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Microbial Remediation as An Emerging Industrial Wastewater Treatment Process for Arsenic Extenuation

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Abstract

In third-world nations where improper handling of industrial effluent treatment and administration has resulted in increased industrial wastewater contamination, this problem has gotten worse. An estimated 80% of wastewater that is contaminated with arsenic (As) is a result of contaminants in pesticides, municipal trash incineration, the leather industry, and consumption in the industry. An extremely dangerous threat to the lives of plants, animals, and people is posed by the deadly metalloid arsenic. Plants and animals are harmed by some As species, including As (III) and As (V). Various traditional techniques are being used for cleanup As in industrial wastewater. The lack of technical skills and limited efficacy of these procedures are their main drawbacks. Industrial water microbial As remediation has recently emerged as a viable solution owing to its widespread acceptability and low cost. The function of microbial remediation of As in industrial wastewater is thoroughly summarized in this current study. The purpose of utilizing microorganisms, as opposed to phytoremediation, is to cause dissolved arsenic species to be transformed microbially into arsine gas that is released into the atmosphere at non-toxic levels (dilution effect). There won't be any solid or liquid waste produced, in contrast to phytoremediation, where arsenic accumulates in plant material (creating trash), and this is only one of the major advantages of the microbial technique because managing solid/liquid arsenic-rich waste is a major problem and financial burden. The review article focuses on the possible ways of arsenic remediation by microbial action selecting industrial wastewater.

Keywords: *Industrial wastewater contamination, municipal trash incineration, leather industry, metalloid arsenic, microbial remediation, non-toxic levels.*

1. Introduction

Due to the growth of industry and the world's rising urbanization, enormous amounts of wastewater are being produced on a global scale. In comparison to the total amount of water consumed worldwide, the industrial sector uses an average of 22%. Approximately 80% of the total wastewater produced is released into waterways, endangering aquatic life and polluting the environment. According to The Trade Council, Embassy of Denmark, India, 2015, India generates over 44 million m3/day of industrial effluent, of which about 6.2 billion liters are dumped into the country's natural aquatic bodies without being treated (Dutta et al., 2021). Industries like chemical, distillery, sugar, food and dairy, paper and pulp, textile bleaching and dyeing, mining and quarries, battery manufacturing, nuclear power, organic chemical, leather/tannery, iron and steel, soap and detergent, electric power plant, metal refining, pesticide and biocide, petroleum and petrochemical, pharmaceutical, metal processing, and electroplating industries can be thought of as the major sources of metals in the wastewater. The list of metals includes Copper (Cu), Zinc (Zn), Cadmium (Cd), Chromium (Cr), Mercury (Hg), Iron (Fe), Lead (Pb), Nickel (Ni), and Arsenic (As) (Awuchi et al., 2020). Untreated wastewater effluents are frequently spilled into water bodies, damaging normal aquatic life, as a result of inadequate wastewater treatment facilities, such as electrical failure, poor maintenance, and a lack of skilled and experienced labor. These polluted water sources, especially groundwater, can pose a threat to human health and contribute to environmental contamination (Bora et al. 2019). Thus, an increase in the variety of companies causes a rise in resource and utilization of water, which results in the release of a significant amount of wastewater that contains various harmful heavy metals. The management of industrial wastewater has so grown to be a major issue on a global scale. There have been several studies and investigations so far concerning treating the wastewater using various methods (Lee et al. 2019) (Alalwan et al. 2020) (Babincev et al. 2020) (Mustafa et al. 2020). However, each of these processes still has significant drawbacks, including limited efficiency, the need for large quantities of solvents and reagents, and the production of secondary pollutants including waste residues, sludge, waste water, hazardous compounds, etc. (Gebretsadik et al. 2020). As a result, efficient wastewater treatment at cheap cost and with minimal environmental impact has become crucially important everywhere in the globe (Dutta et al., 2021). Traditional methods, such as physical, chemical, and thermal treatments, have a number of serious drawbacks, such as the production of toxic intermediates, the transportation of contaminated soil or water for treatment, the high cost of treatment, and the insufficient restoration of natural habitats and fauna. The reduction and neutralization of pollutants from Industrial wastewater through regular biological processes, either by aerobic or anaerobic processes, can be accomplished by using bioremediation approaches that require organisms like microbes (bacteria, fungi, and Actinomycetes, etc.) or their products (Arora 2018, Saxena et al. 2016). An estimated 80% of wastewater that is contaminated with arsenic (As) is a result of contaminants in pesticides, municipal trash incineration, the leather industry, and consumption in the industry. An extremely dangerous threat to the lives of plants, animals, and people is posed by the deadly metalloid arsenic. Plants and animals are adversely affected by certain As species, which include As (III) and As(V). Arsenic is converted by microorganisms into species with varying solubility, motility, bioavailability, and toxicity, which plays a crucial part in the metabolic cycle of arsenic (Hayat et al. 2017).

