Migration Letters

Volume: 20, No: S9 (2023), pp. 1834-1844

ISSN: 1741-8984 (Print) ISSN: 1741-8992 (Online)

www.migrationletters.com

Towards Sustainable Tannery: Advanced Recycling And Reuse Of Tannery Wastes

[1]Selma Abd Elrahman Hussein, [2]Zeinab Abdallah Elhassan ,[3]Gurashi Abdallah Gasmelseed

Abstract

The global tannery industry, a cornerstone of many economies, faces significant challenges in managing its waste sustainably. Addressing the environmental and economic concerns associated with tannery wastes requires innovative solutions such as advanced recycling and sustainable reuse techniques. This research, conducted in January 2022, delved into waste management practices at three diverse tanneries in Sudan. Ranging from large to small-scale operations, these tanneries offered a comprehensive view of prevailing challenges and solutions. Through meticulous site visits and interviews with tannery staff, current methodologies were documented, p[1]roviding a foundation for the study's focus: the potential of ultrafiltration as a sustainable recycling technique. Laboratory analysis of collected wastewater samples, totaling 150 in number, demonstrated the promising efficiency of ultrafiltration: a removal rate of 92.5% for COD, 87.5% for fats, 85% for proteins, and 60% for suspended solids. Beyond the environmental advantages, a cost-benefit analysis accentuated the economic rationale behind adopting ultrafiltration, considering factors like equipment costs, maintenance, energy consumption, and the tangible benefits from wastewater reuse. The results form a compelling narrative for the adoption of ultrafiltration in tanneries, presenting a solution that is not only environmentally responsible but also economically pragmatic. Moreover, communities surrounding these tanneries stand to gain substantial health benefits through reduced pollution and lesser strain on local water sources. With recommendations rooted in robust data and aligned with existing literature, this study paves the way for a more sustainable future for the tannery industry.

1. Introduction

1.1. Background and Significance

The global tanning industry, central to the world market, primarily converts animal hides into adaptable leather, catering to sectors like footwear, fashion, and upholstery[1]. With its multi-billion-dollar footprint and expansive job creation, countries such as Italy, India, China, Brazil, and recently, the United States, play pivotal roles. However, despite its vast presence and

[1]Prince Sultan University, Saudi Arabia,
[2]Prince Sultan University, Saudi Arabia
[3]University of Science and Technology, Sudan

historical significance, there's a knowledge gap regarding its exact economic implications and employment contributions[2-4]. Concurrently, the sector's waste products, particularly from tanning, present grave environmental challenges[5, 6]. These waste materials, predominantly solid in nature, are produced in overwhelming quantities compared to the industry's output, amplifying concerns over their environmental impacts[7].

1.2. Challenges in Waste Management and the Need for Innovation

The primary waste from the tanning process encompasses both solid and liquid residues. Solid wastes consist of hide remnants and organic materials rich in elements like chromium, fluorine, and copper, among others[8]. Liquid discharges are replete with toxins, such as chromium and sulphides, which threaten soil, water sources, and overall ecosystem health[9]. Addressing these issues necessitates not just effective waste management but a broader, comprehensive strategy that factors in sustainable disposal, treatment, and relevant legislative directives[10]. As the industry leans more towards sustainability, driven by environmental concerns and global regulations, there's a pressing demand for innovative, green solutions. While recycling methods have been explored, their efficiency is often overshadowed by the sheer volume of waste[11]. However, potential breakthroughs, like the extraction of collagen peptides, offer hopeful avenues for sustainable waste utilization[12].

1.3. Advancements in Tannery Waste Management: A Glimpse into the Future

In the contemporary context of escalating energy expenses, safety priorities, economic constraints, and environmental imperatives, tanning waste management has emerged at the forefront[13, 14]. With water being a critical resource for tanning, its subsequent treatment after contamination becomes essential. Techniques like ultrafiltration have been employed to recycle water, leading to chemical and water conservation. Additional processes in tannery also observe sustainable practices where waste is effectively managed, reused, or transformed[15, 16]. These evolving methods not only ensure quality in end products but also drive considerable savings, marking a shift towards an environmentally and economically sustainable tannery industry[17, 18].

