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Study on Environment Management Strategies of Leather Tannery Units- Punjab & Kolkata Region

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Abstract: ***This study investigates the environmental management strategies adopted by leather tannery units in Punjab and Kolkata, two major centres of India's leather industry. Despite the sector's significant economic contribution through exports and employment, it remains one of the 17 most polluting industries in the country, primarily due to inefficient resource utilization and inadequate waste management. The research examines the environmental implications of tanning operations, including water, air, and solid waste pollution, and evaluates the technological and policy measures introduced to mitigate these impacts. Using secondary data from government reports, industry assessments, and field-based studies, the paper analyses the effectiveness of common effluent treatment plants (CETPs), waste minimisation initiatives, and cleaner production technologies. The findings reveal that while modernisation and government-led interventions—such as the Integrated Leather Development Programme and the establishment of the Kolkata Leather Complex—have led to measurable improvements, the widespread adoption of sustainable practices remains limited due to space constraints, financial barriers, and a lack of technical expertise. The study underscores the urgent need for integrated environmental policies, advanced treatment infrastructure, and workforce training to ensure sustainable growth. By exploring both ecological challenges and progressive industry responses, this work contributes to the broader discourse on sustainable industrial development. It highlights the path forward for reconciling economic gains with environmental responsibility in India's leather sector.***

Keywords: Deliming, Adsorption, Saddlery, Rechroming, VOCs

Nomenclature:
CPCB: Central Pollution Control Board
MoEFCC: Ministry of Environment, Forest and Climate Change
CREP: Charter on Corporate Responsibility for Environmental Protection
WMC: Waste Minimization Circles
CLRI: Central Leather Research Institute
CETP: Common Effluent Treatment Plant
KLC: Kolkata Leather Complex
GoWB: Government of West Bengal
BOT: Build-Operate-Transfer
ETP: Effluent Treatment Plant
RO: Reverse Osmosis
TDS: Total Dissolved Solids
COD: Chemical Oxygen Demand
BOD: Biochemical Oxygen Demand
TSS / SS: Total Suspended Solids / Suspended Solids
VOCs: Volatile Organic Compounds
Nox: Nitrogen Oxides
SO_2: Sulphur Dioxide
CO_2: Carbon Dioxide
BAT: Best Available Techniques
DPIIT: Department for Promotion of Industry and Internal Trade
SSI: Small Scale Industry
IEM: Industrial Entrepreneurs Memorandum
EM: Eastern Metropolitan
WBSEB: West Bengal State Electricity Board
MLD: Million Litres Per Day
ETI: Effluent Treatment Index
SWDI: Solid Waste Disposal Index
EmI: Emission Index
PCWE: Percentage of Community Welfare Expenditure

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I. INTRODUCTION

The Central Pollution Control Board (CPCB) has ranked the leather tanning industry in India among the 17 most polluting sectors. The sector is primarily composed of small, micro, and medium-sized units, many of which follow traditional, resource-intensive practices that generate significant environmental pollution.

To regulate this, the Environment (Protection) Rules, 1986, under Schedule I, specify the effluent discharge standards for the leather tanning sector. These standards were further revised through Notification No. G.S.R. 730(E), dated August 1, 2018, issued by the Ministry of Environment, Forest and Climate Change (MoEFCC) under the Environment (Protection) Amendment Rules, 2018.

Recognizing the need to go beyond mere regulatory compliance, In March 2003, the Government of India introduced the Charter on Corporate Responsibility for Environmental Protection (CREP). Explicitly aimed at industries such as tanneries, CREP encourages proactive environmental management through waste minimization, in-plant process control, and the adoption of cleaner technologies. The Charter set clear targets in areas such as water and energy conservation, chemical recovery, pollution reduction, elimination of toxic substances, and environmentally sound residue management.

To further address pollution in the leather tanning sector, the MoEFCC introduced the concept of pollution prevention through cleaner production. This included the promotion of Waste Minimization Circles (WMCs) in clusters of small and medium-sized tanneries across the country. These circles facilitated detailed waste audits within tannery operations, using both in-house expertise and government-provided external facilitators. As a result, practical and economically viable measures for waste reduction were identified and implemented, leading to

measurable economic and environmental improvements [1].

Given the sector's significant pollution potential and its adverse effects on rivers, water bodies, and surrounding ecosystems, it has become critical to establish comprehensive guidelines for pollution prevention and control. While compliance with effluent and air emission standards remains essential, a more holistic and integrated approach is needed to manage environmental impacts from the leather tanning industry effectively.

A. Growth of the Leather Industry

India's large livestock population—estimated at around 425 million cattle, buffaloes, sheep, and goats—provides a strong foundation for the country's leather industry. This figure gives India a unique global position, with approximately 57% of the world's buffalo population and 16% of its small ruminants. Despite this vast resource, the supply of hides and skins has remained relatively stable over time, growing at only about 1.2% annually.

