# A Theoretical study on the Microbial Fuel Cells Technology for Waste Water Treatment along with Heavy Metal Reduction and Power Generation using Nano catalysts

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**ABSTRACT-**The biggest challenge that the humanity faces presently is energy crisis. Resource depletion of the conventionally available fossil fuels has dramatically increased due to overconsumption. The overconsumption of these fossil fuels such as coal, petroleum, natural gas, oil, etc., has led to environmental pollution and uncontrollable climatic change causing danger for the future generation. On the other hand treatment of waste water consumes a lot of energy and cost. A solution for this problem is the Microbial Fuel cell (MFC) which is a promising technology and a source for alternative renewable energy due to its potentiality of using the organic matter in waste water directly to produce electricity with the help of bio-catalyst (microbes). The sustainability and reliability of the MFCs has improved due to the incorporation of nanotechnology and the utility of cost effective materials as anode, cathode and proton exchange membranes. Potential removal of toxic heavy metals from effluents and generation of electricity from the treatment of waste water have been focused on this study review.

**KEYWORDS: Microbial fuel cell, Renewable energy, Microbes, Nanotechnology, Heavy metal removal, Waste water, Electricity**

## INTRODUCTION:

India's population is approximately equivalent to 18% of the total world's population and ranks second in the list of countries and dependencies leading to population crisis which in turn leads to high energy consumption and pollution. To reduce this problem the Renewable energy source came to light. Though they have humongous benefits it can't always be a substitute as they have many disadvantages like higher upfront cost, intermittency, storage capabilities and so on.The fuel cells generally do not emitgreenhouse gases, do not generate noise pollution, and have a theoretical efficiency of around 83%. Microbial fuel cell (MFC) is regarded as a promising and less expensive method to achieve Cr(VI) remediation and generate green energy simultaneously *(Huang et al., 2010)*. This innovative idea of employing microbes in generating electricity was conceived and attributed to Potter in 1911 that was only able to produce energy through cultures of microbes by using platinum electrodes. But due to the low current density, his discovery did not have much impact. At present, works mainly address on the improvement of electrode materials, the enhancement of electricity generation performance, or their combinations *(Logan and Regan, 2006)* in the MFC chamber. Mainly the MFC produces energy without causing any kind of pollution when compared to other energy resources. It saves the energy input and also produces a little power thereby adding up to the energy produced. The greatest challenge in MFC technology development for large-scale applications is low and expensive power generation. This is the reason for the difficulty in practical applications which require high power output for low cost. The general MFC set up consists of anodic (anaerobic) and cathodic chamber (aerobic) separated by a Proton Exchange Membrane (PEM). Microbes produce protons and electrons in the anodic side and transfers the protons via PEM and electrons via the external circuit. The main advantages are high energy production, low cost operation and easy maintenance. Multiple studies suggest that higher power production may be better achieved through connecting small size units together rather than the single chamber. The cost varies based upon the cell architecture, materials used for cell components, and consuming chemicals for daily operation. In general, cost can be divided into two parts including capital (initial) costs and operating costs. Biocatalysts, electrodes, membrane, and construction materials of MFC are allocated to capital costs. However, for long-term use of MFC, which is one of the essential features for commercialization of this technology, operating costs are as important as capital costs. Basically, capital costs could be compensated over the long period of operation and electricity production, while operating costs are directly related to daily expenses of the MFC and collectively increase as operation time increases.

## OBJECTIVE

The main objective of this study is to understand and to ascertain the effectiveness of hexavalent chromium reduction and production of electricity simultaneously. The study defines which type of nanoparticle will enhance the process in a limited time using Nafion as a proton exchange membrane.This study also engaged with the understanding ofoxidation reduction reaction held in anodic and cathodic chamber.

## LITERATURE REVIEW

## JAFAR ALI (2020)

Their study focuses on the removal of the toxic heavy metal Cr(VI) using a dual chambered microbial fuel cell technology followed by subsequent generation of electricity as a renewable energy from waste water. They used iron sulfide enclosed with reduced graphene oxide (FeS@rGO) nanocomposites as cathode modification on graphite felt. The characterization for the nanocomposites such as SEM, HR-TEM, XRD, FTIR, and XPS were performed. The polarization curves were studied and the potential drop in the reactors was recorded by using a digital multimeter data acquisition system. The electrochemical performance analysis of the MFC reactors was assessed by electrochemical impedance spectroscopy (EIS) and linear sweep voltammetry (LSV). Cyclic voltammetry (CV) was done to estimate the reduction of Cr(VI) and the standard 1,5-diphenyl carbazide-colormetric method was used to calculate the concentration of Cr(VI). As a result a maximum power density of 154mWm$^{-2}$and

100% efficiency of Cr(VI) removal with 15 $mgl^{-1}$ as catholyte concentration were observed. Their findings proved the beneficial impact of COD reduction along with the Cr(VI) reduction thus contributing to future enhancement in scaling up of the technology.

