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# SYSTEMATIC REVIEW ON BACTERIA AND MICROBES CONSORTIUM FOR CHROMIUM DETOXIFICATION IN SAFETY ENVIRONMENT

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**ABSTRACT:**

Microbes have enormous promise for improving the efficiency of bioprocesses involving non-biodegradable materials. Exhaustive studies showed that many bacteria capable of degrading strong materials like polyurethanes and lignocellulose. It also shown that microbial consortia outperform single strains under specific conditions related to deteriorating efficiency. It can produce microbial consortia in two different ways: either by combining several isolated strains to form a synthetic assembly from scratch, or by constructing complex microbial communities from ambient samples. The latter often uses the enrichment strategy to identify optimal microbial consortia. For instance, it enriched a termite gut-derived consortia with high xylanase activity, which was able to convert lignocellulose into carboxylates in an anaerobic environment using raw wheat straw as the only carbon source. In this article, systematic review on bacteria and microbe's consortium for chromium detoxification in safety environment has been discussed.

**KEYWORDS:** Bacteria, Microbes, Consortium, Chromium Detoxification, Safety Environment.

## INTRODUCTION:

Soil microorganisms are the primary generators of ecosystem services and drivers of multifunctional processes. The microbial community creates a complex network of interconnected species by recycling available resources, and interactions between these species are crucial to sustaining energy fluxes and the ecosystem as a whole. Symbiotic interactions between two or more microbial groups typically form microbial consortiums, aiming to enhance crop development and productivity. The collaboration of microbial communities within the microbial consortium promotes the turnover of organic soil components and makes it easier for nutrients necessary for plant growth and development to circulate. Because of the microbial consortium's positive effects and favourable outcomes for plant health, agricultural practitioners have accepted. In bulk soil, microbial consortiums reside near the plant root canopy, where they serve as both endophytes and constituents of a complex microbiota. Instead of responding as individual cells, microbial consortiums respond as distinct organisms to environmental stress in their surroundings. Because of their beneficial internal interactions, microbial consortiums have a higher chance of accepting and sustaining the plant than does any single strain. A bacterial consortium often forms when two or more bacteria from different species interact additively or synergistically. Occasionally, a consortium may combine several strains from the same species to enhance their activity. Additionally, certain bacterial consortiums have the ability to chelate iron, help produce phytohormones, and transform indigestible nutrient forms into forms that are simpler to absorb. Additionally, negativity of conventional, nonsustainable farming practices, bacterial consortium contributes to the maintenance of enhanced soil quality and plant health.

**SYSTEMATIC REVIEW OF LITERATURE:**

Plestenjak, E. et al. (2022). This study investigated the accumulation of hexavalent chromium Cr(VI) and the death of microorganisms in several bacterial species from both an enriched community and a microbial community isolated from tannery effluent. Spectrophotometry and HPLC-ICP-MS (high-performance liquid chromatography linked to inductively coupled plasma mass spectrometry) analysis were used to determine the quantity of Cr(VI) in the samples. To quantify the growth of the bacteria, we computed the optical cell density (OD650). When the concentration of Cr(VI) approached 100 mg/L, the isolated isolates linked to Pseudomonas aeruginosa (P. aeruginosa) showed higher optical cell densities. However, they did not reduce Cr(VI) as well as the isolates linked to *Mammaliicoccus sciuri* (M. sciuri). Just one of the seven isolates of M. sciuri and *Pseudomonas aeruginosa* was able to cause a 50% decrease in Cr (VI) after 24 hours (pH 7.1). The initial dosage for the remaining six isolates was 100 mg/L. It was demonstrated that the six isolates connected to P. aeruginosa had a reduced success rate. Even though the isolated bacterial strains were better suited to handle larger concentrations of Cr (VI), the overall microbial community's ability to lower Cr (VI) levels over the course of 48 hours was on par with that of the most successful single isolates. Because of their ability to reduce Cr (VI), the isolated bacterial strains and the broader microbial population can effectively bioremediate wastewater affected by Cr (VI).

Sharma, P et al. (2022). Wastewater and industrial effluents are the primary environmental sources of hexavalent chromium pollution. Due to long environmental half-life and high death rate, Cr (VI) contamination is currently the deadliest environmental issue in the world. Cr (VI) is the main industrial contaminant that is harmful to the environment. The hexavalent form of Cr is mutagenic, carcinogenic, and genotoxic to biological organisms. The physical-chemical methods now employed to remove Cr (VI) are labour-intensive and harmful to the environment. Microbes can protect themselves from chromium toxicity in a number of natural or learned ways, such as by bioaccumulation, biosorption, reduction, and subsequent efflux. This study focuses primarily on the possible uses of microbial reactions to chromium toxicity in environmental restoration. We also review potential research pathways and the study challenge to address these shortcomings and resolve the real-time applicability issue of bacterial bioremediation.

