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JOB EXPERIENCE

- Post-Doctoral Fellow at the Zuckerberg Institute of Water Research, Department of Desalination and Water Treatment, Ben Gurion University of Negev, Israel from October 2020 - *Continuing*

  Research Area: *Upscaling of Ion Exchange Membrane Bioreactor (IEMB) for removal of oxyanions from water and wastewater*
- Working as Associate Professor, Department of Civil Engineering, Institute of Technical Education & Research, Siksha 'O' Anusandhan (Deemed to be University) Bhubaneswar, India from June 2016 – *Continuing on Sabbatical leave (from October 2020 to September 2022).*
- Served as Lecturer at Centre for Energy and Environmental Engineering, National Institute of Technology Hamirpur, Himachal Pradesh, India from December 2014 - May 2016.

INSTITUTIONAL PROJECTS AND STUDENT GUIDANCE

- Investigations on the efficacy of electrocoagulation using scrap electrodes for nutrient removal for wastewater (*Completed PG Project*)
- Treatment of Grey water using dolochar as industrial waste (*Completed PG Project*)
- Development of low cost Microbial Fuel Cell for sewage treatment (*Completed UG Project*)
- P.G. Student guided: **05**

QUALIFICATION

- **Doctorate (PhD)** in **Infrastructure Engineering** with specialization in ***Environmental Engineering*** from School of Infrastructure, Indian Institute of Technology Bhubaneswar, India in 2015.
  - **Thesis Title:** *Development of an integrated treatment system for COD and color removal from textile wastewater.*
- **Master of Technology (M.Tech)** in ***Environmental Science & Engineering*** from Indian School of Mines University Dhanbad with CGPA of **8.16** in 2009.
  - **Thesis Title:** *Development of portable filter for arsenic removal from drinking water.*

- **Bachelor of Technology (B.Tech)** in ***Biotechnology*** from Uttar Pradesh Technical University Lucknow, India with **71.94%** in 2007.
    - **Thesis Title:** *Comparative study and production of β-fructofuranosidase enzyme using selective fungal strains and media optimization*.

RESEARCH INTEREST

Water and Wastewater Treatment

- Adsorption and Ion Exchange Processes
- Electrochemical Processes
- Advanced Oxidation Processes
- Biological Treatment using Membrane Bioreactor

REVIEWER/EDITOR/SESSION CHAIR/MEMBERSHIPS

- Editorial Board Member, Journal of Water Process Engineering (Elsevier, IF: 5.48).
- Editorial Board Member, Journal of Chemical Engineering Research Updates, Avanti Publishers.
- Editorial Board Member, Journal of Textile Science and Technology, Scientific Research Publishers.
- Member, European Membrane Society.
- Member Associate, Global Institute for Energy, Environment and Sustainability (GIEES), USA.
- Reviewer of some reputed journals like Journal of Environmental Management, Industrial & Engineering Chemistry Research, Desalination and Water Treatment, Critical Reviews in Environmental Science and Technology, ASCE-Journal of Hazardous, Toxic, and Radioactive Waste, Water Research, Journal of Hazardous Materials, Ecotoxicology and Environmental Safety, Journal of Environmental Science and Health-Part B, Journal of Cleaner Production etc.
- Invited for chairing the session in several international conferences of repute such as SDEWES 2013 in Dubrovnik, Croatia; SEAWE11 in Bangkok, Thailand.
- Life member, International Association of Computer Science and Information Technology (IACSIT), Singapore.
- Life Member, Asia-Pacific Chemical, Biological and Environmental Engineering Society (APCBEES), China.

AWARDS AND HONORS

- Qualified UGC-NET 2017 in Environmental Sciences (Competitive Examination at National Level).
- Young Scientist Award during VIFRA 2015 in Environmental Engineering Category by Venus International Foundation Chennai, India.
- Ministry of Human Resource Development fellowship for perusing PhD at IIT Bhubaneswar from July 2010 to June 2014.
- Council of Scientific and Industrial Research travel award to participate in an international conference SDEWES 2013 in Dubrovnik, Croatia.
- Second prize in 3rd research scholar's day at IIT Bhubaneswar in February 2013.
- Third prize in 1st research scholar's day at IIT Bhubaneswar in February 2011.