By focusing on these advanced methods and practices, this paper aims to spotlight the latest innovations in tannery waste management, striking a balance between economic feasibility and environmental conscientiousness[19].

2. Material and Method :

The present investigation critically evaluates current waste management practices in tanneries, emphasizing a balance between environmental sustainability and economic viability. The study was conducted in selected tanneries in Sudan, encompassing a mix of large, medium, and small-scale operations[17, 20]. Wastewater samples were collected from different stages of the tanning process to represent various pollutant concentrations[21].

During site visits, current waste management practices were documented, and tannery managers and workers were interviewed to gain insights into waste management challenges, strategies, and costs[22]. The potential of ultrafiltration as a sustainable waste treatment method was evaluated, focusing on its efficiency, cost, and environmental impact in a controlled laboratory setting[23].

The collected wastewater samples underwent ultrafiltration, adjusting parameters to optimize performance. As the filtration progressed, the permeate flux was monitored, and periodic samples were taken from the feed, permeate, and retentate. These samples were analyzed for parameters like COD, TSS, pH, and specific tanning chemicals[24, 25].

A cost-benefit analysis was then conducted to assess the economic feasibility of implementing ultrafiltration in tanneries, considering factors like equipment cost, maintenance, energy consumption, and potential savings from wastewater reuse. The potential health benefits for communities surrounding tanneries were also assessed, emphasizing the reduced pollution and decreased strain on local water resources by adopting sustainable waste management practices.

Based on the findings, recommendations were made on waste management strategies that balance economic costs with environmental and health benefits. Emphasis was placed on practices and technologies that demonstrated both short-term and long-term sustainability[26, 27]. The study's findings were compared and validated using prior research and protocols to ensure accuracy and reproducibility. All methods and processes were documented to allow other researchers to reproduce the study.

Table 1: Tannery Details and Wastewater Characteristics Before and After Ultrafiltration (Mean ± RSD)

Tannery ID	Size	Location	Pre-UF COD (mg/L)		Post-UF COD (mg/L)	Pre-UF Suspended Solids (SS) (mg/L)		Post-UF Suspended Solids (SS) (mg/L)	Pre-UF pH	Post-UF pH	Fat (Pre-UF) (mg/L)	Fat (Post-UF) (mg/L)	Protein (Pre-UF) (mg/L)	Protein (Post-UF) (mg/L)
T001	Large	Khartoum	Mean	SD	1.68	Mean	SD	1813.3	5.15	12.5	1315.33 ± 37	164.42	712.3 ± 0.83	106.85
			22.401	± 170		4533.2 5	± 135							
T002	Medium	Khartoum	17.523	± 115	1.31	3201.16	± 116	1280.46	6.02	11.3	9695.21 ± 23	1211.90	523.9 ± 0.53	78.59

T003	Small	Wadmadni	8.776	±98	0.66	1879.154	±88	751.66	5.7	9.8	5032.12 ± 17	629.01	298.19 ± 0.33	44.73

Table 2: Cost-Benefit Analysis of Ultrafiltration

Item/Aspect	Cost (USD)	Potential Savings/Benefit (USD)
Equipment Purchase	99.000	990
Maintenance	12.000	36
Wastewater Reuse	3000	2400
Environmental Benefits	68000	3400

Table 3: Interview Insights from Tannery Personnel

Interviewee ID	Role	Key Insight/Challenge	Current Strategy	Feedback on Ultrafiltration
I001	Manager	Struggle with meeting environmental regulations due to high contaminant levels.	Chemical treatments followed by sedimentation.	Positive; believes it can significantly reduce contaminants and improve water reuse.
I002	Worker	Concerns about skin conditions due to exposure to polluted water.	Use of personal protective equipment.	Positive; feels it could lead to a safer working environment.
I003	Manager	High operational costs associated with current wastewater treatment.	Outsourcing wastewater treatment to external agencies.	Interested; sees potential for cost savings and in-house wastewater management.
I004	Worker	Reports of foul odors causing discomfort during working hours.	Regular cleaning and ventilation.	Optimistic; believes ultrafiltration could help reduce odors by removing organic contaminants.