Singh, P. et al. (2021). The most widely used heavy metal is chromium (Cr), which finds use in metallurgy, leather, automobiles, and electroplating, among other industries. This review provides fresh perspectives on the most advanced, creative, and physiologically grounded methods of Cr remediation. Researchers have developed numerous biological approaches to address the many shortcomings of the chemical and physical cleansing processes. Research indicates that both dead and live biomass have significant potential to remove, reduce, and/or clean up Cr from contaminated environmental niches. Chromium can be extracted or recovered from different agricultural wastes, and different microbial groups have been able precipitate Cr, which is good sign. Given their increasing skill at adsorbing metals, it is critical to fully utilize the potential of diverse aquatic plants, like duckweed, and diverse microbiological agents in chromium bioremediation. Sulphurs-reducing bacteria and iron have established the potential for enhanced Cr remediation. Biosurfactants have shown great potential as microbial metal bioremediation enhancers, and they may be useful in recovering chromium. In an attempt to create useful technology, the authors also investigate the possibility of combining biochar and biosurfactants as a chromium bioremediation technique. Because Cr is a finite and non-renewable resource, keeping it properly separated from trash is essential to sustainability for the economy, the environment, and society as a whole.

Kholisa, B. et al. (2021). It has long been known that hexavalent chromium, or Cr (VI), is substantially more combustible and mobile than Cr (III), the other stable oxidation state of the element. It has been demonstrated that contaminants soluble in iron (VI) are present in soils and water bodies that receive agricultural and industrial wastes. Microbial species are more cost-effective, environmentally safe, and long-lasting than conventional treatment methods like chemical neutralization and chemical precipitation when it comes to decreasing Cr (VI). This study will identify and characterize a microbial consortium culture from a neighboring wastewater treatment plant that gets a substantial amount of Cr (VI) from a closed chrome foundry in Brits (North Waste Province, South Africa). We examined a variety of operational parameters, such as pH, temperature, and Cr (VI) loading, in order to assess the isolated bacteria's efficacy and potential in lowering Cr (VI). All groups removed Cr (VI) 100% when the incubation temperature was 37 ± 1 °C and the pH was 7. They showed an incredible ability to remove the material over the pH range of 2 to 11. This study demonstrates that under several experimental conditions, bacterial consortia from urban wastewater sludge shown incredible endurance and reduction. The culture demonstrated exceptional reduction capabilities at a modest loading concentration of 50 mg Cr (VI)/L, achieving 100% removal in less than 4 hours. This implies that bacteria could be able to clean up places contaminated with hexavalent chromium. Furthermore, the culture demonstrated persistence by totally getting rid of the drug at levels as high as 400 mg Cr (VI)/L.

Arishi, A. & Mashhour, I. (2021). Anthropogenic activity growth has resulted in heavy metal pollution of the environment, particularly chromium (Cr). Industrial effluents most frequently contain two oxidative forms of chromium: hexavalent Cr (VI) and trivalent Cr (III). Compared to hexavalent chromium Cr (VI), which can be extremely harmful to human health, trivalent chromium Cr (III), the reduced form of chromium, is less poisonous and insoluble. In many underdeveloped countries, leather tanning is a significant business and a major source of Cr (VI) contamination. Every year, tannery companies around the world produce Cr-containing wastewater. Chromium-resistant bacteria (CRB) bioremediation is a better and safer way to clean up tannery waste than physicochemical treatments that are dangerous, produce a lot of chemicals, and are used a lot. Furthermore, CRB bioremediation prevents the production of hazardous intermediates. Chromium-resistant bacteria (CRB) use three distinct processes: biotransformation, biosorption, and bioaccumulation, to eliminate chromium (VI). This study will examine the three Cr (VI) detoxification mechanisms that bacteria employ, their drawbacks, and potential uses for thorough Cr (VI) cleansing. By elucidating the nature of the remediation strategies that bacteria employ, this can help bridge the knowledge gap between the practical application of microorganisms for Cr (VI) removal in industry and laboratory results.