PERSONAL DETAILS

Date of Birth :	April 07, 1984
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LIST OF PUBLICATIONS

[https://scholar.google.co.in/citations?user=kK1_gisAAAAJ&hl=en&authuser=3] [Citations: **2063**; h-index: **10**]

(a) Refereed Journals [19]

1. **Verma, A.K.,** Dash, R.R., Bhunia, P. A review on chemical coagulation/flocculation technologies for removal of colour from textile wastewaters, *Journal of Environmental Management*, 2012: 93(1), 154-168 **[Impact Factor: 6.789].**
2. **Verma, A.K.**, Bhunia, P., Dash, R.R. Effectiveness of aluminum chlorohydrate (ACH) for decolorization of silk dyebath effluents, *Industrial & Engineering Chemistry Research,* 2012: 51(25), 8646-8651 **[Impact Factor: 3.764].**
3. **Verma, A.K.**, Bhunia, P., Dash, R.R., Supremacy of magnesium chloride for decolourisation of textile wastewater: a comparative study on the use of different coagulants, *International Journal of Environmental Science and Development*, 2012: 3(2), 119-123 **[Scopus].**
4. **Verma, A.K.**, Bhunia, P., Dash, R.R. Applicability of a new pre-hydrated industrial grade polyaluminium salt for the decolourisation of textile wastewater, *Desalination and Water Treatment*, 2014: 52(22-24), 4553-4561 **[Impact Factor: 1.254].**
5. **Verma, A.K.**, Bhunia, P., Dash, R.R. Chemical coagulation and sonolysis for total aromatic amines removal from anaerobically pre-treated textile wastewater: a comparative study. *Advances in Environmental Research*, 2014: 3(4), 293-306.
6. **Verma, A.K.**, Bhunia, P., Dash, R.R. Reclamation of wastewater using composite coagulants: a sustainable solution to the textile industries, *Chemical Engineering Transactions,* 2014: 42, 175- 180 **[Scopus].**
7. **Verma, A.K.**, Bhunia, P., Dash, R.R. Carbonaceous organics removal kinetics in an upflow anaerobic sludge blanket (UASB) reactor treating physico-chemically pre-treated textile wastewater, *Desalination and Water Treatment*, 2015: 54(6), 1577-1588 [**Impact Factor: 1.254].**
8. **Verma, A.K.**, Bhunia, P., Dash, R.R., Tyagi, R.D., Surampalli, R.Y., Zhang, T.C. Sonolytic decolorization of textile wastewater containing a mixture of reactive, acid and disperse dyes, *CLEAN- Soil, Air, Water,* 2015: 43(5), 767-774 **[Impact Factor: 1.77].**
9. **Verma, A.K.**, Bhunia, P., Dash, R.R., Tyagi, R.D., Surampalli, R.Y., Zhang, T.C., Effects of physico-chemical pre-treatment on the performance of an upflow anaerobic sludge blanket (UASB) reactor treating textile wastewater: application of full factorial

central composite design. *Canadian Journal of Chemical Engineering,* 2015: 93(5), 808-818 **[Impact Factor: 2.007].**

10. **Verma, A.K.**, Bhunia, P., Dash, R.R., Performance of UASB reactor treating synthetic textile wastewater: effect of physico-chemical pre-treatment. *Desalination and Water Treatment*, 2015: 57(18), 8050-8060 [**Impact Factor: 1.254].**

11. **Verma, A.K.**, Nath, D., Bhunia, P., Dash, R.R., Application of ultrasonication and hybrid bioreactor for the treatment of synthetic textile wastewater, *ASCE-Journal of Hazardous, Toxic, and Radioactive Waste*, 2017, 21(2): 04016018 **[Scopus].**

12. **Verma, A.K.**, Treatment of textile wastewaters by electrocoagulation employing Fe-Al composite electrode, *Journal of Water Process Engineering,* 2017: 20, 168–172 **[Impact Factor: 5.485].**

13. Shreya, Dash, R.R., **Verma, A.K.**, Dash, A.K., Pradhan, A., Adsorptive removal of surfactant using dolochar: a kinetic and statistical modeling approach, *Water Environment Research,* 2019, https://doi.org/10.1002/wer.1193 **[Impact Factor: 1.946].**

14. Shreya, Dash, R.R., **Verma, A.K.**, Dash, A.K., Pradhan, A., Mechanistic modelling and process design for removal of anionic surfactant using dolochar, *ASCE-Journal of Hazardous, Toxic, and Radioactive Waste*, 2019, doi:10.1061/(ASCE)HZ.2153-5515.0000492 (*Accepted, in press*) **[Scopus].**

