Open Access
Volume 6 Issue 4
Review Article

International Journal of Water Research
ISSN: 2694-4049

PUBTEXTO

Effective Abatement of Pollutants of Sugar Mill Industry Effluent with Emerging Technologies

Kumari M*

Assistant Professor, Department of Botany, M.J.K. College, Bettiah, B.R.A. Bihar University, Muzaffarpur, Bihar, India

Article Info

Article History:
Received: 11 September, 2024
Accepted: 16 September, 2024
Published: 21 September, 2024
Corresponding author: Kumari M, Department of Botany, M.J. K. College, Bettiah, West Champaran, Bihar, India-845438; Tel no: +91-9450666713;
DOI: https://doi.org/10.36266/IJWR/186

Abstract

There has been a reduction in fresh water resources due to their indiscriminate use and limited recycle of wastewater generated from industries. This has presented a challenge for the sustainability of life on this planet. Aim of the study is to effective abatement of pollutants of sugar mill industry effluent. For conducting the study, extensive literature search was conducted using various search tools including science direct, PubMed etc. The study revealed that: (i) chemical treatment (nanoparticle) and biological treatment (phycoremediation, bioaugmentation, sequencing batch reactor, biochar-based treatment) reduced the organic content of sugar mill effluent effectively. (ii) Chemical treatment with nanoparticles outperform than that of biological processes. Nanoparticles removed 99 % melanoidins and 84.25 % organic content, whereas biological processes reduced 80-70 % melanoidins and 90 % heavy metals (iii) Bioaugmentation also reduced 70% melanoidins and other organic pollutants. (iv) Biochar-based treatment removes 80% organic pollutants. (v) Sequencing batch reactor along with vertical flow treatment wetlands reduced the oxygen demand of wastewater up to 10 times but requires a long retention time for the removal of pollutants. On the whole, the biological process bioaugmentation along with phycoremediation is preferred being economical, eco-friendly and and suitable to tropical environment.

Keywords: Wastewater; Treatment; Pollutant

Introduction

Water is indispensable resource for existence of life on the earth. The industrial development and lifestyle changes pose a serious threat to these water resources due to release of polluted wastewater into them. In order to combat it, the concerned regulatory authorities have given stringent norms regarding the release of industrial effluent into surrounding water bodies. Therefore, the removal of toxic substances from effluent has become imperative. The wastewater contains pollutants including organic materials, nutrients, which can be extracted, recovered and can be reused and recycled, which might be regarded as sustainable development.

One of the most polluting industries in the world is sugar mill industry, which may or may not be associated with distillery unit for alcohol production [1]. Wastewater released from sugar mill industry including distillery unit is a dark semiliquid waste, sludge, which consists of complex molecules including polysaccharides, reduced sugars, lignin, proteins, melanoidins, waxes etc. These compounds are complex and recalcitrant to the oxidation in the environment and are not degraded by conventional treatment processes including physical treatment processes such as coagulation and flocculation and biological oxidation processes such as activated sludge, trickling filter etc. This recalcitrant nature of the wastewater is due to the presence of complex compounds present in the wastewater especially melanoidins, which leads to increase in the oxygen demand of the wastewater and surface water in which these chemicals are released [2-3]. These complex compounds including melanoidins are highly toxic and might adversely affect the groundwater and soil when released without proper treatment into the surrounding. These toxic compounds are translucent to light and might reduce the rate of photosynthesis of aquatic organisms when released into surface water bodies causing death of aquatic flora. In addition, these complex molecules are carcinogenic and might accumulate in the food chain, which will adversely affect human health. Therefore, it is imperative to explore various treatment methods in order to suggest treatment process/or (s) to treat the sugar mill wastewater and reuse and recycle of nutrients. The aim of the study is to suggest effective abatement of pollutants of sugar mill industry effluent.

This audit relatively describes various treatment methods that show remarkable power to eliminate these recalcitrant compounds from sugar mill wastewater. This review describes recent research developments in wastewater treatment generated from sugar mill wastewater. Finally, challenges in the recovery of nutrients from wastewater and future view point are emphasized.