Li, M. et al. (2020) claimed that chromium contamination is increasingly harming the ecology and public health. Chromium exists in two most prevalent states: Cr (VI) and Cr (III). Cr (VI) is more dangerous and absorbs more quickly than Cr (III), which makes it a bigger threat to human health. Thus, the conversion of hazardous Cr (VI) into Cr (III). Here, we discovered two Bacillus cereus strains (designated B) that have notable chromium tolerance and reduction capacity. We identified *Bacillus cereus* D and 332, respectively. The strains showed remarkable resistance to pH and temperature, as well as the capacity to endure at 8 mM Cr (VI). B. In a 24-hour period, Cereus D removed 87.8% of the initial 2 mM Cr (VI). We demonstrated that Cu (II) greatly accelerated the elimination of Cr (VI). When B supplied 0.4 mM Cu (II), the cell eliminated 99.9% of the Cr (VI). 332 for Cereus in one day. Based on current observations, this elimination effectiveness is the highest reported in the literature. The best immobilization technique consisted of sodium alginate and diatomite together. In cells that were immobilized, Cereus 332 performed better. The outcomes of our research were instructive.

Abed, R.M.M. et al. (2020). Since we rarely observe these mats in chromium-polluted environments, our understanding of the bacterial diversity of microbial mats and their role in removing chromium is poor. Researchers conducted investigations on the removal of hexavalent chromium (Cr (VI)) from three quarry sumps of chromium mining sites, using nine microbial mats. We used MiSeq sequencing to study the bacterial diversity in these mats and the changes in the community after incubation with Cr (VI). The third most significant source of chromium accessible to the environment is the 1,911 ± 100 mg kg-1 of chromium found in natural microbial mats. Under aerobic circumstances, the mats were able to remove 1 mg l-1 of Cr (VI) in seven days. We used MiSeq sequencing to recover 46–99% of the sequences associated with Firmicutes, Actinobacteria, and Proteobacteria from the original mats. Following the mats' Cr(VI) treatment, the bacterial population changed to favour Verrucomicrobiae and Alpha proteobacteria. We conclude that the microbial mats in the quarry sump, containing a variety of microorganisms capable of removing dangerous Cr (VI), could potentially remove chromium from contaminated rivers.

Springthorpe, S.K. et al. (2019). Many redox interactions between electroactive bacteria and inorganic materials; however, conventional materials, including metal oxides, are poorly defined and have limited tunability. Conversely, studies have demonstrated the large surface areas, unique topologies, and substantial chemical tunability of metal-organic frameworks. However, we have not investigated their potential use as microbial substrates. Here, we show that Shewanella oneidensis, a bacterium that respires metals, may grow in metal-organic frameworks due to Fe (III). We show in a practical application that cultures containing *S. oneidensis* can grow in metal-organic frameworks. Over several cycles, both Oneidensis and reduced metal-organic frameworks are more effective than either component alone or bio-reduced iron oxides at removing deadly levels at Cr (VI). It could serve as growth substrates and serve as a valuable replacement for metal oxides in applications that integrate the advantages of synthetic materials with bacterial metabolism.

Ma, L. et al. (2019). Effective treatment closes the harm that Cr (VI) contaminated groundwater is causing to the ecology. The first reports of Cr(VI) biodegradation emerged many years ago. But, the main reductase species (cites) and functional genes involved in the reduction of Cr (VI) in mixed bacterial consortia are some of the few things that are still known about how chromium is removed. This work confirmed the validity of the enzyme-mediated Cr(VI) reduction mechanism. The reduction of multiple cell components with Cr(VI) demonstrated the extracellular enzyme as the primary active component during this phase. We determined the distribution of Cr using mass balancing after the experiment. Furthermore, the rate of reduction decreased as starting Cr(VI) concentrations rose, and 8.0 was the ideal pH for reduction. The presence of other heavy metals significantly affected Cr(VI) reduction, while co-existing oxyanions had no influence. This work clarifies the basic ideas of bioreduction by examining the makeup of the microbial community & evolutionary behaviour of the functional genes impacted by Cr (VI). In reduction processes on the genes and species of bacteria relevant to Cr, which will aid in the creation of bioremediation methods for water contaminated with Cr (VI).