15. Bakshi, A., **Verma, A.K.,** Dash, A.K., Electrocoagulation for removal of phosphate from aqueous solution: statistical modelling and techno-economic study, *Journal of Cleaner Production*, 2019, 118988, doi: 10.1016/j.jclepro.2019.118988 (*Accepted, in press*) **[Impact Factor: 9.29].**

16. Barik, M., Das,C.P., **Verma, A.K.,** Sahoo, S., Sahoo, N.K., Metabolic profiling of phenol biodegradation by an indigenous Rhodococcus pyridinivorans strain PDB9T N-1 isolated from paper pulp wastewater, *International Biodeterioration & Biodegradation,* 2021, 158, 105168. doi: 10.1016/j.ibiod.2020.105168 **[Impact Factor: 4.32].**

17. Naik M.R., Barik, M., Prasad, K.V., Kumar, A., **Verma, A.K.,** Sahoo, S.K., Jha, V., Sahoo, N.K., Hydro-geochemical analysis based on entropy and geostatistics model for delineation of anthropogenic ground water pollution for health risks assessment of Dhenkanal district, India, *Ecotoxicology,* 2021, doi: 10.1007/s10646-021-02442-1 **[Impact Factor: 2.823].**

18. Shreya, **Verma, A.K.**, Dash, A.K., Bhunia, P., Dash, R.R., Removal of Surfactants in Greywater using Low-Cost Natural Adsorbents: A Review, *Surfaces and Interfaces*, 2021, doi: 10.1016/j.surfin.2021.101532 **[Impact Factor: 4.837].**

19. Panigrahy, N., Priyadarshini, A., Sahoo, M.M., **Verma, A.K.**, Daverey, A., Sahoo, N.K., A comprehensive review on eco-toxicity and biodegradation of phenolics: Recent progress and future outlook, *Environmental Technology & Innovation*, 102423, S2352-1864(22)00079-7 **[Impact Factor: 5.263].**

(b) Conferences [11]

1. **Verma, A.K.**, Dinur, S., Ronen, Z., Oren, Y., Gilron, J., Investigations on Donnan Dialysis using Different Membranes and Subsequent Scaleup for Nitrate Removal from Water/Wastewater, *Euromembrane 2021*, 28 November to 3 December, 2021, Copenhagen, Denmark.

2. Gayatri, A., **Verma, A.K.,** Geotechnical characterization of expansive soil and utilisation of waste to control its swelling & shrinkage behavior, *Recycle 2018-International Conference on Waste Management*, April 22-24, 2018, Indian Institute of Technology Guwahati, India.

3. Dubey, M., **Verma, A.K.**, Biogas production from food waste: a theoretical study of NIT Hamirpur campus, International Conference on "*Innovative Research in Civil. Computer Science, Information Technology, Mechanical, Electrical and Electronics Engineering*" (CIME 2016), Organized by Krishi Sanskriti Publications, 19-20 March, 2016, JNU New Delhi, India.

4. Nath, D., Bhunia, P., **Verma, A.K.,** Dash, R.R., Ultrasonication integrated with hybrid biological reactor for treatment of synthetic textile wastewater, *Recycle 2016-International Conference on Waste Management,* April 1-2, 2016, Indian Institute of Technology Guwahati, India.

5. **Verma, A.K.**, Bhunia, P., Dash, R.R., Katoch, S.S., On the development of substrate removal kinetics for upflow anaerobic sludge blanket reactor treating physico- chemically pre-treated textile wastewater, *India International Science Festival (IISF 2015),* December 4-December 8, 2015, Indian Institute of Technology Delhi, India.

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7. **Verma, A.K.**, Bhunia, P., Dash, R.R., Reclamation of wastewater using composite coagulants: a sustainable solution to the textile industries (0075-1), *8th Conference on Sustainable Development of Energy, Water and Environment Systems* (SDEWES 2013), September 22-27, 2013, Dubrovnik, Croatia.
8. **Verma, A.K.**, Bhunia, P., Dash, R.R., Decolourisation of simulated reactive dye bath effluents using aluminium and mangnesium based pre-hydrated salts, *International Symposium of Southeast Asian water Environment, Hanoi, Vietnam*, 2012:10(1), 179-186.
9. **Verma, A.K.**, Bhunia, P., Dash, R.R., Decolourisation of textile wastewaters using ultrasonication, *Proceedings of Symposium on Sustainable Infrastructure Development (SID)*, 8th-9th February 2013, Indian Institute of Technology Bhubaneswar, Odisha, India (Page: 161- 167).
10. **Verma, A.K.**, Bhunia, P., Dash, R.R., Performance of ferrous sulphate in combination with calcium hydroxide for removal of colour and COD of synthetic textile wastewater, *International Conference of Environmental Research*, Surat, India, *2011, PS-1279.*