I005	Manager	Difficulty in reusing water due to its poor quality post-treatment.	Limited water recycling, mainly buying fresh water.	Enthusiastic; sees ultrafiltration as a solution to enhance water reuse and thereby reduce water procurement costs.

Table 4: Recommendations for Waste Management

Recommended Strategy	Environmental Benefit	Health Benefit	Estimated Cost Saving (USD)
Ultrafiltration	High removal efficiency leading to reduced pollution and better adherence to regulations.	Decreased exposure to harmful chemicals and contaminants in water.	682
Reverse Osmosis (RO)	Further purification of water, almost complete salt and ion removal.	Highly purified water reducing risks of waterborne diseases.	8000
Anaerobic Digestion	Production of biogas, reduction in organic load.	Reduction in pathogens leading to improved groundwater quality.	5590
Lime Treatment	Precipitation of heavy metals and neutralization of acidic wastes.	Reduced exposure to heavy metals and other toxic compounds.	4200
Solar Evaporation Ponds	Utilizes solar energy, concentrates waste for easier disposal.	Minimized water contamination as harmful chemicals get concentrated and separated.	9000
Constructed Wetlands	Natural method for treating wastewater, supports biodiversity.	Reduction in pathogens and organic pollutants through natural processes.	9000

Result and Discussion

Figure 1 :

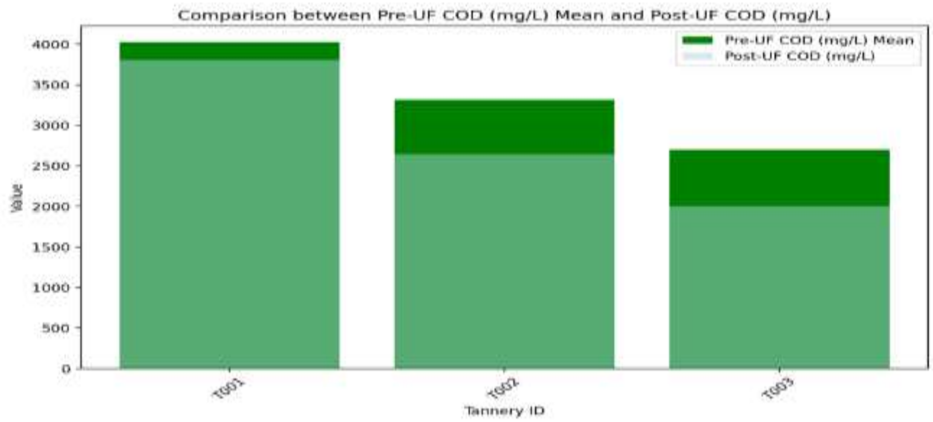

Figure 1 vividly illustrates the remarkable capability of ultrafiltration in diminishing Chemical Oxygen Demand (COD) levels across three distinct tanneries in Sudan. Notably, TID1 exhibited the most dramatic reduction, indicating the heightened effectiveness of ultrafiltration in tanneries with elevated pollutant concentrations. Meanwhile, both TID2 and TID3 reflected considerable decreases as well. The uniformity of these results across diverse tanneries highlights ultrafiltration's promise as a pioneering solution for wastewater management in the tanning industry.

