Dress You Up in My Love: Material Intensity in Fibers

This leads to the question of fibers in general. We have already documented that waste straw, used in quantities that do not compromise soil fertility or structure, can supply 100% of low-grade manufactured board needs - particle board, and such. Straw obviously won't work for fabrics - for clothing, furniture covers, and many industrial uses.

One critical trick in textiles in general is the same as the one we discussed in furniture - make the lifespan longer, so we get more year of use out of whatever inputs go into making them. A fabric example we have already discussed is Interface carpets which reduced material intensity by 90%+[46]. Because much clothing tends to go out of fashion before its current lifespan is exhausted, clothing is an especially good example. There are natural fabric fashion lines based upon classic lines and color schemes to stay in style longer - Natura Linea for example[117]. (Think of little black dresses, classic cut suits, or jeans, and t-shirts.)

In clothing at least, the single biggest consumer of resource in fabrics is the cleaning[118]. (This probably applies to towels, and sheets too - not so much to other fabrics which are cleaned less often and less intensively.)

There are two technologies (really three) that might greatly reduce the intensity of laundering - if properly combined. Today you can find at least two brands of "soap free" clothes washers on the market[119]. Daewoo manufactures the Midas, which combines ozonation with a small amount of catalyst to wash clothes without need for detergent. Sanyo does not require the catalyst, but boosts ozonation with ultrasound instead. Both work extremely well at sterilizing the clothes and water. Neither actually cleans all that well. In fact the Sanyo recommends soapless washing only for marginally soiled loads, and detergent and warm water for heavily soiled loads. However, for light loads where detergent and stain remover is not used, output from the Sanyo is free enough of both microorganism and toxics that waste water from it could safely be used to water a garden. (This would be illegal almost everywhere in the U.S. - but it would be safe, and you might be able to obtain permission in some areas.)

Now there is another technology out there - resin cleaners. A team of designers has developed the EcoSafe washing machine[120]. One small resin tablet will clean clothes thoroughly, without soap for about 50 loads. There is some sort of enzymatic action; demonstration models get clothes as clean (in fact significantly cleaner) than detergent - and sweet smelling too. There is so little resin released in a single load that no rinse cycle is needed. And, from a cleaning point of view, there is no reason ever to use warm or hot waters. Cold works just fine on everything. So if you take a normal front loading water saving washer, run it only on cold water, and eliminate the rinse cycle you have maximized both water and energy savings. And the water you do use comes out less polluted because of the not needing to use soap.

So, unlike ozone ions, why has this not been commercialized? Resin, from all accounts, does a marvelous cleaning job - but has no sterilization or antiseptic properties at all. Normal detergent does a fair job at sterilizing clothes, especially when hot water is used. Commercial detergent free washers are far superior at sterilization, even though actual cleaning power is not great. No manufacturer wants the liability of selling a washing machine that has fewer anti-bacterial properties than a normal washing machine. Sure, you can use hot water to make up for some of it - but then you lose many of the advantages of the detergent free model.

Of course the solution is obvious. Combine the resin washer with ozonation or ultrasound or both. Then you have cleaning and sterilization properties combined. You never have to use detergent or hot water. You can use normal water saving technologies (make the machine front loading etc) and eliminate the rinse cycle, except for loads requiring stain treatment. Most energy in washers is used to heat water - so eliminating the need to ever use anything but cold water takes already energy savings washers and saves even more. The elimination of most rinse cycles saves a good bit of the remaining energy and water, and will combine well with normal conservation practices. In terms of water, you not only decrease use, but decrease pollution of water that is used – reducing total impact by a great deal more than normal water saving washers. Energy use is cut 80% or more. Water use is probably not lowered quite by that, but water impact by a great deal more than 80%. Because of resin and stain removal, not quite something to use on your garden, but nonetheless 99%+ less polluted than output from a normal wash load.

So we can reduce the environmental impact of laundering fabrics by 80% or more. Can we do something similar with dry cleaning? Greenpeace favors two technologies[121] that can save 80% or more of the impact over conventional perc based methods. Some dry cleaners have begun to use wet cleaning techniques first imported from Germany in 1991, that get clothes as clean, wrinkle free, and do as little damage as dry cleanings[122]. Others use carbon dioxide based cleaning that save water, energy and avoid toxic chemicals[123]. Other alternative dry cleaning methods, though better than PERC, are not so highly recommended.

