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Correlation between Different Laundry Parameters and Distressed, Damaged and Fuzzy Clothing Inrelation to Microfibers Detachment

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ABSTRACT

The influence of the clothing type, and the laundry washing parameters have a huge impact on the number of microfibers/fibers being shed during the domestic laundry trials. Distressed and damaged clothing was identified as one of the important aspects of microfiber (MFs) pollution. Although some of the factors affecting the MFs shedding are still to be explored, thus there is a need for rigorous methods of identification and quantification to understand this shedding. A novel method was adopted using different combinations of wash loads and their corresponding temperature, and wash duration on the amount of MFs being shed. Results concluded that recycled polyester fleece and distressed jeans showed heightened shedding levels (approx. 49% of total emission). When real consumer laundry was compared to laboratory laundry, consumer domestic laundry is producing 110% more MFs than the laboratory-tested fabrics. High temperature and increased wash time have a positive correlation (p-value <0.05) to the number of MFs shed.

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KEYWORDS

Damaged clothing, Distressed clothing, Fringe jeans, Fuzzy woolens, Microfiber pollution, Trendy clothing.

1. INTRODUCTION

Microfibers and microplastic pollution is a widespread problem that is being faced by aquatic, marine, and terrestrial animals. Although researchers suggested that synthetic fibers are the main cause of this pollution, several reports back up the data stating that natural fibers also have an equal share in the spread of microfiber pollution [1]. Microfibers (≤5µm) are the fibers that are fibrillated/ detached from the larger piece of fibers. In the current study, only apparel items were considered during the study thus microfibers terms were used consistently rather than microplastics (derived from larger pieces of plastics) or filaments. Diving into the diverse consumer behavior which is changing rapidly related to the purchase and care of apparel and clothing items one can deduce that these behavioral changes have a major impact on the microfiber release from domestic laundry conditions. As the fashion cycle changes, new trends are brought into the consumer's daily life and one such change is the adoption of damaged and distressed clothing. Ripped/ distressed jeans feature frayed and a worn-out look with distinct ripped spaces usually at the knees where the skin peeps out. These rips can be caused due to over usage or can be caused by the manufacturers. The core idea is to loosen the tightly woven fabric and let the loosed fibers and frayed end protrude out. The global market for denim jeans is estimated at US$57.3 billion in the year 2020 and is projected to reach a revised size of US$76.1 billion by 2026, growing at a CAGR of 4.8% over the analysis period [1]

Although there are several previous researchers who are studying about the impact of different variables on the microfiber generation from the domestic laundry and stated that liquid detergent and powder detergent are causing more shedding than deionized water [2], increased shedding was

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observed while using bio-enzyme based detergents [3], lower temperature can be the cause of MFs shedding especially for polyester fibers [4], high water to fabric ratio can also be the major cause for the enhanced shedding [5], usage of fabric softener can reduce the shedding index [6], and several other studies said that new fabrics shed more MFs compared to the used once [7-9], whereas some researchers suggested that when garments were mechanically aged the aged garments were showing heightened shedding than the new apparels [10].

Apart from all these studies, the basic question remains the same, which is how consumer clothing practices are affecting domestic laundry conditions thus ultimately correlating with the increasing or decreasing number of MFs being shed. In the present study fashion trends were followed to assess the type and choice of apparel that are most favored by consumers on a large scale thus deducing the correlation between the garment type and the emission level. One of the main objectives of the study was to obtain the current apparel choice practices favored by the respondents thus estimating the cumulative amount of MFs released into the environment during washing trails from these sources. The preliminary survey on apparel choices stated that teenagers and college-going students were mostly drawn toward ripped, damaged, and distressed jeans. Thus to deduce the emission levels of these clothing items the current study was focused on the domestic laundry of the used consumer distressed clothing rather than the new apparel which were purchased from the clothing stores. The effect of wash duration, temperature, and wash loads on the amount of MFs shed was also studied to find out the inter-relating effect among the variables.

2. METHODOLOGY

2.1 Materials

Soiled clothing (which fulfills the requirements of damaged and distressed clothing, and woolens) from the consumers were procured from the households to conduct the experiments. Apart from those clothing different types of damaged, distressed, and stone-washed jeans and fringe jeans were obtained from the local markets of Rajasthan, India. Double puffer jackets, puffer jackets, fuzzy woolen t-shirts, and fuzzy acrylic shawls were obtained through online fashion websites in India, to study the release rate.