2. Materials And Methods

The appropriate material for this review paper was found by searching PubMed, PubMed Central, Google, and published research work and the review articles from around the world on the environmental pollutants produced by the leather industries and the microbial bioremediation strategy to remove the pollutants for a cleaner world. Only published data were considered, and vague statements of exposure were excluded. Information acquired from reputable sources of publications on the subject is part of these inclusion criteria. The study did not include any other languages than English.

3. Results and Discussion

Arsenic releasing industries via waste water: The major sources of heavy metals especially arsenic in the wastewater can be attributed to the chemical, sugar, textile, bleaching and dyeing and leather/tannery industries during various industrial processes and operations (Dutta et al., 2021).

Industries	Heavy metals
Chemical industry	Cd, Cu, Cr, Pb, Zn, Hg, **As**, Fe, Ni
Sugar industry	**As**, Cd, Cu, Cr, Pb, Hg
Textile industry	Cu, Cr, **As,** Zn, Hg, Fe, Ni
Bleaching industry	Cu, Cr, Zn, Hg, **As**, Fe, Ni
Dyeing industry	Cu, **As,** Cr, Zn, Hg, Fe, Ni
Tannery/leather industry	Cd, Cu, Cr, Pb, Zn, **As**

Table. 1. Showing heavy metal especially arsenic (As) releasing industries via waste water (Dutta et al., 2021)

Environmental and health impacts of arsenic release via industrial waste water: Untreated wastewater effluents are frequently dumped into water bodies, posing a threat to the health of regular aquatic life, as a result of inadequate wastewater treatment facilities, including breakdowns in electricity, poor maintenance, and a lack of educated and inexperienced staff. Water bodies, especially groundwater, become polluted, posing health risks and contributing to environmental degradation (Bora et al. 2019). Arsenic stress results in a reduction in the growth of leaves, stems, and roots since it is very poisonous to all types of plants (Sher et al. 2019). Heavy metal buildup in surface soils can result in a discharge of heavy metals into groundwater or soil solutions that are available for plant consumption due to the soil's decreased capacity to retain heavy metals. In addition to harming plants, soil contamination with heavy metals or micronutrients in phytotoxic concentrations poses a threat to human health (Tadesse et al. 2017).

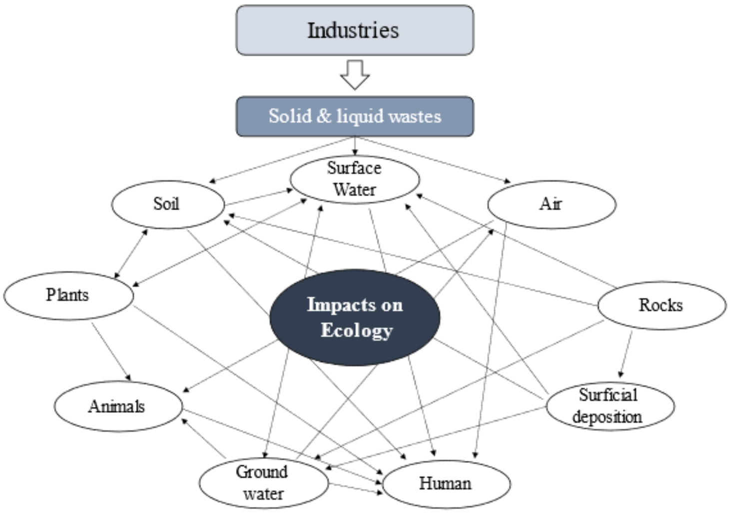

Fig. 1. Showing how industrial wastes contaminate our ecology.