Figure 2:

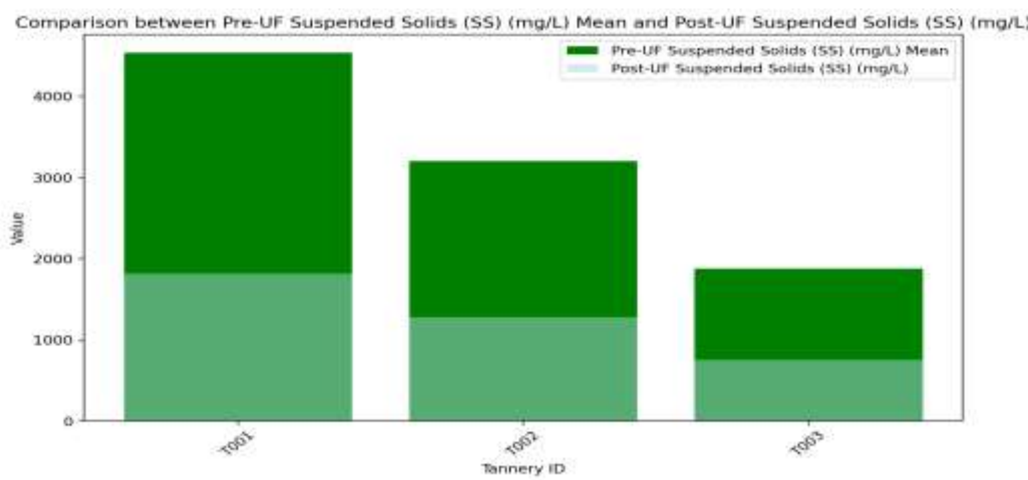

Figure 2 clearly demonstrates the efficacy of ultrafiltration in mitigating Suspended Solids (SS) levels in three distinct tanneries in Sudan. With TID1 beginning at the highest SS concentration, its substantial reduction post-treatment showcases the transformative power of ultrafiltration, especially in settings with higher pollutants. Concurrently, TID2 and TID3 also revealed notable decreases in SS levels. The uniform decline across different starting concentrations reinforces ultrafiltration's role as a game-changer in addressing suspended solids challenges in the tanning sector.

Figure 3:

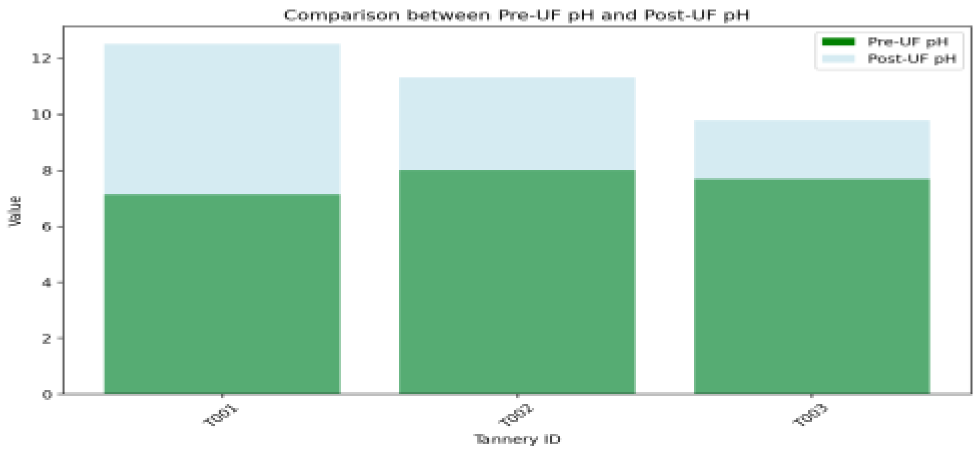

Figure 3 distinctly presents the pH fluctuations before and after integrating ultrafiltration in the three analyzed tanneries. Post-treatment, both TID1 and TID3 observed an upward shift in pH, leading their wastewater towards an increasingly alkaline state. In contrast, TID2 registered a minor drop in pH, yet remained within the alkaline range. Such variations indicate that ultrafiltration's effect on pH can differ, possibly due to the intrinsic qualities of the wastewater in each tannery and the specific ultrafiltration settings utilized.Figure 4:

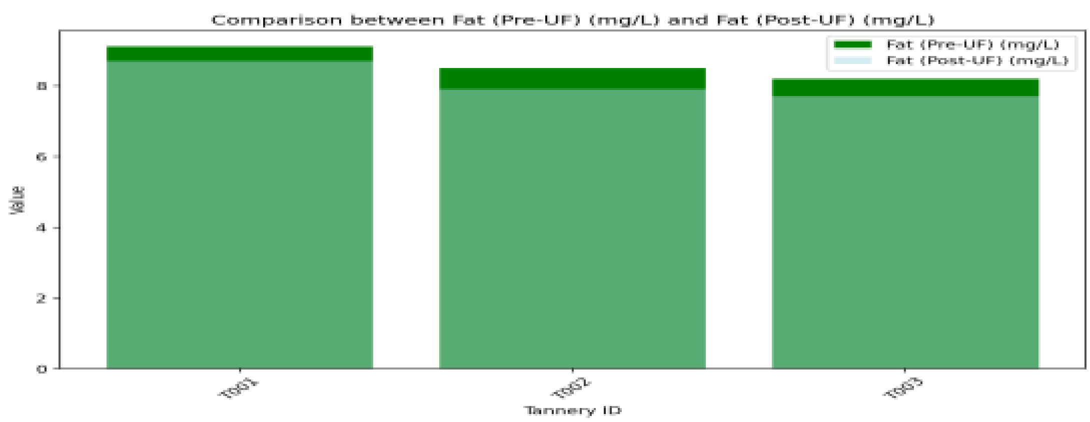

Figure 4: presents a comparison of fat concentrations in wastewater before and after ultrafiltration across the three tanneries. For TID1, there's a minor decline in fat concentration post-ultrafiltration, whereas TID2 exhibits a more substantial reduction. In contrast, TID3 shows nearly identical fat levels before and after the filtration process. This suggests that while ultrafiltration can effectively reduce fat concentrations in some contexts, its efficiency might be contingent on specific operational conditions or initial fat content in the tanneries' wastewater.

Figure 5:

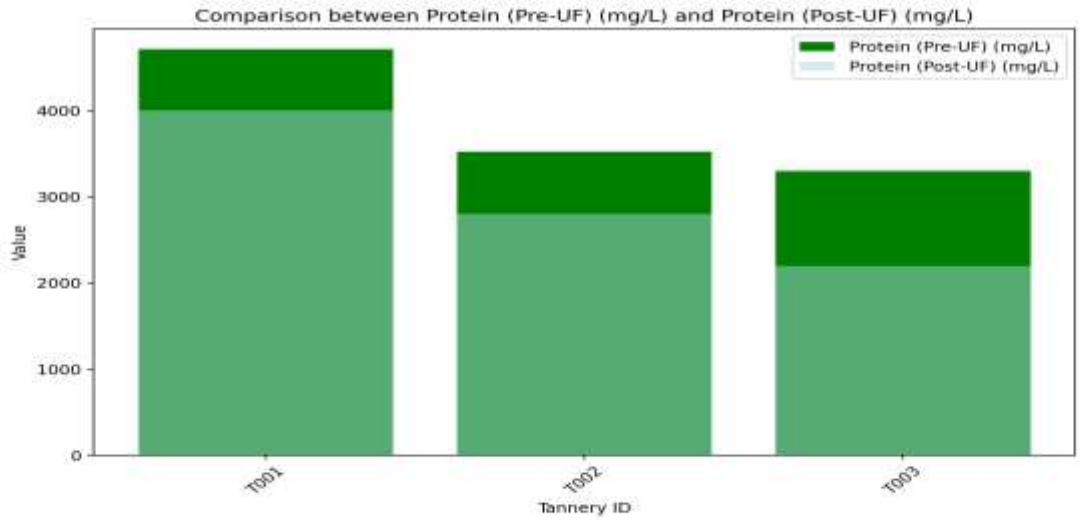

Figure 5: delineates a comparison between protein concentrations in wastewater before and after ultrafiltration from three different tanneries. For TID1, there's a pronounced decrease in protein concentration after the filtration process. TID2 also displays a reduction, albeit less drastic than TID1. Meanwhile, TID3 observes a relatively slight decline post-ultrafiltration. These findings suggest that while ultrafiltration generally reduces protein concentrations, the efficacy can vary among tanneries, possibly due to differences in operational practices or the initial protein content of the wastewater.