A front-load fully automated domestic washing machine was used (Samsung EcoBubble, Model number: WD70M4443JW/TL). Wool (Max. 2Kg) and Cotton (Max. 3Kg) programs were selected which were present in the washing machine were chosen. Normal tap water was used and no changes were made to the temperature settings. Surf excel liquid and powder detergent was used for the jeans, and ezee liquid detergent specially designed for woolen garments was used for woolen garments, along with surf excel powder detergent with added vinegar in the rinse cycle, for the chemical fabric softener comfort brand was used (Ditallowoylethyl Hydroxyethylmonium Methosulfate is the fabric conditioning compound present in the softener).

2.2 Washing Procedure

Ten consecutive wash cycles were run for each garment type. Due to the difference in the shedding index, some garments were washed more, thus increasing the total number of cycles to deduce the resulting anomalies. Laundry effluent was collected using large containers. 1-liter samples were collected after stirring with a wooden ladle, and 10ml aliquots were separated and were raised to 100ml each using distilled water to dilute the dust and laundry additives. The main aim of aliquots was to save time and be able to visually count the MFs.

Before the testing, two empty wash cycles were run to thoroughly uncontaminated the washing machine from the residual MFs from the previous washes. The effluent water was passed through a filtering sieve and then small representative samples were passed through glass microfiber filters. The second wash showed no residual fibers thus rendering the process successful. Apart from this, no washout cycles were run to estimate the accurate amount of shedding, and to replicate the real domestic laundry conditions, as a minute amount of fibers from the previous wash tend to release in the consecutive wash cycles.

Microfiber Analysis

The MFs were filtered using 2.7 µm mesh filters(Axiva Glass Microfiber filter, 47mm diameter circles, GF/4F) and 0.7 µm mesh filters(Axiva Glass Microfiber filter, 47mm diameter circles, GF/5F). Subsequently, the fiber dimensions were calculated through SEM analysis for which filter papers were cut randomly and were analyzed after gold coating to enhance the image quality. Fiber identification was done through FT-IR analysis. The peak values were matched with the spectral library to the accurate fiber type, some of the fibers identified were cotton, wool, acrylic, elastane, and polyester.

2.3 Statistics

A linear mixed mode was used to determine the effect of temperature, wash load, and washing duration during the laundry process on the microfiber generation was calculated. Several other appropriate tests were conducted accordingly and the significance level was kept at $\alpha=0.05$.

3. RESULTS AND DISCUSSIONS

3.1 Effect of fabric type

As all the fabrics have protruding fibers, a high amount of emission was found in all types of fabrics irrespective of the construction type and the fiber content (Figures 1 and 2). The overall emission rates of liquid detergent tend to be 45 percent to 46 percent in jeans and woolens respectively.

Whereas for powder detergent it was 53 percent to 54 percent. Recycled polyester, knit fabrics, and cotton/polyester blends have released a significantly high number of fibers which is consistent with a study conducted by Maggipinto et al. [11], who stated that after five consequent washes cotton and polyester fabrics released up to 1.0×10^6 and 5.0×10^5 fibers per kg of fabric washed.

A paired t-test was conducted to find out that there was a significant difference between the emission rates between the liquid and powder detergents while woolen laundry with a p-value of 0.012. Whereas when damaged and distressed jeans were compared during the wash trials no significant difference was found. One of the major sheddings was observed in the recycled polyester with 36.31 percent, followed by double-sided fleece with 22.25 percent of the overall emission rates. The recycled polyester used in the present study was made out of recycled plastic pellets and other plastic debris collected from marine waste. This results in the weakened fiber structure and easy abrasion and degradation thus resulting in the heightened shedding of approximately 1,00,000 MFs in each wash cycle. These findings suggest that yarn construction and proportions and their composition plays a major role in the MFs generation during the laundry process and cannot be generalized [12].

Table 1 provides a detailed view regarding the wash cycle parameters which were used during the course of study, along with the type of garments and their corresponding sheddability rates. In a study conducted on the denim fabrics domestic laundry and their respective microfiber waste load results showed that 100 percent cotton has the maximum loss [15].

