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Toxic Tanning: An Appraisal on the Environmental Cost of Kolkata's Leather Industry

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ABSTRACT: The leather industry in India contributes significantly to the economy but imposes considerable environmental and public health costs. This study examines chromium contamination at the Calcutta Leather Complex (CLC) in Kolkata, located within the East Kolkata Wetlands. Water and sludge samples from effluent discharge points, canals, and drinking sources were analyzed using Atomic Absorption Spectroscopy. Results show that while drinking water and some surface water sources remain below the permissible chromium limit of 0.05 mg/L, downstream canal water exhibits elevated levels (0.11–0.27 mg/L), and sludge near discharge points reaches 1.39 mg/L. Interviews with 30 residents and workers revealed widespread perceptions of water pollution, drainage overflow, black sludge accumulation, and recurring health issues, including skin and urinary ailments. Findings highlight cumulative environmental contamination, occupational risks, and gaps in water safety and awareness. The study recommends enhanced monitoring, improved effluent treatment, sediment management, occupational protections, and community engagement to mitigate the impacts of Kolkata's leather industry.

KEYWORDS: Chromium, chromium contamination, leather industry, Calcutta Leather Complex, East Kolkata Wetlands, environmental pollution, occupational health, wastewater management

I. INTRODUCTION

Leather has been an integral part of human civilization since prehistoric times. Despite significant societal advancements over the centuries, the fundamental process of leather tanning has remained largely unchanged. With the industrialization of multiple sectors, the leather industry has also gained global significance.

In India, the leather industry is the 10th largest manufacturing sector, contributing substantially to the economy through production, export earnings, and employment opportunities. The sector employs approximately 2.5 million people, with a large portion belonging to economically weaker sections of society, including around 30% women (Suresh & Padmavathi, 2017). Small and medium enterprises dominate the industry, which is geographically diverse, though Tamil Nadu, Uttar Pradesh, and West Bengal account for the majority of production. Key centers for leather and leather products include Chennai, Ambur, Ranipet, Vaniyambadi, Trichy, and Dindigul in Tamil Nadu; Kolkata in West Bengal; Kanpur, Agra, and Noida in Uttar Pradesh; Jalandhar in Punjab; Bahadurgarh and Manesar in Haryana; Bangalore in Karnataka; as well as Delhi and Hyderabad in Andhra Pradesh.

In Bengal, the leather industry initially operated on a small scale as a home-based trade led by Chamar tanners. The arrival of Chinese tanners in the late 18th century led to restructuring, followed by further changes during the Swadeshi and Boycott Movement in 1905. Eventually, in 1996, the industry was relocated to Bantala (Pal, 2024). Its development has been shaped by socio-political and economic factors. The Calcutta Leather Complex (CLC), situated at 22.4920° N, 88.5146° E, lies about 20 km from Kolkata and is part of the Ramsar-designated East Calcutta Wetlands (ECW) ecosystem (Site No. 1208). This complex houses around 300 government-approved tanneries, which process approximately 1,000 tons of raw hides and skins per day (Pal & Mukhopadhyay, 2018).

For nearly a century, effluents from tanneries and leather industries have severely polluted the environment in and around Kolkata. Tannery waste contains toxic heavy metals, including chromium, lead, cadmium, and nickel, which can leach from landfill sites into the surrounding ecosystem (Shackelford, 1990; Yong & Phadungchewit, 1993; Chalermyanont et al., 2009). chromium, extensively used in leather tanning, can accumulate in soil and groundwater, raising serious environmental concerns. The uncontrolled disposal of tannery sludge allows hazardous substances to infiltrate subsurface soil and groundwater, posing significant risks to public health and the environment.

This paper investigates the environmental and human health impacts of effluents released from the Calcutta Leather Complex, highlighting the challenges posed by pollution and potential mitigation strategies.

II. OBJECTIVES

1. To examine the entry points of chromium contamination into the environment
2. To assess the levels of contamination of chromium in the surrounding water sources
3. To assess the impact of chromium on human health

III. LITERATURE REVIEW

The chrome used for tanning eventually finds its way out into the environment through wastewater. Through effluent discharge, it persists into the sludge as chromium hydroxide (Minas et al., 2017) and is adsorbed by sediment/soil. The adsorbed chromium could be eluted to groundwater (Srivastava et al., 2013; Hashem et al., 2015). Studies have detected significant chromium concentrations in soil near tanneries where effluents and sludge are not properly treated (Homa et al., 2016). Research has demonstrated that chromium, particularly hexavalent chromium, bioaccumulates in photosynthetic organisms (Chattopadhyay et al., 2002; Parveen & Arjun, 2011; Homa et al., 2016) and disrupts metabolic processes. Excessive chromium in soil can prevent proper seed germination (Beg & Ali, 2008). chromium also accumulates in freshwater fish, as documented by Chattopadhyay et al. (2002), Vutukuru (2003), Palaniappan & Karthikeyan (2009), Murtala et al. (2012) and Sanyal et al. (2017).

