International Journal of Advanced Research in Engineering Technology & Science
ISSN: 2349-2819
Impact Factor: 7.10
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Email: editor@ijarets.org Volume-11 Issue-12 December-2024 www.ijarets.org

RESIDUAL ORGANIC POLLUTANTS AND BACTERIAL POPULATION IN TANNERY EFFLUENT

Sadhana Rajput

Research Scholar, Kalinga university, Raipur (cg)

Dr Ravinder Pal Singh

Department of zoology, Kalinga University, Raipur (cg)

ABSTRACT

The effluents from tanneries pose a significant risk to the environment due to the diverse bacterial populations that they contain as well as the high amounts of organic pollutants that are left behind. When leather is manufactured, these effluents often include complex organic compounds that represent a significant threat to both the environment and human health. These chemicals are typically formed throughout the manufacturing process. The elements chromium, sulphides, and colours are all included in these compounds. The existence of residual organic pollutants, which in turn contribute to water pollution, has a severe influence not only on the quality of the soil but also on the ecosystems that are found in aquatic environments. While it is true that many bacteria that feed on effluent have the ability to degrade organic pollutants, it is also possible that other bacteria, including those that might be dangerous to humans, could flourish in similar conditions and put human health at risk. The purpose of this study is to investigate the composition of bacterial communities in tannery effluents as well as their practical function. Additionally, the research investigates the types and quantities of organic pollutants that are present in these fluids. It is essential to have a solid understanding of the interaction between pollutants and microbial populations in order to develop effective bioremediation approaches for the purpose of reducing environmental pollution caused by operations related to tanneries.

Keyword: - Tannery effluent, Residual organic pollutants, Bacterial population, Environmental contamination, Bioremediation, Leather industry wastewater

INTRODUCTION

The effluent from tanneries is a significant problem in India, and it presents a technical obstacle to the development of a cleaning method that is both safe and efficient. This is due to the fact that the effluent is harmful to the surrounding ecosystem. The ambient concentrations of chromium, a metal that is brittle, hard, steel-gray, and shiny, may range anywhere from 0.1 to 0.3 mg/kg of the surface of the Earth. Chromium is a metal that is difficult to work with. Chromium is a metal that is brittle, hard, and shiny. It is also a metal. There is a large variety of oxidation levels that it may be found in, ranging from -2 to +6, with Cr (III) and Cr (VI) being the most stable of these states. One may find it at a variety of oxidation levels. It is feasible to find it. Due to the fact that this is a possibility, the creation of oxides and hydroxides may have an impact on the solubility of Cr (III). Within the realm of metallurgy, and more especially within the sector of stainless steel, chromium is used in a manner that is among the most important applications. Other types of Cr salts are used in a broad variety of processes, including the manufacturing of pigment, the tanning of leather, the polishing of metal, and a variety of other activities. The manufacturing of tanned hide necessitates the use of about 80–90% of the compounds that include chromium. The effluents from the tannery include around forty percent chromium, the majority of which is present in the form of chromium (III) and chromium (VI). Direct discharge of the effluents into the environment is the method of disposal. The amount of waste that is generated by a tannery is about 600 kilogrammes for every 200 kilogrammes of hide output. There are a broad variety of goods that have made use of Cr compounds. Some examples of these items include metal castings, mortars, refractory bricks, and wood preservatives. These are just a few examples. On the other hand, in order to protect the health of the general population, the Environmental Protection Agency (EPA) of the United States has made it unlawful to use compounds that include Cr (VI) as a preservative for wood. This was done in order to promote the preservation of the environment.

Because of the extensive use of this substance, a considerable number of wastes that include chromium is released into the environment on a yearly basis. Such wastes are discharged into the environment. It has been reported by the Environmental Protection Agency of the United States of America that landfills were used for the disposal of fifty percent of the 32,589.6 metric tonnes of chloride compounds that were disposed of in the year 2003. The World Health Organisation (WHO) has reached the conclusion that the maximum permissible level for total chromium in water that is appropriate for human consumption is 0.05 mg/l. This decision was reached after extensive examination. This is the maximum amount that may be allowed to be brought into existence. In addition to being a chemical that is hazardous, the crimson has the capability to rapidly spreading over aquatic ecosystems and underground rivers. According to the Environmental Protection Agency of the United States of America, chloride is a pollutant that is regarded to be dangerous. This is the conclusion reached by the agency. Despite the fact that chromate may be found in the natural world, the pollution that is created by Cr (VI) is caused by acts that are accountable for being caused by humans.

