO₄)) spray in extra for achieving the buyer's desired outlook. But eco stone didn't require that process. And an extra rinse were required for pumic stone trial. Also after third bleaching for neutralization extra antiback-staining agent were not required for eco stone trial. Required shade & light colour were established for both trial. The final garments outlook were as per the buyer given standard. As this was light wash garmet 3 times bleach was applied for both trial.

3. RESULT AND DISCUSSION

3.1. Major difference

In jumping process by Pumice stone extra 2 bags (20kg Per bag) new stone were required as previously given Pumice stone were sized smaller for corrosion(in figure 2 it was clearly shown). But in case of eco stone no new stone was not required for jumping process. For Pumice stone trial extra 25 minutes more required which will affect the over head cost per minutes as the machine run for extra 25 minutes. Besides for pumice stone extra storage space required as pumic stone required more than eco stone. Also as the pumice stone create more sludge in ETP than eco stone as a result ETP maintenance and cleaning cost is much higher for pumice stone appication.

On the other hand water consumption is much higher in case of pumice stone. For only enzyme process with eco stone 2000 litres water was required for 250 pieces batch. But for pumic stone extra 800 litres more water required. Also for this garment an extra 2nd enzyme process required where extra 1200 litres of water required.

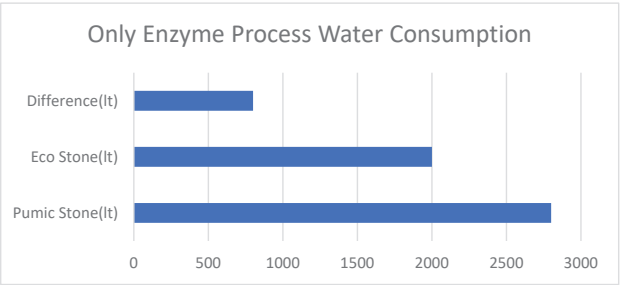


Figure 5: Water Consumption difference

The table given below shown us the overall performance of Eco Stone and Pumice stone.It's clearly seen that by performance and consumption eco

stone was very much sustainable and economical than pumice stone in each and every measures.

Table 4: Overall Performance

Heading	Eco Stone	Pumice Stone
Wastage Percentage	23%	60%
Desired Effect	Good	Good
Damage	Less possibility	High possibility
Water consumption	Less	High
EIM Score	Low	Medium
Sludge discharging time	Low	High
Sustainability status	Yes	No
Space allocation for storage	Less	High
Durability Minutes Maximum	4500	75
Stone size deviation	No	Yes
Co2 Emission	Low	High
Rinse required	Less	More
Cleaners Health	Will not effected	Will be effected
Required Time	Less	More

Cost & other benefits:

Durability of pumice stone was 75 minutes maximum and for eco stone it is 4500 minutes. Eco stone were 60 times more durable than pumic stone. For

less consumption per batch eco stone yearly consumption was only 28 ton where for pumice stone it was 1716 ton.

Local freight cost was 17365 dollars for pumice stone as It was required in huge amount but for eco stone it was only 289 dollars. Also for higher consumption of pumice stone unloading cost was aslo high.For pumice stone it was 2728 dollars but for eco stone it was 45 dollar.

As eco stone required in less amount that’s why store maintain cost was nill for eco stone but for pumic stone store to floor transaction cost was 3714 dollars per year.Also for house keeping extra 752 dollars was required per year for poly, shade and repair in case of pumice stone.

Extra space was required for eco stone and the cost for that was 21621 dollar per year where eco stone didn’t requires any.

Sludge cleaning cost and ckeaner salary cost also required higher in case of pumice stone usage.

Physical appearance and Quality test reports:

Quality Analysis:The figure No.7 It’s shown that the trial with eco stone and pumice stone both were as per by given approval.Besides the eco stone used shade was liked by the buyer.