Drinking arsenic-contaminated groundwater is the most typical method that humans get exposed to the substance (Yu et al. 2018). The two most common inorganic forms of this hazardous metalloid are arsenate and arsenite. While arsenate functions as a phosphate analogue and influences enzymatic activities in cells, arsenite prevents cells from absorbing and using phosphate. People commonly come into touch with metalloid arsenic due to its ubiquitous distribution in the environment. Arsenic has negative short- and long-term impacts on health, including skin damage, color changes, and patches on the hands and feet, diabetes, hypertension, and several other conditions that have a bearing on reproduction. Arsenicosis is brought on by long-term exposure to arsenic-containing water. It may exist in a wide variety of chemical and oxidation states chronic exposure to inorganic arsenic has been related to a range of cancers, including those of the skin, lung, kidney, and oral cavity. Global studies have highlighted the harmful consequences of arsenic on humans brought on by environmental pollution. (Sher et al. 2019) (Ferreccio et al. 2006) (Hong et al. 2014) (Pal et al. 2017). Arsenic also modifies and damages DNA, which results in genotoxicity (Faita et al. 2013).

Green approach for arsenic extenuation: International efforts to clean up many of these environments have increased in recent years in response to the prevalence of environmental deterioration, the estimated size of the number of polluted environments, and its continuous discovery. This is done either to reduce the risk of adverse health or environmental impacts brought on by pollution or to make the area suitable for reconstruction or restoration for use (Luka et al. 2018) (Arora 2018). Bioremediation is a green technique that has potential for tackling environmental deterioration due to its economic viability and environmental friendliness. Bioremediation is the process of eliminating or decreasing toxins from the air, soil, and water by using biological processes. The technique employs an organism that has either been imported from another system or gathered from the environment that is relevant in order to reduce or remove the hazardous component (Sher et al. 2019) (Luka et al. 2018) (Arora; 2018) (Ashraf et al. 2018) (Saravanan; 2022). The majority of the bioremediation process is dependent on microorganisms that break down pollutants into innocuous molecules through enzymatic attack. Since bioremediation can only occur in environments that favour microbial growth and activity, applying it often requires changing environmental conditions to promote microbial growth and breakdown faster (Karigar et al. 2011). The ability of practically any environmental circumstance to produce isolated microbes is crucial. Microbes will adapt to their environment and multiply under a variety of conditions, including extreme cold, intense heat, the desert, water, too much oxygen, anaerobic conditions, the presence of hazardous compounds, and on any waste stream. A source of energy and a source of carbon are the two essential components (Luka et al. 2018).

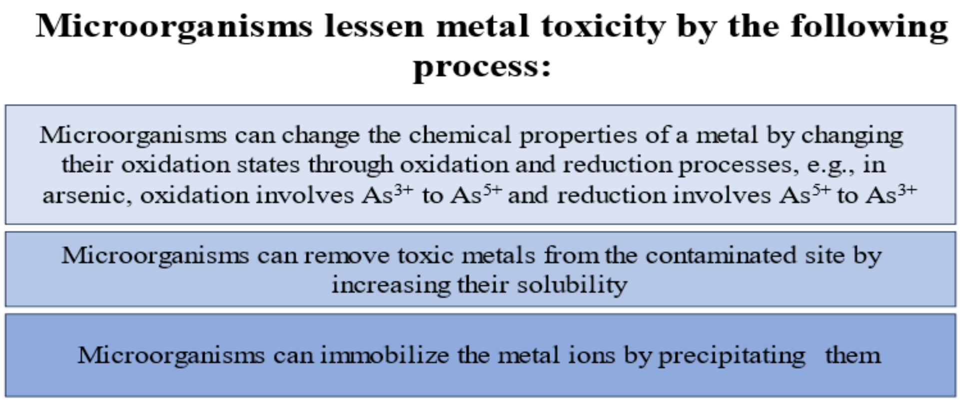

Fig. 2. Showing the process to lessen the metals by microorganisms (Sher et al. 2019).