A significant amount of potential raw material is also lost due to inefficient carcass recovery. As per the Central Leather Research Institute (CLRI) in Chennai, India, it loses over ₹3.3 crore worth of ovine skins each year because many carcasses are not properly flayed. As a result, one of the key challenges facing the future growth of the leather industry is the limited and underutilised availability of raw materials.

Kanpur is one of India's leading centres for leather and leather goods production, particularly known for its specialisation in harness (saddlery) and shoe leathers, as well as in the tanning and finishing of buffalo hides. Similarly, Kolkata plays a significant role in processing cowhides and goatskins for tanning and finishing, making it another vital hub in the national leather supply chain.

Table I: Leather and Leather Goods Exported from India

Category	2019-2020	2020-2021	% Variation	% Share (2021)
Finished leather	524.15	378.23	-27.84%	10.27%
Leather footwear	2081.67	1485.55	-28.64%	40.35%
Footwear components	261.67	197.59	-24.49%	5.37%
Leather garments	429.11	295.56	-31.12%	8.03%
Leather goods	1353.74	944.31	-30.24%	25.65%
Saddlery and harness	151.44	186.18	22.94%	5.06%
Non-leather footwear	281.97	194.16	-31.14%	5.27%
Total	5083.76	3681.58	-27.58%	100.00%

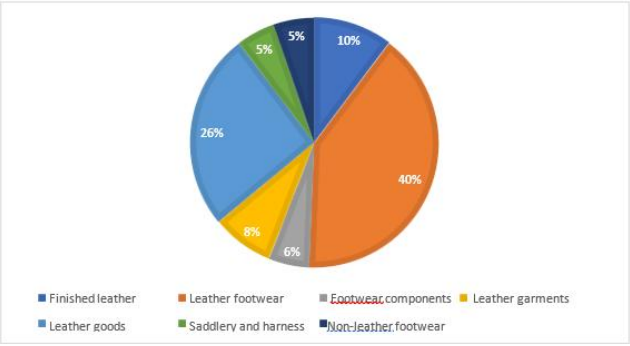
The table shows a significant decline in India's leather and leather product exports between 2019–2020 and 2020–2021, with an overall decrease of 27.58%. Most categories saw sharp drops due to global trade disruptions, likely linked to the COVID-19 pandemic [2].

i. Leather footwear remained the most significant export segment in 2020–2021, accounting for 40.35% of total exports, despite a 28.64% decline.

ii. Leather goods followed with a 25.65% share, and finished leather contributed 10.27%.

iii. The only category to show positive growth was saddlery and harness, which increased by 22.94%, though it represented a smaller share (5.06%).

iv. Other segments like leather garments, footwear components, and non-leather footwear also recorded declines of over 24–31%.



[Fig.1: Leather and Leather Products Exported from India]

II. ENVIRONMENTAL IMPACTS OF THE LEATHER INDUSTRY

The leather industry, despite its substantial contribution to the economy through exports and employment generation, has often been criticized for its adverse environmental impact. One of the major concerns is the waste generated by tanneries, which includes large volumes of wastewater contaminated with hazardous substances, such as chromium, synthetic tannins, oils, resins, biocides, and detergents. Additionally, liquid waste, due to the improper handling and disposal of solid waste and the release of gaseous emissions, further exacerbates environmental degradation.

These pollutants can contaminate soil, surface water, and groundwater, posing serious risks to ecosystems and public health. The situation is often worsened by the lack of adequate waste treatment infrastructure, especially in clusters of small and medium-sized tanneries. As a result, the industry has gained a negative reputation, overshadowing its economic significance. Addressing these environmental issues through sustainable practices and stricter enforcement of environmental regulations is crucial for improving the industry's public image and ensuring its long-term viability.

A. Wastewater from Tanneries: Environmental Concerns

The leather tanning process uses a large amount of water and produces significant volumes of wastewater containing pollutants at different stages of production. Detailed data on water consumption and pollutant load for each step of the tanning process are shown in Table 1. Notably, conventional pre-tanning and tanning operations are responsible for approximately 90% of the total pollution generated by a tannery.

"During the pre-tanning phase, the characteristics of wastewater can vary widely, often showing elevated levels of chemical oxygen demand (COD), total dissolved solids (TDS), chlorides, and sulphates, along with fluctuating pH levels. A particularly polluting step is the conventional dehairing process, which uses sodium

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sulphide and lime. This single step alone accounts for 84% of the biochemical oxygen demand (BOD), 75% of the COD, and 92% of the suspended solids (SS) in tannery effluent [3].

The use of sodium sulphide is especially problematic. It not only has serious environmental consequences but also interferes with the performance of effluent treatment plants. Additionally, the widely adopted chrome tanning method suffers from poor chromium uptake—only 50% to 70% of the chromium used is actually absorbed by the hides [4]. This results in considerable material wastage and poses a threat to surrounding ecosystems through heavy metal contamination.