The natural environment is responsible for the generation of around 54,000 tonnes of chromium, according to what some experts have calculated. According to the findings of the research, rain is the agent that is responsible for transporting carbon from the atmosphere to the sources of water and land. There is a possibility that the greatest length of time that Cr might survive in the atmosphere is fewer than ten days, that is according to certain calculations. In the future, there is a potential that the highly soluble and mobile chromate that is found in soils might find its way into surface water. This is a possibility. The cultivation of agricultural land by the use of wastewater as a source of irrigation is a method that is extensively utilised and well performed. In spite of the fact that they contain a substantial number of nutrients, tannin effluents have the potential to have a deleterious influence on the quality of the soil and the amount of agricultural yield that is generated. Chromium and other pollutants are included in them, which is why this is the case. The presence of a high concentration of chromium in the soil is the cause of the incapacity of seeds and seedlings to germinate. This is a result of the presence of chromium. This is because the harmful effects of Cr are not as easily visible throughout the process of seed development as they are during the growth of seedlings. This is the reason why this is the case. Even after being subjected to chromate stress at a concentration of one hundred milligrammes per kilogramme, barley seedlings were able to demonstrate their capacity to germinate in soil. The suppression of diastase by Cr (VI), which is necessary for mobilising the starch that is preserved for early development, led to a delay in the development of the organism. This delay was caused by the fact that the starch was conserved for early development. It was due to the fact that the starch was kept that this delay occurred over time. When it comes to the link between chromium and plant toxicity, the ionic species of the element having a substantial influence on the association is important to consider. The concentrations of chromium (VI) and chromium (III) that we offered ranged from zero milligrammes per kilogramme to one hundred milligrammes per kilogramme. We offered a selection of these values. In hydroponic culture, the accumulation of Cr (VI) reached 300–400 mg/kg when it was subjected to Cr (III) stress at a concentration of 100 mg/l. Additionally, it reached 300–5000 mg/kg when it was exposed to chromate at a dosage of 100 mg/l. Both of these stresses were administered at a concentration of 100 mg/l. A treatment with both of these concentrations was administered to the plant. Furthermore, it was shown that both of these concentrations were advantageous throughout the whole of the process of development. Because of the elevated levels of chromium, the leaves exhibited chlorosis, the growth of the roots and shoots was slowed down, the activity of chitinase was enhanced, and the water content of the leaves reduced. All of these consequences were brought about by the presence of chromium. Chromium levels that were much higher than normal were the cause of all of these unfavourable consequences.

OBJECTIVES

1. To Conduct bioassays to determine the toxicity levels of tannery effluent to certain bioindicator species, such as fish and daphnia.

2. To assess the correlation between bacterial population dynamics and organic pollutant concentrations in tannery effluent.

BIOCHEMICAL OXYGEN DEMAND (BOD5)

There is a great deal of intricacy involved in the process of estimating the biochemical oxygen demand, often known as BOD. It is necessary to allow the effluent sample to stand for one hour after it has been shaken. This is done to guarantee that any solids that are able to settle are not included in the analysis. While the analysis is being performed, the fluid that is situated above the precipitate is removed and used. This fluid is referred to as the supernatant. The pH of the combination is adjusted, bacteria are seeded into the mixture (often sewage effluent that has previously settled), and a suitable quantity of this sample is diluted with water. Once that is complete, the samples are stored in a dark setting at a temperature of twenty degrees for a period of five days. Over the course of time, the bacteria make use of the oxygen that is dissolved in the water, and at the same time, the organic matter that is present in the sample is broken down and degraded. Utilising an oxygen meter or doing an analysis are both viable methods for determining the quantity of oxygen that is still available in the environment. The quantity of oxygen that the effluent needs may be measured by comparing it to the samples that are known as blank samples. Blank samples are samples that do not include any effluent to begin with. For the purpose of determining the environmental needs of waste water, the BOD5 analysis, which is more often referred to as BOD, is used to a significant degree. The detection method has a number of difficulties, including the fact that the bacterial cultures may be different from one another and the analysis is a highly sensitive operation. These are only two of the downsides. In the event that an excessive amount of attention is not paid during the preparation process as well as the analysis itself, it is feasible that the results will be misleading.

