EMERGING TECHNOLOGIES AND ARTIFICIAL INTELLIGENCE WITH THEIR FUTURE SCOPE IN BIOREMEDIATION

Abstract

According to a statistic from the year 2020 every day there are over 2 millions of sewage, agricultural and industrial wastes are introduced into water that is present all over the world. This causes various diseases based in water such as cholera, dysentery, diarrheal, polio, hepatitis A and typhoid. Along with that there are various issues such as poor hygiene, schistosomiasis and malnutrition. Various different technologies have been introduced for the removal of those pollutants from the water or environment. But even with those technologies we cannot receive the highest removal efficiency. Hence in the recent decades researchers have introduced various technologies and implemented them for the remediation process. One of such techniques is bioremediation that is the usage of biotic organisms for the removal of pollutants. In this chapter the emerging technologies such as nano bioremediation, electro bioremediation, Modified Ludzack-Ettinger process, microbial fuel cell and phytotechnologies have been discussed in detail with their future perspective. One of the fast growing industries that is Artificial Intelligence can also be integrated into the bioremediation treatment process. Some models such as artificial neural networks, fuzzy logic and genetic algorithms have been discussed here.

Keywords: Emerging technologies, bioremediation, artificial intelligence, artificial neural networks, fuzzy logic and genetic algorithms.

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I. INTRODUCTION

Pollution and poor management of wastes are the important environmental issues that humans face in day to day life. This is mainly because of the way the residential and industries operate and they have the potential to affect the environment. There are significant long term effects on the environment such as water resources because of human activities such as dumping of the industrial wastes as well as oil spills. When the contaminants and the oil spills enter the natural cycles they can even spread for over decades and create long term effects that can cause harmful effects. Some of the examples are oil spills, soil mines that are contaminated by acids, underground pipelines that are broken and so on. Some bacterias produce toxins from all these harmful chemicals. Some microorganisms may be produced in the environment that has been contaminated or they may be isolated and relocated. Those types of organisms can convert the pollutants into the chemicals that are needed for their metabolic activities. These activities of the microorganisms commonly lead to the degradation of the chemicals. Thus preventing the increase of pollution.

Bioremediation is an approach that is used for removal of nutrients or chemicals from the wastewater with the help of naturally occurring microbes. This type of method helps to open the door for the economically and environmentally feasible treatment method. There have been various improvements in the wastewater treatment processes in recent decades. Some of the emerging techniques in bioremediation such as nano bioremediation, electro remediation, microbial fuel cell, modified Ludzack Ettinger process and phytotechnologies in remediation have been discussed in this chapter.

The sophisticated technology applications in the wastewater treatment systems can give a correct approach for the improved application in the new scientific and technological improvements for increasing the efficiency of the system. There are various factors that affect the wastewater treatment plants operation. They may include the properties of the streams of wastewater along with the degradation properties that exhibit through the biological processes. Because of the emerging concerns regarding the impacts on environment and economy, the quality of the process control algorithms that have been improved using the artificial intelligence techniques have a lot of audience. The current advancements in control engineering have given suggestions regarding the hybrid control systems. That helps in integration of the ideas that are present into the existing soft computing skills like artificial neural networks, fuzzy logic as well as genetic algorithms. These techniques are discussed in this chapter because they can provide an improved control over the effluent quality.

II. EMERGING TECHNOLOGIES FOR THE BIOREMEDIATION

There are various different types of technologies that are used for the bioremediation purpose. But the results obtained from those traditional and conventional technologies are not very efficient. Hence as a development in this field there are various emerging technologies that have been identified. Some of the emerging technologies have been discussed here along with their future perspectives or outlook.

III. NANO-BIOREMEDIATION

In the recent decades nanobiotechnology has played a important role in remediation of soil, water as well as air pollutants into the compounds that are environmentally friendly. The main three attributes of these techniques are 1) treatment and bioremediation, 2) sensing and detection and 3) prevention of pollution. Significantly, the introduction of nano-bioremediation can improve the environment through the removal of pollutants and the strategies for the removal. The integration of conventional bioremediation methods and the nano-biotechnology approaches or the direct nano-remediation methods can be a feasible method that can be used for the removal of contaminants from the pollutants. Nanoparticles can be used for the removal of heavy metals or pesticides or herbicides or insecticides both organic and inorganic pollutants from the environment that has been polluted.