In this study the use of various treatment processes i.e. sequencing batch reactor, phycoremediation, bioaugmentation, nanoparticles, biochar along with nanocomposite have been explored. In this regard several studies have been conducted for the removal of pollutants using biochar as catalyst [4-6].

Material and Methods

For conducting this study extensive literature search using various search tools such as Google scholar, science direct, PubMed etc. was done using keywords such as sugar mill wastewater treatment, wastewater treatment, eco-friendly treatment of sugar mill wastewater etc. After that, relevant research articles from searched ones (n=100) were screened for various parameters such as publications not older than 10 years, economically feasible, sustainable, reduction of pollutants from effluent by more than 60 %, eco-friendly, easily available in tropical environment, the by-products of the treatment process are easily degradable.

Results & Discussion

Physicochemical Properties of Wastewater

The wastewater released from sugar mill and distillery is a dark coloured viscous liquid, the sludge, which consists of a group of colour producing chemicals known as melanoidins. Melanoidins are formed by reaction of reducing sugar with amino acids, which is known as Millard reaction. In addition, the sludge contains organic and inorganic chemicals and heavy metals [7-8]. The effluent is having a noxious smell, and is antibacterial, antifungal and recalcitrant to conventional treatment processes. The physicochemical properties of distillery effluent before treatment revealed that the effluent is highly acidic (pH =4.5), dark brown with very high total suspended solid (>4000 ppm) and very high chemical oxygen (COD>45,000 ppm), and biochemical oxygen demand (BOD>32000 ppm) [9]. Various treatment processes and their percent removal of pollutants from sugar mill effluent has been shown in (Table 1).

Table 1: *Percent Removal of Pollutants from Sugar Mill Wastewater.*

S.No.	Pollutant removal	Treatment process/ material used	Percent removal (%)	Reference
1.	COD	Photocatalysis using Graphine based nanocomposite (Ag3PO4/FE/GTiP)	80.3	[10]
2.	Color	Photo catalysis using graphene based nanocomposites	85.02	[10]
3.	Melanoidin	Biocatalytic and electrolytic degradation by *Sacromyces cerevisiae* cells suspended ad conjugated on silica and alumina	70 % removal in the presence of inorganic nitrogen	[11]
4.	Melanoidin	Fe impregnated activated carbon prepared from Mangifera indica biomass	85.6 % removal of melanoidins at 75 min contact time & Fe adsorbent ratio of 30% & initial melanoidin dose of 550 mg per liter	[12]
5.	Colour removal	The inoculum used was 2% (v/v) of *Bacillus albus* for 144h	84% removal	[13]
6.	Colour removal	Mixed bacterial culture of *Staphylococcus saprophyticus* and *Alcaligenaceae* sps.	71.8 % color removal from distillery wastewater	[14]
7.	Inorganic nutrient uptake (Nitrogen, phosphorous, potassium)	Diluted distillery spent wash used for irrigation of dahlia plant.	1:3 ratio dilution of spent wash showed higher growth rate and higher inorganic nutrient uptake.	Chanraju
8.	Metal uptake from sugarcane molasses	Melanoidin like product (MLP) from sugarcane molasses isolated using an adsorbent -column chromatography	MLP showed chelating property for metal ions in the order: Pb>Zn>Ni>Cu>Fe>Cd>Co. Japanese radish has been used for phytoextraction of these metal ions.	[15]
9.	Biodegradability, Color and toxicity removal	Nano catalytic ozonation of bio-methanated distillery wastewater	Enhancement of biodegradability, toxicity and color reduction occurred.	[16]
10.	Melanoidin removal	Fly ash adsorption is used to remove melanoidin reduction.	84% removal of melanoidins at 1100 mg per liter melanoidin concentration, pH 6, and contact time of 120 min.	[17]