Moreover, chromium is hazardous to human health. It is known to cause dermatitis, mucosal ulcers, respiratory illnesses, and cancer, among other health problems (Verma et al., 2001; Chandra et al., 2011; Madhavi et al., 2013; Mishra & Bhargava, 2016). In tanneries, the workers are exposed daily to high levels of chromium. chromium enters their bodies through inhalation (Proctor et al. 2021). The oral route exposure to Cr is due to contaminated drinking water (U.S. EPA, 1998).

At the Calcutta Leather Complex (CLC), chromium-laden wastewater is discharged into canals that ultimately flow into the East Calcutta Wetlands (EKW). Chattopadhyay et al. (2002) documented chromium bioaccumulation at six sites across EKW, while Agarwal et al. (2023) examined chromium contamination in the Dhapa dumping grounds within the wetlands. Additionally, Patra et al. (2001) reported chromosomal aberrations in mice and rats that consumed garbage and sewage-cultivated vegetables such as cauliflower, spinach, and radishes from the wetlands. Maurya et al. (2023) further investigated chromium toxicity among leather industry workers at CLC, highlighting significant occupational exposure risks.

Despite significant research on tannery sludge contamination in CLC and EKW, studies focusing on chromium contamination in the drinking water of tannery workers and local residents remain limited. Ghosh et al. (2012) investigated chromium contamination in vegetables and food fish in areas affected by tannery discharge, highlighting potential dietary exposure risks. However, there is still a crucial gap in understanding pathways of chromium exposure including direct chromium exposure through drinking water in the region. Addressing this issue is essential for assessing public health risks and developing mitigation strategies.

IV. MATERIALS AND METHODS

A. Analysis of Water for Heavy Metal Contamination

To investigate chromium contamination in and around the Calcutta Leather Complex (CLC), six samples were collected from strategically chosen sites representing effluent discharge points, surface water bodies, and potable water sources within the complex. These sites were selected to evaluate both environmental impact and potential human exposure.

1) **Sampling Sites:** Samples were collected from a few locations and labelled as follows:
   - BAN-G2-1-WATER: Wastewater sample from the main effluent canal near the final discharge point.
   - BAN-G2-1-SLUDGE: Sludge sample from sediment deposits at the same discharge site.
   - BAN-G2-2: Intermediate canal segment within the complex.
   - BAN-G2-3: Canal entry point near the post-tanning unit.
   - BAN-G2-DW: Drinking water sample from water can used within the complex, identical to ones used largely throughout CLC..
   - BAN-G3-P: Surface water from a freshwater pond within the CLC frequented by workers and residents.

2) **Sample Collection and Preservation:** Water samples were collected using sterile 20 mL polypropylene syringes to minimize contamination and microbial interference. Each sample was immediately transferred to acid-washed polyethylene bottles, pre-labeled and rinsed three times with the sample water before final collection.

The sludge sample was collected using an identical methodology.

3) Analytical Procedure: Chromium concentrations were determined using Atomic Absorption Spectroscopy (AAS) at the specific absorption wavelength of 357.9 nm, corresponding to total chromium. Chromium analysis was conducted in accordance with national guidelines (Bureau of Indian Standards [BIS], 2019a). Results below the threshold of IS 10500:2012 (Bureau of Indian Standards [BIS], 2019b) drinking water standards were recorded as <0.05 mg/L.

B. Qualitative Interviews

A qualitative, exploratory study was also conducted using semi-structured interviews to document individual perceptions, experiences, and concerns related to the environmental and health impacts of the leather industry. The goal was to understand both direct and indirect effects of tannery operations on people residing or working in the CLC region.

A convenience-based saturation approach was used, aligned with purposive field interception. The research team physically walked through different zones of the CLC-tannery units, adjoining residential areas, local markets, and informal workspaces-and interviewed individuals on the spot until the target of 30 interviews was reached. Participants were approached randomly in terms of location and timing, with inclusion criteria of being over 18 years of age, having a direct association with the CLC, and willingness to speak voluntarily.