Recent studies and research has shown a promising scope for control of pollutants by applying either integrated or direct application of the nanoparticles. The most prominent features of the nano-bioremediation lies on the application ability of nano-biotechnology that mainly comprises of three attributes such as benign, clean and green nanoparticles utilization, solution for the removal of toxic materials from the sites that are contaminated and they can be used as a environmental sensor agent. The environmental improvement can be achieved depending mainly on the nano-remediation is also known as reactive or adsorption technique that will be applied at in situ or ex situ application of the pollutants. The gradual development in the growth of the technologies of bioremediation can bring some scope to the achievement of mitigation of the pollutants from the environment.

Biogenic nonmaterials have also been explored for strategies of remediation. Compared to other methods, in situ treatment methods can be considered as the feasible approach that has higher efficiency, cost effectiveness and the large scale approach [1].

- **Future Outlook:** The environment is polluted because of various reasons such as dyes, medicinal wastes, metal ions, oil spills, and industrial waste release and so on. Green nanotechnology can be used as one of the methods for the removal of pollutants and has few harmful effects. In future the industrial products can be prepared using the green nonmaterial’s that can help in reducing environmental issues and can be considered as a preventive method.

IV. ELECTRO BIOREMEDIATION

This is a hybrid technology that combines bioremediation and electro kinetics principles. It is commonly used in the treatment of hydrophobic organic compounds. This method mainly involves the DC (direct current) passage between the electrodes in the soils that are polluted and it is critical in the placement of electrodes. The current supply orients the pollutants' transportation and accelerates the mechanism that is derivative of the indigenous microorganisms of the soil that is polluted. A small or weak electric field is applied in the electro kinetics of the current of 0.2-2. V/cm. Some of the basic phenomena of electro kinetics remediation are diffusion, electrolysis, electro migration, electro osmosis and electrophoresis.

Because of the DC supply the adverse effects on the microbes must be in concern. On top of that the main function of this study is removal of pollutants and transportation over large areas for the purpose of metabolism of the microbes. Just like other emerging techniques of bioremediation the electro bioremediation also has some limitations. The first concern of the electrodes is their toxic effects that have been used in the process of treatment. Even if there are studies that show that there are no negative effects on cell electron of microbes, changes in the physicochemical properties of surface or dielectric cell membrane breakage and the changes in the cell metabolism under the influence of electric current and electrons cannot be ruled out. Along with that the solubility of the pollutants that have been removed and their properties of desorption from the matrix of soil. The pore fluids conduction for the pollutants mobilization into the matrix of soil are of great concern. Also if the contaminated area has rocks and gravels then it will be very difficult to use electro bioremediation methods. Also the availability of the microorganisms in the contaminated sites is also a major concern [2].

V. MICROBIAL ELECTROCHEMISTRY

Microbial electrochemistry is a branch of bio electrochemistry that helps in analysis and applies for electron transfer reactions that takes place between the living microbes and electron conductors like naturally available electrodes or solid state electrodes. This research has been made systematic only in the last two decades. This study approach has not only helped to understand the fundamental aspects regarding the extracellular electron transfer of microbial cells but has also contributed for identifying the key aspects that are challenging for the development of the technology and also in the applications of industries and environment.

This technology can also be called the “Microbial electrochemical technology” that helps in implying the metabolism of microbes that is being linked to the electron donor or acceptor deliberately. Here the electron functions as the acceptor that is anode. As an emerging technology in bioremediation, this system integrates the microbial and the electrochemical process for releasing organic compounds and converting the chemical energy to the electrical energy. The Microbial metabolism mediated cascade of red ox reaction, can help in the reduction of the contaminants to less harmful or value added products.

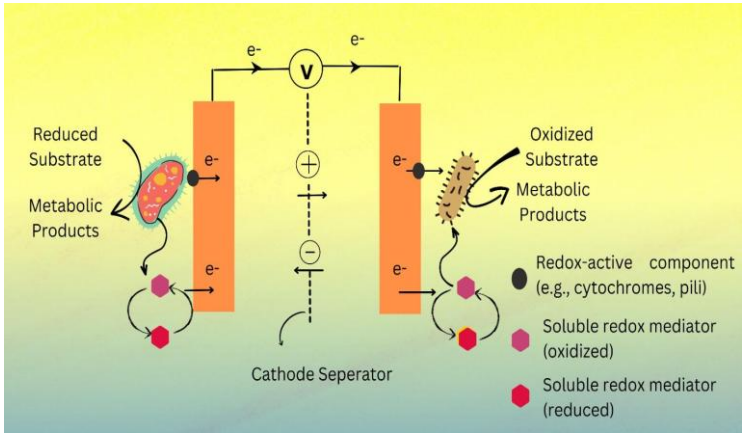

Figure 1: Schematic overview of microbial electrochemical systems.