11.	Organic load & Color removal	A bacterial consortium comprising *Pseudomonas aeruginosa*, *Stenotrophomonas maltophila* & *Proteus mirabilis* used.	67 % color removal within 24 h and 51% chemical oxygen demand reduction within 72h by the bacterial consortium.	[18]
12.	Organic load and color removal	Anaerobic treatment employing : (1) biological treatment by different fungi, bacteria and algae; and (2) physicochemical methods including adsorption, coagulation/precipitation, oxidation and membrane filtration.	The process removed 80 % organic load (BOD) and there is energy recovery in the form of biogas.	[19]
13.	Color removal	Activated carbon obtained from bagasse bottom ash is used to remove melanoidin from distillery effluent.	8.3 kg bagasse bottom ash reduced 100 mg per litre melanoidin to 10 mg per litre in unit volume of effluent.	Smaratanamonkol and Thiravetyan
14.	Color, total organic carbon (TOC) and dissolved organic carbon (DOC) removal	Natural manganese oxide is used to remove color, TOC and DOC from anaerobically treated molasses distillery wastewater.	Anaerobic treatment removes most of TOC and DOC. The color removal was much higher than TOC and DOC.	[20]
15.	Color removal	Microbial degradation of melanoidin by *Coriolus hirsutus* (a white rot fungus)	The white rot fungus decolorizes melanoidin in organic nitrogen free culture medium. Inorganic nitrogen enhanced the removal efficiency.	[21]
16.	Color and chemical oxygen demand (COD) removal	Ferric chloride as a coagulant was used to treat molasses effluent.	86% color and 96% COD removal from molasses effluent was observed.	[22]
17.	Color removal	Anaerobic digestion followed by color removal by biological and other methods	Anaerobic digestion removes organic material and other methods are effective in removal of color	[23]
18.	Melanoidin removal	Melanoidin removal from molasses effluent using activated carbon	Adsorption using activated carbon is effective in removal melanoidins	[24]
19.	Color removal	Color removal from spent wash through coagulation using *Moringa oleifera* seeds	53 % and 67 % color removal using NaCl and KCl salts.	[25]
20.	Melanoidin removal	Adsorption of melanoidin using sugar mill waste.	Sugarcane bagasse activated carbon removal occurred.	[26]

Use of Nano-Particles for the Treatment of Wastewater

Nano particles are one of the recent techniques for the treatment of sugar mill effluent. One of the advantages of this process is that a relatively less amount of chemicals was required for the formation of zero valent iron nanoparticles for the removal of organic pollutants from distillery wastewater. The nanoparticle used is nanosized zero valent iron nanoparticle along with ferrous sulphate heptahydrate [9]. The nanoparticle is highly reactive due its large surface area and is more effective at low concentration. The nanoparticle can be synthesized by borohydride reduction of Fe (II) or Fe(III) ions in aqueous medium. Sodium borohydride was used for reduction of FeSO4. 7H2O in aqueous medium. During this reaction, the colour changes from brown to black. The nanomaterial formed can be characterized by a number of methods including X-ray diffraction and scanning electron microscopy. The method is quite effective in removal of melanoidins at low concentration of the iron nanoparticle. The dark colour of the polluted water was removed after treatment. Also, there was 99.07% colour, 84.25 % COD, 89.20% BOD, and 86.5% TSS reduction in the effluent when sample containing nanosized zero valent iron nanoparticle along with ferrous sulphate heptahydrate and sodium borohydride in the ratio of 4:1 was used.

Use of Sequencing Batch Reactor and Vertical Flow Treatment Wetlands

Sequencing batch reactor along with vertical flow treatment wetlands removed organic material from highly concentrated wastewater of sugar mill industry. In this process, the organic material was removed with the help of hyper accumulator plants, which can either phytoextract or accumulate organic material and nutrients present in the wastewater. The major hurdle in this process was that the wastewater generated from distillery is acidic (pH =3). Hence, soda solution and urea may be added to it. This enhances the bacterial oxidation process, which oxidises the complex carbon sources into simple reducing sugars [27]. The heavy metals uptake by plants is also enhanced due to presence of bacteria in their rhizosphere, which help in their uptake and adsorption on the root surface [28-29]. The hyperaccumulator plants including Eclipta alba L., Altenanthera philoxeroide L. are able to bioabsorb metals and metalloids from the wastewater [29].

