TOWARDS ZERO HAZARDOUS: SUSTAINABLE APPROACH FOR ACID WASH ON KNIT GARMENTS

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Abstract: *The focus of this study is on the problem occurred during acid washing on knit garments. Hazardous chemicals like Potassium Permanganate and Sodium Metalbisulphite used in acid wash create health issues as well as harm the environment during wastewater discharge. The main aim of this study is to explore and evaluate the alternatives of Potassium Permanganate and Sodium Metalbisulphite during acid wash on knit garments. The method employed to evaluate the feasibility of acid wash with PP alternative was conducted by EIM (Environmental Impact Measurement) software. This software evaluates the environmental impact of garments in four key areas: water usage, chemical use, energy consumption during production, and labor implications. Acid wash with PP alternative demonstrated minimal energy, water, and chemical demands, resulting in less waste and pollution than conventional acid wash with Potassium Permanganate. This study suggested that acid washing with PP alternative is a beneficial strategy for reaching zero risks on knit garments.*

Keywords: Acid wash, Knit, Potassium Permanganate, Sodium Metalbisulphite, EIM.

KA NULTOJ OPASNOSTI: ODRŽIVI PRISTUP ZA PRANJE PLETENE ODEĆE KISELINOM

Apstrakt: *Fokus ove studije je na problemu koji se javlja tokom pranja pletene odeće kiselinom. Opasne hemikalije poput kalijum permanganata i natrijum metalbisulfita koje se koriste u pranju kiselinom stvaraju zdravstvene probleme, kao i štete životnoj sredini tokom ispuštanja otpadnih voda. Glavni cilj ove studije je istraživanje i procena alternativa kalijum permanganata i natrijum metalbisulfita tokom pranja pletene odeće kiselinom. Metoda koja je korišćena za procenu izvodljivosti pranja kiselinom sa PP alternativom sprovedena je pomoću EIM (Environmental Impact Measurement) softvera. Ovaj softver procenjuje uticaj odeće na životnu sredinu u četiri ključna područja: potrošnja vode, upotreba hemikalija, potrošnja energije tokom proizvodnje i implikacije na radnu snagu. Pranje kiselinom sa PP alternativom pokazalo je minimalne potrebe za energijom, vodom i hemikalijama, što rezultira manjim otpadom i zagađenjem nego konvencionalno pranje kiselinom sa kalijum permanganatom. Ova studija je sugerisala da je pranje kiselinom sa PP alternativom korisna strategija za postizanje nultog rizika na pletenoj odeći.*

Ključne reči: acid wash, pletivo, kalijum-permanganat, natrijum-metabisulfit, EIM.

1. INTRODUCTION

Garments serve both social and environmental purposes [1]. Garments that incorporate novel trends are increasingly popular among young people worldwide [2]. Garment washing involves applying chemicals or other auxiliaries to the dyed or printed surface of garments to change their shade, color, and appearance. These also provide comfort and design diversity. The effects varied depending on the materials and application procedures [3]. The demand for faster fashion trends and improved aesthetics has led to an increase in clothing washing. Faded textile products are increasingly popular among young clients globally [4,5]. Knit fabric has the potential to attract new clients due to its ease of manufacture and appeal. Knitwear is often subjected to wet wash [6,7]. Acid wash is one of the most common process of wet wash that is applied on knit garments [8,9]. Knitted clothes are typically acid washed using potassium permanganate, pumice stone, or other replacements [10]. Potassium permanganate is a strong oxidizing chemical used to create a color fading effect on knit garments. It may be utilized with or without a hand sanding area. Because it is a strong oxidizing agent, it is required to neutralize the clothing after application with any suitable neutralizing agent. After fading with potassium permanganate with the knit garments is neutralized with sodium metabisulphite [10,11].

Potassium Permanganate is a strong oxidizing agent that can color most organic things, including skin. Direct contact with Potassium Permanganate can cause skin irritation, burning, redness, discomfort, and itching. Eye injury can lead to permanent eyesight loss. Exposure to it might irritate the respiratory system and induce nausea, diarrhea, and gastrointestinal difficulties. Doses of 10 g can lead to serious health issues, including cardiovascular collapse, nose and lung irritation, kidney damage, and even death [12-15]. Being in proximity with it can cause irritating and intense smell. In addition, Potassium permanganate corrodes the washing machine's stainless steel drum. The discharge from acid wash contains pollutants of potassium permanganate that harm the environment and tend to occur at large concentration in wastewater discharge at elevated pH level [10,16].