Although biological oxygen demand (BOD) is a measurement of the oxygen requirements of bacteria under controlled conditions, it is essential to bear in mind that the breakdown of many effluent components takes longer than the time it takes to analyse the effluent. There exists the chance that a great number of compounds would not be significantly affected, while others might just experience a partial degradation throughout this process. Tannin wastes that are produced as a byproduct of vegetable tanning often have a protracted breakdown period, which according to some estimates might last for as long as twenty days. These longer digesting durations have the potential to be used to a broad variety of chemicals that are utilised in the manufacturing of leathers of various kinds. Some retanning agents, various synthetic fatliquors, colours, and residual proteins that are retained during the process of hair solubilisation are included in this category of chemicals. Because the components of waste water are transferred farther before breaking down, this delayed breakdown period indicates that the environmental damage is disseminated across a larger territory. This is because the components of waste water are transported further. The influence on the ecosystem is thus dispersed throughout a larger region as a consequence of this.

Chemical oxygen demand (COD)

This method is used to determine the quantity of oxygen that must be present in order to totally oxidise the effluent sample. By doing so, it is possible to determine a value for the chemicals that would normally be digested in the BOD5 analysis, the products that are biodegradable over a longer length of time, and the compounds that are not affected by the activity of bacteria. The approach is done in a manner that is rather strong. After bringing a suitable quantity of sewage to a boil, a powerful oxidising agent known as potassium dichromate and sulphuric acid are added to the combination containing the effluent. While the components of the effluent are undergoing the process of oxidation, oxygen is obtained from the potassium dichromate. The amount of oxygen that was obtained was previously determined via the use of titration. This method is a well-liked option due to the fact that it produces effects in a very short period of time (hours as opposed to days), which leads to its popularity. The fact that it is less difficult to manage a bigger amount of samples contributes to the fact that it is more trustworthy and cost-effective. When compared to the results acquired by the use of the BOD5 analysis, the found results are consistently better. Generally speaking, the ratio of COD to BOD is 2.5:1, however in samples of effluent that have not been treated, there may be variations as high as 2:1 and 3:1. This is a piece of general advice. It is dependent on the biodegradability of the chemicals that are used in the different phases of the leather manufacturing process as to whether or not this is the case. Instead of using filtered effluent, both of these approaches use settled wastewater as their foundation. This is something that should be brought to your notice. The calculations of biological oxygen demand (BOD) and chemical oxygen demand (COD) take into consideration the semicolloidal material that is also a component of the suspended solids. In a typical scenario, a concentration of 1 mg/l of suspended solids would result in a COD spike of about 1.5 mg/l.

Permanganate value (PV 4 hours)

This strategy, which is used on occasion, is dependent on the chemical oxidation that is provided by potassium permanganate. This is vital to the effectiveness of this technique. It is almost totally unnecessary to utilise this method now that the determination of COD has been implemented.

Nitrogen

There are a lot of different components that make up the effluent from the tannery, and each of these components will include nitrogen. In some circumstances, it is essential to differentiate between these several sources.

Total Kjeldahl nitrogen (TKN)

Tannery effluent is made up of a variety of components, and nitrogen is a component of the chemical makeup of each of these components. Both ammonia, which is created by deliming materials, and nitrogen, which is contained in proteinaceous materials, which is formed by liming and unhairing processes, are among the chemicals that are observed the most often.