(c) Book Chapters [05]

1. **Verma, A.K.,** Rout, P.R., Bhunia, P., Dash, R.R., Anaerobic treatment of wastewater, *Green Technologies for Sustainable Water Management*, 2016, 297-336, American Society of Civil Engineers, doi: 10.1061/9780784414422.ch09.
2. Sarkar, P., **Verma, A.K.,** Bhunia, P., Dash, R.R., Adsorption of Reactive Red 120 from aqueous solution by locally available modified adsorbents, *Advances in Environmental Engineering*, 2015, Astral International Pvt. Ltd. New Delhi, India.
3. Rout, P.R., **Verma, A.K.,** Bhunia, P., Surampalli, R.Y., Zhang, T.C., Tyagi, R.D., Brar, S.K., Goyal, M.K., Introduction to Sustainability and Sustainable Development, *Sustainability: Fundamentals and Applications*, 1st Ed. 2020, John Wiley & Sons Ltd.
4. **Verma, A.K.,** Rout, P.R., Lee, E., Bhunia, P., Bae, J., Surampalli, R.Y., Zhang, T.C., Tyagi, R.D., Lin, P., Chen, Y., Biodiversity and Sustainability, *Sustainability: Fundamentals and Applications*, 1st Ed. 2020, John Wiley & Sons Ltd.
5. Ismaiel, Z., **Verma, A.K.**, Analysis of Risk Assessment and Management of Wastewater Treatment Plants. Recent Developments in Sustainable Infrastructure (ICRDSI-2020)—Structure and Construction Management. *Lecture Notes in Civil Engineering*, 2022, Springer, Singapore. https://doi.org/10.1007/978-981-16-8433-3_31

(d) Filed provisional U.S. patent (applications no. 63/282,729) on the "Unique Way To Operate The Pilot Scale IEMB" with Post Doc Supervisors Prof. Jack Gilron, Prof. Yoram Oren and Prof. Zeev Ronen.

References

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Treatment of textile wastewaters by electrocoagulation employing Fe-Al composite electrode

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ABSTRACT

In the present study, electrocoagulation process employing Fe-Al composite electrode was applied for treatment of different types of textile wastewaters. Effect of major operating parameters such as pH, reaction time, current density, voltage and inter-electrode distance were investigated for chemical oxygen demand (COD) and colour removal efficiency. The process was found promising and produced more than 90% COD and colour removal efficiency at optimised operating conditions of pH 8, reaction time 80 min, current density 20 A/m^2 with an inter-electrode distance of 3 cm. Robustness of the process was investigated on real and anaerobically pre-treated textile wastewater. For real textile effluents, the process produced approximately 99% colour removal efficiency, creating virtually colourless solution even at a lesser reaction time of 60 min. Electrocoagulation effectively detoxified the anaerobically pre-treated textile wastewater by eliminating 78% of aromatic amines within a reaction time of 180 min.