The rise in labour productivity significantly contributed to the overall growth of total factor productivity. Although the leather industry performed strongly during the study period, a considerable portion of its capital remained underutilized, particularly after economic liberalization. Post-liberalization, the sector was recognized for improving the efficiency of both labour and capital use. To revitalize the Tamil Nadu leather industry, it is essential to enhance the effective utilization of available resources and focus on increasing the gross value added. Strengthening research and development efforts will also be crucial in achieving this goal. The Government of India has identified the Leather and Footwear Sector as one of the 12 key focus areas with strong potential for global competitiveness. Through various industrial development and export promotion programmes, the Indian leather industry aims to expand production, increase exports, and generate employment by leveraging its skilled workforce, adopting modern technologies, adhering more to international environmental standards, and receiving robust support from allied industries. [5].

B. Solid Waste from Tannery Operations

In addition to wastewater pollution, the leather tanning industry also generates a significant amount of solid waste throughout various stages of processing. These wastes originate from the physical preparation and chemical treatment of hides and skins.

On average, tanning operations produce:

i. 80–120 kg per ton (T) of raw trimmings,
ii. 40–50 kg/T of hair or wool,
iii. 250–300 kg/T of fleshing waste,
iv. 100–110 kg/T of wet blue trimmings,
v. 90–120 kg/T of wet blue shavings,
vi. 6–8 kg/T of crust trimmings, and
vii. 1–2 kg/T of buffing dust.

These wastes contribute significantly to the industry's overall pollution load and require proper handling, treatment, and disposal. If not managed effectively, solid tannery waste can cause soil and groundwater contamination, emit foul odours, and pose public health risks.

A detailed breakdown of the characteristics of effluents generated at each processing stage is presented in the table below (JCHP)

Table II: Characteristics of Tannery

Parameter	Soaking	Liming/ Reliming	Deliming	Pickling	Chrome Tanning	Neutralization	Rechroming Dyeing, Fat Liquor	Total (Including Washings)
Volume of effluent/ton of hide/skins	6-9 m^3	3-5 m^3	1.5-1 m^3	0.5-1 m^3	1-2 m^3	2-3 m^3	3-6 m^3	30-40 m^3
pH	7.5 –8	10.0-12.8	7.0-9.0	2.0-3.0	2.5-4.0	4.0-6.5	3.5-4.5	7.0-9.0
BOD 5-day at 20 °C (Total)	1,100-2500	5,000-10000	1,000-3000	400-700	350-800	800-1100	1000-2000	1200-3000
COD (Total)	3,000-6000	10,000-25000	2,500-7000	1000-3000	1000-2500	2000-4500	2500-7000	2500-8000
Sulphides (as S)	-	200-500	30-60	-	-	-	-	30-150
Total Solids (TS)	35,000-55000	24,000-48000	5,000-12000	35,000-70000	30,000-60000	10,000-14,000	4000-9000	12,000-23,000
Total Dissolved Solids (TDS)	32,000-48000	18,000-30000	3000-8000	34,000-67000	29,000-57500	9000-12,500	3600-8000	9000-18000
Suspended Solids (SS)	3,000-7000	6000-18000	2000-4000	1,000-3000	1,000-2500	1000-1500	400-900	2000-5000
Chlorides (as Cl)	15,000-30000	4,000-8000	1,000-2000	20,000-30000	15,000-25000	1500-2500	300-1000	6000-9500
Sulphate as SO4	800-1500	600-1200	2000-4000	12,000-18000	12,500-19000	1000-2000	1200-2500	1600-2500
Chromium (as Total Cr)	-	-	-	-	1500-4000	15-30	50-300	120-200

C. Improvements in Production and Exports Over the Last Three Decades

The Indian leather industry has seen significant growth over the past five decades. Data highlighting the progress made in the last three decades is presented in the table below. (JCHP)

Table III: Leather Industry Improvement in India (Value in Million Rupees)

Item	1972	1991	1998	2001	2011
Value of production	3,000	59,570	110,560	160,000	2,80,000
Export	1,830	32,170	69,560	92,120	2,33,323
Domestic consumption	1,170	27,400	41,000	67,880	92,320

Note: 1. Export figures based on actual (Source: Council for Leather Exports. 2. Domestic consumption figures, estimated

III. AIR EMISSIONS

While much attention is often given to the water and solid waste pollution caused by the leather industry, air emissions are an equally critical environmental concern that cannot be overlooked. Throughout the various stages

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of leather processing—particularly during liming, deliming, tanning, dyeing, drying, and finishing—numerous airborne pollutants are released into the environment.

One of the primary air pollutants emitted from tanneries is volatile organic compounds (VOCs). These are especially prevalent during the finishing stage, where solvents, lacquers, and other chemical coatings are applied to the leather to enhance its appearance and durability. Common VOCs include toluene, acetone, and ethyl acetate, many of which are hazardous to human health and contribute to the formation of ground-level ozone and smog.