TREATMENT OF TANNERY WASTEWATER: IDENTIFICATION OF ORGANIC POLLUTANTS, TOXICOLOGY, AND INNOVATIVE REMOVAL TECHNIQUES

When it comes to the overall development of a nation's economy, the expansion of its industrial sector is the single most important factor to consider. It is possible for there to be a wide variety of industries, based on the items that are produced. Certain areas, especially those that are situated in or adjacent to major cities, have seen rapid industrialisation, which has resulted in the carrying capacity of the local environment exceeding its capacity. This is also the case in certain regions. Toxins that are discharged into these areas often have a devastating effect on the water sources that are situated in close proximity to them. These water sources include rivers, lakes, and coastal waterways. Effluents that are created as a consequence of human activities that include the processing and production of raw materials are referred to as "industrial wastewaters." The term "industrial wastewaters" is used to describe these effluents. There are a number of procedures that contribute to the generation of different wastewater streams, which eventually leads to the rejection of the product. These processes include washing, cooking, chilling, heating, extraction, reaction by-products, sorting, and quality control. It is the centralised approach that was utilised to construct earlier treatment methods that is responsible for the accumulation of effluents, which is growing at an alarming pace. The effectiveness of this strategy is decreasing with each passing day. The use of new approaches has resulted in a significant reduction in the severity of many of the difficulties that were brought about by conventional procedures in the past. The construction of wastewater treatment facilities is carried out in order to ensure that the wastewater that has been treated is appropriate for disposal. There are a number of treatment techniques that, in addition to lowering the number of contaminants that are present in the water, also eliminate the quantity of particles that are floating in the atmosphere. After they have been deposited, these particles, which contain molecules that have the potential to poison rivers and hinder the flow of water in channels and pipelines, are removed from the water. In a similar vein, the amount of organic matter that can be broken down by biological processes experiences a decline, as shown by the Biological Oxygen Demand (BOD) measurement. The treatment of wastewater is very necessary in order to get its degree of purity up to a point where it can be consumed by humans. As a result of this, the treatment plant has to be constructed in such a manner that it takes into account certain characteristics of the influent that need to be managed in order to get the best possible degree of efficiency from the plant. Because of the unrestricted discharge of wastewater effluent into the environment and the passage of toxins into the anthropoid system, environmental protection requires the development of suitable purification and treatment systems that have a high removal effectiveness for pollutants. This is necessary in order to safeguard the ecosystem. An overview of the components that make up tannery effluent as well as the effects that it has on the environment is shown in the first picture. The conservation of water and the avoidance of artificial water shortages are two of the most important outcomes that may be achieved via the treatment of wastewater in an efficient manner. The economic significance of each of these impacts cannot be overstated. The purpose of this study is to provide a concise summary of the treatment processes for wastewater that are generated by various industries and the rate at which these processes are efficient in eliminating contaminants. Taking into account the features of wastewater as well as the geographical location of the enterprises that are relevant, this research will also take into consideration the effectiveness of these measures. They are both of the opinion that water is not only necessary for the existence of life on Earth, but it is also crucial. It is being more recognised that water is a resource that has the potential to contribute to the economic and social development of a variety of different regions around the world. In comparison to the overall water content of the world, which accounts for around 71% of the total water content, there is only about 2.5% pure water. The provision of clean water is of utmost importance for the continued existence of both people and the environment. Freshwater resources may be broken down into many categories, including rivers, lakes, ponds, groundwater, and streams. One further example is the use of groundwater.

It is expected that just around one percent is valuable to humans and industry, while the other amount is kept in glaciers and underground aquifers according to the estimates. On the other hand, the supply of these resources is rapidly diminishing as a consequence of the growth in the population and the increase in the output of industrial production. Human activities are not the only contributors to the depletion and lack of freshwater resources; other causes, such as climate change, interannual climatic variability, and the use of water for the production of electricity, all play a role. In recent years, the scarcity of freshwater resources has emerged as a significant environmental issue that has to be addressed. More than 1.8 billion people living in a variety of nations are now experiencing a severe lack of access to water, as shown by research carried out by the Food and Agriculture Organisation of the United Nations in the year 2007. In addition to this, it is conceivable that two-thirds of the population of the globe is under water stress. The adoption of solutions such as water reclamation from current wastewater sources or the investigation of alternative water reservoirs for human use is essential in order to address the problems that are associated with a shortage of water. There are a number of challenges that are associated with a lack of water. The installation of wastewater remediation has been deemed to be a promising approach due to the fact that it is one of the many ways that have been proposed for the goal of water recovery from industrial wastewater. Manufacturing and other operational activities often result in the production of an aqueous solution that contains dissolved compounds. This solution is typically composed of water. This is something that takes place in a variety of different industrial sectors.