The usage of microbial electrochemical technology has advantages over the other remediation methods such as 1) uses small amounts of energy compared to other methods, 2) even if the electricity generated is marginal it can help in powering the remote indicators or sensors that can be used as the monitoring of environmental factors, 3) generation of secondary contaminants id low, 4) can give transformation of both oxidation and reduction that is flexible for different types of contaminants.

VI. MICROBIAL FUEL CELL

One of the archetypes of microbial electrochemical technology is the Microbial fuel cell. These are mainly applied for the organic pollutants. Through diverse metabolisms electro active microorganisms will oxidize the substrates of organic acids or hydrocarbons that uses anode as electron acceptor. The electrons will flow from the anode to the cathode when suitable catalysts are present and the potential electron acceptors are reduced. From this the current flow over the positive potential difference, the net electricity is generated. There is an anodic study that focused on two microbial models initially focused on Shewanella oneidensis MR-1 and Geobacter sulfurreducens PCA. They are both mesophilous gram negative bacteria that use insoluble iron or manganese oxide as the respiratory electron acceptors in the metabolism of energy. Till date there are various microbial organisms that have generated electric currents of various levels.

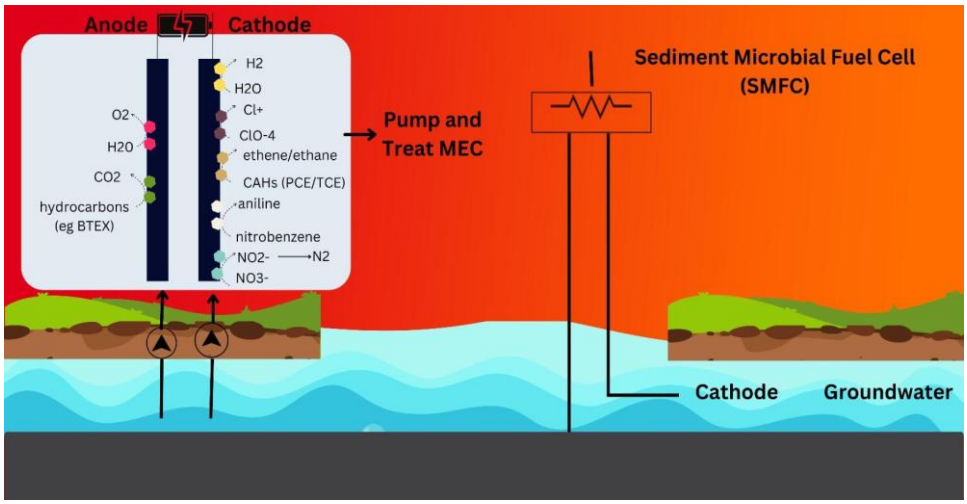

Figure 2: Schematic representation of working of electrochemical bioremediation methods.

The electron flow in the MFC has been obtained for power generation of electricity. Meanwhile in the microbial electrolysis cell the additional energy is used as input for the production at the cathode so that it will be feasible for the formation because of the thermodynamic or kinetic strains. In principle, some reductions can take place either in the MFC or MEC mode that mainly depends on the aspects such as the anode reaction or the current density. In most of the cases there will be a need for adding a small amount of electrical energy into the circuit for the drive or there will be energetically unfavorable cathodic reactions that may take place. Initially non-living catalysts were used exclusively for the drive of the cathodic reactions, primarily the hydrogen evolution at sustainable rates. In the present decade there has been an ever increasing interest in the microbial catalyzed

cathodic reaction that can in turn open new possibilities for the MEC and the microbial electrochemical technologies generally [3].