Ammonia and hydrogen sulphide gases are typically released during the early stages of hide processing, such as soaking, liming, and unhairing. These gases not only produce foul odours but also pose respiratory risks to workers and surrounding communities. Additionally, particulate matter and dust are generated during mechanical operations like buffing, shaving, and polishing, which further degrade air quality inside and around tannery units.

In facilities using combustion-based drying or heating systems, emissions may also include sulphur dioxide (SO_2), nitrogen oxides (NO_x), and carbon monoxide (CO)—all of which are known contributors to air pollution and climate change.

The lack of proper ventilation systems, combined with outdated technology and inadequate emission control measures in many small and medium-sized tanneries, exacerbates the impact of air pollution. Long-term exposure to these pollutants can cause respiratory disorders, eye irritation, skin problems, and other health issues among workers, while also affecting air quality in nearby residential areas.

Mitigating air emissions in the leather sector requires a shift toward cleaner production techniques, including the use of water-based finishes, low-VOC chemicals, and enclosed processing systems. Installing air filtration and scrubbing systems, along with ensuring regular maintenance and monitoring of emissions, is also essential. Encouraging industry-wide adoption of Best Available Techniques (BAT) and enforcing compliance with ambient air quality standards can significantly reduce the environmental footprint of the leather industry [6].

Tanning facilities emit the following pollutants into the air: (leather industry)

Table IV: Sources of Air Emissions and Preventive Methods

Emission to Air	Source Operations in Tannery	Suggestive Methods of Prevention
Organic Solvents	Degreasing Finishing	▪ Usage of water-based formulations for spray dyeing ▪ Usage of roller coating techniques or curtain coating machines wherever applicable ▪ Usage of spraying units with economizers and high-volume / low-pressure spray guns ▪ Avoid the use of internationally banned solvents ▪ Usage of wet scrubbers, activated carbon adsorption, bio-filters (to remove odours), cryogenic treatment, and catalytic or thermal oxidation.
VOCs	Spray-finish Machines Dryers	
Sulfides	Beam house and Effluent treatment	▪ Maintain a basic pH over 10 in the equalization and sulphide oxidation tanks. ▪ Avoid breeding anaerobic conditions in sulphate-containing materials. ▪ Add manganeese sulphate to treated effluent. ▪ Use adequate ventilation
Ammonia Beam	House Deliming Dehairing Drying after dye penetration	Adequate ventilation followed by wet scrubbing
Dust	Storage handling of powdery chemicals, Dry shaving, Buffing, Dust removal machines, Milling drums, Stalking	▪ centralized system ▪ employing cyclones ▪ Usage of scrubbers/bag filters, as needed.

Emissions of sulfur dioxide may occur during bleaching, post-tanning operations, or carbon dioxide (CO2) deliming, but they are not typically a significant source of emissions.

A. Key Challenges in the Leather Industry

The leather industry plays a vital role in the economy but faces several significant challenges, particularly related to environmental sustainability, resource management, and industry capabilities.

i. *High Resource Consumption:* The process of transforming raw hides into finished leather requires substantial amounts of water and energy. This intensive resource use puts pressure on local supplies and raises environmental concerns.

ii. *Inadequate Effluent Treatment:* Many tanneries in India lack proper effluent treatment facilities. This shortfall not only contributes to pollution but also reflects deeper issues in design and product development capabilities within the sector, limiting its overall efficiency and sustainability.

iii. *Skilled Workforce Shortage:* There is a noticeable shortage of trained and qualified workers in both tanneries and leather goods manufacturing units. This gap affects product quality, innovation, and the ability to adopt modern technologies.

iv. *Insufficient Market and Fashion Information:* Indian leather manufacturers often struggle with limited access to reliable market data, fashion trends, and related services. The lack of up-to-date information hampers their ability to stay competitive, innovate, and respond to global demand effectively.

v. *Weaknesses in the Footwear Industry:* Although India's footwear sector is growing, it still faces challenges in marketing and product design. These weaknesses make it

difficult for Indian footwear brands to establish a strong presence in both domestic and international markets.

Addressing these issues through improved infrastructure, workforce training, enhanced research and development, and better market linkages is essential for the sustainable growth and global competitiveness of India's leather industry [7].