Metal ions interact with the microorganism's surface cell wall during the biosorption process. It is an ATP-independent mechanism as ATP is not necessary for it to function. As a result of its inability to penetrate cells and its absence from the cell's metabolism, it has no harmful effects. According to biosorption tests on sulfate-reducing bacteria, their cell pellet can extract 6.6% arsenite and 10.5% arsenate from water that contains arsenic (Teclu et al. 2008), but Pseudomonas aeruginosa has a 98% biosorption capability (Tariq et al. 2019). Gram-positive and gram-negative bacteria engage in a process known as bioaccumulation in which metal ions attach to the surface of their cell walls before entering the cell through transfer proteins and accumulating there. Due to the bioaccumulation process' dependency on ATP, the entry of metal ions into the cells from the external environment requires some energy in the form of ATP. This process is engaged in the metabolism of the cell. This is a long and permanent procedure. Inside the cell, metal ions build up through a process known as bioaccumulation, which has a harmful outcome. A mutant strain of Corynebacterium glutamicum may collect arsenic intracellularly and behave as a biocontainer for the heavy metal (Sher et al. 2019) (Satyapal et al. 2016). Chemical processes result in a material changing chemically, which is known as biotransformation. Metals' poisonous properties can be altered by adding and removing electrons. When arsenic is exposed to arsenite-oxidizing genes, which turn As^{3+} into As^{5+}, its toxicity is lowered, and in the event of reduction, As5+ may be turned into As^{3+}, which is 100 times more lethal than As^{5+} (Mujawar et al. 2019). Through the use of microorganisms, harmful metal ions or their compounds that are insoluble can be transformed into soluble forms for simple removal through a process called bioleaching. Traditional bioleaching techniques include calcination, membrane dialysis, acid extraction, and selective adsorption. The efficiency of other operations can be improved by the usage of this mechanism. It is an individual precipitation process between hazardous metal ions and microorganisms for metal bioleaching. It is based on a technology called microbially initiated calcite precipitation (MICP), which has the potential to remove arsenic from the environment (Sher et al. 2019).

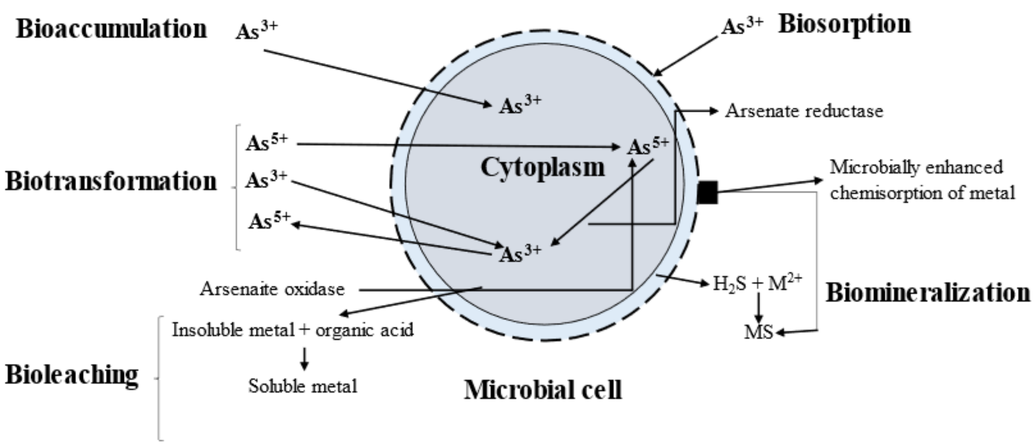

Fig. 3. Showing various processes used to remove hazardous metal ions from contaminated areas (Sher et al. 2019).

Bioremediation using bacteria: Bacteria are an excellent bioresource for green chemistry to eliminate environmental arsenic due to their multiple metal tolerance and effective bioremediation capability. Due to the low level of nutrients in the polluted location, metal-resistant bacteria may survive in low-nutrient environments (Sher et al. 2019).

Bacterial species	Max tolerable arsenic (As) concentration	Arsenic (As) removing capacity
Klebsiella oxytoca, Citrobacter freundii, Bacillus anthracis	240, 290 mg/L	-
MNZ1, MNZ4 and MNZ6	300, 370 mg/L	-
Strain MLHE-1	0.13 mg/L	-
Corynebacterium glutamicum	0.16-5.33 mg/L	-
NT-26	0.066 mg/L	-
Strain ULPAs1	500 mg/L	-
Agrobacterium tumefaciens, Pseudomonas fluorescens, Variovorax paradoxus, Flavobacterium sp., Microbacterium sp., and Arthrobacter sp.	0.001-0.003 mg/L mM	-
Ralstonia eutropha MTCC 2487	15-25 mg/L	86-67%
Pseudomonas putida MTCC 1194	15 mg/L	60%
Bacillus indicus MTCC 4374	15 mg/L	61%
Penicillium canescens	-	26.4 mg/g
Micrococcus luteus AS2	-	99%

Table. 2. Showing the bacterial species that have as removing capacity (Hayat et al. 2017) (Sher et al. 2020) (Dutta et al., 2021).

