Mitigating Tannery Pollution in Sub Saharan Africa and South Asia

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Abstract

The value of the global leather market was estimated at 271.21 billion in 2021 and has been steadily increasing over the past five years (Statista 2021). This is despite the rising use of synthetic fibers and plastics for a variety of consumer goods. Leather is still the source for a range of apparel items, including handbags, belts, shoes, wallets, gloves, and various other products, such as furniture, car seats, and luggage. Behind all leather goods is the tannery industry, with much of the raw materials processing located in the Global South (Lund-Thomsen, 2009). Unlike most synthetic fibers, which are derived from plastics and so problematically associated with the petrochemical industry, leather has the potential for a comparatively lighter footprint because it is based on natural and renewable materials not associated with the carbon emissions of fossil fuels. However, leather has suffered from concerns around its production process, including animal rights and toxic effluents. In fact, it is ranked as the fourth most dangerous global industry to human health, with many tanneries in the South where lacking basic protection for the workers and leaching toxic chromium into rivers (Green Cross and Pure Earth 2016). This article explores the prospects for reducing the environmental footprint of tanneries in the Global South, focusing on the Sustainable Manufacturing and Environmental Pollution program (SMEP), a series of projects in South Asia (SA) and Sub-Saharan Africa (SSA) funded by the UK government to explore ways to reduce tannery waste. In the context of a complex set of global value chains, there is the possibility for a series of technical and managerial interventions that would vastly reduce the negative impacts of the industry on human health and the natural environment.

Why Focus on Leather

The SMEP (Sustainable Manufacturing and Environmental Pollution Programme) is a series of projects in South Asia and Sub-Saharan Africa funded by the U.K. Government at ₤24.6 million designed to reduce pollution and promote the transition to a more circular production process. The SMEP approach focuses on reducing manufacturing waste at the source, rather than remediation or cleaning up products after they are discarded. SMEP identifies three key steps in the manufacturing process where interventions are needed: in substituting or removing harmful inputs; in improving process efficiency; and in developing by-product capture and treatment. The first step requires reducing input waste, including energy and materials. The second step involves upgrading technology and reducing waste through an examination of the entire process, including transport, inventory systems, and quality control. The last step includes examining ways to recycle or reuse waste products for re-use in the manufacturing process (PA Consulting 2019, 15-19). Leather was selected as an industry of interest for the program as it is the fourth most polluting industry in the world after used lead acid battery recycling, mining and ore processing, and lead smelting (SMEP 2018, 11). It ranks among the top 4 industries in SSA based on the number of establishments and among the top 10 for export value according to the SMEP Baseline Report (SEI and U. of York 2020, 23). It is also among the top 5 industries for export value in Bangladesh, Nepal and Pakistan (55, 62). The baseline report also highlights the lack of detailed historical data series, or ongoing valid environmental monitoring data on industries in the two regions (50). Furthermore, there are no objective in depth studies of environmental interventions, making assessment of current initiatives, such as a series of common effluent treatment plants (CETPs) in the regions challenging (75). In the rest of this article, we provide a profile of the leather industry and then examine the challenges and opportunities for mitigating its environmental footprint in the two regions, informed by the SMEP projects.

Leather Production Shifts South

Leather remains a ubiquitous material source for apparel, luggage, and other goods, including luxury items around the globe. Yet, most consumers are unaware of where their leather comes from or the conditions of its production. Most leather is derived from cowhides and other animal skins. The leather industry (Leather Dictionary, 2021) estimates that while 75% of leather was used in shoes in 1950, by 2013, that ratio declined to 53.6%. Among the other major categories, leather for clothing took 14.4%; furniture leather took another 13%; car leather 10.7%, and approximately 8.3% went to other uses. As the industry has gradually shifted the Global South, concerns have increased around the labor and environmental conditions of production.

The global trade in leather and raw hides is dominated by countries such as China, Italy, USA, and Brazil. In 2019, China and Italy were the main importers of raw hides and leather at 18% and 12%, respectively. *In short, China and Italy depend heavily upon imports of raw materials from the South for their leather industries.* In sub-Saharan Africa and South Asia, India, Pakistan, South Africa and Nigeria play important roles in the global trade of raw hides and leather (Conseil National du Cuir 2021). Tables 1-4 highlight the changes in the value of raw hides and leather trade in the two focus regions over the last two decades (as recorded in the UN Comtrade Database in 2022).

Table 1: Raw hides and leather exports from Sub-Saharan Africa (SSA) (US$)

	2000	2005	2010	2015	2019
Ethiopia	47,581,170	75,339,071	66,645,201	88,370,188	59,680,993
South Sudan	15,636,269	20,655,571	28,405,010	N/A	N/A
Kenya	12,850,633	32,680,867	53,016,410	64,508,991	30,401,176
Namibia	13,043,430	18,404,531	16,895,974	25,546,093	12,370,585
Nigeria	1,707,192	N/A	3,060,840,991	158,300,955	75,253,087
South Africa	222,699,121	179,718,689	187,543,153	291,742,283	186,565,454
Uganda	14,091,886	7,064,365	17,060,775	63,017,634	21,302,505
Zimbabwe	22,038,572	14,240,160	20,328,622	36,433,449	32,436,632
Rest of SSA	43,090,597	39,426,930	48,453,409	118,643,170	33,698,923

Table 2: Raw hides and leather imports from SSA (US$)

	2000	2005	2010	2015	2019
Kenya	187,783	1,393,835	8,350,120	7,352,952	2,510,875
Madagascar	844,096	1,008,756	4,731,361	4,580,305	5,202,758

Mauritius	4,008,752	3,247,699	10,546,504	10,893,811	6,853,112
Namibia	1,632,354	2,594,672	2,595,658	2,919,004	1,353,731
Nigeria	396,862	N/A	120,111,367	24,474,269	48,889,900
South Africa	104,024,340	87,869,736	125,208,366	98,510,737	41,610,669
Zimbabwe	3,497,970	354,710	669,281	2,587,011	1,951,143
Rest of SSA	2,453,843	1,864,235	5,210,550	28,819,782	16,811,201

Table 3: Raw hides and leather exports from South Asia (SA) (US$)