IV. GOVERNMENT POLICIES SUPPORTING THE LEATHER INDUSTRY

The Government of India has introduced a range of initiatives aimed at boosting the competitiveness and modernization of the leather sector. These policies focus on easing regulations, encouraging investment, and enhancing infrastructure and design capabilities. Some of the key measures include:

- **De-licensing of Integrated Tanneries:** The government has eliminated licensing requirements for integrated tanneries that convert raw hides and skins into finished leather. This move helps reduce bureaucratic hurdles and encourages new entrants and expansion in the sector.
- **De-reservation of Leather Goods:** Several leather products have been deregulated from the Small-Scale Sector reservation, allowing larger manufacturers to enter and compete more freely, thereby encouraging growth and innovation.
- **Free Import and Export Policies:** The government allows the unrestricted import and export of raw hides, skins, and both semi-finished and finished leather products. This policy facilitates easier access to raw materials and markets, helping Indian businesses remain competitive globally.
- **Concessional Duties on Machinery and Chemicals:** To support modernization, concessional import duties have been applied to machinery and chemicals used in leather production. This reduces costs for tanneries and encourages the adoption of advanced technologies.
- **Modernization Assistance through the Integrated Leather Development Programme:** Launched in June 2005 with a budget of approximately ₹2788.45 million (around 50.82 million Euros), this program offers financial support for upgrading leather tanning and product units. Small Scale Industry (SSI) units can receive assistance covering up to 30% of the project cost, while non-SSI units can get 20%, subject to a ceiling of ₹4,792 thousand (about 87,360 Euros) per unit.
- **Establishment of Leather Parks:** "To develop world-class infrastructure clusters, the government allocated ₹4,792.7 million (approximately 87.36 million Euros) to establish five leather parks—two in Chennai and one each in Nellore, Agra, and Kolkata. The Council for Leather Exports estimates that these parks could attract investments exceeding ₹11,633.1 million (around 2,120 million Euros) in the coming years
- **Promotion of Design Centers:** To improve product design and innovation, the government supports the creation of design centers within individual manufacturing units. Under the market access initiative of the Ministry of Commerce and Industry, units receive 25% of project costs as assistance. This scheme has already motivated several companies to establish their own in-house design facilities [8].

A. Government Support for the Leather Industry

Recognizing the vast potential of the leather sector, the Government of India has introduced a range of supportive policies aimed at maximizing the use of available raw materials and boosting overall value generation. Special attention has been given to the integrated development of the tanning sector, with initiatives focused on raw material augmentation, technological advancement, environmentally sustainable processing, quality standardization, and workforce skill development.

To address the shortage of skilled labor—particularly among unorganized artisan workers—the government has supported the establishment and strengthening of well-equipped training institutions. These centers are encouraged to collaborate with reputed international companies and experts to deliver high-quality training programs, improving the skill base of the industry.

B. Licensing Policy

As part of its industrial liberalization efforts, the government has simplified licensing procedures in the leather sector. Following the de-reservation of 11 key leather items—including semi-finished hides and skins, leather shoes, shoe components, polyurethane soles, eyelets, and other accessories (Notification No. SO 603(E), dated 29th June 2001)—most leather manufacturing activities no longer require an industrial license.

Instead, businesses wishing to set up units for these products must file an Industrial Entrepreneurs' Memorandum (IEM) with the Secretariat for Industrial Assistance, under the Department for Promotion of Industry and Internal Trade (DPIIT), Government of India. The process is designed to be straightforward, involving a prescribed format and fee submission.

However, while licensing requirements have been relaxed, new projects must still comply with central and state environmental regulations, including zoning laws and land-use policies. These measures ensure that industrial development aligns with sustainable and responsible practices.

Some leather products—such as leather sandals and chappals, garments, industrial gloves, travel goods, purses, handbags, fancy leather goods, and watch straps—remain reserved for the small-scale sector. Investment limits in plant and machinery define these. Suppose a non-small-scale unit wishes to manufacture these reserved items. In that case, it must obtain an industrial license, which is granted on the condition that at least 50% of the annual production is exported.

Overall, the government's policy framework aims to promote investment, upgrade technology, support skill development, and encourage export-oriented growth, while ensuring that environmental and social standards are upheld.

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V. OVERVIEW OF STUDY REGIONS

A. Leather Industry in Kolkata and Punjab (CLC)

Kolkata: A Key Tanning Hub in India. Kolkata, the capital of West Bengal, is one of the most prominent leather tanning centres in India. The city currently hosts around 538 operational tanneries, which are distributed across three major clusters: Tangra, Tiljala, and Topsia.

i. Tangra is the largest cluster, with 267 tanneries, primarily processing hides. It has an estimated annual leather production capacity of 31 million square meters, handling approximately 565 tonnes of hides per day.

ii. Tiljala follows with 223 tanneries, also focused on hide processing. Its estimated annual capacity is 7 million square meters of leather, using 125 tonnes of hides per day.

iii. Topsia, the smallest of the three, consists of 48 tanneries, mainly processing skins. Despite having fewer units, it boasts a high output, producing 14 million square meters of leather per year with 160 tonnes of hides per day.

Combined, these clusters have a total estimated production capacity of 52 million square meters of leather per year, processing around 850 tonnes of hides daily. However, actual output falls short of this potential. According to current estimates, the clusters produce less than 50% of their capacity—approximately 23 million square meters annually.

The tanning industry in these areas is predominantly based on chrome tanning, which accounts for about 85% of the processes. Vegetable tanning, or bag tanning, constitutes only 15%, reflecting its relatively limited role in the region.