Comparing different types of denim jeans on the sheddability index, it was evident from Figure 2 that the statistical box plot showing that ripped all-over jeans have shown the maximum emission rates contributing to 49.22 percent of the total emission, whereas the least emission (1.33%) was found in stone-washed jeans as no protruding and loose ends were observed on the surface of the jeans. It can be concluded from the results that ripped overall jeans shed more MFs due to the fact that more the number of rips and tears and more protruding/ raw ends thus resulting in more MFs released when abraded against the nearby surfaces during the laundry process.

SEM analysis was carried out to find out whether there was any difference in the fiber dimensions which were released under different laundry conditions. But the obtained images showed that irrespective of the wash cycle and the type of fiber content, similar categories of fibers were seen such as fiber which are ≤5µm namely microfibers (49.16%), 50-100 µm (26.95%), 100-500 µm (15.11%) and >500µm (8.76%). It was also observed that apart from the microfibers nanofibers were also found on the samples suggesting the increasing level of fiber fibrillation. The only difference found was in the amount or number of the fibers being shed.

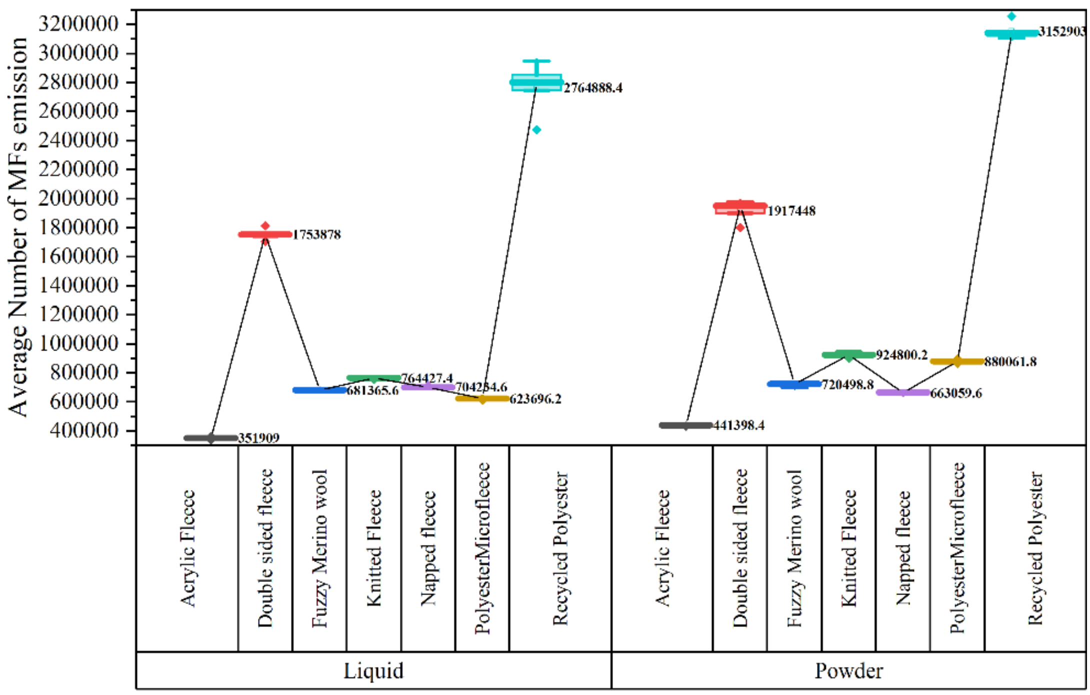

Figure 1. Distribution of the average number of MFs released during the ten wash trails of fuzzy wollen/ synthetic clothing

Table 1. Depicts the detailed view of the washing parameters along with the type of garment and the MFs detached in each wash cycle