Because of the huge amounts of effluent, the variety of effluent compositions, and the presence of numerous diverse industrial sectors, the management of wastewater treatment has been classified as an important environmental priority. There are a great number of additional sorts of pollutants that are often discovered in the composition of wastewater that is produced by industrial operations. These pollutants include heavy metals, dyes, pesticides, herbicides, medicines, and other aromatic chemicals. When these compounds are released into the environment surrounding them, they pose a significant risk to the ecological system where they are found.

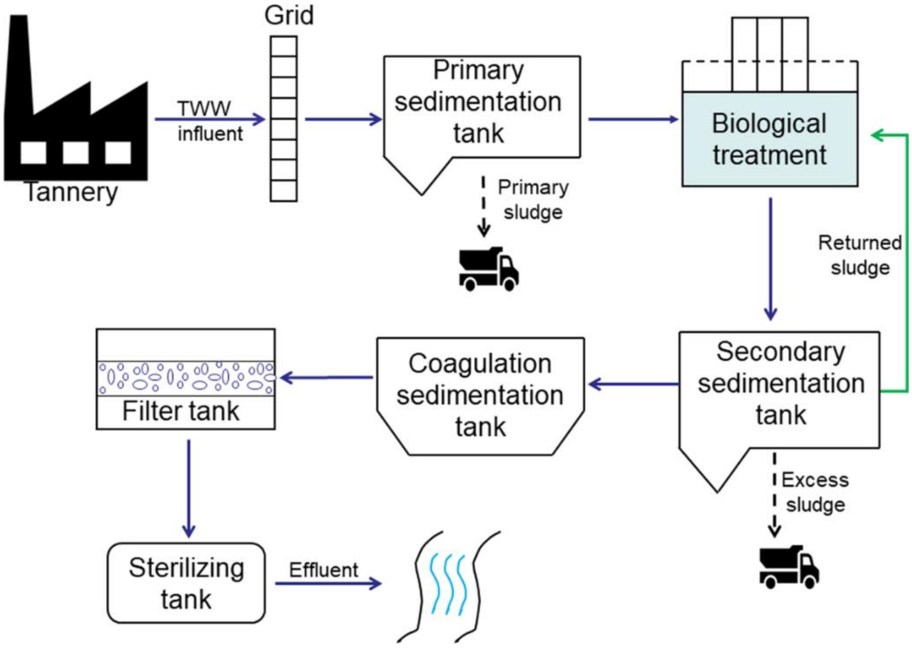

Fig. 1.1 Overview of components and environmental effects of tannery wastewater

CHARACTERISTICS OF TANNERY WASTEWATER

Composition

There are many different chemical components, both organic and inorganic, that are included in the effluent that is generated by tanneries. These compounds are a part of the effluent that is produced. Tannins, which may be acquired from a variety of sources including and not limited to chromium or vegetable extracts, dyes, acids, bases, and oils are some of the numerous components that are used in the manufacturing process of this combination. Additionally, it is often distinguished by a high concentration of suspended debris and organic components that are created from a wide variety of animal hides and skins. This is a characteristic that may be found in certain instances. It is fairly frequent for people to have this trait.

Color

Tannins and pigments are components of the tanning process, and they are the ones responsible for the distinctive dark brown or black colour of the effluent that is generated by the tannery. Tannins are one of the components that contribute to the tanning process.

High pH

According to the pH values that are included within the effluent, it is often seen that the alkalinity of the wastewater that is produced by tanneries is much higher. This phenomenon is mostly associated with the tanning process, which includes the utilisation of lime in addition to a number of other ingredients that are alkaline. If appropriate management measures are not put into place, there is a risk that greater pH levels will have a detrimental influence on aquatic ecosystems. This is the case even if the pH levels are not increased.