Historically, these tanning zones were located on the outskirts of the city, away from residential areas. However, over the decades, urban expansion has led to dense populations surrounding these clusters. This has created several challenges, especially related to environmental management and modernization [9].

According to the Central Leather Research Institute (CLRI), around 30,000 people are employed in the tanneries of Kolkata. Yet, these tanneries now face significant constraints:

i. Lack of space prevents the installation of modern pollution control equipment.

i. Effluent treatment and waste disposal systems are largely absent, leading to severe environmental degradation.

ii. Wastewater is often discharged into open roadside drains, which frequently become clogged, causing local flooding.

iii. Solid waste is dumped without regulation, worsening hygiene and health conditions in the surrounding areas.

iv. A persistent foul odour affects the quality of life for nearby residents.

v. Local water bodies, including the Bhangar and Beleghata canals, have been heavily polluted due to untreated discharges from these clusters.

In 1999, CLRI conducted a comprehensive inventory of 303 operational tanneries in these clusters. The report categorized them based on their production stages and daily processing capacity:

i. *Raw to Wet Blue to Finished Leather:* 206 units processing 490 tonnes per day

ii. *Crust to Finished Leather:* 26 units processing 142 tonnes per day

iii. *Mixed Processes:* 2 units processing 1.3 tonnes per day

iv. *Wet Blue to Finished Leather:* 33 units processing 240 tonnes per day

This situation underscores the urgent need for sustainable solutions, such as relocation, modernisation, or the development of centralised treatment and waste management facilities, to support the long-term viability of Kolkata's leather industry without compromising the environment or public health.

Tanneries, or leather processing industries, generate significant pollution throughout the production cycle — from raw hide preservation to the creation of finished leather. Processing 1,000 kilograms of hides or skins typically produces about 30–40 cubic meters of wastewater and 800–850 kilograms of solid waste, which together contain roughly 300 kilograms of harmful chemicals. Bangladesh holds considerable potential for growth in this sector, thanks to its ample supply of high-quality raw materials and relatively low production costs. However, the industry struggles to remain competitive due to poor environmental sustainability (ES) practices among its tanneries. In recent years, ES has become a critical concern for the global leather industry, primarily driven by climate change and environmental degradation. Additionally, many international buyers and consumers now prefer sourcing leather and leather goods from environmentally responsible producers. As a result, adopting sustainable practices has become essential for the long-term viability and competitiveness of the leather processing industry worldwide [10].

B. Kolkata Leather Complex (KLC): A Step Toward Sustainable Industrial Relocation

The West Bengal Government (GoWB) recognised the urgent need to address the growing environmental issues caused by the concentration of tanneries within Kolkata's urban zones as early as 1992. In response, it proposed relocating tanneries to a new, modern industrial complex equipped with a Common Effluent Treatment Plant (CETP) to manage wastewater safely and sustainably.

A concept report for this project was prepared in 1993 by the Central Leather Research Institute (CLRI), Chennai, under the UNIDO-assisted National Leather Development Programme. Initial steps to develop the Kolkata Leather Complex (KLC) began soon after. However, public complaints over environmental degradation intensified during the mid-1990s, prompting further action.

In 1996, the Supreme Court of India intervened and ordered that all tanneries be relocated to the new site being developed by the state. This judicial directive accelerated the implementation of the KLC, giving the project national importance and legal urgency.

i. *Location and Scope*

The proposed site for the complex covers 438 hectares

in the South 24 Parganas district, located about 22 km from Kolkata along the Eastern Metropolitan (E.M.) Bypass, near the Bhangar Kata canal. Most of the land was government-owned and was acquired by the state with relative ease. Some portions—54 hectares—are still under litigation, while 84 hectares are currently in the process of being purchased. Approximately 300 hectares have already been secured.

The KLC is designed to be a comprehensive hub for the leather industry, accommodating all activities from tanning to finished leather goods manufacturing. The project is being developed under a Build-Operate-Transfer (BOT) model, given the government's limited technical and financial capacity. In 1997, the BOT contract was awarded to M.L. Dalmiya & Co. Ltd., Kolkata.

ii. Infrastructure Development

Construction began in 1997, with significant activities including landfilling, construction of roads, canals, and water bodies. The site, initially flat and low-lying, has been raised by about 1 meter to reduce flood risk, though it remains 1.8 meters below the level of the Kolkata–Basanti Road.

iii. Key infrastructure components include

- **Electricity Supply:** The estimated demand is 80 MVA, to be supplied by the West Bengal State Electricity Board (WBSEB) at 132 kV. The state government has already established a substation.
- **Water Supply:** Groundwater will be the primary source, drawn from 25 deep tube wells (300 meters deep), yielding approximately 36.75 million litres per day (MLD). Rainwater harvesting will supplement this, using ponds and canals developed within the complex.

iv. CETP and Waste Disposal

- 8.7 hectares have been allocated for the Common Effluent Treatment Plant, located in the eastern section of the complex.
- An additional 20.2 hectares just south of the KLC will be used for solid waste and sludge disposal.