South Asia	2000	2005	2010	2015	2019
Afghanistan	N/A	N/A	14,675,589	9,301,434	7,971,772
Bangladesh	173,498,629	237,189,044	257,216,832	298,994,297	N/A
Bhutan	N/A	23,232	15,592	N/A	N/A
India	336,663,309	644,169,664	789,831,536	1,096,322,905	554,800,715
Nepal	4,706,403	N/A	10,205,232	9,048,811	3,740,748
Pakistan	N/A	306,699,305	415,651,831	425,085,116	227,941,327
Sri Lanka	941,215	1,088,107	388,948	790,793	295,100

Table 4: Raw hides and leather imports from SA (US$)

South Asia	2000	2005	2010	2015	2019
Afghanistan	N/A	N/A	N/A	N/A	3,312,800
Bangladesh	5,920,865	11,165,561	44,738,234	169,200,895	N/A
Bhutan	N/A	485	3,768	N/A	N/A
India	188,071,748	303,683,319	481,122,589	674,858,788	561,885,573
Maldives	449	2,445	18,953	16,863	62,983
Nepal	25,719	N/A	313,065	924,432	735,399
Pakistan	N/A	78,940,306	77,964,411	73,914,674	50,787,124
Sri Lanka	16,177,234	9,221,506	18,693,762	16,686,426	15,391,341

Source for all Tables: UN Comtrade database

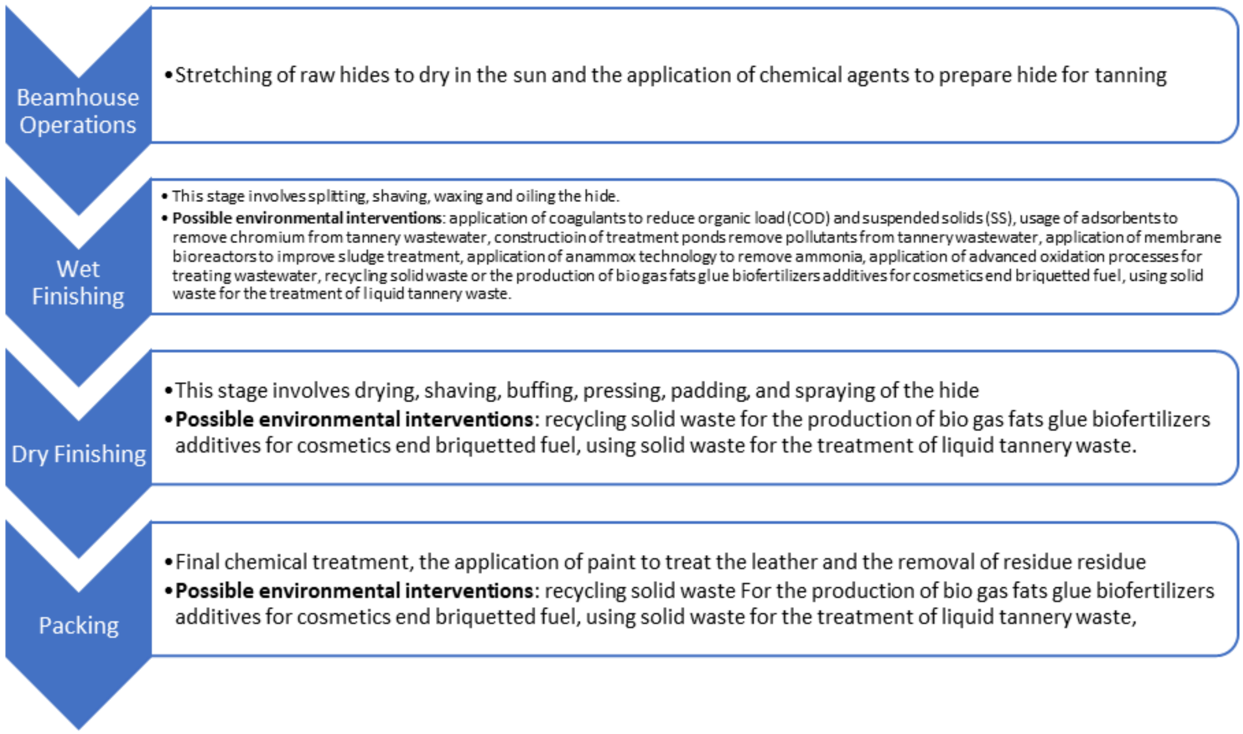
The shift of raw leather production to the South has been accompanied by reports around the negative health and environmental consequences of such production (Human Rights Watch 2012). So far, there are no viable substitutes for leather. Animal rights concerns have led to the development of a plant-based leather substitute industry. Sources of these substitutes include plant fibers and recycled synthetic fibers such as polyester. So far, substitutes lack the economies of scale do not match the unique characteristics of leather product, such as firmness and longevity, so more R&D is needed to improve synthetic substitutes before this represents a threat to the leather market. Synthetics are also more expensive to produce. However, some industry analysts project rapid growth in the coming years for leather substitutes and report the adoption of such materials by leading auto manufacturers for upholstery leather seating (Infinium 2021). Before examining possible solutions, we review environmental concerns.

Environmental Challenges and Solutions in the Tannery Process

Environmental Issues at Each Stage of Production

Tannery waste has serious environmental consequences for air, water, and soil, *if untreated*. These are reflected in the tannery production process. Rydin (2012) points to an array of chemicals that are used, including: calcium hydroxide, sodium chloride, sodium sulphide, acids, carbonates and sulphates, particularly chromium sulfate. Kokkinos and Zouboulis (2020) point to hazards throughout the production process. Without proper treatment, negative effects can be borne through three basic methods: gaseous emissions, wastewater, and solid waste. Gaseous emissions are airborne particles and chemicals that come principally during the cutting and preparing of hides, as well as when workers handle chemical reagents. Large amounts of water are used in the soaking, liming and de-liming processes to remove hair from the hide, which involves highly alkaline chemicals. Wastewater also contains high levels of organic waste as the excess material is discarded. Finally, solid waste is produced in copious quantities, including hair, grease, oils, fleshing and trimming waste, all of which is labeled tannery "sludge". Perhaps the most important concern is the widespread technique of chrome tanning, which is used in 80-90% of all leather production, according to Oruku et al. (2020, 370). The same authors point out that just a medium-sized tannery can discharge over 300 million cubic meters of waste liquor and tanning sludge with high levels of chromium *per day*.