Phycoremediation of sugar mill and distillery wastewater

Phycoremediation or removal of pollutants from wastewater with the help of algae grown in the wastewater is one of the most widely used techniques. The algae reduced organic pollutants by utilizing them in the process of photosynthesis as substrate. Some cyanobacteria were found to be available in the environment i.e. in the wastewater including Nostoc, Calothrix, Gloeotrichia, Scytonema. These grew well in the distillery effluent due to the presence of abundant amount of organic material, nitrogen, phosphorous and an anoxic conditions, which were favourable for cyanobacterial growth [8]. The cyanobacterial community containing Oscillatoria, Spirulina, Phormidium, Synechococus were able to degrade and decolorize melanoidins. Among these cyanobacteria, Oscillatoria sps. showed higher degradation capacity.

Bioaugmentation as Treatment Process

Bioremediation along with bioaugmentation is a promising technique for the removal of pollutants from distillery effluent. Bioaugmentation is the introduction of a known microbial community into the wastewater for the removal of pollutants. The treatment process is a type of bioremediation, which is eco-friendly and economical as well. The distillery effluent contains organic material as well phenolic compounds, heavy metals including (Fe, Zn, Cu, Cd, Ni) in very high concentrations. The organic material is degraded (up to 70%) and heavy metals are biotransformed by the consortium of bacteria, which contains enzymes of the process of biotransformation. In addition, the colour of the effluent is also removed up to 90% [30-31]. This process of augmentation is eco-friendly and might be a sustainable treatment process for the degradation of highly concentrated effluent and recovery of nutrients and reuse of wastewater for irrigation process. Use of Biochar based catalyst and nanocomposites for the treatment of distillery wastewater.

Adsorption is a low cost and sustainable technique for the removal of pollutants from wastewater. Based on this, various adsorbents such as zinc oxide nanoparticle, biochar as a biological adsorbent, activated carbon etc, have been used. Biological biochar can be made from bagasse, bamboo waste, bark, coca husk, saw dust, wheat straw, rice husk, rice straw, empty fruit bunch, palm fiber, forest residue, saw dust, wheat straw and energy crops by various processes including pyrolysis. The biochar is a cheap adsorbent as it is formed through the pyrolysis of bagasse obtained from sugar mill industry. Biochar was used to remove pollutants from solid waste such as polluted soil [4]. Similarly, biochar can act as an adsorbent as well as catalyst for the removal of pollutants from distillery wastewater. It can remove pollutants from wastewater [32].

In addition, the treatment of wastewater with biochar based nanocomposites for industrial wastewater treatment is a promising technique. This removes pollutants through adsorption and photocatalytic degradation. The major limitation of the process is that it has a low surface area with negative charge, which reduces its capacity for adsorption. Due to its low density and small particle size, it is difficult to remove the biochar from wastewater after treatment. These limitation can be overcome by loading biochar with a range of nanoparticles, the compound thus formed are nanocomposites. These nanocomposites are innovative biochar based materials with high specific surface area, more number of surface active sites, high porosity, stronger stability and improved reusability. A range of nanocomposites have been formed by changing the ratio of the biochar and nanomaterials. These nanocomposites show a synergistic effect of biochar and nanomaterials. The biochar enhances the adsorptive capacity, while nanomaterials provide free radicals due to presence of nanocatalysts on its surface. In addition, the adsorption process can be enhanced further by doping photocatalysts on the surface of biochar. Thus, biochar based nanocomposites have been proved to be one of the most effective way to remove various pollutants from wastewater. The pollutants are adsorbed on the active site of the adsorbent.