## TINGTING ZHANG (2019)

In this work they used *Platanus acerifolia* leaves as a biosorbent in order to remove the hexavalent chromium from both soil and groundwater by using A-MFC. The adsorption efficiency of Cr concentration after 16h was reduced up to 98%. This result was obtained when comparing the *P. acerifolia* leaves to saw dust and bark powder. Hence appreciable results were obtained using the method combining both adsorption and MFC (A-MFC) without extra energy supplied.

## CHUNG-YU GUAN (2018)

This study combines microbes, electrochemical elements and plants together to create renewable energy. According to the result obtained by this PMFC, they achieved 99% removal of soil Cr(VI). There are many mechanisms followed but they tried *Chinese pennisetumin* (high biomass plant) which removes Cr(VI) efficiently. In addition to it the higher power density was observed appreciable under the electrode carbon felt than the normal electrodes used in PMFC. Their research concluded that PMFC was an effective technique for both the hexavalent chromium reduction and for the production of electricity simultaneously.

## HE-XING HAN (2018)

In this paper, the improvement of chromium reduction was done by Photo-MFC using Pd-decorated p-type silicon nanowire as photocathode and bioanode under visible light. This method is improvised to 42.5% when compared to the MFC present in darker conditions. The power density was also found to be high with Pd/SiNW photocathode when compared without light. They also studied that lower pH value, initial Cr(VI) concentration and external resistance enhances the reduction of Cr(VI).

## MENG LI (2018)

This study demonstrates both the electricity production and the hexavalent chromium reduction can be done simultaneously in dual chamber using MFC technology. This study compared the carbon cloth, carbon brush and carbon felt electrodes and concluded that the carbon cloth of lower resistance reduces Cr(VI) experiments better than other two electrodes. A 100% removal efficiency of hexavalent chromium in 72h at pH of 2 was reported which is higher than other literatures. Their MFC produced power density at a maximum of 1221.91$mWm^{-2}$ at 120$mgL^{-1}$ of Cr(VI). After the reduction process the Cr(III) was interpreted and verified by EDS analysis. Hence the study proved that both reduction process and generation of renewable energy works simultaneously by high power density and high Cr(VI) reduction.

## YINING WU (2018)

This research was carried out in a membrane-less single chambered MFC configuration with copper removal and production of electricity were the key tasks. Carbon brush and carbon felt coated with Platinum nanocatalyst were used as the anode and cathode respectively. The necessary experiments were conducted and the positive results such as 98.3% of copper removal efficiency for $Cu^{2+}$ concentration of 12.5mgl$^{-1}$, open circuit voltage of 0.78V and maximum power density of 10.2 Wm$^{-3}$ were observed. The activity of microbial community and formation of biofilms on electrodes were assessed in their study. Cost effective setup and efficient removal of copper at lower concentration were notable in their research.

## M.T. NOORI (2018)

This study focuses on anode modification with nanocatalyst for the enhanced performance of the MFCs. The nanomaterial used by them for the coating on carbon felt were graphene oxide-zeolite composite (GZMA) or only graphene oxide (GMA). Various experimental studies and calculations electrochemical analysis, cyclic voltammetry, coulombic efficiency were done and as a result the power potential was 3.6 times higher for the GZMA modified anode MFC when compared to the control MFC.

## XIANBIN YING (2018)

In this research work, to improve the power density, a thin film of titanium dioxide was coated on stainless steel mesh and applied as anode modification in MFCs. A maximum current density of 69.5±1.2 Am$^{-2}$ was obtained from the modified anode which was comparatively better than the bare control reactors. Thus their work had enhanced the potential of the cell initiated with anode modification and the future trends of stainless steel materials being incorporated in MFCs.

## A. CARMALIN SOPHIA (2016)

In this investigation synthetic chromium liquor effluents consisting hexavalent chromium heavy metals of two different varying concentrations (4 and 8 mgl$^{-1}$) were used in the general two chambered setup MFCs. Their approach was cost efficient with the usage of uneconomical salt bridge as proton exchange membrane instead of costly nafion membrane. A maximum power density of 89 ± 3 mWm$^{-2}$ and 69.5 ± 2.1 mWm$^{-2}$ and heavy metal reduction of 95% and 86% was observed in Cr(VI) of concentrations 4 mgl$^{-1}$ and 8 mgl$^{-1}$ respectively.

## TIAN-SHUN SONG (2016)

The study consists of Graphene as a biofilm was fabricated microbially as a cathode inside the MFC. With comparison they found that the self-assembled graphene bio cathode was efficient with the rate constant of Cr(VI) reduction with an increase from 0.031 h$^{-1}$ to 0.168 h$^{-1}$ and the electricity production was from 28.6 mWm$^{-2}$ to 63.8 mWm$^{-2}$ than the graphite felt biocathode. According to the results, the graphene produces more surface area to provide more adsorption sites at the cathode and improves the electrical conductivity of the electrode.

## ELNAZ HALAKOO (2015)

However the carbon nanotube- platinum (CNT/Pt) was uneconomical in MFC system this study experimented using CNT/Pt as a novel cathode catalyst and studied the comparison between platinum and CNT/Pt in MFC system. CNT provides high surface area and this enhances the oxidation reduction reaction to improve the efficiency of the cathode.