1) **Interview Protocol and Ethics:** Each participant was asked 14 open-ended questions on environmental conditions, health concerns, waste management, and institutional responses. Interviews were conducted in Bengali or Hindi and lasted 10–25 minutes. All participants gave verbal informed consent, and no personal identifiers were recorded.
2) **Data Analysis:** Responses were transcribed and thematically coded into categories such as environmental impact, health perception, institutional trust, and community resilience.

V. RESULT

A. Results of Chromium Quantification

Table I: Chromium Concentrations Detected in Water and Sludge Samples from the Calcutta Leather Complex

Sample ID	Detectable Chromium (mg/l)	Maximum Permissible Concentration in Drinking Water (as per IS10500) (in mg/l)
BAN-G2-3	<0.05	0.05
BAN-G2-2	0.11	
BAN-G2-1-WATER	0.27	
BAN-G2-1-SLUDGE	1.39	
BAN-G2-DW	<0.05	
BAN-G3-P	<0.05	

Chromium concentrations varied significantly across the sampled locations (Table I). Samples from the drinking water source (BAN-G2-DW), the pond near Gate No. 3 (BAN-G3-P), and the discharge point of the post-tanning unit (BAN-G2-3) all had chromium concentrations below 0.05 mg/L, the maximum permissible concentration for drinking water (IS 10500:2012). However, higher concentrations were detected further downstream.

In contrast, the water sample collected further downstream (BAN-G2-2) shows higher levels of chromium (0.11 mg/l). The water (BAN-G2-1-WATER) sample and sludge (BAN-G2-SLUDGE) sample collected near the canal discharge point show increased levels of chromium (0.27 and 1.39 mg/l, respectively).

The sludge sample near the discharge point exhibited a particularly high concentration of chromium, indicating significant accumulation of chromium in the sediments.

B. RESULTS OF INTERVIEWS

The survey covered 30 individuals associated with the Calcutta Leather Complex (CLC), encompassing tannery workers, residents, and small business owners. The responses provide a grassroots-level understanding of the lived experiences of pollution, awareness, and infrastructural conditions in the area. Key findings are outlined below:

1) **Awareness of Chromium and Environmental/Health Hazards:** Only 8 respondents explicitly recognized chromium as a harmful substance. Another 8 were aware of pollution-related health issues but not specifically about chromium. A substantial

number (10) were entirely unaware of any health or environmental dangers, while 4 chose not to respond. **Perception of Water Contamination:** All 30 respondents reported the *consistent* presence of unusual color, smell, or foaming in their nearby water sources, indicating widespread and visible signs of contamination.

2) **Drainage and Sewage Overflow:** 22 respondents noted that drains overflow onto roads or workspaces *throughout the year*, while the remaining 8 reported such overflows *during the monsoon season*, confirming chronic infrastructural inadequacies.
3) **Use of Contaminated Surface Water:** Although the area is surrounded by ponds and canals, only 4 respondents reported *rare* usage of these water bodies for daily chores; the remaining 26 reported *never* using them, possibly due to visible pollution or health concerns.
4) **Water-Related Illnesses:** While 11 respondents reported *frequent* (usually) cases of water-related illnesses in their families, 4 experienced such issues *rarely*, and 15 denied any occurrence. The results suggest health problems are common but not uniformly experienced.
5) **Types of Ailments:** Among specific ailments, *skin diseases* (8 respondents) and *urinary tract infections* (UTIs, 4 respondents) were the most commonly cited. One respondent mentioned that toxic gases released from drains posed fatal risks to cleaners. 15 respondents did not report any relevant illnesses, and 2 chose not to disclose.
6) **Seasonal Aggravation of Health Issues:** Only 4 respondents reported a direct *increase* in health problems during the rainy season. However, 11 noticed *occasional* worsening of conditions during rains, suggesting that stagnant water and overflow may exacerbate existing issues.
7) **Black Sludge in Canals and Drains:** All respondents observed the presence of black sludge. 11 reported it as a *constant* feature, while 19 noted it appeared *especially* when canals were not cleaned, reinforcing the connection between poor waste management and sludge accumulation.
8) **Perceived Source of Sludge:** A majority (23) identified *rawhide waste* as the primary source of sludge. Four chose not to disclose this information, and three were unsure.
9) **Awareness of Sludge Cleaning or Drainage Projects:** 14 respondents were *aware* of dredging or widening operations. However, 6 had limited or vague awareness, and 10 were *not aware* of any remedial efforts, highlighting gaps in public communication.
10) **Access to Treated Water:** Only 8 respondents reported having access to filtered water at their workplaces. The remaining 22 stated they relied on *external sources*, often at personal cost, to obtain clean water.
11) **Occupational Background:** The interviewees included a mix of professions: 11 *finished goods workers*, 4 *raw goods workers*, 4 *machinery repairmen*, and 11 *food shop owners*, representing both industrial and service sectors around the CLC. **Workplace Safety and Precautions:** While 8 respondents affirmed that their companies *took safety measures*, 4 noted a *lack of precautions* especially for rawhide handlers. Eleven marked this question as *not applicable*, and 7 declined to answer, reflecting variability in working conditions.
12) **Common Issues Faced by Workers/Residents:** The most cited concern (19 respondents) was the *lack of proper water sources*, forcing them to rely on bottled water. Additional issues included *skin diseases* (4) and *water stagnation on roads* (4), indicating both health and infrastructural challenges.