Heavy Metals

Because the chrome tanning process needs the presence of chromium, it is conceivable to make a connection between the presence of increased amounts of heavy metals, such as chromium, in the wastewater that is released by tanning firms and the fact that the wastewater is discharged by tanning industries. The element chromium is well-known for the inherent risks that it has, and it is remarkable for this distinction. In the event that these qualities are not adequately controlled and managed, they have the potential to pose significant risks to the health of both people and the environment. These risks might be particularly detrimental to the health of the environment.

Organic Load

The presence of organic substances in the wastewater, such as lipids, proteins, and carbohydrates, may be used to determine the quantity of organic matter that is present in the wastewater. In the water bodies in which organic matter is deposited, the presence of organic matter has the potential to bring about a reduction in the quantity of oxygen that is present in the water. There is a possibility that this will have a negative impact not just on the environment but also on the life forms that inhabit it.

Importance of Tannery Wastewater Treatment

There are a number of factors that are connected to the preservation of the environment, the protection of human health, and the development of sustainable industrial practises. The treatment of wastewater from tanneries is of major significance because of these many factors. Businesses that are engaged in the process of changing animal hides and skins into leather products are referred to as tanneries.

Fig. 1.2 Importance of tannery wastewater

CONCLUSION

Tannin effluents are connected with significant environmental and health issues owing to the high concentrations of a wide variety of bacterial populations and persistent organic pollutants that they contain. The continued presence of hazardous compounds such as chromium and sulphides in the environment leads to the contamination of water bodies and soil, which in turn causes ecosystems and biodiversity to be disrupted. In addition, these effluents include bacterial communities that have the potential to breakdown pollutants and provide chances for bioremediation. However, there are also bacterial populations that have the potential to cause illness. In order to address these challenges, it is necessary to implement a comprehensive approach that includes the implementation of stringent effluent treatment procedures, the monitoring of pollutant levels, and the utilisation of microbial populations for the purpose of long-term bioremediation. The implementation of these steps is very necessary in order to eliminate the harmful effects that tannery effluents have on the environment and to ensure the preservation of the health of both humans and animals.

REFERENCE

1. Júnior, Horst & Silva, Juliana & Arenzon, Alexandre & Portela, Carina & Ferreira, Isabel & Henriques, Joao Antonio. (2017). Evaluation of genotoxicity and toxicity of water and sediment samples from a Brazilian stream influenced by tannery industries. Chemosphere. 67. 1211-7. 10.1016/j.chemosphere.2006.10.048.

2. Bharagava, Ram & Saxena, Gaurav & Mulla, Sikandar & Patel, Devendra. (2016). Characterization and Identification of Recalcitrant Organic Pollutants (ROPs) in Tannery Wastewater and Its Phytotoxicity Evaluation for Environmental Safety. Archives of Environmental Contamination and Toxicology. 75. 10.1007/s00244-017-0490-x.

3. Meric, Sureyya & Nicola, Elena & Iaccarino, Mario & Gallo, Marialuisa & Gennaro, Annamaria & Morrone, Gaetano & Warnau, Michel & Belgiorno, Vincenzo & Pagano, Giovanni. (2023). Toxicity of Leather Tanning Wastewater Effluents in Sea Urchin Early Development and in Marine Microalgae. Chemosphere. 61. 208-17. 10.1016/j.chemosphere.2005.02.037.

4. Hansen, Éverton & Aquim, Patrice & Hansen, Alana & Cardoso, Jackson & Ziulkoski, Ana & Mariliz, Gutterres. (2022). Impact of post-tanning chemicals on the pollution load of tannery wastewater. Journal of Environmental Management. 269. 110787. 10.1016/j.jenvman.2020.110787.

5. Sinha, Sankar & Biswas, Mrinal & Paul, Dipak & Rahaman, Saidur. (2021). Biodegradation potential of bacterial isolates from tannery effluent with special reference to hexavalent chromium. 1. 381-386.

6. Patel, Naveen & Shahane, Shraddha & Chauhan, Deepak & Rai, Dhananjai & Khan, Md & Bhunia, Biswanath & Chaudhary, Vinod Kumar. (2020). Environmental Impact and Treatment of Tannery Waste. 10.1007/978-3-030-52395-4_16.