Various mechanisms involved in this process are pore-filling, electrostatic interaction, creation of hydrogen bonds, pie bond interactions between the biochar and the pollutant. The adsorption process might be affected by various factors including temperature, pH, retention time, pollutant concentration, biochar dose and other factors [33]. Out of these, pH plays an important role in the process of adsorption of pollutants on the surface of nanocomposite. The photocatalytic pH zero plays an important role in photocatalysis. If the pH is below the point of zero charge (pHzero) then, the photocatalyst acquires a positive charge, while when the pH is above the pH zero, the catalyst becomes negatively charged. In case of pH below point of zero charge, the adsorbent active surface is filled with protons and make it positively charged, which reduces the pollutant removal efficiency by repelling the positively charged divalent ions. On the other hand, at pH above pH zero, the surface of adsorbent become negatively charged and attract the positively charged metal ions. The retention time also affects the removal of pollutants. The removal of pollutants enhances with increase in retention time initially and then declines. The decline in the removal process might be due to the filling of active sites on the surface of adsorbent. Similarly, the adsorption process increases with increase in pollutant concentration initially until all surface active sites are filled and after that the process of adsorption and removal of pollutant reduces. The biochar dose plays an important role in pollutant removal. The optimal concentration of biochar should be used so that the process remains economically efficient. Initially when the biochar dose is increased the process of pollutant removal enhances due to increase in active sites for the adsorption of pollutants, while further increase in biochar dose leads to decline in the removal of pollutants [5].

Reuse of Wastewater and Recovery of Nutrients

The wastewater generated from distillery contains high organic content as well as inorganic content including nitrogen, phosphorous, trace metals. The organic and inorganic load can be reduced by various techniques including nanoparticles, sequencing batch treatment along with vertical flow treatment wetlands and bioremediation augmented with microbial degradation. After treatment, the organic and inorganic content has been either recovered or degraded successfully and the water generated can be reused in agricultural activities.

Challenges & Future Prospects

Bioremediation with bioaugmentation has been proved to be a promising technique for the removal of pollutants from wastewater. Major challenges in the implementation of the technique is long retention time required for the treatment. Similarly, phycoremediation has a drawback that the carbon dioxide released during the process by microalgae is less than aerobic oxidation. The reuse of carbon dioxide released is possible through its sequestration into sludge as aerobic process. The energy evolved can be used in the form of biodiesel, biogas, biohydrogen and phenols. One of the methods used for the recovery of melanoidins and polyphenols, and water is forward osmosis and resin adsorption, which recovers up to 70 % water and melanoidins and 90% polyphenols [34]. The bioremediation of distillery wastewater is found to be cost effective. However, pilot-scale and full scale investigation is required. The scheme of sugar mill wastewater treatment in this study has been shown.

Conclusions

The comprehensive assessment of various treatment technologies revealed that the biological treatment process phycoremediation along with bioaugmentation is the best option to reduce sugar mill industry pollutants. The treatment process degraded 80 % organic content (melanoidins) and 90% heavy metals. The process is an economically feasible process; it can be easily established in a tropical environment and it is an eco-friendly process. In addition, the process does not produce any by-product, which is recalcitrant to degradation. On the other hand, the chemical treatment processes removed 99% melanoidins and 84.25 % other organic content. However, the process is not economical and eco-friendly. The other biological process sequencing batch reactor abate organic content 10 times the initial content. However, this process requires a long retention time. The biochar-based treatment process reduced 80% of organic content.

On the whole, the biological treatment process bioaugmentation along with phycoremediation treatment processes might be used for the effective abatement of organic pollutants from sugar mill industry. However, the results may vary based on environmental conditions and other factors, which requires further investigation at small and large scales.

Acknowledgments

Author is thankful to B.R. A. Bihar University, Muzaffarpur, Bihar, India for providing required facilities in order to conduct the research work.

Data availability: All data generated or analysed during this study are available from the corresponding author and upon reasonable request.

Compliance with ethical standards

Ethical approval: The submitted work is original and has not been published elsewhere in any form or language (partially or in full), In addition, there is no human participation in this study, so ethical approval in this consent in not required.

Informed Consent:

In this study, human participation is not involved. So, consent from participants is not applicable.

Consent to publish: This is not applicable as there is no human participation.

Author's contributions: The author confirms sole responsibility for the following: study conception and literature review, data collection, analysis and interpretation of results, and preparation of initial draft of manuscript and review of the manuscript.

Funding: The study received no specific grant from any funding agency in public, commercial or not-for -profit sector.

Conflict of interest: Author declare that she has no conflict of interest.