Clothing Type	Detergent Type	Wash cycle	Temperature	Wash Time	RPM	Replicates										Mean	SD
						1	2	3	4	5	6	7	8	9	10		
Knitted Fleece	Liquid	Wool	40°C	53 min	800	754416	770406	736680	795506	764406	785601	754213	741264	763878	765214	763158.4	18091.70
	Powder					923776	912357	985214	965742	958724	912345	912365	923657	954782	902345	935130.7	28440.56
Acrylic Fleece	Liquid	Synthetic	60°C	78 min	1000	351953	324570	326580	345216	368745	325412	312085	325671	326598	302145	330897.5	19425.00
	Powder					447763	452368	452136	485213	401236	425136	412378	468521	487521	485236	451750.8	30963.18
Napped Fleece	Liquid	Wool	40°C	53 min	800	703023	765231	741258	701236	742103	702154	700102	702145	702314	702454	716202	23889.13
	Powder					667981	652142	645712	678546	658974	632105	671203	671230	621031	674123	657304.7	19292.33
Polyester Microfleece	Liquid	Synthetic	60°C	78 min	1000	626894	601235	610234	621430	678451	651201	645210	602341	612354	617851	626720.1	24598.92
	Powder					880142	895412	874523	801235	897410	896320	874236	851479	896214	874569	874154	29511.25
Fuzzy Merino Wool	Liquid	Wool	40°C	53 min	800	689968	685123	654785	698745	625898	689475	680123	645896	675230	680021	672526.4	22990.06
	Powder					725031	721202	710236	732548	742103	720145	701245	701259	741023	721036	721582.8	14487.81
Recycled Polyester	Liquid	Synthetic	60°C	78 min	1000	2800356	2845612	2845120	2745612	2657848	2845610	2974125	2901234	2874106	2610476	2810009.9	110724.29
	Powder					3142584	3316397	3289755	3183462	3283157	3233971	3311799	3281809	3282092	3146151	3247117.7	66560.92
Double-sided fleece	Liquid	Wool	40°C	53 min	800	1741706	1744118	1747408	1746915	1746232	1748134	1749632	1743255	1748025	1747527	1746295.2	2487.64
	Powder					1900166	1902699	1906336	1904279	1917011	1909605	1905635	1901570	1909238	1908526	1906506.5	4902.42
Stone Washed	Liquid	Denim	60°C	73 min	800	120261	120311	120347	120310	120296	120350	120283	120345	120348	120322	120317.3	30.87
	Powder					109814	109924	109589	109239	109183	109366	109601	109485	109353	109581	109513.5	237.96
Ripped All over	Liquid	Denim	60°C	73 min	800	4315371	4301255	4329453	4286513	4363552	4243105	4398800	4285090	4248018	4226291	4299744.8	54448.10
	Powder					4194486	4119562	4113146	4115286	4099218	4190423	4126988	4098771	4199521	4127544	4138494.5	40094.87
Acid Wash	Liquid	Denim	60°C	73 min	800	530691	529605	527777	533875	530190	533364	526710	531537	533723	529002	530647.4	2489.88
	Powder					762593	763190	755052	758005	766022	772041	767764	778400	763614	752545	763922.6	7747.56
Distressed	Liquid	Denim	60°C	73 min	800	1055497	1135246	1136038	1087581	1125426	1073858	1051568	1013367	1011626	1101892	1079209.9	46365.51
	Powder					2168747	2243057	2171994	2338339	2224539	2240345	2329773	2287051	2279251	2212970	2249606.6	58918.26
Ripped Knee	Liquid	Denim	60°C	73 min	800	592571	592624	593289	592686	593500	593307	593124	593028	592965	592632	592972.6	332.85
	Powder					725351	733430	726253	728730	734824	733335	722570	722897	732579	729368	728933.7	4530.91
Fringed	Liquid	Denim	60°C	73 min	800	648122	651076	644541	641705	634640	646423	644935	638616	650463	643434	644395.5	5126.07
	Powder					711208	712706	710354	714968	722570	712551	721620	713243	711438	715516	714617.4	4254.83
Damaged	Liquid	Denim	60°C	73 min	800	652195	655195	644745	648570	648551	650558	643054	654593	642248	652431	649214	4631.35
	Powder					699485	695145	699608	692555	694741	692422	690952	694692	690671	690969	694124	3297.44