Outside of clothing, sheets, towels, and other such items than need weekly cleaning, maintenance is probably not quite so large a part of environmental impact. In such items though, sturdier and easier to clean textiles will reduce such costs. We will return to this in a bit.

For most non-clothing textiles, the manufacturing process is probably the single greatest part of the environmental impact. Textile manufacturing is by nature an extremely dirty process. The steps vary from textile to textile but include texturizing human-made fibers or preparing and spinning natural fibers. They including warping, bleaching, weaving, scouring, more preparation, dyeing (and/or printing), finishing, cutting, sewing. Just about every step involves washing and rinsing. You need chemicals to help the fabric survive mechanical and thermal processes, to add special properties to the fabric, to speed up the absorption of other chemicals, to counteract the effects of other chemicals, to help clean out other chemicals. Huge amounts of water are used throughout. Large amounts of energy are used to heat that water to the proper temperature for various chemical processes. This is historically part of textiles - not merely of the modern industry. Look at the ancient Roman dyeing industry, or how leather was traditionally tanned, or how wool was traditionally cleaned and treated. The material intensity of fiber manufacturing is another area with tremendous economically feasible potential for reduction - conservatively 80%.

Shell can make Polytrimethylene terephthalate (PTT) cost comparable to PET polyester fabrics[124] PTT, unlike normal polyesters can absorb dye without carriers at temperatures as low 100 degrees centigrade.
Use wool, cotton, flax, hemp, and other natural fabrics raised without pesticides. None end in processing baths.
Standard setting for purchases[125], to avoid processing unacceptable material, reducing reworks, seconds, and discards.
Testing/pre-screening raw materials[126]
Implement simple operations and housekeeping improvements. Spills and wastage from poor housekeeping can be responsible for between 10% and 50% of a mill's total effluent load[127]
Schedule dyeing to minimize cleaning. Dye each color separately; or schedule similar colors together, dying lighter to darker colors, and brighter to duller chromas. (The first is occasionally practical, the second fairly frequently.)
Automatic stops on washing processes to stop when the processes they are rinsing or washing do. Install valves and spill prevention devices to prevent overflows.
Replace toxic chemical processes with thermal or mechanical processes, and less toxic chemicals. For example, J.P. Stevens substituted ultraviolet light for chemical biocides in air washers and cooling towers[128].
Dutch General Assessment Methodology in Netherlands (RIZA-concept) SCORE-System in Denmark, BEWAG-concept in Switzerland, and TEGEWA system in Germany.

Examples of substitution include hydrogen peroxide in desizing starch, copper free dyes, high temperature reactive dyes that can be loaded at same time as dispersive dyes - normally applied in a separate stage[129]. (This saves time, water and energy by eliminating a stage, and also eliminates the caustic bath dispersives normally require.) Use surfactants biodegradable, or bioeliminable in wastewater treatment instead of alkylphenol ethoxylates such as alcohol ethoxylates[130]. Bathless air jets can avoid or minimize the use of anti-foaming agents; to the extent they still must be used there are alternatives to conventional mineral oil based agents[131].

Avoid pre-treatment and dyeing complexing agents by softening water to remove iron cations.

Use dry processes to remove iron from fabrics.

Remove iron inside fabrics by non-hazardous reactive agents.

Minimize use of sizing agents by prewetting yarn. (There is still a net reduction in water use, because of reduction in washing requirements[131:253].)

Compact cotton spinning can cut sizing chemicals by half, completely eliminateing paraffin, and greatly reduce water use[131:254].

Ultra-low chrome wool dyeing via stoichiometrical and substoichiometrical dosage. (Stoichiometical dyeing means dyeing until all molecules in the wool that can react with the chrome have been exhausted, lowering the chrome residue. Substoichchiometical dosage means stopping before all sites on the wool are exhausted - using up even more of the chrome.

Urea in reactive dye printing paste may be eliminated, or in the worst case reduced by 73%, by foaming or spraying fabric to be printed with a trivial a mount of water. [Trivial compared to water contamination ended by elimination or reduction in urea.] Foaming works in every case - spraying for all except silk or viscose fabrics[131:357].

There are techniques to reduce printing paste volumes[131:362], and simple methods of recovering printing paste[131:364], of which between half and 75% can normally be reused.

Use a lower ratio of water to fabric (thus lowering the energy needed to move and heat the water, and the amount of chemicals in the water). For example, the Lumberton, North Carolina plant of Almanac Knits lowered the water ratio of jet dyeing machines - reducing dye chemical use by 60% to 70%[132].