There are four basic steps to the tanning process, each of which creates its own environmental risks. The first is called beamhouse operations. In this step, the raw hides are stretched onto frames to dry in the sun. At this stage chemical agents are used to preserve the hides and skins. The second stage is tanning, or converting the raw hides and skins into leather. This is accomplished through two stages. First, wet finishing, which includes "splitting, shaving, waxing and oiling" the hide. This is followed by dry finishing, which is "drying, shaving, buffing, pressing, padding, and spraying" it further. The final stage is crust and finishing or "packing", whereby workers may use final chemical treatment and paint to treat the leather, as well as cleaning the residue. Throughout the process, workers can be exposed to dust and over 40 chemicals and toxic or poisonous substance, including "chromate and bichromate salts, aniline, butyl acetate, ethanol, benzene, toluene, calcium salts, chlorine, surfactants salts, sodium sulfide, sulphuric acid, organic matters, , and dyes" (Rabbani et al. 2020). We can add to this the final stage of waste treatment and recycling of tannery wastes.



Both solid organic waste and liquid wastewater resulting from the above processes contain high levels of salinity and pollutants, particularly chromium, that are toxic to plant, animal, and human life at high concentrations (Ahmad et al. 2020) are generated. In particular, the tanning process uses trivalent chromium to treat rawhides and, if preventative measures are not applied, this becomes hexavalent chromium in the oxidation process, which is a carcinogen. Tannery wastewater is poorly biodegradable, with high salinity and levels of sulfates and chlorides. The solid organic waste can also act as growth center for pathogenic vectors (Green Cross and Pure Earth 2016, 26; Hansen et al. 2021). As Oruku et al. (2020, 373) point out, chromium negatively affects marine ecosystems, plant life, and thereby animals and humans exposed to it. Chromium has been traced to higher levels of morbidity, respiratory, and gastrointestinal disease around South Asian tannery districts.

The good news is that there are a series of technical solutions that have been suggested to reduce waste and its toxic effects on human health and the nearby environment.

An Array of Solutions for Tannery Waste

There is ongoing experimentation with the tanning process to reduce environmental contamination. There are several well-known methods for reducing waste, particularly chromium. To reduce toxic airborne pollution, Kokkinos and Zoubroulis (2020) recommend the use of liquid reagents, and long with proper ventilation with filters or scrubbers to capture particles.

Zhao and Chen 2019 suggest the following steps to reduce wastewater contamination. The first step is to develop screening and grilles to remove solid waste materials such as hair. Aeration can then be used to separate out water from oils. Because tannery wastewater is often alkaline, pH neutralization is required through adding chemicals to the wastewater. Coagulation methods of adding other chemicals can further separate remaining solids in the water. Another method is to use adsorption, such as adding agricultural waste that picks up chemicals such as chromium from the water. Kokkinos and Zoubrolis (2020) add the need for a pre-treatment of waste by applying chemical reagents to reduce the toxicity of chemical residues. Physicochemical treatment through settling/sedimentation and chemical reagents should be followed by biological treatment to metabolize organic matter (Kokkinos and Zoubroulis 2020).

For solid waste, there are different requirements based on the stage of production during which they are produced. There is the possibility for recovery and reuse of some materials, such as glue, collagen, inorganic salts, and hair/wool. However, most solid waste will likely end up in landfills, according to the authors, though there are emerging potential alternatives, including composting, anaerobic digestion, combustion for energy recovery, chromium recovery, and use as an additive for ceramics or for reuse in the tanning process (Kokkinos and Zoubroulis 2020).

There are ongoing experiments to recover chromium for reuse int eh tanning process, including direct recycling, chemical precipitation, coagulation, solvent extraction, exchange processing, and ion exchange (Oruku et al. 2020, 379). Nur-E-Alam et al. (2020) argue that adsorption is cheap, safe and effective at removing a variety of chemicals from wastewater using readily available agricultural residue. Micro-electrolysis, photocatalysis, and electrodialysis are more advanced techniques for removing chemical ions. In terms of removing biological contamination, common methods include oxidation technology, using a sequencing batch reactor, anaerobic, and microalgae treatment. Anaerobic treatment creates methane, which can be used as a fuel source.

Despite that fact, other options are available for handling solid waste. Alibardi and Cossu (2016) find that with aerobic stabilization techniques followed by compaction and drying, the biodegradability of the solid waste is improved. In a similar vein, Lazaroiu et al. (2017) suggest that animal fat from tanneries can be used to create biodiesel or biogas. Agustini et al. (2018) find that methane from animal waste can be used to produce biogas and recycled to reduce the energy and heating needs for tanneries. Velusamy et al. (2020), by contrast, argue for incineration of solid waste to create electricity. Juel et al. (2017) offer a third option- creating bricks from the solid sludge which they argue are safe and competitive with normal bricks.

Oruku et al. (2020, 377) report on various ongoing experiments to find substitutes for chrome in the tanning process. These include urea, melamine, phenol, and formaldehyde, however there are concerns about their health effects. Thus they suggest that a combination of organic substances such as vegetable-syntans, D-amino acids, aldehydes, biocatalysts and other syntans with inorganic metals, nanocomposites and biopolymers are being tested for their potential.

There is also an attempt to examine if vegetable-based tannins can substitute for the use of chromium. Rolence China et al. (2020) report on the testing of various barks for tannins in Tanzania with mixed results. They find the *A. xanthopholoea* bark to be the most promising candidate. Alternatively, Ma et al. (2017) find that using a bioleachate for tannery sludge can create a reusable tanning agent thus dramatically reducing the use of chromium. There are reports of using less harmful silica-based chemicals to replace chromium. However, both processes are more expensive and less efficient than chrome processing at present, though luxury car makers are increasingly turning to vegetable-based tanning and leather that is recyclable due to customer concerns about sustainability (Ross 2021).