## PRAVEENA GANGADHARAN (2015)

This study deals with the dual chambered MFC used for the toxic heavy metal reduction of Cr(VI) into its non-toxic form of Cr(III) along with energy retrieval. The work indulges in the simultaneous treatment of domestic waste water and heavy metal. A maximum power density of 767.01mWm$^{-2}$ was obtained. The total amount of Cr(VI) recovered was 99.87%. It was reported that acidic pH value of 2.0 made the reduction reaction of Cr(VI) beneficial.

## CONCLUSION

From various literatures studied, we found that,

- Platinum nanoparticle can be used as a reference with the main nanoparticle used, as this nanoparticle has no other competition in producing electricity at the highest.
- Hexavalent chromium reduction concentration differs with different concentrations fed into the reactor.
- Various method studied for the reduction of toxichexavalent chromium to trivalent chromium in MFC technology itself.
- Microbesentrapped Microbial Fuel cells produces more electricity and the chromium reduction process is also fast in its nature.
- Without consuming energy as input , MFC technology produces electricity as output.

## REFERENCES

[1]Ali, J., Wang, L., Waseem, H., Djellabi, R., Oladoja, N. A., & Pan, G. (2020). FeS@rGO nanocomposites as electrocatalysts for enhanced chromium removal and clean energy generation by microbial fuel cell. *Chemical Engineering Journal*, *384*, 123335. https://doi.org/10.1016/j.cej.2019.123335

[2] Zhang, T., Hu, L., Zhang, M., Jiang, M., Fiedler, H., Bai, W., Wang, X., Zhang, D., & Li, Z. (2019). Cr(VI) removal from soils and groundwater using an integrated adsorption and microbial fuel cell (A-MFC) technology. *Environmental Pollution*, *252*, 1399–1405. https://doi.org/10.1016/j.envpol.2019.06.051

[3] Guan, C., Tseng, Y., Tsang, D. C. W., Hu, A., & Yu, C. (2018). Graphical abstract SC. *Journal of Hazardous Materials*. https://doi.org/10.1016/j.jhazmat.2018.10.086

[4] Han, H. X., Shi, C., Zhang, N., Yuan, L., & Sheng, G. P. (2018). Visible-light-enhanced Cr(VI) reduction at Pd-decorated silicon nanowire photocathode in photoelectrocatalytic microbial fuel cell. *Science of the Total Environment*, *639*, 1512–1519. https://doi.org/10.1016/j.scitotenv.2018.05.271

[5] Li, M., Zhou, S., Xu, Y., Liu, Z., Ma, F., Zhi, L., & Zhou, X. (2018). Simultaneous Cr ( VI ) reduction and bioelectricity generation in a dual chamber microbial fuel cell. *Chemical Engineering Journal*, *334*(November 2017), 1621–1629.

https://doi.org/10.1016/j.cej.2017.11.144

[6] Wu, Y., Zhao, X., Jin, M., Li, Y., Li, S., Kong, F., Nan, J., & Wang, A. (2018). Copper removal and microbial community analysis in single-chamber microbial fuel cell. *Bioresource Technology*, *253*, 372–377. https://doi.org/10.1016/j.biortech.2018.01.046

[7] Paul, D., Noori, M. T., Rajesh, P. P., Ghangrekar, M. M., & Mitra, A. (2018). Modification of carbon felt anode with graphene oxide-zeolite composite for enhancing the performance of microbial fuel cell. *Sustainable Energy Technologies and Assessments*, *26*(July), 77–82. https://doi.org/10.1016/j.seta.2017.10.001

[8] Ying, X., Shen, D., Wang, M., Feng, H., Gu, Y., & Chen, W. (2018). Titanium dioxide thin film-modified stainless steel mesh for enhanced current-generation in microbial fuel cells. *Chemical Engineering Journal*, *333*, 260–267. https://doi.org/10.1016/j.cej.2017.09.132

[9] Sophia, A. C., & Saikant, S. (2016). Reduction of chromium(VI) with energy recovery using microbial fuel cell technology. *Journal of Water Process Engineering*, *11*, 39–45. https://doi.org/10.1016/j.jwpe.2016.03.006

[10] Song, T. shun, Jin, Y., Bao, J., Kang, D., & Xie, J. (2016). Graphene/biofilm composites for enhancement of hexavalent chromium reduction and electricity production in a biocathode microbial fuel cell. *Journal of Hazardous Materials*, *317*, 73–80. https://doi.org/10.1016/j.jhazmat.2016.05.055

[11] Halakoo, E., Khademi, A., Ghasemi, M., Yusof, N. M., Gohari, R. J., & Ismail, A. F. (2015). Production of sustainable energy by carbon nanotube/platinum catalyst in microbial fuel cell. *Procedia CIRP*, *26*, 473–476. https://doi.org/10.1016/j.procir.2014.07.034

[12] Gangadharan, P., & Nambi, I. M. (2015). Hexavalent chromium reduction and energy recovery by using dual-chambered microbial fuel cell. *Water Science and Technology*, *71*(3), 353–358. https://doi.org/10.2166/wst.2014.524