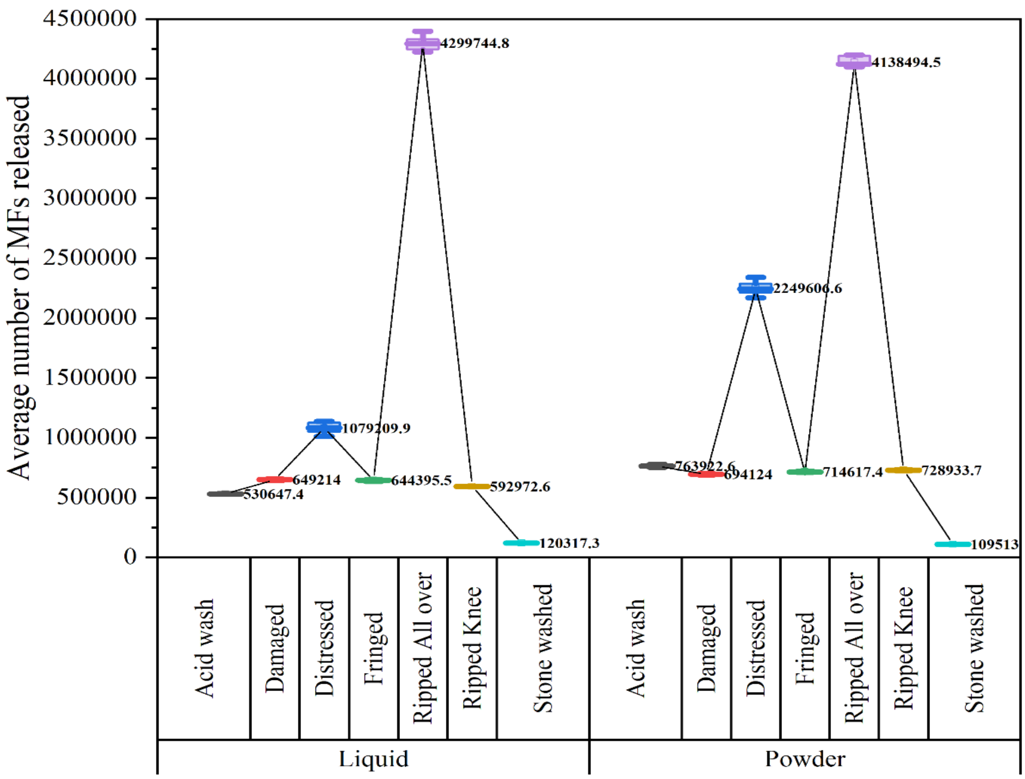

Figure 2. Distribution of the average number of MFs released during the ten wash trails of the damaged/ distressed and other types of denim jeans

3.2 Effect of detergent

Denim garments were washed using a surf excel liquid detergent (40ml) and powder detergent (40gms) with and without fabric softener (45ml) in the rinse cycle. Whereas the woolen garments were washed using eeze liquid specialty detergent (40ml) and two tablespoons (30ml) of vinegar were added as a fabric softener substitute in the rinse cycle. The effect of the detergent on the microfibers shed can be seen in Figures 1 and 2. All the fabrics were washed using the standard program suggested by the washing machine manual is used but the amount of laundry detergent is kept constant to note whether each type of cycle have a difference in the shedding and a statistically significant difference was only found in the (p-value <0.05) fuzzy woolen clothing.

About a 5 percent to 10 percent difference was observed between the liquid and powder detergent during the correlative analysis, which cannot signify that one can be prioritized over the other. A two-sample t-test was performed to find out the difference between the liquid and powder detergent and the p-value obtained was 0.068, which states that there was no significant difference. Fabric softener was also adopted to find out any variance, but the results obtained stated that no particular difference was observed in the case of these types of garments which have protruding and raw edges. Whereas, some of the previous studies [13-14] stated that the usage of fabric softeners has reduced the shedding by causing a sliding effect on the garments being laundered.

3.3 Effect of temperature

Cold water and 60°C (the most favored temperature by consumers) were used. Results obtained enumerated that an average of 5835.25 fibers were being released per filter during the 60°C temperature setting, whereas 4420.75 fibers were released when washed in cold water. These can be interpreted in such a way that cotton fibers are hydrophilic and during the laundry process the cotton fibers absorb the water and swell according to their inbuilt nature and when these fibers are prone to heightened temperature and agitation there is a highly likely chance that these fibers burst and split into to smaller fibers thus releasing more MFs.

Woolen fibers can be considered the natural hair of animals when these fibers are laundered at the highest temperatures causing damage. It is always advised that cold water should be used for laundering woolen garments. Woolen substitutes such as acrylic and polyester fills do not have any significant impact when washed in both cold and hot water as they are resistant to high temperatures. One of the major drawbacks of the temperature setting is that to obtain such high temperatures wash time is increased simultaneously, thus increasing the overall wash time which results in heightened agitation and increased MFs shedding. Yang et al. [5]conducted a study correlating the effect of washing temperature on the microfibers shedding in synthetic fibers and found that with the increase in the temperature (≥60°C), there was a greater increase in the microfibers.