Daddi et al. (2017) suggest that clustering all leather operations close to livestock farms in the same industrial district can allow the firms to share the costs of waste treatment facilities. This is illustrated in life cycle assessments of the Italian leather industry. In a similar methodological vein, Gianetti et al. suggest examining different mitigation pathways from the lens of optimizing both energy and materials use, including possibly recycling chemical residue waste. In South Asia, several cities combine municipal with industrial waste treatment through a CETP (common effluent treatment plant); this offers the possibility to link such operations with leather production.

Considering the damage that already exists, there are some nascent efforts at examining remediation of tannery contaminated environments. Oruku et al. (2020) suggest that there are an array of emerging techniques for remediation, including: bioremediation to reduce or eliminate chemical contaminants (chromium); phytoremediation using plants to detoxify soils; to physiochemical methods to transform dangerous residues into less toxic forms. Bashir et al. (2021) suggest that adding biochar to soil helps to mitigate chromium contamination. Sallam et al. (2017) suggest a polymer-clay composite. Meanwhile, others suggest that certain types of plants can absorb some of the toxic chemicals from tanneries (Bareen and Tahira 2011; Saeed et al. 2012).

Unfortunately, there are no studies yet that empirically compare the various treatment options in terms of advantages and disadvantages, or accessibility to countries with lower technical and managerial capacity. More research is needed to examine the tradeoffs of these different techniques, which naturally would have to be adapted for local conditions and capacities.

Challenges for Tannery Treatment in South Asia and Sub-Saharan Africa

Following the logic that solutions must follow local conditions, we now lay out the context in each of the regions of interest. For each region, we highlight the economic contribution, turn to the negative environmental and health consequences, and close with a comment about the limitations of current efforts. We focus on the countries in each region where SMEP projects took place.

South Asia- with a focus on Bangladesh

As reflected in Tables 1-2, the leather industry in South Asia is one of the most active in the world, reflecting large amounts of activity in Bangladesh, Pakistan, and India. In each of these three giant contributors, there are serious concerns about tanneries. For the purposes of this article, we focus on Bangladesh, the main focus of SMEP activity.

The Bangladesh leather industry has acquired a negative reputation for the working conditions of its tanneries, and so has received the lion's share of attention in the region. The leather sector is increasingly important to the economy, having surpassed $1 billion in annual exports in 2014. It contributes 4% of exports and employs some 50,000 workers (Al-Muti 2017, 11). According to the Government of Bangladesh, the leather industry is the country's 2nd largest foreign exchange earner, contributing 4% of total exports. It employs 600,000 people directly and another 300,000 indirectly. As a result, the Government declared it the "product of the year" in 2017. It hopes to increase the size of the sector to $5 billion by 2024 (Ministry of Industries 2019, 31).

The area around Hazaribagh was the traditional home to 95% of the 150 formally registered tanneries, from where an estimated $663 million in leather goods were exported in 2012 (Human Rights Watch 2012). Saha (2021, 77) suggests that there are 220 tanneries in the country, but only 113 "are effectively in function." Of these, 20 are large, 45 medium, and 53 small. In terms of source material, 56% comes from cows, 30% from goats, and the rest from buffalo. From 2017, 123 of the tanneries, including the largest ones, shifted to the Tannery Industrial Estate (TIE) in Savar. The government offers cash subsidies as a percentage of the value of exported leather goods, presumably an effort to increase local value-added. While there are environmental and health safety laws on the books, they are not enforced. Moreover, there are reports of the use of child labor (Human Rights Watch 2012).

A 2016 study by Green Cross and Pure Earth (4, 22) of the health effects of industries found that tanneries were the fourth most toxic industry, after used lead acid battery recycling; mining and ore processing; and lead smelting. The study included an assessment of the Hazaribagh tannery zone near Dhaka, Bangladesh, which houses 95% of all Bangladesh tanneries. In Bangaladesh, 85,000 tons of rawhides and skins are processed annually. Processing one metric ton of rawhides produces 200 kg of leather, 250 kg of non-tanned solid waste, 200 kg of tanned waste, and 50,000 kg of wastewater. Together these create 8 kg of chromium. Over 8,000 workers in the regions suffered from gastrointestinal, dermatological, and other diseases. These reflect the real human costs of the industry where waste products are left untreated and have created a negative reputation among an admittedly small group of conscientious business buyers and consumers.

Furthermore, the Bangladesh leather industry creates an estimated 75 tons of solid waste and 21,600 cubic meters of liquid waste daily (Al-Muti 2017, 13). Rabbani et al. (2020) found compelling evidence that the longer workers were employed in the Bangladesh industry the higher the incidence of respiratory and dermatological issues. The local industry employs an estimated 12,000-15,000 seasonal workers who create an estimated 98 metric tons of solid waste and 7.7 million liters of wastewater, negatively affecting the local river Buriganga. Consistent with Human Rights Watch (2012) and other studies, Rabbani et al. (2020) find water samples with toxins well in excess of national standards. There is also a lack of ventilation, exposing workers to toxic dust. Akhtar and Shumul (2012, 141) echoing numerous other reports, including studies from India, Pakistan, Ethiopia, and Sudan (Mahamudul Hasan 2016; Chandrasekaran et al. 2014; Mohamed and Musa 2017; Shahzad et al. 2006; Butt et al. 2021; Kashyap et al. 2021; Gebrekidan et al. 2013) find that just 20% of Bangladeshi tanneries have adequate exhaust fans, only 30% wear shoes, 12% gloves, and just 4% aprons or masks. As a result, 90% of tannery workers die before the age of 50; 58% suffer from ulcers; 31% from skin diseases; 17% from malnutrition; 11% from rheumatic fever; 23% have persistent coughs, and 19% from jaundice. Workers regularly complain of dizziness, headache, weakness, eye problems, abdominal pain, nausea, diarrhea, allergy, burning sensation in the chest, throat, palm and toes, urinary problems and pain in the body, waist, legs, back, throat, neck, shoulder and ankles. Yet most workers seem unaware of the hazards of the job, and do not use personal protective equipment. Moreover, most production is done by contract workers of subcontractors, and thus the purchasing company is not directly employing and so not responsible for most of the workers making the leather (Rabbani et al. 2020), making it difficult for them to organize for better working conditions.