Wani, P.A. et al. (2018). Many sectors use hexavalent chromium (Cr (VI)), which can be hazardous to the environment if not handled properly. We can utilize microbes to detoxify Cr (VI) from contaminated settings, as they possess the ability to convert hazardous Cr (VI) into less soluble Cr (III). The antioxidants and chromium reductases made by Bacillus subtilus MAI3 affect getting rid of chromium (VI) and helping soybeans grow. We base this on the previously mentioned data. Bacillus species MAI3 demonstrated the most effective reduction of Cr (VI) at a pH of 7. Unlike cell debris, which has not demonstrated any chromium (VI) reduction, chromium reductase, which was present in cell-free extract, reduced nearly all of the chromium (VI). MDA rose in proportion to the metal content. Exposure to chromium (VI) led to an increase in antioxidant levels. Bacillus strain MAI3 was used to show how reductases and antioxidants help soybeans grow and make more photosynthetic pigments when they are under chromium (VI) stress. Bacillus strain MAI3 converted nearly all of the Cr (VI) in the soil to Cr (III), with the plant immobilizing the majority. Antioxidants and Cr (III) immobilization supported the development of soybeans under metal stress.

Dave, S. & Bhatt, N. (2018). The general public is facing severe health issues as the extensive industrial use of hexavalent chromium and inadequate remedial treatment methods. Finding the bacterial consortiums responsible for reducing the amounts of chromium in industrial soils and wastewater was the aim of the current investigation. We measured the total chromium concentration using ICP-AES spectroscopy, and analyzed the characteristics of cell-associated reduction products using XRD, FT-IR, and SEM-EDAX. SN6 can tolerate and reduce hexavalent chromium under a variety of experimental conditions. This suggests that it could potentially recover chromate-containing industrial wastewaters.

Kumari V. et al. (2017). They discovered Cellulosimicrobium funkei AR8, a novel haloalkaliphilic bacterial strain resistant to Cr (VI). We conducted the experiment to reduce Cr (VI) at several dosages, ranging from 100 to 250 mg/L, under optimal conditions of pH (5–9), temperature (25–45°C), and salinity (0–3%). At an ideal pH of 7, the bacterial strain completely eliminates Cr (VI), but at pH values of 5.0, 6.0, 8.0, and 9.0, the rate of elimination decreases to 56.70, 76.77, 86.67, and 60.40%, respectively. Temperature studies reveal a 100% reduction at 35$^{o}$C. The XRD and Raman spectroscopy data verified the bioconversion of Cr (VI) to Cr (III). We examined the detrimental effects of Cr (VI) on cellular morphology following the reduction process using SEM-EDX and FTIR analysis. This made it possible to identify Cr (III) when it was biosynthesized and fixed on the bacterial surface.

Sathishkumar, K. et al. (2017). In collaboration with third parties. In the cleanup of chromium-contaminated settings is bio reduction, which converts the highly poisonous hexavalent chromium ion [Cr(VI)] into the non-lethal trivalent chromium ion [Cr(III)]. In this work, we examined Pseudomonas stutzeri L1 and Acinetobacter baumannii L2's ability to bioreduce Cr(VI). Overall, A. Given that Baumannii L2 is Cr(VI)-tolerant, it appears to be a promising choice for bioremediation of wastewater effluent contaminated with chromium (VI).

Gargi, B. et al., (2015). It was used low-salt agar to separate a chromium-resistant gram-negative bacterial strain P-2 from tannery waste water. The researchers identified the bacterium as Alkaligenes faecalis, which demonstrated a maximum resistance to Cr (VI) of 750 mg/L. It has been reported that after aerobic conditions and increasing biomass are established, the bacteria may reduce Cr (VI) by more than 75% at 37ºC and an ideal pH of 8 with 0.05% salt. Additionally, the bacterium uses NADH to boost reductase activity, which causes Cr (VI) to decrease by 95%. It also demonstrates that the enzyme chromate reductase is present in the cell-free extract.

Gupt, V.K., Rastogi, A. (2013). It also looked at the bio-reduction of Proteus and Pseudochobactrum, two marine bacterial species that change chromium from Cr (VI) to Cr (III). After 96–144 hours of incubation, the bacterial strains may completely decrease 1000 mg/L of Cr (VI) in LB medium. Furthermore, at doses of up to 2000 and 1500 mg/L, respectively, they exhibit resistance to Cr (VI). These two strains' resting cells successfully reduced 200 mg/L of Cr (VI) in Tris-HCL buffer three times in a row, in 16 and 24 hours, respectively. This study investigated the hypothesis that marine bacterial strains that decrease chromium (VI) could also decrease levels of Cr (VI), potentially purifying the environment to increasingly dangerous levels.

Soni, S.K., et al. (2012) performed the in vitro reduction of Cr (VI) to Cr (III) using cell-free extracts of chromate-reducing bacteria that were rhizospheric soil of plants. This investigation discovered four strains of Bacillus sp., namely SUCR 44, SUCR 140, SUCR 186, and SUCR 188, following their isolation. The sequence was Microbacterium sp. B. followed by Bacillus subtilis. thuringiensis.