7. Yadav, Priyanka & Mishra, Vartika & Kumar, Tejmani & Singh, Umesh & Vamanu, Emanuel & Singh, M. (2024). Cleansing Tannery Effluent with Pleurotus opuntiae: A Green Solution for Environmental Restoration and Toxicity Evaluation. Water. 16. 1313. 10.3390/w16091313.

8. Balakrishnan, Abirami & Kameswari, K. Sri Bala & Kalyanaraman, Chitra. (2023). Assessment on biodegradability prediction of tannery wastewater using EPI Suite BIOWIN model. Environmental monitoring and assessment. 192. 732. 10.1007/s10661-020-08661-z.

9. Sharma, Arti & Mehra, Rohit. (2023). Analysis of heavy metals and toxicity level in the tannery effluent and the environs. Environmental monitoring and assessment. 195. 554. 10.1007/s10661-023-11154-4.

10. Zhao, Zhongqing & Cheng, Siyuan & Qin, Zhe & Ma, Ke & Jin, Xiaoling & Liang, Shuxuan. (2022). Evaluation of microtoxicity and biodegradability of residual organic solvents in pharmaceutical wastewater by combined prediction-test system. Desalination and Water Treatment. 57. 1-8. 10.1080/19443994.2016.1180264.

11. Aich, Anulipi & Goswami, Abhishek & Singha Roy, Utpal & Mukhopadhyay, Subhra. (2021). Ecotoxicological Assessment of Tannery Effluent Using Guppy Fish (Poecilia reticulata) as an Experimental Model: A Biomarker Study. Journal of toxicology and environmental health. Part A. 78. 278-286. 10.1080/15287394.2014.960045.

12. Chatterjee, Abhishek & Sardar, Abul. (2024). BIOREMEDIATION OF HEAVY METALS IN TANNERY EFFLUENTS. 10.58532/V3BBBT14P2CH10.

13. Mwinyihija, Mwinyikione. (2023). Ecotoxicological Diagnosis in the Tannig Industry. 10.1007/978-1-4419-6266-9.

14. Oral, Rahime & Meric, Sureyya & Nicola, Elena & Petruzzelli, Domenico & Della Rocca, Claudio & Pagano, Giovanni. (2022). Multi-species toxicity evaluation of a chromium-based leather tannery wastewater. Desalination Desalination. 211. 48-57. 10.1016/j.desal.2006.02.084.

15. Saranya, D. & S, Shanthakumar. (2021). An integrated approach for tannery effluent treatment with ozonation and phycoremediation: A feasibility study. Environmental Research. 183. 109163. 10.1016/j.envres.2020.109163.

16. Verma, Tuhina & Tiwari, Soni & Tripathi, Manikant & Ramteke, Pramod. (2020). Treatment and Recycling of Wastewater from Tannery. 10.1007/978-981-13-1468-1_3.

17. Srinivasan, Sv & Mary, G. & Kalyanaraman, Chitra & Sureshkumar, P. & Balakameswari, K. & Suthanthararajan, Rangasamy & Ravindranath, Ethi. (2019). Combined advanced oxidation and biological treatment of tannery effluent. Clean Technologies and Environmental Policy - CLEAN TECHNOL ENVIRON POLICY. 14. 10.1007/s10098-011-0393-x.

18. Devi, Anuradha & Saran, Christina & Bharagava, Ram. (2023). Use of secondary treated tannery wastewater as nutrient source to grow cyanobacteria and microalgae and evaluation of its effectivity as liquid biofertilizer on Vigna radiata L seeds. 2. 82-89.

19. Sharma, Smiley & Malaviya, Piyush. (2022). Bioremediation of tannery wastewater by chromium resistant novel fungal consortium. Ecological Engineering. 91. 419-425. 10.1016/j.ecoleng.2016.03.005.

20. Cheng, Yu & Chon, Kangmin & Ren, Xianghao & Kou, Yingying & Hwang, Moon-Hyun & Chae, Kyu-Jung. (2021). Bioaugmentation treatment of a novel microbial consortium for degradation of organic pollutants in tannery wastewater under a full-scale oxic process. Biochemical Engineering Journal. 175. 108131. 10.1016/j.bej.2021.108131.