- **Future Outlook:** Most of the limitations in usage of electro bioremediation must be taken into account and it can be modified. These limitations can be solved easily by the upcoming technologies. Electrochemical remediation is also a branch of electro bioremediation. The usage of electrons and electric current is an important innovation in the removal of pollutants. The evolution of this technology can be used in the variety of improvements and production of byproducts. The different types of secondary metabolites can also be produced while using the MFC. The improvements in this technology will definitely produce dramatic changes in the bioremediation technology.

VII. MODIFIED LUDZACK-ETTINGER PROCESS

This method is a most commonly used biological nutrient removal in MBR. It is a commonly used method for the removal of nitrogen biologically. The original Ludzack-Ettinger design has been refined in 1973 by Barnard. The modification has been given at internal cycle where the mixed liquor was introduced with more nitrates into anoxic reactor directly from the aerobic reactor.

This MLE process mainly consists of a conventional activated sludge process that is created by or addition of the anoxic upstream of the aerobic zone. This setup has an internal recycle pump system that returns the nitrate-rich mixed liquor that has been produced in the aerobic zone and they are mixed with influent present in anoxic zone. The potential amount of nitrates are removed in anoxic zone mainly depends on the recycle flow and the influent BOD availability.

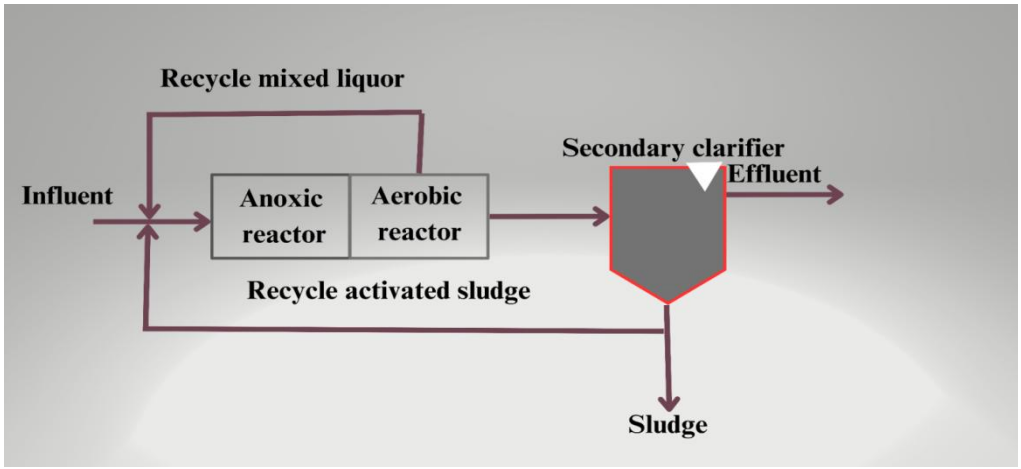

Figure 3: Process of Ludzack-Ettinger System [4].

There is an overall increase in the denitrification rate and the overall removal efficiency of nitrogen. The internal flow ratio has been determined as:

$$IFRF=q_r/q_i \quad (1)$$

Here q_r means internal recycled flow rate and q_i means the flow rate of influent.

- The typical range of IFRF is from 2-4.
- For the effective reduction of nitrate by the pre-anoxic process needs BOD/TKN ratio at the range of 4:1 in the wastewater influent.
- The detention time of the anoxic tank is 2-4 hours,
- The effluent standard can be met at less than 10 mg/l of total nitrogen.
- The range of 4 - 7 mg/l of total nitrogen concentration has been achieved for the domestic water that has been treated.

This method can also be used in existing activated sludge wastewater treatment [4].

VIII. PHYTOTECHNOLOGIES

Phytotechnologies are defined as the application of science and engineering for studying the problems and providing the solutions by involving the plants or they can also be defined as the set of technologies used for the remediation of pollutants using plants. These technologies include the phytoextraction, phytovolatilization, photodegradation and photostabilization. These are the commonly used promising techniques for the remediation. But the commercial and industrial applications of these techniques are scarce.

Just like other organisms plants will also be affected by the environment and terrestrial pollution. The effects of these pollutants can be seen dependent on the concentration of the pollutants and the response of the plants towards the pollutants. The main mechanisms of removal of pollutants with the help of plants are either by immobilization or improving the microbial degradation process. This phytoremediation process is most commonly used in the sewage and municipal wastewaters, tannery effluents, dumping sites of heavy metals and the minefields. The phytotechnology based method is used for the treatment of the dyes and the dye-containing effluents as a developing technology. There are various types of plants from various habitats that have been used for the treatment of textile effluents. Some of those plants are Petunia grandiflora, Aster amellus, Zinnia augustifolia, Glandularia pulchella, Grindelia grandiflora; they are known for their excellent degradation ability of aromatic dye compounds.