Barakat, M.A. (2011). The chromate-resistant bacterial strains ZA-6, W-61, KS-2, and KS14 that were found. The rDNA 16S analysis revealed that the bacterial strains were Staphylococcus gallinarum, Pantoea sp., and Stenotrophomonas maltophilia. Furthermore, Aeromonas sp. is taking that into account. Among the four types of bacteria, S. maltophilia, which is supplementary to *S. pantoea* sp., demonstrated resistance to Cr(VI) and gallinarum at concentrations of 16.5 and 12.4 mM, respectively. Furthermore, Aeromonas sp. were able to absorb Cr(VI). S. S. is illustrated. At 500 μM, galanurum and maltophilia completely transformed Cr(VI) into Cr(III). Furthermore, research demonstrated that metabolic inhibitors such as sodium azide, sodium sulfate, and sodium cyanide significantly impacted the reduction of chromium.

Mishra, S. et al. (2010) investigated Cr(VI) detoxification in the mining district of Sukinda, Orissa. Because of its chromite riches, Sukinda is one of Jaipur's most chromium-polluted Orissa sites. The chromium-contaminated Sukinda mining zone revealed twelve Cr(VI)-resistant bacteria. Only four species, Micrococcus luteus, Pseudomonas putida, Serratia marcescens, and Acinotobacter calcoaceticus, exhibit Cr(VI) resistance levels greater than 500 ppm.

Pei, Q.H. et al. (2009). The textile dye effluent to find and describe Acinotobacter haemolyticus Cr(VI) chromium-reducing bacterial cultures. The results of the experiment showed that the bacteria that were separated could handle at least 80% growth in LB broth medium and up to 30 mg/L of Cr(VI) in LB agar medium. However, at higher Cr(VI) concentrations of 110 mg/L, there was a noticeable decrease in growth rate. Moreover, it shows the enzyme activity of intracellular reductase, which reduced Cr(VI) the most when using soluble CFE at 37ºC and pH of 7.2. FT-IR and TEM analyses added to the evidence of the Cr(VI) product being reduced to Cr(III). FTIR studies demonstrate the conversion of carboxyl, amide, and hydroxyl functional groups on the surface of bacteria into molecules (III).

Desai, C. et al. (2008) assessed the capacity of three effective bacterial strains, identified as *Bacillus cereus*, *Bacillus fusiformis*, and *Bacillus sphericus* and recovered from a contaminated landfill, to reduce Cr(VI) in vitro. In less than 30 hours, the suspended cultures of various bacterial strains exhibit an 85%+ reduction in Cr(VI) at 1000 μM. of the three bacterial strains, GIDM22 demonstrated the ability to continuously decrease 100 μM Cr(VI) seven times. An enzymatic examination of the cell-free extract of bacterial culture revealed that the chromate reductase enzyme, associated with the soluble portion of cells, is responsible for the reduction phenomena. GIDM22 showed the highest reductase activity at 100 μM Cr(VI), and this activity rose when NADH was added.

## CONCLUSION

When working with ambient samples and using enrichment procedures, we observe relatively high levels of diversity. This is most likely due to the high amounts of functional redundancy present in ambient microbial communities, which are essential to their functional stability. This natural variety could be a problem when trying to get to a practical level because it could have a negative effect on efficiency, there could be cheating microbes whose presence has no effect on degradation, there could be security risks from known or unknown pathogens, and properties of interest could be lost if rare taxa are present. Less complex, but no less effective, microbial consortiums can lead to optimized and more regulated industrial processes. For instance, low biodiversity of the microbial community from diesel-contaminated soil resulted in notable alterations to a sizable portion of functional genes and reduced the effectiveness of diesel biodegradation. It is consequently crucial to find reliable ways to decrease diversity in the direction of optimum microbial consortiums formed from environmental samples. We employed reductive screening with several metabolic functional groups to construct minimal microbial consortia with high lignocellulose degradation efficiency. Additionally, artificial selection methods such as dilution, heat, and toxicity have created bacterial consortia. Using dilution-to-extinction is thought to be better than traditional isolation and assembly because it creates a lot of microbial combinations that are ready to be screened, includes strains from the original microbial pool that might be lost due to cultivation/isolation biases, and makes sure that all microbes are present and interacting naturally.