1. Introduction

Textile industry effluents are one of the major sources of environmental contamination and public well-beings, mostly in many urban regions. These effluents are severely polluted with the complex organic and inorganic chemicals which are used during various steps of textile processing. The unused constituents from each step are discharged as wastewater which possesses strong colour due to the presence of residual dyes, high organic and inorganic matters, turbidity, pH and toxic chemicals. Presence of a very small amount of residual dye in water is highly visible and consequently, affects the receiving environment not only aesthetically, but also disturbs the aquatic life by hindering the light penetration and oxygen transfer. The carcinogenic and mutagenic ability of various azo dyes and their precursors produces detrimental effects to the environment [1]. Therefore, to protect the environment, textile wastewater must be treated up to the safe discharge limits as recommended by legal bodies of different countries. Various physico-chemical, chemical and biological processes, as well as some of the new emerging techniques like sonochemical or advanced oxidation processes are practiced to treat the textile wastewater [2,3]. Each of them has some limitations and drawbacks in their application. Biological treatment by activated sludge offers appreciable efficiencies for COD removal, but does not effective for the elimination of the colour of the wastewater and often operational problems such as bulking of sludge appear. Coagulation/flocculation process has been found to be robust, cost effective, easy to operate and energy saving treatment options, but the coagulation process does not work well for all the types of textile dyes [4]. Advanced oxidation processes such as ultrasonication, ozonation, UV-radiation H_2O_2, and their combinations have a great interest, but the costs are still very high due to the high doses required and power consumption [5]. Adsorption and nanofiltration processes are not always enough to satisfy the discharge limits [6]. In addition, few electrochemical technologies such as electrochemical oxidation, electrochemical reduction, indirect electro-oxidation with strong oxidants, emerging photo-assisted electrochemical treatments and electrocoagulation have received considerable attention for treating dye wastewaters during last decade [7]. Electrocoagulation (EC) process has been successfully used for the treatment of textile wastewater being attractive for its versatility, safety, selectivity, amenability to automation, ease of control and environmental compatibility [8]. These processes are popular because of the ease of distribution and moderate requirement of chemicals [9,10]. It involves the generation of coagulant in situ by the dissolution of metal ions from the consumable anode with subsequent formation of hydroxide ions at the cathode [11,12]. In EC, contaminants are encroached up towards the surface of the EC cell by small bubbles of hydrogen gas produced from the cathode. Therefore, as an alternative of chemicals and microorganisms, electrons are the only working agents in electrochemical cell being responsible for facilitating wastewater treatment [13]. The most widely used electrode materials in electrocoagulation process are aluminum and iron. Many researchers reported appreciable treatment efficiency of electrocoagulation employing aluminum, iron and copper electrodes for

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Electrocoagulation for removal of phosphate from aqueous solution: Statistical modeling and techno-economic study

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A B S T R A C T

The focus of this study is to evaluate electrocoagulation as a process for the remediation of phosphate contaminated synthetic aqueous solutions using scrap aluminium plate electrodes in monopolar-parallel mode. An attempt was made in modeling the phosphate removal as a function of the significant parameters as well as to optimize the process statistically with the help of Response Surface Methodology using Design Expert software Version 7.0.0. The full factorial central composite design was followed to obtain the required number of runs for batch study. Five parameters namely initial pH, inter-electrode distance (IED), the concentration of the supporting electrolyte (SEC), electrolysis-time and voltage were considered for the experimentations. A valid model to predict the removal efficiency was established and the removal efficiencies witnessed were as high as 98%. The techno-economic optimization yielded the following set of parameters as the most economical solution: pH = 7, Voltage = 11.23 V, IED = 3 cm, t = 14.03 min and SEC = 0.46 g/L exhibiting a 90% removal efficiency and an operating cost of 0.22 \$/m^3 of water treated or 2.52 \$/Kg of phosphate removed. The study of crystallinity of the electrocoagulation byproduct was also conducted using XRD analysis, which showed the presence of amorphous or poorly crystalline phases.

1. Introduction

Since the late 1960s, phosphate removal has received commendable attention Rabbani et al. (2012). Nitrates and phosphates are the major nutrients required by plants and microorganisms for their physiological processes Singh and Ramesh, 2013. The main forms of phosphates in water bodies are orthophosphate, polyphosphate and organic phosphates Rabbani et al. (2012). Orthophosphates are formed by either chemical or enzymatic hydrolysis Park et al. (2016). They are the only form of phosphorus that can be assimilated by algae, bacteria and plant Correll (1998). The abundance of nutrients in water bodies give rise to eutrophication. This phenomenon is particularly common in closed water systems, like lakes, enclosed bays where there is hardly any flow Oguz et al. (2003). It leads to a reduction of dissolved oxygen, death of fish Hudson and Marson (1970), poisoning of livestock Reynolds (1981); Rout et al. (2014), malfunctioning and shutdown of water treatment plants due to clogging Collingwood (1977); Greene and Hayes (1981). The major sources of phosphates are human waste, domestic and industrial wastes Barnes et al., 1984, agricultural runoff Kauppi (1985) and various other industrial processes Kobya et al. (2010); Akyol et al. (2013); Kuokkanen et al. (2014). In the United States and India, discharge limits of phosphates are (0.5 mg/L-1 mg/L) and 5 mg/L as P, respectively Vasudevan et al. (2009). These limitations are brought about by means of various techniques, which include chemical precipitation and crystallization Huang et al. (2015); Su et al. (2014), ion exchange, membrane filtration Chen et al. (2014), wetlands, enhanced biological phosphate removal (EBPR) Zeng et al. (2016) and adsorption Rout et al. (2014). Electrocoagulation (EC) is a coagulant-dosing technology, wherein, a sacrificial anode dissolves itself by the passage of electric current through it. Various products are formed due to hydrolysis of the dissolved metal cations and bring about the charge neutralization of negatively charged species (colloids or dissolved pollutants) (Verma, 2017). The amorphous metal hydroxide (and/or polyhydroxide) precipitates formed because of cationic hydrolysis incorporate the impurities in them and sweep those out of the solution Mollah et al. (2004). EC exhibits lesser energy requirement, less chemical cost, compact arrangement, provision for precise coagulant dosage via control of applied voltage, ability to

