

# **Bioremediation of Low Level Uranium (VI) Waste Including Denitrification Using Microbial Fuel Cell**

*A Thesis submitted by*  
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## CONCLUSIONS

In conclusion, it can be stated that a MFC process for high rate denitrification has been developed. Also, a MFC process for simultaneous nitrate and U (VI) removal was developed. Screening various inoculum sources helped identify cow manure mixed with soil as the best available source for denitrifying bacteria. Direct use of cow manure mixed with soil resulted in very high nitrate removal rates. A synergy between heterotrophic and bio-electrochemical denitrification was evident. The highest nitrate removal rate of  $7.1 \pm 0.9 \text{ Kg NO}_3\text{-N m}^{-3} \text{ net NCC day}^{-1}$  was achieved at cathode COD/  $\text{NO}_3\text{-N}$  ratio of 7.31. Although cow manure and soil are very good sources of bacteria, direct use of cow manure and soil is bound to give variable results owing to the variations soil microbial community undergoes with to a season, water activity level, fertilizer use, etc. Cow manure, too, is expected to have the variable composition (although not too drastic) from animal to animal and feed to feed.

Considering this and to ensure reproducibility in the developed process, a consortium was developed from cow manure and soil. The consortia were developed under two different conditions namely autotrophic and heterotrophic. The developed consortia were used multiple times and gave reproducible results. The studies were done to compare denitrification rates and power outputs using these consortia and it was found that heterotrophic conditions supported high denitrification rates. The electrochemical analysis confirmed these observations. Although the denitrification rates were lower than when using cow manure and soil directly, but were reproducible. Autotrophic conditions, on the other hand, exhibited high power output. The microbial community analysis revealed several common species prevailing in autotrophic and heterotrophic conditions with heterotrophic conditions supporting higher diversity and denitrifying gene copy numbers. The adaptability and resilience of microbial community were evident and this made the system accept wastewater with different C/N ratios.

Considering the diversity of bacteria obtained in HD MFC, it can be stated that effective microbial consortia were developed from cow manure and soil. Further, identification of denitrifying genes which are the molecular marker of the denitrification pathway revealed the presence of all the genes (*narG*, *nirS*, and *nosZ*) in both the conditions. This observation was an important step towards ensuring the successful denitrification process. The consortia developed in this study brought together the best of the denitrifiers enabling an efficient process for nitrate removal and power generation.

Next, a process for simultaneous U (VI) and nitrate removal was developed. This involved the use of heterotrophic denitrifying consortia developed in the previous study. The U (VI) has high redox potential and can serve as electron acceptor at the MFC biocathode. However, this process is not very promising because it needs specialized consortia which can carry out U (VI) reduction and reduced form of U (IV) reoxidizes back upon air exposure. In our system, U (VI) and nitrate were present together, the consortium was denitrifying, and presence of nitrate ion ensured that bioreduction does not operate. The nitrate is preferably used as electron acceptor supporting the growth of denitrifying bacteria. The growth is associated with the production of phosphatase activity which in turn helps precipitate soluble U (VI) as insoluble uranyl phosphate. The formation of this precipitate was confirmed by XRD and EDX.

The application of the process could be successfully demonstrated on the effluents collected from BARC nuclear fuel recycle operations. These wastes have low-level nitrate

contamination and were contaminated with some other radionuclides. The nitrate removal and power output were attainable from these wastes when they were added without any modification. This indicated the utility of the process for real-time application.

The results from all the studies were promising. However, the process needs to be scaled up for field applications. The operation has to be done in a continuous mode. The MFC design needs improvements in terms of fabrication costs and scalability. Also, the scope for improving the microbiology, physiology and eventually the denitrification rates and power outputs in MFCs always exist. The future studies should, therefore, focus on all these aspects.

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