Green discovered the first arsenite-oxidizing bacteria, the *Bacillus arsenooxydans*, in 1918 (Gosh et al. 2018). In the meanwhile, a number of microorganisms that oxidise arsenic have been found and named. Some bacterial strains that are responsible for the oxidation of arsenic were isolated and characterised, including *Alcaligenes faecalis*, *Pseudomonas arsenitoxidans*, *Microbacterium lacticum*, *Agrobacterium tumefaciens*, *M. oxydans*, *P. stutzeri*, *Aeromonas sp.*, *Agrobacterium sp.*, *Comamonas sp*. (Sher et al. 2019). Methanogen bacteria, namely the *Methanobacterium bryantii*-MOH strain, were shown to be able to volatilize as, and they may be the most effective treatment option for as in industrial effluents. (Hayat et al. 2017). Numerous bacterial species, including *Pseudomonas*, *Alcaligenes*, *Herminiimonas*, *Agrobacterium* and *Thermus* have been reported to oxidise As^{3+}. These particular bacterial strains could still employ As^{3+} as their own personal electron donor and were cultivated as lithotrophs. Arsenite-oxidizing heterotrophic bacteria may receive energy via As^{3+} oxidation and as a result, arsenic detoxification occurred. They feed on both live and dead species (Sher et al. 2019) (Hayat et al. 2017). Recently, 64 isolates of the genera *Rhizobium*, *Ochromobactrum*, and *Achromobacter* that are extremely resistant to As(III) and As(V) and can grow chemolithotrophically and use As as an electron donor were identified (Sarkar et al. 2013).

PhoS, PstC, and PstB (Pi) transporters are primarily responsible for the absorption of arsenate As(V) into bacterial cells and for arsenic transport in bacteria. The GlpF aquaglyceroporin (AQGP) allows arsenite As(III) access to bacterial cells. By employing glutathione (GSG) as a reductant, bacterial ArsC arsenate reductase converts As(V) to As(III). As(III) is extruded into the environment by ArsB, an As(III):H -antiporter, or ArsAB, an As(III) ATPase. Additionally, after further methylation processes carried out by As(III)-Sadenosylmethionine methyltransferase, As(III) can be released into the environment in volatile form (Hayat et al. 2017).

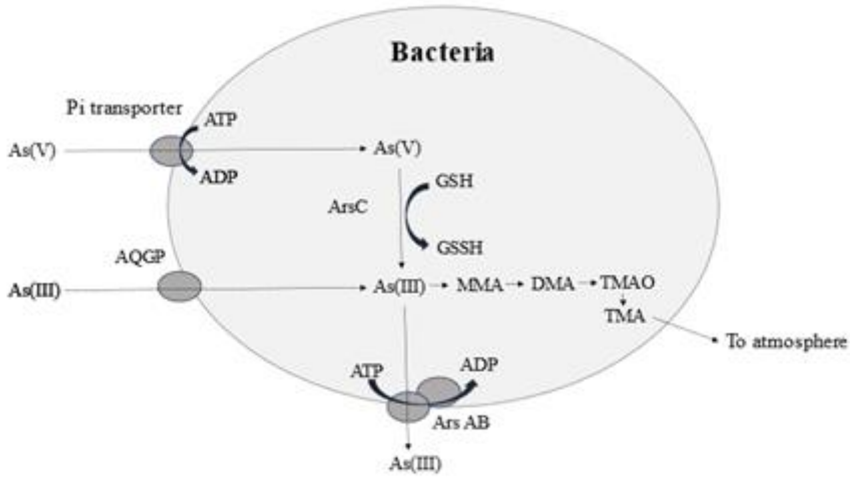

Fig. 4. Transportation of as in bacteria. MMA: monomethylarsonic acid, DMA: dimethylarsinic acid, TMAO: trimethylarsine oxide, TMA: trimethylarsine (Hayat et al. 2017).

Bioremediation using fungi: It is feasible to use fungus to remove arsenic from drinking water or wastewater. The *Aspergillus* and *Trichoderma* groups of fungus are often those that are arsenic-resistant. Additionally, additional fungi strains such as *Neocosmospora, Sordria, Rhizopus,* and *Penicillium* are also capable of reducing arsenic (Srivastava et al. 2011). Fungi have been used for As removal from industrial effluent for over a century because they may produce inorganic As compounds as cupric arsenite and copper aceto-arsenite, which can release the toxin trimethylarsine. Aqueous arsenite and arsenate species may be converted to dimethylarsine and monomethylarsine, respectively, by *Penicillium brevicaule, Scopulariopsis sp., Aspergillus glaucus, Candida humicola, and Gliocladium sp.* These methylated forms of as are flammable and easily discharged into the environment, where oxidation may cause them to return to the oxidised form As(V). (Hayat et al. 2017).