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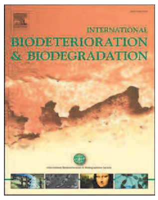

Metabolic profiling of phenol biodegradation by an indigenous *Rhodococcus pyridinivorans* strain PDB9T N-1 isolated from paper pulp wastewater

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A R T I C L E   I N F O

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Paper pulp wastewater
Oxalocrotonic acid pathway
Culture media components
Central composite design

A B S T R A C T

In the present study, a phenol degrading *actinomycetes* strain was isolated from paper pulp wastewater. The isolated strain was identified as *Rhodococcus pyridinivorans PDB9T*N-1 using 16S rRNA gene sequencing technique, which yielded the complete degradation of 1600 mg l^{-1} of phenol within 56 h. Moreover, the *Rhodococcus* species could remove over 97.5% of total organic carbon (TOC) at an initial phenol concentration of 1000 mg l^{-1}. The metabolic profile of phenol biodegradation by the actinomycetes species has been investigated using liquid chromatography–mass spectrometry (LC-MS) and Fourier-transform infrared spectroscopy (FT-IR). The key intermediate products detected in the *actinomycetes* culture were hydroquinone, protocatechuic acid, beta-carboxycis-cismuconate, maleyl acetate, 4–oxalocrotonic acid and 3-fumarylpyruvic acid. Further, a tentative oxalocrotonic acid pathway has been proposed on the basis of the detected intermediate products. The culture medium constituents are highly indispensable for the microbial growth, enzyme and other cellular metabolic activities associated with phenol biodegradation. Therefore, the effect of media components were modelled with the help of response surface methodology (RSM) and central composite design (CCD). A reliable quadratic model was established which predicted the degradation efficiency as high as 99.5% with an appreciable correlation coefficient (R^2) of 0.98. Moreover, phenol degradation efficiency was improved with concentrations beyond the central values for all media components except K_2HPO_4 and NaCl.

1. Introduction

Phenolic compounds are one of the most challenging pollutants present in the wastewater discharged from different industries. The major industries associated with discharging phenolic pollutants to the environment are petrochemicals (2.8–1220 mg l^{-1}), petroleum oil refineries (6–500 mg l^{-1}), coal mining (9–6800 mg l^{-1}) and coke oven plant (28–1200 mg l^{-1}) (Busca et al., 2008; Pal and Kumar, 2014; Cetinkaya and Ozdemir, 2018). Phenolic pollutants undergo an active transformation inside the living organisms and generate more toxic electrophilic metabolites mediated by cytochrome P450 enzyme system. These active metabolites may bind and damage DNA or other vital enzyme systems of the living organisms, consequently causing mutagenicity and carcinogenicity (Michałowicz and Duda, 2007; Dayana et al., 2019). Therefore, these phenolic compounds have been listed as the priority pollutants both by US- Environmental Protection Agency and European agency.

Over the past decades, several conventional techniques have been explored for the treatment of phenolics wastewater, for instance; adsorption, fenton reagent, ozonation, membrane-based technologies, electrochemical processing and photocatalysis (Pal and Kumar, 2014; Sahoo et al., 2020). Among the different techniques available for degradation of toxic phenolic pollutants, biodegradation is the most promising and popular due to its numerous advantages such as; eco-friendly nature, economical feasibility and practical viability (Panigrahy et al., 2020a). Therefore, different microbial strains have been isolated for degradation of phenolic pollutants from different wastewaters such as; *Pseudomonas* species, *Citrobacter* farmeri SC01, *Debaryomyces* species, *Bacillus* species, *Arthrobacter* species (Panigrahy et al., 2020b; Ren et al., 2014; Jiang et al., 2017; Felshia et al., 2017; Sahoo