References

1. MoEFCC. Ministry of Environment Forest and Climate Change Notification, The Gazette of India, part 2, section 3, sub-section (i), Govt of India Press, Ring road, New Delhi, India. 2016.
2. Chaudhary P, Raj A, Bharagava RN. Environmental pollution and health hazards from distillery wastewater and treatment approaches to combat the environmental threats: a review. Chemosphere. 2018; 194: 229-246.
3. Fito J, Tefera N, Van Hulle SWH. Sugarcane biorefineries wastewater: bioremediation technologies for environmental sustainability. Chem Biol Technol Agric. 2019; 6: 6.
4. Xia C, Liang Y, Li X, Garalleh HA, Garalleh M, Hill JM, et al. Remediation competence of nanoparticles amalgamated biochar (nano biochar nanocomposites) on pollutants: A review. Environ Res. 2023; 218: 114947.
5. Wang J, Yuan S, Dai X, Dong B. Application, mechanism and prospects of Fe based/Fe-biochar catalysts in heterogeneous ozonation process: A review. Chemosphere. 2023; 319: 138018.
6. Wong Y, Luo J, Qin J, Huang Y, Ku T, Luo Y, et al. Efficient removal of phytochrome using rice straw derived biochar: Adsorption performance, mechanism and practical application. Biores Technol. 2023; 376: 128918.
7. Ratna S, Rastogi S, Kumar R. Current trends for distillery wastewater management and its emerging applications for sustainable environment. J Environ Manage. 2021; 290: 112544.
8. Ravikumar Y, Rajak SA, Yun J, Zhang G, Zabed HM, Lu XQ. Recent advances in Microalgae based distillery wastewater treatment. Environ Technol & Innovation. 2021; 24: 101839.
9. Srivastava K, Srivastava A, Singh P, Sharma V, Singh P. Remediation of distillery wastewater using zero valent iron nanoparticles. Current Research in Green and Sustainable Chem. 2021; 4:100072.
10. Nahyoon NA, Liu L, Saleem W, Nahyoon SA, Rabe K Efficient photocatalytic treatment of sugar mill wastewater with 2%