Various different forms of phytoremediation have been introduced as the advancement in the technology. Some of those advancements are as follows, development of constructed wetlands - it is an advanced form of the phytotechnology on remediation mainly used for the ex situ and in-situ treatment of the wastewater that has dyes. Plant-microbe phytoremediation - it is one of the most powerful phytoremediation techniques that includes rhizoremediation. It can occur naturally or can be triggered or induced by augmenting the specific pollutants degrading microbes or can even be the plant growth promoting microorganisms.

There are various advantages in using phytotechnology. Some of them are that the usage of this technology can help in increasing the revenue from the nonproductive polluted soils if they are connected with the biomass production. Biochar can be produced as well as crop rotation of different crops in the polluted sites can help in increasing or restoring the nutrients of the soil. There is also a possibility of phytomining that is the usage of plants to

mine the metals. But some practical aspects can prevent it from being used on a large scale [2].

The present fundamental research in the phytotechnologies mainly focuses on two fields: genetics or biochemistry or physiology for increasing the tolerance of the plants metabolism to the organic pollutants or other elements and the process in the rhizosphere that can influence the pollutants photo availability. The original concept of phytoremediation is mainly focused on the phytoextraction when the phytostabilization has less attention. The first focus of the phytotechnology was the removal of pollutants from the soil by degrading them or volatilizing them. Some phytoremediation studies have mainly focused on the high metal extraction rates by the plant species. Because of this the research has been focused on the hyperaccumulator plants or the usage of biotechnology for increasing the mineral uptake. This development in the technology has given important results in the plant science that can relate to the plant-pollutant interactions and selection of the plant species that has the hyperaccumulation characteristics.

- **Future Outlook:** The phytotechnology mainly related to the biochemical process that is able to modify the ecosystem permanently. The plants affect the evapotranspiration rates, immobilize, mobilize or extract the metals and chemicals from the soil and can also release various chemicals. The categorization of the phytostabilization or phytoextraction can change as the progress of the project progresses. There is a new way for the understanding of the phytotechnologies as the phyto management that is based on the usage of contaminated land in the economic yield production. Then here the remediation can be redefined with the dynamic system that maintains the contaminants risks at the level of safety levels. From this it is understandable that the phytoremediation technologies no longer has the only goal of soil remediation but also the generating economic benefits and this makes it necessary to redirect the current research lines to the aspects of applications.

IX. AI TECHNIQUES IN BIOREMEDIATION

In the last few decades the fuzzy logic, artificial neural network and genetic algorithms are having significant growth and have more impacts on environmental remediation. But these methods have only limited use in the application because of the risk assessment, analysis of cost-benefits and the assessment of life cycle. But now they are being currently used for the environmental remediation and have various positive impacts on the environment and have high efficient results.

X. ARTIFICIAL NEURAL NETWORK

Artificial neural network is an approach that is mainly based on the intelligence based modeling technique that relies on the biological information for the processing of data and building the models. These ANN are computer based systems that mainly employ a number of neurons for simulating learning pattern of the human brain. Here the neurons will be grouped in layers that were hidden and connected with synapses called weights. These approaches are specifically suited for the stochastic situations such as production because they can typically detect the overwhelming non linear relationships for facilitating a better model for the process.

There is research in which the secondary effects of the pollutants have been examined using ANN. These models have been replaced in recent times for the multiple linear regressions in the development of the prediction simulations mainly for soil pollutants. The important improvement in the ANN models is that they are trained to non-linear and complex relationship comprehension that takes place between the configurations of input and output. They also do not put any limitations on input or output spaces.

As ANN are the methods of intelligence in advanced computing that quantitatively analyzes the information by training as well as learning in the same way as the operation of human intelligent systems. The ANN compositions that include an array of several neurons are connected together and function as a processing system that can be used for solving specialized problems. The individual neurons will represent the input unit that has been transmitted to hidden layers for the processing and then to the neuron in the last layer that is an output. The output of each node has been termed as the activation and the weight value that is related to each node is called as bias. The iterative movements of the training data that is present around the network will determine the weight value. There will be an input space, hidden layers and the output space in order.

$$y_i^k = f(v_i^k) \quad (2)$$

In ANN output, i is neuron, k is layer and f is activation function [5].