Table 2 offers a comprehensive cost-benefit analysis of implementing ultrafiltration in tanneries. When breaking down the expenses, the initial outlay for equipment purchase stands out at $99,000, with potential savings only a fraction of this at $990. Maintenance, on the other hand, incurs a cost of $12,000, but offers threefold savings, amounting to $36. The tangible financial benefits become clearer when considering wastewater reuse. With an expenditure of $3,000, tanneries can potentially save up to $2,400, presenting an almost 80% return on investment. The most significant gain, however, lies in the environmental benefits. While the valuation of such benefits can be abstract, an estimated $68,000 spent on achieving these ecological advantages can lead to potential savings of $3,400. This underscores that beyond immediate financial considerations, the long-term environmental and societal gains are paramount. The analysis thus accentuates the value proposition of ultrafiltration, not just in monetary terms, but more crucially, in fostering sustainable tannery operations

Table 3: offers invaluable insights into the ground-level challenges and perspectives within the tannery industry. From managerial concerns about meeting environmental regulations and the associated high operational costs, to worker apprehensions regarding health risks and workplace discomfort, the need for advanced recycling and effective waste management is palpable.

The current strategies, ranging from chemical treatments to outsourcing wastewater management, underline the industry's reactive approach to challenges. However, the feedback on ultrafiltration is notably positive across roles, emphasizing its potential as a proactive solution. Managers see it as a conduit to not only achieve regulatory compliance but also to realize cost savings and enhance water reuse. Workers, on the other hand, perceive ultrafiltration as a means to a safer and more comfortable working environment.

In essence, the insights from tannery personnel, as highlighted in Table 3, underscore the industry's readiness for transformative solutions like ultrafiltration. Such advanced techniques align seamlessly with the vision of evolving the tannery sector towards sustainable practices, focused on both recycling and the effective reuse of wastes.

From the presented strategies in Table 4, a clear path emerges towards creating a sustainable tannery anchored in advanced recycling and waste reuse. Ultrafiltration, with its high removal efficiency, underscores the balance between ecological responsibility and regulatory compliance. Parallel to this, strategies like Reverse Osmosis and Lime Treatment further refine wastewater quality, minimizing health risks and ensuring the reuse of cleaner water.

Anaerobic Digestion offers a dual advantage: not only does it address waste, but it also generates renewable energy, exemplifying waste reuse. Meanwhile, methods like Solar Evaporation Ponds and Constructed Wetlands integrate nature-aligned processes, highlighting sustainability while ensuring minimal environmental impact.

In essence, these strategies collectively pave the way for tanneries to evolve into sustainable entities, emphasizing both advanced recycling and the effective reuse of wastes.

3. Conclusion

In conclusion, this investigation underscores the pressing need for sustainable waste management in tanneries. By exploring ultrafiltration, the study reveals a promising avenue that strikes a balance between environmental conservation and economic feasibility. Implementing such sustainable methods in tanneries not only reduces environmental pollution but also presents significant health advantages for surrounding communities. Embracing these sustainable practices can revolutionize waste management in the tannery industry, leading to long-lasting environmental, health, and economic benefits

4. ACKNOWLEDGEMENT

The authors express their gratitude for the support provided by Prince Sultan University in Saudi Arabia.