3.4 MFs generated from soiled consumer apparel

Real consumer laundry conditions were also studied to find out any persistent differences between the laboratory and consumer laundry trials. It was also observed that during real-life domestic laundry conditions metal buttons and zippers from one garment were entangling with the other garments making the raw edges of the jeans more prone to abrade thus resulting in the enhanced MFs release. From Figure 3 we can see that there was a difference in the mean values between the household laundry (more shedding) when compared to the laboratory laundry.

Further a statistical analysis was carried out to find out a p-value of 0.035, which states that there is a significant difference between the laundry types at a 5% level of significance. From Figure 3, interpretations can also be drawn out that wearing and abrasion caused during bodily movements also have an impact on the raw edges/ protruding fibers. When these abraded garments are washed the laundry process also causes an enhanced level of agitation depending on the temperature and wash cycle time chosen thus resulting in a greater sheddability index than the laboratory experiments.

4. CONCLUSION

Real domestic laundry conditions were shedding significantly more number of microfibers in the laundry effluents. Although both natural and synthetic fibers are being shed in almost equal amounts natural fibers due to the fuzzy weave structures and conscious distressing of jeans are resulting in the addition to the already existing problem. While washing these types of garments it is suggested to wash them in quick wash cycles and preferably in cold wash cycles. Some of the suggestions which can be made from the current study were that it is advisable to always modify the wash cycle according to the clothing needs which in turn reduces the agitation levels thus reducing the MFs shedding. The main barrier to consumer adoption is knowledge and awareness. Results also found that fabric softener does not play a huge role in heightening or lowering the emission, but further study is needed to fully justify and understand these types of fabrics.

Results inherently state that both consumers and manufacturers are equally responsible for microfiber pollution. Significant intervention is much needed such as encouraging consumers to use lint filters, reducing the usage of damaged or distressed clothing, usage of mesh/ laundry bags while washing fuzzy garments which helps to reduce agitation levels. Further investigations can be done in the direction of home textile (mink/woolen blankets, and other furry/fluffy textile materials) items as well, which represents the sheddability index of a significant shareholder in the households. One of the important factors is that any new studies being conducted in these areas require an appropriate scope of application thus finding the ultimate solution.

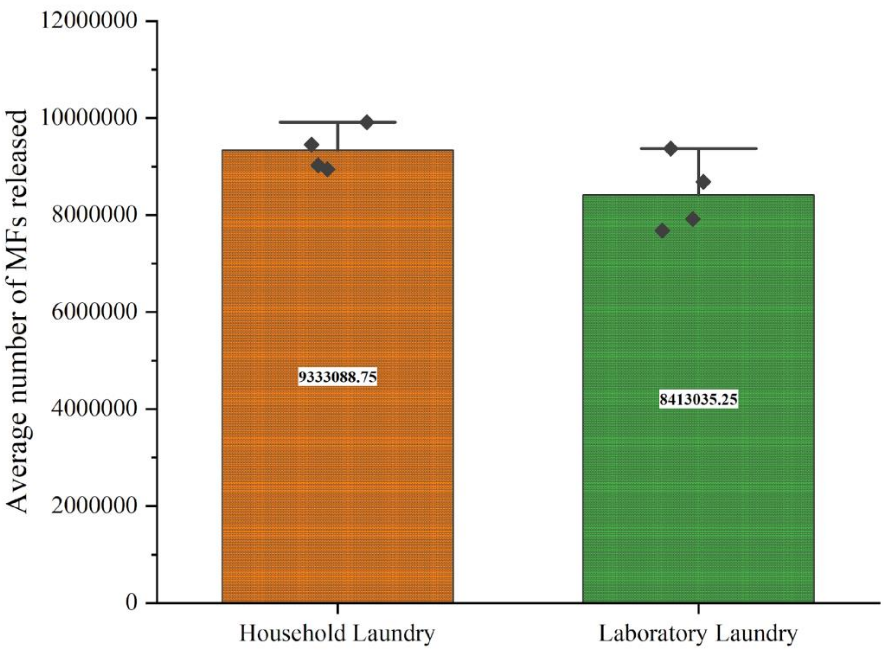

Figure 3. Distribution of MFs shedding during different laundry conditions

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