The eco stone trialled final garments had less damage points than the pumice stone trial.For the irregularities of surface of pumice stone the damage

Cost & Others Benefit Comparison in between Pumic Stone & ECO Stone					
Stone Purchase Cost (Upto CTG Port)					
Particulars	Pumic Stone	Eco Denim Stone	Reduction Qty	Reduction %	Remarks
Durability Minute Max.	75	4500	4425		ECO Denim Stone Durability 60 times instead of Pumic Stone
Yearly Consumption (Ton)	1716.00	28.60	-1687	-98%	Average Consumption Per Month 6500 Bag
Yearly Stone Price	\$377,520.00	\$371,800.00	(\$5,720)	-2%	Pumic Stone 220.00 USD and ECO Stone Price - 13000.00 USD
Local Freight (Port to Factory)	\$17,365.92	\$289.43	(\$17,076)	-98%	Per Ton 850 TK
Yearly Unloading Cost (At Factory Point)	\$2,728.44	\$45.47	(\$2,683)	-98%	2.90 TK per Bag @ 25 KG
Subtotal	\$399,405.36	\$376,663.51	-\$22,741.85	-66%	
Stone In house Cost (Port to Factory)					
Particulars	Pumic Stone	Eco Denim Stone	Reduction Qty	Reduction %	Remarks
Stone to Floor Transaction Cost	\$3,714.29	\$0.00	(\$3,714.29)	-100%	Stone Transection Purpose Loaders are busy of their 50% Working Hour
Space Rent Cost	\$21,621.71	\$0.00	(\$21,621.71)	-100%	5766 SFT & 16000 SFT @ 6.00 TK
Cleners Salary Cost	\$7,428.57	\$1,428.57	(\$6,000.00)	-81%	Pumic Stone 4 Cleaner Required & ECO Stone Monthly 2 People 20000.00 TK
Others Cost (Poly, Shade & Repair)	\$752.38	\$0.00	(\$752.38)	-100%	Poly 5 Months & Shade Rectify Yearly
Sludge Discharged by ECC Certified Vendors	\$4,285.71	\$1,071.43	(\$3,214.29)	-75%	Pumic Stone Month 10-12 Times & Eco Stone Yearly 3 Times
Subtotal	\$37,802.67	\$2,500.00	(\$35,302.67)	-94%	
Overall Yearly Cost USD	\$437,208.03	\$379,163.51	(\$58,044.52)	-13%	

Figure 6: Cost & Others Benefit Comparison between Pumice Stone & ECO Stone



a)



b)

Figure 7: First Wash garments (a) Final Wash garments (b)

tendency was high in case pumice stone for long term wash. But for eco stone the result was quite good and acceptable.



Figure 8: First Wash garments damage issue in case of pumice stone trial

Tearing Strength: The eco stone trialled garments showed very good result in tear strength test for both warp and weft thread. Where in case of pumice stone the strength got a bit less than the eco stone.

Test method was EN ISO 13937-2:2000 standard. Firstly, denim fabric was taken. Warp and weft direction of the fabric in both directions having the dimension of 100 × 63 mm. The sample was fixed in the jaws of the tearing tester. A cut of 20 mm was made along the width of the fabric using the cutter in the tearing tester. By using the falling pendulum of the tearing tester, the fabric was a tear and the readings

were noted from Elmendorf's testers scale. The same procedure was done for the different samples and the result was taken [16,17].

4. DISCUSSION

This paper showed us there are many advantages of using eco stone instead of Pumice stone. Pumice stone required extra amount of chemical, water and also required extra process with time for same amount of production. Besides pumice stone produces extra amount of sludge for ETP as it's higher amount of usage for same production as it's higher corrosive in nature. So for extra requirement of water, chemical & time pumice stone is less sustainable than eco stone and creates a huge negative impact on environment. Because higher amount of water and chemical usage will affect the environment as the water body and soils contaminated by extra usage of chemicals [18-21].

On the other hand the eco stone trialled garments showed good physical and mechanical properties after wash. Eco stone trialled garments showed better result in tear strength test. Besides the buyer was satisfied as his required shade and quality was established. Also the garments physical damage points were also minimized by using eco stone. Because pumice stone had very rough and irregular surface where eco stone's surface is smooth as showed in Figure 2 and 3.

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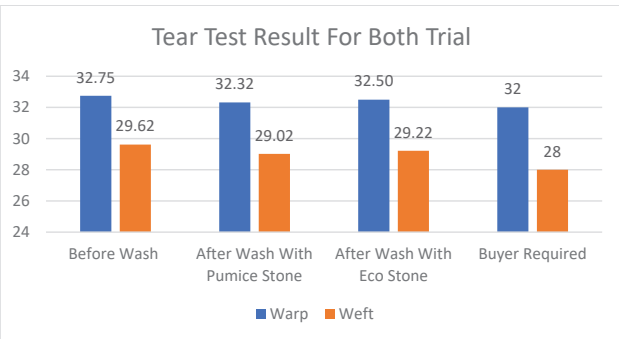


Figure 9: Tear strength test result for both trial.

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