Fungal species	Max tolerable arsenic (As) concentration	Arsenic (As) removing capacity
Aspergillus niger	25-100 mg/L	70-76%
Neosartorya fischeri, Aspergillus clavatus, Aspergillus niger	4-17 mg/L	70-76%
Aspergillus flavus, Rhizopus sp.	25-50 mg/L	-
Aspergillus clavatus, A. niger, Trichoderma viride, Penicillium glabrum	5-20 mg/L	-
Aspergillus sp. P37	0.66 mg/L	-

Table. 2. Showing the fungal species that have As removing capacity (Hayat et al. 2017) (Vala et al. 2012).

Aspergillus niger, Aspergillus clavatus, Aspergillus flavus, and *Rhizopus sp.* are examples of fungal species that have been reported to be able to volatilize As at 25 mg L1 and 50 mg L1. Additionally, they stated that *Rhizopus* has greater accumulation potential than *Aspergillus flavus* (Hayat et al. 2017) (Vala et al. 2012).

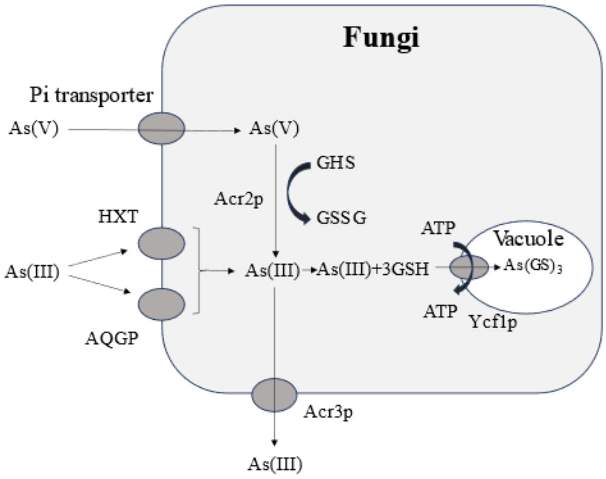

Fig. 5. Transportation of As in fungi (Hayat et al. 2017).

Arsenite is mostly absorbed by AQGP Fps1p in fungi, whereas absorption of arsenate is aided by Pho87 type phosphate transporters. Hexose penneases (HXTs) can also be used to enter cells. The Acr2p arsenate reductase uses glutathione reduction (GSH to GS) to convert arsenate to arsenite to arsenite in yeast cells. The ABC transporter Ycf1p sequesters glutathione (As(GS)3), which may be used to remove cytoplasmic As(III), into vacuoles. Alternatively, As(III) can be extruded via the plasma membrane transporter Acr3 (Hayat et al. 2017).

4. Conclusion

A thorough investigation demonstrates that the large amount of arsenic released through waste water from diverse businesses has a significant influence on the environment as a whole. The negative impacts of the leather industry have brought attention to the need for green technologies. The physio-chemical therapy methods also make extensive use of chemicals while being ecologically safe. Bioremediation technologies, which are environmentally friendly, economically viable, and offer a promising method to improve environmental quality, may be a good option to safely degrade and detoxify the solid wastes and wastewater containing heavy metals produced by the industries. This study demonstrates a variety of microorganisms that have been shown to be capable of removing or remediating hazardous risks found in waste products produced by the industries. Even with so many microorganisms and excellent eco-friendly and cost-effective ways, industrial wastes and wastewater still regularly create environmental pollution and toxicity problems. This study serves as a social massage for the population's goodwill on that note. To take appropriate action, handle solid waste and industrial waste water in an eco-friendly manner, reduce the use of harmful chemicals, and bring this critical situation to the governments' and various industries' real attention.

Future Scope: Prior to its final disposal into the environment, it is vital to search for more effective microorganisms for the decontamination and degradation of arsenic, which impacts the aquatic ecology, soil, and human health. It is vital to comprehend their genetic structure and biochemistry in order to build efficient bioremediation strategies. Natural ecosystems on surface and in the water will be more likely to survive in the long run as a result**.** Every arsenic releasing industry via wastewater, need to employ more cost- and environmentally-friendly waste-treatment methods.