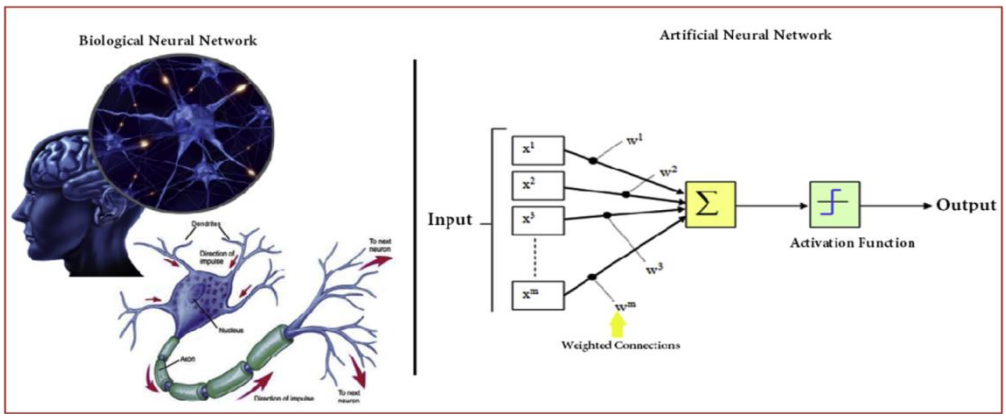

Figure 4: Illustration comparing the biological neural networks and artificial neural networks [5].

The usage of ANN in the remediation process can help in the analyzing of large amounts of data. Data analyzing is one of the most important processes for the implementation of any planning process. The simulation models help in the detailed analysis of the pollutants and their removal efficiency. This method is a growing technique and it is necessary to improve and implement them in various bioremediation studies. They help in identifying the accurate concentration of the pollutants, microbes or any chemicals that are used or treated in the remediation process. This accurate prediction with the help of artificial intelligence can help in solving most of the unknown characteristics and disadvantages that could occur during the treatment process.

XI. FUZZY LOGIC

While modeling the environmental problems that are, researchers have mostly failed in making accurate statements about the inputs and the outcomes we get from them. But fuzzy logic can be applied for the development of the environment in a way that can solve various problems that occur commonly. The environment protection and the quality of water is becoming a very important issue in the policies of the public throughout the world. Fuzzy logic is one of the powerful methods that helps in solving problems that has many applications in the control and processing of information. The usage of the fuzzy controllers has eventually reduced the problem of control.by using the fuzzy controllers where the values of the control are obtained by the fuzzy rules basics that are very similar to the human reasoning. The efficiency of the wastewater treatment systems under the dynamic loading conditions is one of the tough tasks. This is mainly because of the operation of the system of wastewater treatment has been connected to the sources of wastewater, composition of the chemicals, rate of flow, conditions of biological process and the rate of recycling of sludge that has been settled, to all this process control can be a valuable tool for minimizing the impacts of environment and economy.

For the problems related to science the fuzzy logic can be used as an alternative for comforting the challenges and can also become an appropriate solution. Because of the complex behavior of the models the collection of simple if-then rules can make the fuzzy logic and correct modeling tool. The fuzzy arithmetics is a method that does not need more well characterized inputs of statistical distribution. The main advantage of the fuzzy logic is in the assessment of the risk that has the ability to combine multiple objectives that have different values and meanings [6].

The fuzzy logic has been applied in an activated sludge plant and also for the wastewater treatment modelling methodology mainly based on excel and the Matlab Simulink that is basically for the researchers who do not have the expertise in programming.

XII. GENETIC ALGORITHMS

It is a method that is used for solving the problems that are constrained and also unconstrained. That is mainly based on the process of natural selection that can mimic the evolution of biology. This type of algorithm will repeatedly modify the population of separate solutions. At every step the GA will randomly select the individuals from population that are present and then use them as the parent population in the purpose of producing children for next generation. For over next generations population will evolve to the solution that is optimal. This is an advanced approach for the bioremediation process where there is a large amount of data and they can be used for accurate results.