Ag3PO4/Fe/GTiP nanocomposite. Arabia J Chem. 2020; 13: 3624-3632.
11. Triakiri EP, Sompatzi E, Voukia F, Sotiropoulos S, Pantazaki PP. Biocatalytic and bioelectrolytic decolorization of simulated melanoidin wastewaters by Saccharomyces cerevisiae cells suspended and conjugated o silica and alumina. J Environ Chem Eng. 2020; 8: 104078.
12. Rizvi S, Goswami L, Gupta SK. A holistic approach for melanoidin removal via Fe impregnated activated carbon prepared from Mangifera indica leaves biomass. Bioresour Technol Rep. 2020; 12:100591.
13. Kumar V, Agrawal S, Shashi SK, Motghare A, Singh S, Ramamurthy PC. Bioremediation potential of newly isolated Bacillus albus strain VKDS9 for decolorization and detoxification of biomethanated distillery effluent and its metabolites characterization for environmental sustainability. Enviorn. Technol Innov. 2022; 26: 102260.
14. Chawdhary P, Sammi SR, Pandey R, Kaithwas G, Raj A, Singh J, et al. Bacterial degradation of distillery wastewater pollutants and their metabolites characterization and its toxicity evaluation by using Caenorhabaditis elegans as terrestrial test models. Chemosphere. 2020; 261: 127689.
15. Hatana K-I, Kanazawak K, Tomura H, Yamatsu T, Tsunoda KI, Kubota K. Molasses melanoidin promotes copper uptake for radish sprouts: the potential for an accelerator of phytoextraction. Environ Sci Pollut Res Int. 2016; 23:17656-17663.
16. Malik SN, Khan SM, Ghosh PC, Vaidya AN, Das S, Mudliar N. Nanocatalytic ozonation of biomethanated distillery wastewater for biodegradability enhancement, color and toxicity reduction with biofuel production. Chemosphere. 2019; 230: 449-461.
17. Ahmed S, Unar IN, Khan HA, Maitlo G, Mahar RB, Jatoi AS, et al. Experimental study and dynamic simulation of melanoidin adsorption from distillery effluent. Environ Sci Pollut Res. 2020; 27: 9619-9636.
18. Mohana S, Desai C, Madamwar D. Biodegradation and decolorization of anaerobically treated distillery spentwash by a novel bacterial consortium. Bioresour Technol. 2007; 98: 333-339.
19. Satyawali Y, Balakrishnan M. Wastewater treatment in molasses - based alcohol distilleries for COD and color removal: A review. J Environ Manage. 2008; 86:481-497.
20. Arimi MM, Zhang Y, GeiBen SU. Color removal of melanoidin rich industrial effluent by natural manganese oxides. Sep Purif Technol. 2015; 150: 286-291.
21. Miyata M, Mori T, Iwahori K, Fujita M. Microbial degradation of melanoidin- containing wastewaters: combined use of activated sludge and the fungus Coriolus hirsutus. J Biosci Bioeng. 2000; 89: 145-150.
22. Liang Z, Wang Y, Zhang Y, Liu H. Coagulation removal of melanoidins from biologically treated molasses wastewater using Ferric chloride. Chem Eng J. 2009; 152: 88-94.
23. Arimi MM, Zhang Y, Gotz G, Kiriamiti K, Sven UG. Antimicrobial colorants in molasses distillery wastewater and their removal technologies. Int Biodeter Biodegr. 2014; 87: 34-43.
24. Liakos TI, Lazaridis NK. Melanoidins removal from molasses effluents by adsorption. J Water Process Eng. 2016; 10: 156-164.
25. Prasad RK. Color removal from distillery spent wash through coagulation using Moringa oleifera seeds: use of optimum response surface methodology. J Hazard Mater. 2009; 165: 804-811.
26. Jembere AL, Genet MB. Comparative adsorptive performance of adsorbents developed from sugar industrial wastes for the removal of melanoidin pigment from molasses distillery spent wash. Water Resour Ind. 2021; 26: 100165.
27. Boucle SP, Pelus L, Becheau E, Cervoise L, Troesch S, Molle P. Combination of sequencing batch reactor and vertical flow treatment wetlands: a full - scale experience for rum distillery wastewater treatment in tropical climate. Nature-Based Solutions. 2023; 3: 100056.
28. Kumari M, Tripathi BD. Effect of Phragmities australis and Typha latifolia on biofiltration of heavy metals from secondary treated effluent. Int J Environ Sci Technol. 2015; 12: 1029-1038.
29. Sharma P. Efficiency of bacteria and bacterial assisted phytoremediation of heavy metals: an update. Bioresour Technol. 2021; 328: 124835.
30. Su X, Yuan J, Dang W, Sun F, Wang M, Dong Z, et al. Organic and nitrogenous pollutants removal paths in vegetation activated sludge process (V-ASP) for decentralized wastewater treatment by using stable isotope technique. Bioresour Technol. 2021; 330: 124959.
31. Tripathi S, Sharma P, Purchase D, Tiwari M, Chakrabarty D, Chandra R. Biodegradation of organometallic pollutants in distillery wastewater employing a bioaugmentation process. Environ Technol & Innovation. 2021; 23: 101774.
32. Ahmad A, Priyadarshini M, Yadav S, Ghangrekar MM, Surampali RY. The potential of biochar-based catalysts in advanced treatment technologies for efficacious removal of persistent organic pollutants from wastewater: A review. Chem Eng Res & Design. 2022; 187:470-496.
33. Amdeha E. Biochar-based nanocomposites for industrial wastewater treatment via adsorption and photocatalytic degradation and the parametes affecting these processes. Biomass Conv Bioref. 2023.
34. Singh N, Basu S, Balakrishnan M. Comprehensive treatment scheme for distillery wastewater targeting recovery of water, antioxidant compounds and biogas. J Water Process Eng. 2020; 38: 101663.
35. Dorner M, Lokesh S, Yang Y, Behrens S. Biochar-mediated abiotic and biotic degradation of halogenated organic contaminants- A review. Sci Total Environ. 2022; 852: 158381.