The Bangladeshi government has hopes for its new tannery site in Savar, 20 km west of Hazaribagh, and where they hope to develop a central wastewater treatment plant. The move was delayed for several years due to resistance by existing tanneries who demanded compensation to pay for the costs of relocation (Human Rights Watch 2012). The impetus for the shift was pressure from the EU whereby import restrictions would be put in place on Bangladeshi leather absent effluent treatment facilities (Harris 2016, 26). As of 2020, (Hasan et al. 2020) report that a central effluent treatment plant (CETP) had been constructed at Savar, however water samples revealed continuing high and dangerous discharge of toxic elements, including chromium. The authors suggest that the plant is not operating at standard, and that unauthorized dumping from tanneries is taking place. Another source notes that the plant is only equipped to deal with effluent from which chrome has already been separated. Companies are supposed to send discharges to Effluent Pumping Stations, where chrome can be recovered for recycling. However, the stations were not operational as of the time of writing in 2017. The same was true for the solid power generation system, designed to create electricity from solid waste. The report notes that despite not being equipped to do so, the CETP was accepting effluent with chrome content, and such was probably being discharged into the Daleshwan River. The report noted that what happened to the solid waste was "unclear" (Arbeid 2017, 41).

The SMEP study of Bangladesh highlights the urgency for change in tannery practices as the EU will no longer permit the sale of leather products polluted with chromium (VI) (2021b, 9). The report offers a pointed assessment of the Savar tannery CETP. It states that the plant is not yet up to Bangladeshi standards. It locates the problem as emanating primarily from tannery process technologies, "such as excess desalting, hair-save unhairing method, water management, and chemical conservation method(s)". (SMEP 2021b, 12). It further notes that water consumption at more than 40 cubic meters per ton of wet salted hides processed exceeds the 1997 Bangladesh Environmental Conservation rule of 30. Thus, new water management techniques are needed, including monitoring, batch vs. running water usage and reusing and recycling water where possible (SMEP 2021b, 13). Furthermore, there is insufficient knowledge about CETP management by both the government and private sector. A Chinese contractor developed the CETP, with construction supervision by the Bangladesh University of Engineering Technology, however, plans for local maintenance are not yet fleshed out. This includes the need for pre-treatment of the water before it reaches the CETP, and not charging tanneries for water usage possible solutions. Furthermore, there is a lack of regular consultation among industry stakeholders (14). At present, there are no provisions for dealing with solid waste, missing the opportunities for valuable by-products (15). Improving the situation will require significant technical and financial resources, including more training of key stakeholders. One crucial step is requiring the use of small amounts of vegetable tanning agents, which will reduce the resulting amounts of chromium. Input materials are readily available locally (16-17). On the other hand, finding substitutes for oxidation agents used to bleach leather is still required. not clear Stakeholders should be educated to reduce oxidation agents wherever possible (19). The last recommendation of the study is to establish an LWG (Leather Working Group, the international industry organization) certification system for the tanneries, requiring attendance at a few days of training, which could be complimented by exchange visits to certified tanneries in India. It is important that the certification process take place as part of a wider industry dialogue between the government and tanneries. (22-23). Possible solutions

The report concludes that the sector needs to be re-organized to improve environmental standards compliance. This includes formalizing single-stage processors into small and medium size businesses, creating tannery clusters around CETPs. About half of the tanneries conduct just one stage of the tanning process (SMEP 2021c, 9). New techniques are also needed, such as reducing salt by cold storage preservation of hides; using filtration during the unhairing process monitoring water use; and employing solar panels for energy usage possible solution. Above all, the report calls for the creation of a sector database, including ongoing environmental monitoring data (3-4, 35-6). There is a growing appetite for knowledge in the country. This is reflected in a new research collaboration between the University of Veterinary and Animal Sciences and a Chinese University. There is also a National Institute of Leather Technology in Korangi, founded by industry and government in 1998. However, more funding is needed for advanced studies of the sector (13). Including expanding further training of skilled personnel.

The conditions appear to be similarly hazardous in India and Pakistan. Amaranth and Krishnamoorthy (2001) find similarly serious negative effects on local agriculture from tannery waste in Tamil Nadu state, where 53% of the Indian industry is located. The same is true for Pakistan, where leather is the third largest export earning industry. A World Bank report (Sanchez-Triana et al. 2012, 195-210) notes the familiar bifurcation in the industry between small and large tanneries, where the smaller operations lack knowledge and means to reduce effluents. Moreover, there is little pressure from local customers who purchase items from small tanneries nor activity by provincial authorities to meet national environmental quality standards (NEQS), which most firms see as unattainable. Beyond education and waste infrastructure, the authors recommend a tax on chromium that can be used to defray cleanup costs. There appears to be an "institutional void" in the government in terms of taking responsibility for upgrading the sector in both economic and environmental terms. Nonetheless, outside forces, particularly external buyers, have led to the development of a Cleaner Production Centre and Cleaner Production Institute in the early 2000s. Both are funded by outside donors with support from UNIDO (Wagha et al. 2017). As in Bangladesh, a Common Effluent Treatment Plant (CETP) was set up in 2001 outside of the Kasur Tannery district. It was funded by the UNDP and the Punjabi government. The plant was effective in reducing organic materials by 50%. A second plant was established in the Korangi Industrial Areas of Karachi with support from the Ministry of Commerce and the Netherlands government (Qureshi 2005, 93).

Sub-Saharan Africa (SSA)

The leather industry is far smaller in sub-Saharan Africa, but it is of growing importance to certain countries in the region, as reflected in Tables 1-2. In this section, we review the limited current analysis of the region, highlighting information from the two main countries of SMEP's focus, Ethiopia and Kenya. As in South Asia, we find that the economic growth in the industry is not matched by adequate improvements in waste treatment. Oruku et al (2020, 379-80, 382) found via a 2018 questionnaire in SSA, that while 70% of the countries in the region use physical and chemical treatments, but the effect is limited because the methods are rudimentary. For example, some countries allow the waste to dry into sludge in order to reduce discharge into water bodies. However, there are inadequate techniques to deal with the solid waste. In other instances, the effluent goes straight to water bodies, and in some to municipal wastewater treatment facilities that are ill-equipped to handle it. Solid waste is often simply dumped in landfills, where through leaching and rain it can enter into water systems. In other instances, it is burned with few safeguards. In short, there is scant evidence of treatment across the region, despite promising experiments in biological treatment, and microfiltration. Simply put, African governments and the private sector lack the capacity to implement such technologies.