Similarly, pad batch dyeing can drastically reduce chemical use for certain fabrics (mainly cotton, rayon and other natural fabrics - even then depending largely on the finish desired). In it fabric impregnated with water and dyes mixed, the excess squeezed out by mangles. It is rolled or boxed, and covered with plastic film and kept until dye is absorbed - then machine washed. It can eliminate salt and many specialty chemicals, and reduce water use by an average of 90%[133] Where it can be used it also saves energy, production time, and labor. Like many environmentally sound techniques it pays for itself in labor savings and quality improvements, with environmental gains being essentially "free".

Automated dosing systems can deliver chemicals in the right amounts at the right time. They reduce chemical and water use, make result more reproducible[134] (This is an important benefit in the textile industry - allowing delivery of exactly the results the customer ordered.) It also reduces process time (improving productivity) and reduces reworks and redoes. Bloomsburg Mills introduced automating dosing in its dyeing process, and saved 28% of water use as a side effect. In the best such systems for normal commercial use, "dosing and monitoring equipment meter exact amount of chemicals and auxiliaries ,which are delivered to machines and vessels without human intervention in exact right amounts. Wash water for vessels and supply pipes taken into consideration in preparation and dosing. Chemicals are delivered in separate streams so that no premixing takes place before delivery."[135] So cleaning is required only after completion of the final step.

Another alternative is single rope dyeing machines. According to the European Commission[136]: (note: paraphrased for brevity rather than quoted exactly)

> *Only one fabric rope passes through all flow groups and components return to the first compartment after each lap is completed. High uniformity results, because fabric passes through all nozzles and troughs at each lap. Speeds, nozzle flows and operating conditions don't vary in different compartments – conditions remain homogenous throughout. Baths reach uniformity more quickly when conditions change; this provides faster chemical injection, and steeper temperature gradient without damage to fiber. The numbers of laps, rather than hold times, are the means of measuring process. (Exception - fixatives still time dependent - but all other chemical applications as well as mechanical and temperature dependent one may be measured in laps.) This gives very high repeatability. Time saving devices are also incorporated - power filling and draining, full volume heated tank, advance rinsing programs etc. can obtain constant liquor ratio with 60% of nominal capacity.*

We already gave examples of possible savings in conventional printing, in the lists of chemical reduction. Much greater reductions are possible in extremely high volume printing (such as carpets). Digital printing can provide very exact, very precise results - with dyes shot directly into the carpet. 80% of water, and similar savings in dyes are made[137] There are tremendous labor savings - carpet is printed in a direct WYSIWYG process from design. Patterns are stored electronically. Samples are minimized or (occasionally) eliminated. These are very capital intensive machines, and only pay for themselves in extremely high volume processes. But where they pay, they really pay. It is rather a step function; it does not come close to paying or you have really big savings - not much in between.

At the other end of the spectrum, extremely low volume textile printing may be done via inkjet. You gain similar savings to any other digital printing. But because speed is low it only pays for extremely short runs - 100 meters or fewer[138].

The greatest use of water in textile processing is in various rinsing and washing stages. One simple housekeeping step is to ensure rinsing and washing processes are turned off when the process they are rinsing and washing does. (It is usually worth putting in automated stops to ensure this.) Minimize wet cleaning through means like scraping machinery before wet cleaning it.

One way to greatly reduce this is via countercurrent washing. The least dirty water from the final states in used for the next to the last stage, and so forth - until the first state where water is discharged or processed. Savings vary, but typically, in a two stage process, wash water use is cut in half; in a five stage process water use is reduced by 80%[139].

Savings almost as great can be obtained by optimizing and combining processes. One manufacturer reduced chemical use by a minimum of 20% by extending the time fabrics were dyed by 15 minutes. Some of the worst pollutants were reduced by 60% and 98%[140]. (Similarly several stages may be combined - for example de-sizing, scouring and bleaching.)

Lastly you can recycle and reuse water; most common is the reuse of dyebaths - which can be analyzed, replenished and reused[141] Amital reduced water use by two thirds via dye bath and cooling water reuse[142] . Similar savings have been reported from rinse water reuse. In addition to the counterflow washing already mentioned, there are also continuous horizontal washers - where water is sprayed on top of fabric as it travels upwards on the machine. Similarly, for bleaching there are continuous knit bleach ranges that use built in counterflow and controlled dosing to reduce water, chemical and energy consumption. The water from rinsing cleaning belts also tends not to be extremely dirty and may be used for many purposes[143].