VI. DISCUSSION

Sampling results show that while some water sources remain below detection limits, chromium concentrations increase along effluent canals and are particularly high in sediment sludge. These findings indicate that industrial discharges contribute to a persistent and cumulative build-up of heavy metals in the local ecosystem. The low levels of chromium in the pond near Gate No. 3 (BAN-G3-P) and the drinking water source within the complex (BAN-G2-DW), both below the detection limit of 0.05 mg/L, indicate that these particular water sources do not pose an immediate risk of chromium exposure via ingestion. These values suggest that either the groundwater source is currently unimpacted, or effective filtration and treatment mechanisms-such as those at this particular water treatment and bottling plant-are successfully removing chromium to meet potable water standards.

Similarly, the low chromium concentration at the post-tanning unit discharge point (BAN-G2-3), which is also below 0.05 mg/L, indicates that chromium contamination is not occurring directly at this location, outside of designated effluent pathways. This supports the inference that chromium entry into the surrounding environment is largely restricted to specific points of discharge, rather than being widespread across the complex.

However, as the canal system progresses downstream, there is a clear accumulation of chromium, with 0.11 mg/L detected at an intermediate canal point (BAN-G2-2) and 0.27 mg/L near the canal outlet (BAN-G2-1-WATER). These values exceed the IS 10500 drinking water limit of 0.05 mg/L, suggesting that cumulative discharge-likely from multiple sources including both tannery and post-tanning units-is progressively contaminating the effluent stream. As the effluent canal flows into the Science City canal, which ultimately drains into the East Kolkata Wetlands (EKW), chromium is introduced into the broader environment through this discharge pathway. This finding aligns with earlier studies that have documented bioaccumulation of chromium in aquatic systems and organisms across EKW (Chattopadhyay et al., 2002; Parveen & Arjun, 2011; Homa et al., 2016), as well as soil contamination and adverse biological effects resulting from sewage-irrigated agriculture and landfill leachates within the wetlands (Patra et al., 2001; Agarwal et al., 2023).

Most notably, the sludge sample near the canal outlet (BAN-G2-1-SLUDGE) exhibited a chromium concentration of 1.39 mg/L, reflecting significant accumulation in sediment. This is consistent with studies such as Minas et al. (2017), which highlight the tendency of chromium to precipitate as chromium hydroxide and settle in sediments, potentially acting as a long-term reservoir of contamination. During events like heavy rainfall or dredging, such sediments may resuspend, reintroducing chromium into the water column and extending the risk of downstream exposure.

These trends in chemical contamination strongly resonate with the perceptions and lived experiences of the local residents and workers interviewed in this study. All 30 respondents reported unusual colour, odour, or foam in nearby water sources-consistent with signs of industrial discharge-while 22 observed constant drainage overflow in their areas. Furthermore, black sludge was observed either constantly or periodically by all respondents, with 23 specifically identifying rawhide processing units as the primary source.