In a general review of impediments to light manufacturing in the region, including leather, the World Bank (Dinh et al. 2012, 60-1, 123) finds that lack of access to high volumes of quality skins and to finance impede the quality and quantity of inputs needed for developing larger leather manufacturing enterprises. They link this to land holding patterns including traditional rights which limit economies of scale in cattle raising and lead to inconsistent quality hide skins. They also state the need for low-cost energy and the need for better infrastructure as well as improved skills for exports. They use the example of Ethiopia for how such problems could start to be alleviated, citing the effectiveness of a USAID program to reduce ectoparasites in cattle. Not surprisingly, they believe Ethiopia should eliminate all export restrictions on raw materials and import tariffs on leather products to create greater competitiveness. In addition, setting up 1-2 industrial parks where tanneries could be centrally located would reduce the investments required to improve logistics.

UNIDO (2003, 21-22, 2010 37) reaches similar conclusions that lack of quality standards and materials impede the African leather industry, together with poor access to basic infrastructure and capital for exports. There are few training programs and low-level technology in the industries. Beyond these is a lack of understanding and facilitation to reach export markets. For these reasons, it calls for more foreign direct investment. Beyond improving macroeconomic conditions, improvement of the handling of environmental waste would be necessary to attract investment. Despite these challenges, there are signs of potential for significant growth among producers. For example, Kenya exported $800 million of goods between 2006-15, with just 15 companies accounting for 90% of the volume. These large firms have cracked overseas markets, with 42% going to Europe and North America, and another 30% to China. The successful companies are larger in size, and so have access to capital to purchase equipment needed to meet global quality standards (Pasquali 2021).

In Ethiopia, the Derg regime (1974-91) nationalized the 8 tanneries and 6 large shoe factories, placing them into the national Leather and Shoe Corporation. The result was a predomination of raw hides and skins exports until the 1980s, when they were banned. The post-Derg government led by the TPLF party began to embrace an industrial policy with a view to further developing the sector. In the 1990s the newly privatized sector was able to increase exports of semi-processed leather goods. By the end of the 1990s, the government began offering preferential access to finance and land, tax exemptions, discretionary liberalization of direct investment, and export incentives (Grumiller 2019, 10). The SMEP project reports highlight the impressive growth of the industry in Ethiopia, though such progress might be sidelined by the current civil conflict. The sector is one of the targets of the government's Industrial Development Strategy, laid out in 2002. This follows from the perception of comparative advantage, since the country has one of the world's largest livestock populations with 60.9 million heads of cattle. The Ethiopian government's efforts appear to be paying off. The value of leather and leather products exports increased from $53 million in 1996 to $135 million in 2017. Investments in recent years have been concentrated in footwear and gloves; foreign firms account for 87% of leather products exports. Employment has likewise increased from 11,365 in 2012 to 21,094 in 2017, with most increases in footwear, whereas employment in tanneries has stagnated (SMEP 2021a, 18).

Whitfield et al. (2020) support the shared idea that the rapid rise of Ethiopia's apparel sector including leather goods, particularly shoes, as owing to industrial policy. Exports of apparel increased from less than $1 million in 2001 to $117 million in 2017. The Ethiopian government courted foreign direct investment, but also supported local manufacturers. Support included subsidized loans; priority foreign exchange; tax holidays; and export targets. The government also worked with development aid donors to offer new skills and management training, including instruction on how to export. The government, through the Ethiopian Investment Commission also set up industrial parks, working with global apparel buyers to offer facilities for local producers. It also set up the Leather and Leather Products Technology Institute (Sonobe et al. 2009). Reflecting industrial policy goals, the government has also invested in hydropower, resulting in the lowest electricity costs in the region. All of this has been orchestrated by the Prime Minister's office and a ministry of capacity building. Such orchestration included developing close relations with the Ethiopian Leather Industry Association (ELIA) courting foreign companies to start producing in Ethiopia, including Chinese firms. Value added was reinforced by banning the export of raw hides and placing prohibitive taxes on semi-finished leather (Brautigan et al. 2018). State capture by local producers was mitigated by setting up benchmarks for firm performance and sunset clauses for firms who failed to meet export goals (Mbate 2015). The approaches draw directly from that of East Asia (Hira 2007). Despite such progress, the authors (Whitfield et al.) report that local firms still face serious challenges. They sell to just a handful of foreign buyers. They struggle to meet large and/or custom orders. Local supply chains are also challenged to provide consistently high-quality inputs. Finally, there are thus far limited signs of upgrading of skills to downstream parts of the supply chain or related businesses. Not surprisingly, there appears to be a bifurcated cluster in Ethiopia. One part of it is vertically integrated larger firms who are upgrading through their export ties. The other, far larger in number, are smaller firms with few supply chain ties who rely mostly on well-known or imitative techniques, selling to local markets (Gebreeyesus and Mohnen 2013).

Despite the impressive growth, few tanneries have managed to upgrade to finished products (Grumiller 2019, 10). In response, current Ethiopian government policies include the banning of raw hides and skins in 1986; a 150% tax on the export of pickle and wet blue leather materials in 2008; and of a 150% tax on semi-processed exports in 2012. This led to the establishment of the Leather Industry Development Institute. In recent years, several agro-processing parks have arisen, including ones owned by Chinese and Taiwanese manufacturers. The tanning and leather industry employed approximately 5% of the manufacturing workforce in 2017. As of 2018, there were 23 tanneries making finished leather, 21 footwear manufacturers, 4 gloves producers and more than 43 leather goods and garments producers. (SMEP 2021a, 14-15, 18-19).

However, there are serious environmental issues accompanying the leather sector's growth in Ethiopia. A study in Addis Ababa found that 35.5% of tannery workers suffered from occupational asthma. A study of vegetables grown near tanneries also showed significantly high concentrations of metals, including chromium. At present, the industry does not separate out solid waste, thus creating the environmental hazards discussed above. Plans include the establishment of an industrial park, the Modjo Leather City, which is envisaged to create a common wastewater and solid waste treatment plant. (SMEP 2021a, 20-1). The study recommends a follow up study to examine how to reduce the toxic content of waste material to develop a comprehensive waste management plan for tanneries. This could include occupational and health safety training and studies around the feasibility of anaerobic digestion and safer ways to produce glue. By-products could include biogas. However, it also highlights the challenge of raising the capital for a CETP and new processing technologies, particularly in the absence of enforced health and safety rules (SMEP 2021a, 23).