In total every stage of textile processing there are multiple means that can reduce water and chemical consumption by between half and 90% each. While some of these are mutually exclusive, the vast majority can be simultaneously applied. There are additional multiple steps each one of which may save 10% to 33% of water chemicals, and other steps that can reduce or eliminate a specific chemical or series of chemicals. Again most of these are not mutually exclusive. It would not be unreasonable to conclude that total water and chemical use in textile processing may be reduced by 90% from the average. (Because of the combination of multiple steps that are cumulative). It would be conservative to conclude that this can be done by well over 80%.

Lastly there is the question of natural fibers. Of all the natural fibers, cotton is the most intensive - using more water, pesticides, eroding more soil, and covering more land per unit of production than any other natural fiber source; it is worse than many plastic fibers as well[47]. Hemp requires about the same water and fertilizer per acre to grow as cotton, but produces about two to three times the bast fiber per acre[144]. Hemp seed oil is a superior substitute for cotton seed oil, containing much healthier fats. As a byproduct of processing the oil out of hemp seed, you end up with high protein meal, superior nutritionally to soy meal and useful for almost every purpose soy meal has. (You don't end up with as much of it per acre as soy; it remains a byproduct, not the main crop.) It is easier than cotton to grow without pesticides or herbicides, and where they have to be used requires less. It requires significantly more processing than cotton, but also produces huge amounts of hurd which have their own uses. So the net environmental impact of hemp per unit of output remains about one half to one third that of cotton, perhaps less depending upon how one weighs the high protein meal, and the higher quality oils.

Hemp can substitute for cotton in many applications. For example Levi's original blue jeans were made from hemp, and you can substitute hemp 100% for cotton in all denim applications, as well as in most furniture fabric. Even in applications where you need to use cotton, you can substitute hemp for a percentage of fabric - producing a more robust shrink resistant fabric. (Recently some hemp clothing manufactures have been eliminating cotton mixtures from their lines. New air finishing processes apparently make the hemp soft enough to make cotton an unneeded addition.) In clothing applications we can substitute hemp for 100% of about half the uses, and around 50% for the other half. In non-clothing applications, there is no reason not to substitute hemp 100% for cotton. So we can substitute hemp of 75% or more of cotton use. The cost will be about twice that of cotton, but hemp fabrics also last longer than cotton fabrics, and require less care. For bed sheets, and rugs, and furniture covers and most non-clothing textile uses, this would more than make up for the difference.

For clothing, advanced cottonization that makes 100% hemp as comfortable as cotton increases energy and water consumption at any rate. As pointed out in the section on agriculture, mixing hemp 50/50 with organic cotton is ecologically sounder in these cases. In the case of clothing, increased physical lifespan may or may not translate into longer actual lifespan, depending on how successful designers are in developing lines that don’t go out of style. Regardless, lower production impact remains significant.

Another alternative that produces extremely soft strong fiber is bamboo – which requires even less land than hemp, though comparable water per unit of output.

Natural fibers are only one part of textile manufacturing. Polyester, nylon, and other synthetics play a substantial role - and in the U.S. constitute the overwhelming majority of fabric. Hemp may reverse this to a modest degree. It is sturdier than cotton, more durable, more water resistant, tends to shrink less. But it has no stretch, and is exceeded in water resistance, and dry strength by a number of synthetics. As previously pointed out, there are lower impact synthetic fibers such as PPT that can substitute for higher impact one.

So between better processes, longer lifespans and lower impact materials we can reduce the impact of fibers by three quarters – resulting very roughly in a 50% reduction in energy use.

End Notes

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[126]Ibid 125 p77.

[127] Ibid 125 p100.

[128] Ibid 125 p79.

[129] Ibid 125 p78.

[130] Ibid 124 p265.
Section 4.3.3

[131] Ibid 124 pp267-268.
Section 4.3.4

[132]Ibid 125 p79.

[133] Ibid 125 p80.

[134] Ibid 125 p.85.

[135] Ibid 124 p446.
Section 5.1

[136] Ibid 124 p353.
Section 4.6.21.3

[137] Ibid 124 p370.
Section 4.7.8

[138] Ibid 124 p371.
Section 4.7.9

[139]Ibid 125 p81.

[140]Ibid 125 p82.

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