There are various optimization techniques that are used in the bioremediation process; one of such mythos is genetic algorithms. In the traditional techniques there are linear programming, dynamic, nonlinear, quadratic and mixed integer programming while the new optimization techniques have been introduced; they are simulated annealing, neural networks and genetic algorithms. The new techniques are used for eliminating the computing derivatives requirements with respect to the decision variables. These types of derivatives are hard to calculate numerically or analytically with highly nonconvex and nonlinear

groundwater remediation problems. The above mentioned new techniques are very robust and can be combined with the models of groundwater simulations.

The main advantage of GAs is that they include straightforward formulations and there is no requirement for the derivatives of computing systems. The genetic algorithms that are using the parallel programming can use the network or multiprocessor computers that help in accelerating the solution convergence. The computational performance has been compared with eight optimization algorithms that is used for the pumping costs optimization for the in situ bioremediation of the groundwater that is contaminated. The optimized algorithms are divided into three classes they are: 1) evolution algorithm - binary coded genetic algorithm, real coded genetic algorithm, derandomized evolutionary strategy, 2) direct search method - Nelder - Mead simplex, modified simplex, parallel directive search, 3) derivative based optimization methods - implicit filtering for constrained optimization, SALQR.

The real coded genetic algorithm can be used for determining the optimal rates of pumping and the locations of wells for the minimization of the total pumping cost of the system of in situ groundwater remediation. The real coded genetic algorithm along with the directive recombination and the replacement of screening performed well compared to the standard binary-coded genetic algorithm in context of performance [7].

XIII. CONCLUSION

Environmental pollution caused by industries and other sources are the most troublesome problem that needs to be tackled. In this present study the emerging technologies in bioremediation such as nano bioremediation, electro bioremediation, microbial fuel cell, modified Ludzack-Ettinger process along with phytotechnology based remediation has been discussed in detail. The future perspectives and improvements in the technologies presented in this chapter can be used for the fast and efficient development in the remediation process. The introduction of artificial intelligence models into the bioremediation process can increase the efficiency and the quality of the bioremediation process. Because they provide accurate and quick data for the process. The recently introduced and the easier model of artificial intelligence implemented in bioremediation such as artificial neural networks, fuzzy logic and genetic algorithms are discussed in this chapter. The combination of both emerging technologies and artificial models can give effective results in the bioremediation technology which inturn improves the quality of the environment and water resources that are polluted.

REFERENCE

[1] Madhu Sri Sekar, Gokila Shanmugam, Gowri Kalimuthu, and Krishnamoorthy Bellie Sundaram. “Nano-Bioremediation for Environmental Pollutions – A Review.” Letters in Applied NanoBioScience, 175, 12, no. 4 (February 25, 2023). https://doi.org/https://doi.org/10.33263/LIANBS124.175.

[2] Srivastava, Ankita, Radha M. Rani, Dipesh S. Patle, and Sushil Kumar. "Emerging bioremediation technologies for the treatment of textile wastewater containing synthetic dyes: a comprehensive review." Journal of Chemical Technology & Biotechnology 97, no. 1 (2022): 26-41.

[3] Wang, Xiaofei, Federico Aulenta, Sebastia Puig, Abraham Esteve-Núñez, Yujie He, Yang Mu, and Korneel Rabaey. "Microbial electrochemistry for bioremediation." Environmental Science and Ecotechnology 1 (2020): 100013.

[4] Yorkor, B., and Y. Momoh. "A review of anoxic wastewater treatment: an overlooked aspect in wastewater treatment in Nigeria." American Journal of Water Resources 7, no. 4 (2019): 136-145.
[5] Olawoyin, Richard. "Application of backpropagation artificial neural network prediction model for the PAH bioremediation of polluted soil." Chemosphere 161 (2016): 145-150.
[6] Vijayaraghavan, G., and M. Jayalakshmi. "A quick review on applications of fuzzy logic in waste water treatment." Int. J. Res. Appl. Sci. Eng. Technol 3, no. 5 (2015): 421-425.
[7] Shieh, Horng-Jer, and Richard C. Peralta. "Optimal in situ bioremediation design by hybrid genetic algorithm-simulated annealing." Journal of Water Resources Planning and Management 131, no. 1 (2005): 67-78.