The combined chemical and qualitative data illuminate not only the pathways of chromium contamination at the Calcutta Leather Complex (CLC) but also the complex socio-occupational factors shaping local perceptions and disclosures.

i. **Occupational Context and Perceptual Biases:** Observations of environmental conditions-such as drainage overflow and black sludge-varied with respondents' occupations. Finished-goods and rawhide workers, who spend long hours adjacent to effluent canals, were more likely to report constant overflow and sludge accumulation. In contrast, food shop owners, whose workstations are set back from the tannery precincts, sometimes qualified their observations ("when the canal hasn't been cleaned," 19 of 30) rather than stating an unqualified "always." This suggests that proximity to pollution sources heightens both the frequency and the certainty of pollution reports.
ii. **Silence and Vulnerability among Rawhide Workers:** Among rawhide handlers-four of whom "chose not to answer" when asked about chromium awareness-reluctance likely stems from a combination of low technical literacy about specific contaminants and fear of employer reprisal. These workers occupy the most precarious tier of the tanning process, handling untreated hides without formal safety training. Admission of ignorance could expose them to accusations of negligence, while admission of awareness might invite scrutiny of their employers' practices. Their silence thus reflects both an information gap and a protective response against potential job insecurity.
iii. **Non-Response among Food Shop Owners on Workplace Safety:** All 11 food shop owners selected "not applicable" when queried about workplace safety measures-an understandable choice given that their businesses do not involve direct contact with industrial chemicals or raw hides. Their exclusion from this question underlines the importance of tailoring occupational health inquiries: questions about PPE and effluent exposure must distinguish clearly between industrial and ancillary workers to avoid conflating disparate work environments.
iv. **Interplay of Environment, Health, and Access:** Nearly two-thirds of all respondents (19 of 30) identified "no proper water sources" in the CLC as their principal grievance, forcing reliance on bottled or external water supplies. Yet only 8 reported employer-provided filtration units, primarily in larger factories.

VII. LIMITATIONS

A. Sample Size and Scope

Only six water/sludge samples were analyzed, which limits the spatial resolution of contamination mapping. Likewise, interviews were conducted with 30 participants via convenience sampling, so findings may not fully represent all occupational or residential experiences around CLC.

B. Seasonal Bias

Sampling and interviews occurred during a single season. Chromium concentrations and overflow events may vary between monsoon and dry seasons, affecting both analytical results and community observations.

C. Chromium Speciation

Total chromium was measured by AAS without distinguishing between trivalent [Cr(III)] and hexavalent [Cr(VI)] forms. Since Cr(VI) poses greater human-health risks, future work should include speciation

VIII. FUTURE SCOPE

These findings highlight several priorities.

1) Longitudinal monitoring across seasons and expanded sampling-incorporating chromium speciation (Cr(III) vs. Cr(VI))-would capture temporal spikes and better quantify health risks.
2) Bio-monitoring in fish, macrophytes, and sediment will clarify ecological transfer, while clinical health surveys (e.g., urinary chromium, dermatological screenings) can objectively assess human exposure.
3) Geospatial modeling of effluent plumes, combined with community-driven data collection, could pinpoint high-risk zones for targeted remediation.
4) Finally, pilot trials of advanced effluent treatments (e.g., electrocoagulation, bioremediation) at small tannery units would test scalable solutions to reduce downstream chromium loads.

IX. CONCLUSION

This study establishes that the Calcutta Leather Complex (CLC) poses significant environmental and public health challenges linked to chromium contamination. Sampling results show that while some water sources remain below detection limits, chromium concentrations increase along effluent canals and are particularly high in sediment sludge. These findings indicate that industrial discharges contribute to a persistent and cumulative build-up of heavy metals in the local ecosystem.

Field interviews confirm the environmental data, with residents and workers describing discoloured water, drainage overflow, and sludge accumulation around canal and tannery areas. Although few respondents identified chromium specifically, many reported skin infections, gastrointestinal issues, and other water-related illnesses. The widespread dependence on external water sources further reflects growing mistrust of local supplies.

Working conditions within the tanneries reveal additional risks. Limited use of protective equipment, lack of regular health monitoring, and minimal awareness of chemical exposure point to weak occupational safeguards. Several participants expressed reluctance to discuss industrial operations, suggesting socio-economic vulnerability and fear of reprisal. Together, these factors expose a situation where environmental degradation and human insecurity reinforce one another.

The study therefore concludes that chromium contamination at the CLC is not an isolated problem but part of a larger system of unregulated industrial growth and social inequity. Effective response requires stronger monitoring, improved waste and effluent management, and inclusive mechanisms to protect workers and surrounding communities. Without these interventions, the pollution legacy of the leather industry will continue to undermine both ecological health and human well-being in the region.

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