Inhaling large amounts of sodium metabisulphite can trigger irritation of the respiratory system, causing coughing and shortness of breath. In some cases, it may result in an allergic reaction, asthma, or other disease. Consumption of sodium metabisulphite may result in vomiting, diarrhea, abdominal pain, nausea, circulatory disturbance, and central nervous system depression. Skin contact can cause irritation, itching, redness, and severe pain. Direct contact with the eyes can aggravate symptoms such as irritation, pain, stinging, tears, redness, swelling, corneal damage, and blindness. These impacts could potentially be severe. It turns out toxic when combined with potassium permanganate. Phosphoric acid is used as an acidic accelerator. It is an inorganic acid that produces a foul odor when combined with potassium permanganate. Workers who inhale these mixtures get a burning sensation in their respiratory system and begin coughing instantly. Higher concentrations may cause throat and lung cancer [14].

A thriving notion marketed as "sustainable apparel wash" seeks to reduce the impact of the garment wash procedure on workers' well-being and the surrounding environment through minimizing discharge contaminants, using environmentally friendly substances and auxiliaries, and utilizing fewer water and energy resources [17]. To address the negative effects of potassium permanganate and its neutralizer, chemical companies have been working to improve both the chemical and procedure to achieve the same function. Researchers are investigating alternatives to potassium permanganate for fading, with the goal of reducing the adverse impacts of chemicals. Numerous studies explored the possibilities of using alternatives for potassium permanganate such as Ceric sulphate, alternative potassium permanganate (Oximagic), and other chemicals to achieve fading in acid wash on knit garments [13,18,19].

The goal of this study is to investigate the feasibility of utilizing a novel substitute for potassium permanganate and sodium metabisulphite in acid wash on knit garments. This study explores the implementation of Environmental Impact Measurement (EIM) scores on acid washed knit garments. EIM (Environmental Impact Measurement) software is unique in its capacity to assess the environmental impact of garment finishing processes. It also serves as an effective self-validation tool, allowing manufacturers, brands, and retailers to monitor the amount of energy, water, and chemicals utilized in product creation, as well as any potential health concerns to personnel. A working group of multiple EIM users incorporates further industry efforts into tool management, allowing brands and garment finishers to customize EIM software to their requirements. EIM's environmentally friendly features address issues by utilizing less energy, water, and less polluting chemicals, allowing for better decision-making [19]. Resolving moral quandaries is also a signifcant factor. Employee health suffers as a result of eliminating potentially hazardous contami-

nants and performing physical chores. To encourage rapid adoption, it is ideal to provide new technology, methods, or services when they can be produced at a cost-neutral rate, rather than when production costs grow [20]. Furthermore, this study depicts the product qualities of the knit garment, as well as the after-care cycle assessment, by using a number of tests.

2. EXPERIMENTAL

2.1. Materials and Preparation

For this study knit sample was collected from a reputed knit manufacturing garment industry in Bangladesh. For the alternative of potassium permanganate Novo Denifade BE-700; an acid activated Natural Mineral Clay which contains no hazardous chemicals in its composition. It had ZDHC - Zero Discharge of Hazardous Chemical Gateway 03 certification. This product had no detrimental effects on human health or the environment. In the step of neutralization, OrganIQ neutral was applied as a replacement of sodium metabisulphite. This is an organic substance, and there will be no health risks if any of the chemicals enter the operator's mouth. It has no odor (Table 1).

Table 1: Materials and methods with specification

SL.	Materials and Methods	Specification
1	Fabric construction	Single Jersey
2	Fiber composition	100% Cotton
3	Primary chemical	Novo Denifade BE-700; OrganIQ neutral
4	Primary objective	Alternative of potassium permanganate and sodium metabisulphite

After selecting the necessary chemicals, the chemical liquor was prepared properly with 45-50'C temp hot water before spraying to Acid Wash Machine. For Light to medium color, the dosage amount 15-20 g/l 'Novo Denifade BE -700' was implemented and for the darker color 25-30 g/l dosage was implemented. After Acid Wash, to get the desired effect the neutralizer dosage amount 2-3 g/l was applied for all color ways. After neutralization of the garments bio-polish was done. Bio-polish removed the projecting/Floating fiber from the surface of the garments & it highlights the effect more (Table 2).