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Removal of surfactants in greywater using low-cost natural adsorbents: A review

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Surfactants
Adsorption
Low-cost natural adsorbents

ABSTRACT

Water scarcity problem due to both natural and human-made phenomenon is on the rise. Development and implementation of efficient and cost-effective methods to treat and reuse wastewater has become a subject of prime importance. Greywater constitutes approximately 70% of total wastewater from a household, if treated can address major water shortage problems. The current review is focused on the use of low cost materials as adsorbents for the removal of surfactants from gray water. Based on the literature survey, common adsorbents like wood and activated carbon have long been used as conventional adsorbents to remove typical greywater pollutants. In particular, waste materials as low-cost adsorbents tested in the past for the removal of surfactants, which constitute major proportion of pollutants in greywater, have been the focal point of the present study. The values of typical parameters of wastewater as studied by various researchers were closely observed and were found as pH 6.2–9.4, turbidity 20–444 NTU, total dissolved solids (TDS) 237–2385 mg/L, chemical oxygen demand (COD) 58–1340 mg/L, biochemical oxygen demand (BOD_5) 42.1–6250 mg/L, TSS 25–1852 mg/L and surfactants 3–118 mg/L. Myriads of research have investigated the potential use of agricultural waste as cheap and natural adsorbents for the removal of pollutants from both industrial and domestic wastewater. The fact that some of such bio-sorbents have been tested specifically for removing surfactants from greywater makes it an untouched and naive field of research. Adsorbents that have been tested include granite sand, granular charcoal, dolochar, rice husk, coconut shell, zeolites etc. Such studies have not only portrayed a wide range of removal efficiencies but also depicted a pH dependent adsorption process. In a nutshell, there is a tremendous scope to explore such cost-efficient and simple alternatives and subsequently be implemented in the near future.

1. Introduction

In today's era, fresh water sources are rapidly on the decline. Unrestricted anthropogenic activities have led to increasing problems of water pollution, stress and related diseases. Many regulatory authorities and international agencies have given importance to the reuse and recycling of wastewater. Therefore, the need for treatment of wastewater generated from industries and households has become an important focus of current research. As per the United Nations Development Program (UNDP) goals, by 2030, it is aimed to reduce water pollution, improve the water quality, reduce discharge of toxic substances into the environment and focus on recycle and reuse [1]. Recent reports furnished by the United Nations reiterate the problem of water stress faced by 700 million people in 43 countries. It is approximated that 663 million people do not have access to uncontaminated and reliable source of drinking water. In addition, roughly 1.8 billion people are without good quality water considered to be safe for human consumption [2].

A typical household generates two types of wastewater viz.:

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ASSIGNMENT

WHEREAS We,

Jack Gilron, an Israeli citizen residing at 2 HaRevava St., Beer-Sheva 8422514, Israel;

Yoram Oren, an Israeli citizen residing at 20 Vered St., Beer-Sheva 8485247, Israel,

Zeev Ronen, an Israeli citizen residing at Midreshet Sde Boker, 8499000, Israel, and

Akshaya Verma, an Indian citizen residing at Midreshet Sde Boker 8499000, Israel,

are the inventors of provisional U.S. patent applications no. 63/282,729 which was filed on November 24, 2021, in relation to an invention entitled "METHODS OF TREATING WATER";

WHEREAS We, B.G. Negev Technologies and Applications Ltd., at Ben-Gurion University, P.O. Box 653, Beer-Sheva 8410501, Israel, hereinafter referred to as the Assignee, are interested in obtaining all rights in respect to said invention, including the priority rights under the Paris Convention, and all patent applications related thereto;

NOW, THEREFORE, we hereby assign and transfer to said Assignee our rights in said invention and in said U.S. provisional patent applications and the priority rights under the Paris convention stemming from said provisional patent applications and including all patent applications that will be filed in relation to said invention or on the basis of said provisional patent applications, in the U.S.A. or elsewhere, and including international patent applications and national/regional phase applications derived therefrom and including any divisional applications, applications for patent of addition and continuation applications, and any patent that may be granted on said patent applications, for consideration duly received. We hereby undertake to sign all documents that may be required in any proceedings relating to the patent applications and patents rising therefrom, and to do anything to assist said Assignee in any examination or litigation proceedings associated with said invention and with said patent applications and/or patents, the costs of which will be borne by said Assignee.

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