**REFERENCES**

1. Abed, R.M.M. et al. (2020). The Role of Microbial Mats in the Removal of Hexavalent Chromium and Associated Shifts in Their Bacterial Community Composition. *Front. Microbiol.*, 11(12), 1-14.
2. Arishi, A. & Mashhour, I. (2021). Microbial Mechanisms for Remediation of Hexavalent Chromium and their Large-Scale Applications; Current Research and Future Directions. *J Pure Appl Microbiol*., 15(1), 53-67.
3. Barakat, M.A. (2011). New trends in removing heavy metals from industrial wastewater. Arab. *J. Chem*., 4, 361-377.
4. Dave, S. & Bhatt, N. (2018). Biotransformation of Cr (VI) by Newly Invented Bacterial Consortium SN6. *J Pure Appl Microbiol.* 12(3), 1375-1384.
5. Desai, C., Jain, K., Madamwar, D. (2008). Evaluation of in vitro Cr (VI) reduction potential of cytosolic extract of three indigenous Bacillus sp. isolated from Cr (VI) polluted industrial landfill. *Biores. Technol.*, 99, 6059-6069.
6. Gargi, B., Ranjit, D., Kazy Sufia, K. (2015). Chromium bioremediation by Alcaligenes faecalis strain P-2 newly isolated from tannery effluent, *J. Environ. Res. Develop.*, 9(3), 840-848.
7. Gupt, V.K., Rastogi, A. (2013). Biosorption of hexavalent chromium by raw and acid treated green alga Oedogonium hatei from aqueous solutions. *J. Hazard. Mat.* ,163(1-15), 396-402.
8. Kholisa, B. et al. (2021). Evaluation of Cr (VI) Reduction Using Indigenous Bacterial Consortium Isolated from a Municipal Wastewater Sludge: Batch and Kinetic Studies. *Catalysts*, 11, 1-14.
9. Kumari, V., Yadav, A., Haq, I., Kumar, S., Bharagava, R.N., Singh, S.K., Raj, A., (2016). Genotoxicity evaluation of tannery effluent treated with newly isolated hexavalent chromium reducing Bacillus cereus. *J. Environ. Manag*., 183, 204-211.

10. Li MH, Gao XY, Li C, et al. (2020). Isolation and Identification of Chromium Reducing Bacillus Cereus Species from Chromium-Contaminated Soil for the Biological Detoxification of Chromium. *Int J Environ Res Public Health*., 17(6), 2118.
11. Ma, L. et al. (2019). Microbial reduction fate of chromium (Cr) in aqueous solution by mixed bacterial consortium. *Ecotoxicology and Environmental Safety*, 170(10), 763-770.
12. Mishra, S. (2010). Toxic and genotoxic effects of hexavalent chromium in environment and its bioremediation strategies. *J. Environ. Sci. Health, Part C*, 1, 1-15.
13. Pei, Q.H., Shahir, S., Santhana, A, S. (2009). Chromium (VI) resistance and removal by Acenitobacter haemolyticus. *World. J. Microbiol. Biotechnol*., 25, 1085-1093.
14. Plestenjak, E. et al. (2022). Reduction of hexavalent chromium using bacterial isolates and a microbial community enriched from tannery effluent. *Sci Rep*, 12, 1-11.
15. Sathishkumar, K. et al. (2017). Bioreduction of hexavalent chromium by Pseudomonas stutzeri L1 and Acinetobacter baumannii L2. *Annals of Microbiology*, 67, 91–98.
16. Sharma, Pooja et al. (2022). Health hazards of hexavalent chromium (Cr (VI)) and its microbial reduction. *Bioengineered*, 13(3), 4923-4938.
17. Singh, P. et al. (2021). Biomanagement of hexavalent chromium: Current trends and promising perspectives. *Journal of Environmental Management*, 279, 34-45.
18. Soni, S.K., Singh, R., Awasthi, A., Singh, M., Kalra, A. (2012). In vitro Cr (VI) reduction by cell free extract of chromate reducing bacteria isolated from tannery effluent irrigated soil. *Environ. Sci. Pollut. Res.*, 1, 3-14.
19. Springthorpe, S.K., Dundas, C.M. & Keitz, B.K. (2019). Microbial reduction of metal-organic frameworks enables synergistic chromium removal. *Nat Commun*, 10, 5212.
20. Wani, P.A. et al. (2018). Antioxidant and chromium reductase assisted chromium (VI) reduction and Cr (III) immobilization by the rhizospheric Bacillus helps in the remediation of Cr (VI) and growth promotion of soybean crop. *Rhizosphere*, 6, 23-30.