2.2. Environmental Impact Measurement (EIM) Software

Jeanologia's EIM program assesses the environmental consequences of textile treatment and production, integrating into consideration water, chemical, power, and worker factors. It is a straightforward and transparent technology that breaks down entire processes and provides reliable measures to assist in determining where the greatest impact is and developing efficient initiatives to improve overall textile processing and output. EIM analysis can help create an environmentally conscious, ethical, efficient, and revolutionary manufacturing system [21,22]. The EIM program specifies an environmentally friendly impact as a score of 0 to 33, a medium environmental impact as a score of 34 to 66, and an extreme environmental impact as a score greater than 66 [23].

2.3. Bursting Strength

For knitted fabrics, Bursting Strength is a key quality control and performance measure used to describe the mechanical properties. It is the force required to rupture a fabric by applying pressure over a defined area, simulating multi-directional stress conditions [24,25]. The Bursting Strength of five fabric sample were measured following ISO 13938-2:2019 (Pneumatic method). Tests were conducted at (20±2) °C temperature and (65±2) % R.H% (According to ISO 139) using a Pneumatic Bursting Strength Tester (model: M229P, 30.5 mm aperture) [26].

Table 2: Acid wash on Knit garment with alternatives of PP and Neutralizer

Process	Batch Weight in Kg	Garments loading in a batch in Pcs	Name of Dyes/ chemicals	Dosage Amount
Acid Wash	100 kg	300-350	Novo Denifade BE-700	25 g/l
Neutralizing	100 kg	300-350	OrganIQ Neutral	2.0 g/l
Bio-Polish			Prmagreen Power Finish	0.2 g/l
			Syrix NE	0.3g/l
Softener-Silicon			Wet Soft	2 g/l
			Ceproton UNP	0.5 g/l

3. RESULTS AND DISCUSSIONS

The knit samples acid washed with alternatives of Potassium Permanganate and Sodium metabisulphite show identical visual effects compared to that of conventional acid wash, which indicates the application of zero hazard chemicals in acid washing fulfils is able to satisfy the customers in terms visual effect while maintaining a positive footprint on the environment (Figure 1).

3.1. EIM Score

Based on the washing processes employed on the knit samples, the EIM software compared traditional acid wash with potassium permanganate to acid wash with PP substitution. Acid washing with PP substitution has been shown to be sustainable, with minimal environmental impact. It had a low environmental impact, as evidenced by numerical data. Traditional acid wash, on the other hand, has a concerning environmental impact, indicating higher EIM evaluations (Table 3).

Acid washing using PP substitutes uses less water than usual methods. To address consumer demand for fashionable designs and styles, acid washing procedures aim to produce vintage effects on the knit surface. The alternatives reduce the usage of toxic chemicals while increasing the looks of knit items. Acid washing with PP replacements has a lower water impact than traditional washing. The application of acid wash with PP replacements scored only 25 on EIM, indicating a low water impact, as opposed to conventional acid wash, which scored 40 on the water impact category.

The EIM software monitors greenhouse gas emissions from energy consumption and emphasizes the usage of energy-saving technology or practices. It also investigates the possibility of energy savings. Analyzing these variables can assist businesses in reducing their carbon footprint, operational costs, and increasing sustainability. This decreases their environmental impact and promotes larger environmental aims. The EIM software determines the energy impact of apparel in kWh/kg. The scores go from 0 to 2.5 for low

Figure 1: Knit garments after Conventional acid wash with Potassium Permanganate and Acid wash with PP alternative

Table 3: EIM Score for plasma faded denim

	Total EIM Score	Water	Energy	Chemical	Worker	Remarks
In-built EIM Benchmark	0-33	0-45	0-2.5	0-33	0-13	Low Impact
	33-66	45-90	2.5-3.6	33-66	13-29	Medium Impact
	+66	+90	+3.6	+66	+29	High Impact
Conventional acid wash with Potassium Permanganate	55	40	0.66	69	0	Medium Impact
Acid wash with PP replacement	32	25	0.48	47	0	Low impact

impact, 2.5-3.6 for medium impact, and >3.6 for great impact. When compared to traditional acid washes including potassium permanganate, acid wash with PP alternative has a low energy impact score of 0.48 kilowatt-hour per garment. It simply illustrates that acid washing with the PP substitute significantly meets the more general goal while saving 0.18 kilowatt-hours per garment treated with conventional acid wash with Potassium Permanganate.