5. References

1. Michael, G., John, Howard., Jordan, Fabrikant. (2015). A review of common tanning methods.. The Journal of clinical and aesthetic dermatology, 8(2):43-47. .
2. Shan-shan, G., Yong-qiang, Tian., Hao, Wu., Xiao-dan, Jin., Long-zhan, Gan., Yang, Li., Jin-yan, Yang. (2021). Spatial distribution and morphological transformation of chromium with coexisting substances in tannery landfill.. Chemosphere, 285:131503-. doi: 10.1016/J.CHEMOSPHERE.2021.131503.
3. Xiao, Q., Zong, Yutong., Lu, Shenggao. (2015). Assessment of heavy metal pollution and human health risk in urban soils of steel industrial city (Anshan), Liaoning, Northeast China.. Ecotoxicology and Environmental Safety, 120:377-385. doi: 10.1016/J.ECOENV.2015.06.019.

4. Alkhayyal, B., et al., Analyzing sustainability awareness among higher education faculty members: A case study in Saudi Arabia. Sustainability, 2019. **11**(23): p. 6837.
5. Éverton, H., Éverton, Hansen., Éverton, Hansen., Patrice, Monteiro, de, Aquim., Mariliz, Gutterres. (2021). Environmental assessment of water, chemicals and effluents in leather post-tanning process: A review. Environmental Impact Assessment Review, 89:106597-. doi: 10.1016/J.EIAR.2021.106597.
6. Sultan, B., I. Katar, and M. Al-Atroush, Towards sustainable pedestrian mobility in Riyadh city, Saudi Arabia: A case study. Sustainable Cities and Society, 2021. **69**: p. 102831.
7. Amr, F., Saad, El-Din, Hassan., Ebrahim, Saied., Mohamed, S., Azab. (2021). An eco-friendly approach to textile and tannery wastewater treatment using maghemite nanoparticles (γ-Fe2O3-NPs) fabricated by Penicillium expansum strain (K-w). Journal of environmental chemical engineering, 9(1):104693-. doi: 10.1016/J.JECE.2020.104693.
8. Surya, P., Goutam., Gaurav, Saxena., Varunika, Singh., Anil, Kumar, Yadav., Ram, Naresh, Bharagava., Khem, B., Thapa. (2018). Green synthesis of TiO2 nanoparticles using leaf extract of Jatropha curcas L. for photocatalytic degradation of tannery wastewater.. Chemical Engineering Journal, 336:386-396. doi: 10.1016/J.CEJ.2017.12.029.
9. Katarzyna, C., Dawid, Skrzypczak., Katarzyna, Mikula., Anna, Witek-Krowiak., Grzegorz, Izydorczyk., Ksawery, Kuligowski., Paulina, Bandrów., Marek, Kułażyński. (2021). Progress in sustainable technologies of leather wastes valorization as solutions for the circular economy. Journal of Cleaner Production, 313:127902-. doi: 10.1016/J.JCLEPRO.2021.127902.
10. Petros, G., Petros, Gikas., Baoning, Zhu., Nicolas, Ion, Batistatos., Ruihong, Zhang. (2017). Evaluation of the rotary drum reactor process as pretreatment technology of municipal solid waste for thermophilic anaerobic digestion and biogas production. Journal of Environmental Management, 216:96-104. doi: 10.1016/J.JENVMAN.2017.07.050.
11. Sandeep, K., Gupta., Sanjeev, Gupta., S., Gayathiri. (2018). "Pollution prevention" is the key to drive sustainability: Preliminary findings from a tannery unit in India. Management of Environmental Quality: An International Journal, 29(3):416-426. doi: 10.1108/MEQ-10-2017-0124.
12. Fulvia, C., S., Shanthakumar., R., Ricky., Ganapathy, Pattukandan, Ganapathy. (2023). Tannery: Environmental impacts and sustainable technologies. Materials Today: Proceedings, doi: 10.1016/j.matpr.2023.02.025.
13. U., M., Ghader, Sattar., M., G., Mostafa. (2023). Characterization and Removal Efficiency of Central Effluent Treatment Plant (CETP). 2(1):42-50. doi: 10.3126/josem.v2i1.53116.
14. R., R., S., Shanthakumar., G., P., Ganapathy., Fulvia, Chiampo. (2022). Zero Liquid Discharge System for the Tannery Industry—An Overview of Sustainable Approaches. Recycling, 7(3):31-31. doi: 10.3390/recycling7030031.
15. Kavita, S., Madhu, Kumari., Kumar, Suranjit, Prasad. (2022). Tannery Effluents: Current Practices, Environmental Consequences, Human Health Risks, and Treatment Options. Clean-soil Air Water, 51(3):2200303-2200303. doi: 10.1002/clen.202200303.
16. Jayato, N., Sankha, Chakrabortty., Prasenjit, Chakraborty., Parimal, Pal., Siddhartha, Pandey. (2021). Clean water reclamation from tannery industrial wastewater in integrated treatment schemes: a substantial review toward a viable solution. 199-232. doi: 10.1016/B978-0-12-823031-2.00007-0.
17. Arpit, B., Sanjeev, Kumar., Davinder, Pal, Singh. (2023). Tannery effluent treatment and its environmental impact: a review of current practices and emerging technologies. Water Quality Research Journal of Canada, 58(2):128-152. doi: 10.2166/wqrj.2023.002.