v. Employment and Economic Impact

Once fully operational, the KLC is expected to generate around 80,000 jobs, with approximately 33,000 positions in the tannery sector alone. The project aims not only to address environmental concerns but also to modernise the leather industry, support job creation, and increase the sector's global competitiveness [11].

vi. Note on Punjab Leather Industry

While the focus of this section is on Kolkata, it is also important to note that Punjab has a longstanding leather tradition. Known for its skilled craftsmanship, Punjab's leather industry has evolved significantly—from its pre-colonial agricultural roots to the adoption of modern processing technologies during and after the colonial period. Today, the region contributes meaningfully to exports and employment, producing both traditional leather goods and contemporary fashion items [12].

VI. RESULTS & DISCUSSIONS

A. Environmental Impact of Leather Processes

The leather industry plays a significant role in global trade and holds substantial economic importance. However, it continues to face criticism for its environmental impact, particularly as a major contributor to water pollution.

Tannery effluents contain a range of pollutants, including proteins, hair, salts, lime, sludge, and sulphides. Over time, these contaminants severely degrade the quality of groundwater around tannery sites. Local farmers often report a decline in soil fertility, attributing it to the dumping of untreated tannery waste and effluents.

One of the key reasons behind the industry's high environmental footprint is the extensive use of chemicals during processing. These chemicals contribute to soil and water pollution when released as effluents. Additionally, air pollution is caused during dehairing (from hydrogen sulfide emissions), deliming (ammonia release), and through the emission of solvent vapours. The pollutants are often slow to degrade, increasing their environmental persistence [13].

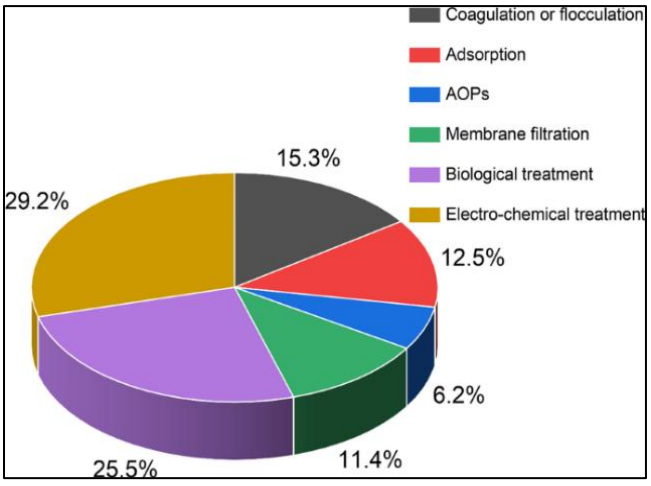
To address these issues, cleaner tanning technologies have been introduced. These involve using higher-quality chemicals with optimal dosing and incorporating water conservation practices throughout the process. Modern tanneries have also adopted advanced wastewater treatment technologies. These systems not only treat the wastewater for reuse within the plant but also enable salt recovery from concentrated waste, significantly reducing environmental harm.

B. Water Consumption and Pollution Load

Producing leather from one ton of raw hides requires approximately 15,000 to 40,000 litres of water. For individual sheepskins, the water requirement ranges from 110 to 260 litres [14]. These processes generate 20% to 80% of their input as effluent, which contains 100–400 ppm of chromium, 200–800 ppm of sulfides, fats, solid waste, and pathogens.

Additionally, pesticides used to preserve hides during transport contribute further to the pollution load.

Figure 3 illustrates the volume of water used across various leather processing stages, along with the corresponding volume of wastewater discharged. Both are expressed in litres per kilogram of processed hides or skins.



[Fig.2: Water Use and Wastewater Generation in Different Leather Processing Stages]

C. Solid Waste Generated by Tanneries

Tannery operations produce substantial amounts of solid

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waste throughout different stages of the leather production process. (Daniels, 2005). The waste includes a variety of byproducts, with approximate quantities (per tonne of raw material) as follows [15]:

i. *Raw trimmings:* 80–120 kg
ii. *Hair/wool:* 40–50 kg
iii. *Fleshing waste:* 250–300 kg
iv. *Wet blue trimmings:* 100–110 kg
v. *Wet blue shavings:* 90–120 kg
vi. *Crust trimmings:* 6–8 kg
vii. *Buffing dust:* 1–2 kg

These waste materials contribute to the overall pollution load of the tanning industry and require proper disposal or treatment [16]. The characteristics of tannery effluents at various stages of processing are summarized in Table 4.