A score of 0 to 33 indicates a low impact, 34 to 66 suggests a medium impact, and > 66 indicates an extreme effect, which corresponds to known chemical impact levels. The treated samples from the typical acid wash with potassium permanganate obtained chemical impact ratings of 69, in that order. On the other hand, acid wash with PP substitute received a score of only 47. Acid washing with PP decreases environmental effect by avoiding the use of hazardous chemicals such as potassium permanganate and sodium metabisulphite, lessening both the health and environmental impact of washing.

It is critical to assess the effects of traditional and sustainable denim washing procedures on workers, including the use of chemicals and hazardous effluents. Sustainable technologies have several benefits, such as improved health and safety, reduced pollution, and labor practices that comply with environmental rules. The EIM program divides data into three categories: high effect (> 29), medium impact (14–29), and low impact (0–13). Both traditional acid wash and acid wash with PP need less labor per garment, yielding an EIM worker impact score of zero. This strategy involves fewer dry procedures and has a low risk of occurring by minimizing operations involving repeated movement, force posture, and occupational hazards.

3.2. Bursting Strength

The bursting test result showed a mean bursting strength of 81.0 psi for Acid wash with PP and 85.0 psi for PP replacements, exceeding the required minimum of 60 psi, thereby receiving a „PASS" rating (Table 4). A total of five specimens were tested, confirming the material's adequate mechanical performance. E. Khalil et al. (2016) also found similar results, reporting a decrease in fabric bursting strength when using potassium permanganate (PP) in acid wash (Figure 2) [27].

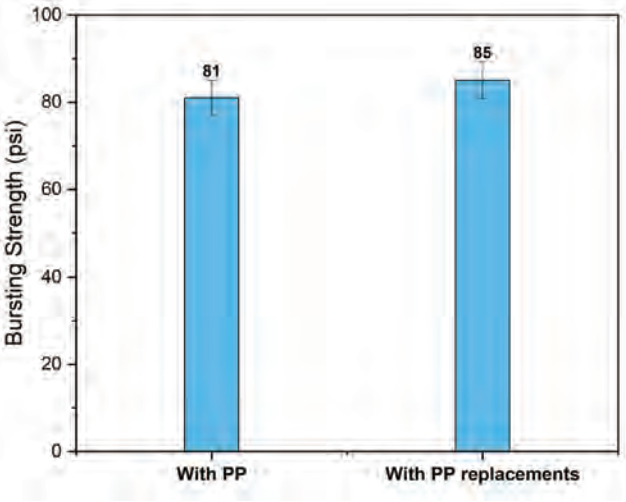

Figure 2: Bursting strength of single jersey fabric with pp and pp replacements Acid wash

4. CONCLUSION

This study confirms that substituting hazardous acid wash chemicals—Potassium Permanganate and Sodium Metabisulphite—with sustainable alternatives like Novo Denifade BE-700 and OrganIQ Neutral significantly reduces environmental and health impacts in knit garment processing. Using Jeanologia's EIM software, the alternative process achieved a Low Impact total score of 32, compared to 55 for conventional methods. Notable reductions were observed in water (40 to 25), energy (0.66 to 0.48 kWh/kg), and chemical impact (69 to 47), while worker safety remained uncompromised. The sustainable process preserved garment aesthetics and enhanced quality through bio-polishing. This approach is commercially viable and applicable for eco-conscious brands, ZDHC-compliant industries, and export-focused manufacturers seeking sustainable, regulatory-compliant solutions. Overall, the findings support the adoption of safer, environmentally friendly acid wash alternatives in the textile industry.

Table 4: Bursting test result summary table

Wash process	Test property	Requirement	Test result	Rating
With PP	Bursting Strength	>200 g/m^2: min 60 psi	81.0	Pass
With PP Replacements			85.0	Pass
Remarks	Number of tested specimen: 5			

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