In Kenya, tanneries are estimated to create 15% of industrial emissions (SMEP 2021, 4). The International Trade Center (2010, 2-2) finds a lack of sufficient and consistent good quality hides and skins. The report notes that the opening of the domestic market to global competition, including the removal of 22% export compensation in 1990 led to the decline in the number of tanneries from 18 in 1998 to just 10 in 2010. A large footwear maker, Bata Shoe Company, sells mostly to the local regional market. It runs some of the 15 operational footwear factories. A 2015 World Bank report states that "most Kenyan leather is produced and sold as a commodity with little quality or design differentiation". Indeed 89% of exports are semi-processed wet blue leather and another 5% are raw hides and skins. The percentage of raw hides and skins went down precipitously when an 80% export tariff was imposed in 2009. The report estimates employment at 14,000 during peak periods, with a similar amount in the informal sector. They cite higher costs as being the primary deterrent to expansion, stemming from labor (reflecting a lack of skills leading to low productivity), and electricity costs being higher than in Ethiopia. According to the authors, the industry in Kenya is highly fragmented with few clear linkages across the supply chain or among stakeholders preventing the development of quality and economical inputs, preventing the development of a coherent strategy. One alarming statistic reflecting the underdeveloped state of the industry is their estimate that 11.7 million leather shoes are imported into Kenya vs. just 3.3 million pairs being made domestically, a fact replicated across Africa where low costs imports crowd out local industries. Beyond the aforementioned issues, there is a clear lack of knowledge about marketing, including lack of understanding about how to design for target markets and to find dedicated distribution channels. The authors recommend organizing the sector around a strategic network and considering the development of industrial parks to facilitate cluster organization. More recently, a Kenyan government report states that the Government is investing $62 million into the establishment of a Leather (industrial) Park in Kinanie. It will be part of an Export Processing Zone and be designed to ensure compliance with EU environmental regulations (International Trade Centre 2018, 26-7).

Tanzania is another potential hub for leather making given its large cattle population. The sector was privatized in the 1990s. There are currently 9 tanneries operating with a capacity to process 4.6 million hides and 12.8 million skins per year. However, they are only operating at 86% capacity for hides and 61% for skins. Just 9-10% of these are processed into leather, the rest is exported as raw hides and skins or semi-processed wet-blue leather. The lack of environmental controls has led to widespread damaging of local water bodies (REPOA 2020, 20-1). A World Bank review of manufacturing in Tanzania (Dinh and Monga 2013, 65-71, 110) reports on the government's leather strategy initiated in 2007 to revive the sector as part of the Industrial Development Strategy 2025. The country has the third largest livestock population after Sudan and Ethiopia, but only 60% of hides are collected for processing. The rest are defective or used for traditional purposes. As in other African countries, most herders are smallholders, impeding economies of scale, and improvements in quality of the hides. The government imposes a 40% tax on the export of raw hides and skins, putting the revenues into the Livestock Development Fund. Annual export revenues are estimated at $1 million. There are seven formal tanneries, all privately owned, who produce only to the semi-processed stage. They export, primarily to China, Italy, and Turkey. Only two of the tanneries produced finished goods, one for the domestic market and one also able to export to Kenya and the US. There are some 13 firms in leather processing, including 8 in footwear employing an estimated 200-300 people. As with other countries in the region, while there are advantages in labor costs, the processors need to import inputs, including chemicals, glue, treads, laces and soles, which creates an overall cost disadvantage. On top of this is higher material waste and higher infrastructure costs, including electricity and transport. Worker and management skills, as well as access to finance for equipment and inventory are lacking. The Tanzanian Government is aware of these issues and is developing a sectoral strategy to address then. It reports that smuggling has undermined the effect of its tariffs on raw materials exports. Also, the local sector is swamped by cheaper imports of leather products. In terms of environmental regulations, the proposed strategy suggests the promotion of new cleaner technologies, audits, and the development of CETPs. The strategy document proposes new investments into R&D; modernization of slaughter techniques to improve hide quality; developing industrial clusters to reduce the environmental footprint; and partnering with international counterparts to improve environmental technologies. Once improvement in supply conditions is obtained, it anticipates increases in foreign direct investment. The government proposes setting up a public-private joint steering committee to guide strategy (United Republic of Tanzania no date, 38, 41, 53, 56, 61).

The pollution challenges associated with tanneries are also evident in South Africa. Oruko et al. (2021) investigated soils at tannery dump sites in Kenya and South Africa and found high risks from soil contamination that could adversely affect local agriculture. While they cite readily available treatment options, they conclude that such are not being adopted because of low margins, poor enforcement of regulations, and the lack of waste treatment options. As a result, similar to South Asia, much of the solid waste is illegally dumped in open or public spaces to avoid responsibility.

Conclusion

While recognizing the deleterious nature of the leather industry as practiced in the Global South at present, we have also highlighted the important potential it offers for economic development, including light industry that links with local inputs and provides considerable employment. The intense competition from rivals in China, Italy, and, to a lesser extent, India, who enjoy economies of scale and better access to finance and infrastructure, seemingly relegate other countries in the two regions to providers of raw materials. More importantly, the incumbents have developed the technology and know-how for producing elaborate leather goods as well as the distribution channels for profitable sales well beyond the current capacity of late developing producers.

As seen in the example of Ethiopia, a well-thought out industrial policy can help to grow the sector, improving value-added through concerted efforts and government support. The elements of that policy as outlined above include a long-term sectoral strategy, government fiscal support, the development of a knowledge and training institute, incentives for value added processing, and consultation between the private, public, and international trading sectors. What has been missing from the conversation so far is the promotion of sustainability.