Conflict of Interest: There is no conflict of interest related to the study.

Author contributions: Acquisition and interpretation of data is done by Rupesh Dutta Banik. Conception, design and revising of the article are done by Dr. Pritha Pal.

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References:

Alalwan, H. A., Kadhom, M. A., and Alminshid, A. H. (2020). Removal of heavy metals from wastewater using agricultural byproducts. *Journal of Water Supply: Research and Technology-Aqua*, jws2020133, DOI: 10.2166/aqua.2020.133

Arora, N. K. (2018). Bioremediation: a green approach for restoration of polluted ecosystems. *Environmental Sustainability*, 1(4), 305–307, DOI: 10.1007/s42398-018-00036-y

Ashraf, S., Naveed, M., Afzal, M., Ashraf, S., Rehman, K., Hussain, A., and Zahir, Z. A. (2018). Bioremediation of tannery effluent by Cr- and salt-tolerant bacterial strains. *Environmental Monitoring and Assessment*, 190(12), DOI: 10.1007/s10661-018-7098-0

Awuchi, C.G., Twinomuhwezi, H., Awuchi, C.G., Igwe, V.S., and Amagwula, I.O. (2020). Industrial waste management, treatment, and health issues: wastewater, solid, and electronic wastes. *European Academic Research*, 8 (2), 1081–1119.

Babincev, L., Guresic, D., Draskovic, N., and Jovic, S. (2020). Measurement of heavy metals in industrial wastewater by filters based on perlon and wool. Journal of Water Process Engineering, 37(2020), 101354, DOI: 10.1016/j.jwpe.2020.101354

Bora, A. J., and Dutta, R. K. (2019). Removal of metals (Pb, Cd, Cu, Cr, Ni, and Co) from drinking water by oxidation-coagulation-absorption at optimized pH. *Journal of Water Process Engineering*, 31(2019), 100839, DOI: 10.1016/j.jwpe.2019.100839

Dutta, D., Arya, S., and Kumar, S. (2021). Industrial wastewater treatment: Current trends, bottlenecks, and best practices. *Chemosphere*, 285, 131245, DOI: 10.1016/j.chemosphere.2021.131245

Faita, F., Cori, L., Bianchi, F., and Andreassi, M. G. (2013). Arsenic-induced genotoxicity and genetic susceptibility to arsenic-related pathologies. *Int. J. Environ. Res. Public Health*, **10**(4):1527-1546, DOI: 10.3390/ijerph10041527

Ferreccio, C. and Sancha, A. M. (2006). Arsenic exposure and its impact on health in Chile. *J Health Popul Nutr*,**24**(2):164-175.

Gebretsadik, H., Gebrekidan, A., Demlie, L., and Suvarapu, L. N. (2020). Removal of heavy metals from aqueous solutions using Eucalyptus Camaldulensis: An alternate low cost adsorbent. *Cogent Chemistry*, 6(1), DOI: 10.1080/23312009.2020.1720892

Ghosh, D., Bhadury, P., and Routh, J. (2018). Coping with arsenic stress: Adaptations of arsenite-oxidizing bacterial membrane lipids to increasing arsenic levels. *MicrobiologyOpen*, (2018), e00594, DOI: 10.1002/mbo3.594

Hayat, K., Menhas, S., Bundschuh, J., and Chaudhary, J. H. (2017). Microbial biotechnology as an emerging industrial wastewater treatment process for arsenic mitigation: A critical review. *Journal of Cleaner Production*, 151(2017), 427–438. DOI: 10.1016/j.jclepro.2017.03.084

Hong, Y. S., Song, K. H., and Chung, J. Y. (2014). Health effects of chronic arsenic exposure. *J. Prev. Med. Public Health*,**47**(5):245-252, DOI: 10.3961/jpmph.14.035

Karigar, C. S., and Rao, S. S. (2011). Role of Microbial Enzymes in the Bioremediation of Pollutants: A Review. *Enzyme Research*, 2011, 1–11, DOI: 10.4061/2011/805187

Lee, S. H., Kim, K. H., Lee, M., and Lee, B. D. (2019). Detection status and removal characteristics of pharmaceuticals in wastewater treatment effluent. *Journal of Water Process Engineering*, 31(2019), 100828, DOI: 10.1016/j.jwpe.2019.100828