D. Industry Improvements over the Last Three Decades

The leather industry significantly contributes to environmental pollution and degradation, necessitating government intervention. Furthermore, resource allocation to this sector should be approached with caution. Policymakers should explore strategies to minimize leather usage wherever feasible, while remaining mindful of global market competition. The lack of transparency in the Indian leather industry's social and environmental practices restricts both the availability of reliable data and the capacity of researchers to diagnose issues and propose solutions accurately. For example, several critical performance indicators—such as the Effluent Treatment Index (ETI), Solid Waste Disposal Index (SWDI), Emission Index (EmI), and Percentage of Community Welfare Expenditure (PCWE)—had to be excluded due to insufficient data. Moving forward, comprehensive case studies focusing on leading states are essential to evaluate the impact of different leather production technologies across the three dimensions of sustainability. In addition, the operation of Common Effluent Treatment Plants (CETPs)—particularly regarding capital investments and operational costs—requires detailed examination to ensure both their long-term sustainability and that of the industry. The proposed sustainability framework can also be adapted to other high-impact sectors such as textiles, sugar refining, and pharmaceuticals [17].

Table V: Characteristics of Tannery

Parameter	Soaking	Liming/ Reliming	Delimin g	Pickling	Chrome Tanning	Neutralisation	Rechroming Dyeing, Fat liquor	Total (Including Washings)
Volume of effluent/tone of hide/skins	6-9 m^3	3-5 m^3	1.5-1 m^3	0.5-1 m^3	1-2 m^3	2-3 m^3	3-6 m^3	30-40 m^3
PH	7.5 – 8.0	10.0-12.8	7.0-9.0	2.0-3.0	2.5-4.0	4.0-6.5	3.5-4.5	7.0-9.0
BOD 5-day at 20 °C (Total)	1,100-2,500	5,000-10,000	1,000-3,000	400-700	350-800	800-1100	1000-2000	1200-3000
COD (Total)	3,000-6,000	10,000-25,000	2,500-7,000	1000-3000	1000-2500	2000-4500	2500-7000	2500-8000
Sulphides (as S)	-	200-500	30-60	-	-	-	-	30-150
Total Solids (TS)	35,000-55,000	24,000-48,000	5,000-12,000	35,000-70,000	30,000-60,000	10,000-14,000	4000-9000	12,000-23,00
Total Dissolved Solids (TDS)	32,000-48,000	18,000-30,000	3000-8000	34,000-67,000	29,000-57,500	9000-12,500	3600-8000	9000-18,000
Suspended Solids (SS)	3,000-7,000	6000-18,00 0	2000-4000	1,000-3,000	1,000-2,500	1000-1500	400-900	2000-5000
Chlorides (as Cl)	15,000-30,000	4,000-8,000	1,000-2,000	20,000-30,000	15,000-25,000	1500-2500	300-1000	6000-9500
Sulphate as SO4	800-1500	600-1200	2000-4000	12,000-18,000	12,500-19,000	1000-2000	1200-2500	1600-2500
Chromium (as Total Cr)	-	-	-	-	1500-4000	15-30	50-300	120-200

As per Table 4, the leather industry's effluent is complex, highly variable, and laden with organic matter, salts, and heavy metals. It requires comprehensive treatment measures, including the segregation of waste streams, chromium recovery, sulphide oxidation, and advanced physico-chemical and biological treatment systems, before discharge.

Table VI: Leather Industry Improvement in India (Value in Million Rupees) [18]

Item	1972	1991	1998	2001	2011
Value of production	3,000	59,570	110,560	160,000	2,80,000
Export	1,830	32,170	69,560	92,120	2,33,323
Domestic consumption	1,170	27,400	41,000	67,880	92,320

Table 5 clearly indicates a significant and consistent growth in India's leather industry between 1972 and 2011. The value of production increased almost 93 times, while exports grew over 127 times during the same period, showing the industry's strong export-oriented nature. Although domestic consumption also expanded substantially, the rate of increase in exports was much higher, highlighting the sector's growing integration into global markets and its importance as a major contributor to foreign exchange earnings.

VII. CONCLUSION

The leather industry has played a significant role in India's economic development, serving as a primary source of employment and foreign exchange. However, traditional leather processing methods have also posed serious environmental challenges due to the discharge of harmful organic and chemical pollutants into soil and water bodies. Over time, growing awareness of environmental issues—mainly since the 1990s—has led to a shift in focus toward

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more sustainable production methods. The industry's ecological footprint has gradually decreased, thanks to the adoption of effluent treatment technologies and cleaner tanning processes. To tackle the problem of wastewater, Effluent Treatment Plants (ETPs) were established across leather clusters. In recent decades, further advancements—such as Reverse Osmosis (RO) systems—have enabled the treatment and reuse of wastewater within the tanning process. Smaller units often manage RO brine through solar evaporation, while larger facilities use multiple-effect evaporators to recover salt and reduce waste. These efforts reflect the industry's ongoing commitment to sustainability. The integration of clean technologies and modern wastewater treatment solutions has not only helped minimise environmental damage but also positioned the leather sector to meet global expectations for environmentally responsible manufacturing.

DECLARATION STATEMENT

After aggregating input from all authors, I must verify the accuracy of the following information as the article's author.

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