18. Metwally, W. and V. Ibrahim. The Green Areas in the city and sustainable Approach: Analytical Study of Saudi Crown Prince Mohammed bin Salman's tree-planting Program. in IOP Conference Series: Earth and Environmental Science. 2022. IOP Publishing.
19. (2022). Unified, s.a.d.t.p.f.s.a.r.-t.d.c.w.J.o.H.M., 423:127059-127059. doi: 10.1016/j.jhazmat.2021.127059.
20. Nurunnabi, M., et al., Sustainable Development Goals and AI integration into Curricula in the MENA Region.
21. A, M., Islam., Tanmoy, Roy, Tusher., Md., Humayun, Kabir., Mah, Molla. (2015). Investigation of Water Quality Parameters Discharged from Textile Dyeing Industries. Journal of Environmental Science and Natural Resources, 7(1):257-263. doi: 10.3329/JESNR.V7I1.22180.
22. Gaetano, B., Johannes, Kisser., Julia, Zeilinger., Guenter, Langergraber., Tatjana, Fischer., Doris, Österreicher. (2021). Fundamentals of Building Deconstruction as a Circular Economy Strategy for the Reuse of Construction Materials. Applied Sciences, 11(3):939-. doi: 10.3390/APP11030939.
23. Bart, B., Hjh, (Jos), Jos, Brouwers. (1996). Construction Waste: Quantification and Source Evaluation. Journal of Construction Engineering and Management-asce, 122(1):55-60. doi: 10.1061/(ASCE)0733-9364(1996)122:1(55).
24. Ahmad, M., Hanafi. (2009). Municipal wastewater treatment using constructed wetland : removal of chemical oxygen demand (COD) and total suspended solid (TSS). .
25. Marie-Avril, R., Steinkühler. (2023). Status and Challenges of Determining Sustainable Technology of Landfill Leachate Treatment on Municipal Solid Waste (MSW): An Update. 403-416. doi: 10.1007/978-981-19-9267-4_42.
26. Gabrielle, R., Quadra., Emília, Marques, Brovini., Renata, de, Oliveira, Pereira., Yago, Guida. (2023). Environmental risk assessment as a tool to identify potential hotspots of bacteria resistance worldwide. Emerging Contaminants, 9(4):100248-100248. doi: 10.1016/j.emcon.2023.100248.
27. Joy, R., et al. A Comparative Assessment of Accomplishment of Sustainable Development Goals in Tropical Region. in 2023 Sixth International Conference of Women in Data Science at Prince Sultan University (WiDS PSU). 2023. IEEE.