Luka, Y., Highina, B. K., and Zubairu, A. (2018). Bioremediation: A Solution to Environmental Pollution-A Review. *American Journal of Engineering Research*, e-ISSN: 2320-0847 p-ISSN: 2320-0936 Volume-7, Issue-2, pp-101-109

Mujawar, S.Y., Shamim, K., Vaigankar, D. C., Dubey, and S. K. (2018). Arsenite biotransformation and bioaccumulation by Klebsiella pneumoniae strain SSSW7 possessing arsenite oxidase (aioA) gene. *BioMetals*, DOI: 10.1007/s10534-018-0158-7

Mustafa, R., and Asmatulu, E. (2020). Preparation of activated carbon using fruit, paper and clothing wastes for wastewater treatment. *Journal of Water Process Engineering*, 35(2020), 101239, DOI: 10.1016/j.jwpe.2020.101239

Pal, P., Raychowdhury, R., Dolai, T. K., Roy, S., Dastidar, R., and Halder, A. (2017). Study of arsenic exposure in oral/ oropharyngeal carcinoma in West Bengal. *Int J Occup Med Environ Health*,**30**(2), 271-279. DOI: 10.13075/ijomeh.1896.00806

Saravanan, A., Kumar, P., S., Duc, P. A., and Rangasamy, G. (2022). Strategies for microbial bioremediation of environmental pollutants from industrial wastewater: A sustainable approach. *Chemosphere*,2023 Feb, 313:137323, DOI: 10.1016/j.chemosphere.2022.137323

Sarkar, A., Kazy, S. K., and Sar, P., 2013. Characterization of arsenic resistant bacteria from arsenic rich groundwater of West Bengal, India. *Ecotoxicology*, 22, 363e376, DOI: 10.1007/s10646-012-1031-z

Satyapal, G. K., and Rani, S. (2016). Potential Role of Arsenic Resistant Bacteria in Bioremediation: Current Status and Future Prospects. *Journal of Microbial & Biochemical Technology*, 8(3), DOI: 10.4172/1948-5948.1000294

Saxena, G., Chandra, R., Bharagava, R. N. (2016). Environmental Pollution, Toxicity Profile and Treatment Approaches for Tannery Wastewater and Its Chemical Pollutants. *Reviews of Environmental Contamination and Toxicology*,31–69, DOI: 10.1007/398_2015_5009

Sher, S., and Rehman, A. (2019). Use of heavy metals resistant bacteria—a strategy for arsenic bioremediation. *Applied Microbiology and Biotechnology*, DOI: 10.1007/s00253-019-09933-6

Sher, S., Hussain, S. Z., and Rehman, A. (2020). Phenotypic and genomic analysis of multiple heavy metal–resistant Micrococcus luteus strain AS2 isolated from industrial waste water and its potential use in arsenic bioremediation. *Applied Microbiology and Biotechnology*, DOI: 10.1007/s00253-020-10351-2

Srivastava, P. K., Vaish, A., Dwivedi, S., Chakrabarty, D., Singh, N., and Tripathi, R. D. (2011). Biological removal of arsenic pollution by soil fungi. *Sci Total Environ*, 409(12):2430–2442, DOI: 10.1016/j.scitotenv.2011.03.002

Tadesse, G. L., Guya, T. K. (2017). Impacts of Tannery Effluent on Environments and Human Health. *Journal of Environment and Earth Science*, ISSN 2224-3216 (Paper) ISSN 2225-0948 (Online) Vol.7, No.3, 2017

Tariq, A., Ullah, U., Asif, M., and Sadiq, I. (2018). Biosorption of arsenic through bacteria isolated from Pakistan. *International Microbiology*, DOI: 10.1007/s10123-018-0028-8

Teclu, D., Tivchev, G., Laing, M., and Wallis, M. (2008). Bioremoval of arsenic species from contaminated waters by sulphate-reducing bacteria. *water research*, 42(19), 0–4893. DOI: 10.1016/j.watres.2008.09.010

Vala, A. K., and Sutariya, V. (2012). Trivalent Arsenic Tolerance and Accumulation in Two Facultative Marine Fungi. *Jundishapur Journal of Microbiology*, 5(4), 542–545, DOI: 10.5812/jjm.3383

Yu, S., Liao, W. T., Lee, C. H., Chai, C. Y., Yu, C. L., and Yu, H. S. (2018). Immunological dysfunction in chronic arsenic exposure: From subclinical condition to skin cancer. *J. Dermatol.*,**45**(11):1271-1277, DOI: 10.1111/1346-8138.14620