The growing resistance of Western buyers, including the large automakers, to purchase leather made under hazardous conditions, particularly those linked to chrome tanning, reflects the fact that the time for that conversation is overdue. Growing awareness is reflected in the EU requirements for global standards to be met in the production process for any imports. Thus far, the potential substitutes for leather have not yet met the grade. Thus, there is still an opening for Southern producers, including Ethiopia, to shift their techniques to assuage potential buyers about the safety of their practices.

There is a plethora of technical solutions to address such issues, as we have reviewed. These range for simple and straightforward such as ventilation, and basic worker occupational safety, including personal protective equipment. There are also substitute techniques, such as vegetable tannins, chemical additives, and bioleachates, but each have their tradeoffs, and the opportunity costs among them are not yet fully investigated. Nor is their transferability in all cases to the Global South clear. Perhaps, the core problem around feasibility of implementation is the bifurcated nature of the industry in the South, where the formal larger enterprises who export are under pressure and have the potential to shift production, but the larger informal and less organized sectors, from livestock providers to the multitude of small and medium tanneries producing for local markets are much less capable and organized for change. Indeed, there is no evidence yet that the local consumers demand it, or that workers, mostly on temporary contract, can organize to demand safer conditions.

Another solution is to provide basic occupational health services clinics in the tannery zone. When Médecins Sans Frontiérs did this in 2016 in Bangladesh, 3200/5000 (64%) eligible workers came in for at least one consultation or treatment over a 6-month period. Lund-Thomsen's (2009) study of international projects designed to improve the environmental footprint of tanneries in Pakistan reveals the crucial role that civil society can play in pressuring authorities to regulate the sector and contributing to monitoring and enforcement. He recommends international actors help to organize civil society stakeholders and that attention be paid to the distributional effects on tanneries of regulations. This is because the tanneries sector in Pakistan is dominated by a few large enterprises who export, and can afford to adopt, while smaller enterprises would struggle to adapt to new standards.

The holy grail solution favored in practice by many governments in the South appears to be to try to cluster tanneries into an industrial district, one which could have companies from different industries in the same location, in order to apply circular economy principles of reuse and recycling. The centerpiece of such efforts is a common treatment plant. However, as the SMEP studies reveal, CETPs so far have underperformed. They have not been built to accept all forms of tannery waste, nor have they required tanneries to shift their techniques to meet such requirements. As the SMEP points out, changing techniques such as oxidation processes, using cold storage to reduce salinity, and reusing chromium from wastewater could make serious dents into the waste problem. An even bigger gap lies in the complete neglect of solid waste, which could yield valuable by-products.

Despite the array of available solutions, health and safety regulations, wastewater treatment, and health and safety treatment for workers are still not regularly enforced (Rabbani et al. 2020). Padda and Asim (2019) studied which factors affected tannery firm compliance with a cleaner production program (CPP) in Pakistan, designed to improve environmental standards from 1999-2005. The CPP was funded by the Governments of Norway and Pakistan, and the Pakistan Gloves Manufactures and Exporters Association. The CPP was a voluntary program designed to spread information and skills into the sector via local centers around helping firms to adopt an environmental management system. They find that larger firms and those exporting were more likely to adopt environmental standards. The CPP had no effect on improving labor standards. Regulatory enforcement as well as international pressure had positive effects. The education levels of tannery owners was also an important factor. The authors suggested that firm adoption over the long-term was *not* linked to the CPP, because owners saw the support as temporary in nature. Most are so pressed by low profit margins that they cannot afford to be proactive on externalities. They thus cite long-term support and enforcement of regulations as the ways forward. Ortolono et al.'s (2014) review of the same program largely agrees with these conclusions. While they state that valuable information was passed onto firms by the centers, the overall program did not deal with the realities on the ground. Because of the lack of enforcement of regulation, they conclude that the best way forward is to find cleaner production techniques, such as materials and energy efficiency that will also save firms money. They further note the lack of capacity of the public and private sector to audit environmental effluents. Finally, they note that the lack of capital and small size of most firms prevents them from investing adequately into waste treatment plants, thus a shared treatment plant is more likely to be feasible.

Moreover, the private sector clearly must embrace the values and systems around sustainable production, but this has yet to happen in the two regions. Turki et al. (2017) found that the introduction of environmental management principles made a difference to the practices of Tunisian tanneries. However, there is no evidence around the adoption of such principles more widely across the private sector. Both factors suggest that industries in the South could benefit from external assistance to reduce tariffs on their products and help towards solving these waste issues. Needed interventions range from improving government and private sector capacity to providing capital and technology.

Beyond such challenges lie even deeper challenges related to global commodity-type production. As Atkind et al. (2017) point out in their study of resistance to new technology by Pakistani soccer ball manufactures, the microeconomics of an industry can play a crucial role as to whether regulatory innovation occurs. In their example, since subcontracted employees were paid by the piece, there was little incentive to reduce waste or take up new technologies, and they lacked the capital and knowledge to do so. In the same way, the plethora of small tanneries in the Global South lacks the incentives to transform their traditional approaches, including the lack of local enforcement. Similar to apparel, the main factors in the industry are price, and short-turnaround time for production. Thus, it is not surprising that even when government investments are made in new wastewater infrastructure, which is a crucial part of the solution, it is not enough to reduce waste. Even where the formal sector moves towards regulation, the informal sector undermines such efforts through continued illegal dumping. In a parallel way, the vacuum of environmental enforcement is matched by a lack of labor rights. Workers would naturally be expected to be the main champions for improving safety and reducing hazards during the production process. While we have discussed evidence of industrial upgrading in terms of quality and productivity through exports, there are thus reasons to doubt that is the case for externalities such as labor and environmental conditions. For example, Lund-Thomsen and Coe (2015) relate that Nike's active efforts to improve conditions related to its soccer ball stitching operations in Pakistan met with limited effectiveness. Similarly, the multiple corporate social responsibility initiatives created by Western firms in the aftermath of the Rana Plaza disaster proved no substitute for environmental and labor rights enforcement (Hira and Benson-Rea 2017).

All of this suggests a new and more concerted effort is required among both internal and external stakeholders to solve the leather waste problem, including financial and technical assistance to build local capacity. Creating requirements for production standards on imports is but a first step to the transformation needed. The next steps are to build wastewater and solid waste treatment plants, and to support the diffusion of both technical and managerial shifts in the production process towards sustainable and locally accessible and appropriate practices.

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