A mini-review of petroleum and sludge bioremediation using microorganisms

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Abstract. Bioremediation, a process led by microorganisms, is gaining prominence for its effectiveness in transforming environmental pollutants into harmless compounds, particularly in heavily contaminated areas. Microbes in polluted environments showcase impressive genetic and enzymatic adaptability, reducing toxicity. This approach offers a promising avenue for eco-friendly and cost-effective remediation, with intricate mechanisms and metabolic approaches that address various challenges, including petroleum contamination and sludge management, thus presenting sustainable solutions for environmental and waste management issues.

Keywords: Bioremediation, microorganisms, petroleum, sludge

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1. Introduction

Bioremediation, a natural process primarily orchestrated by microorganisms, plays a pivotal role in immobilizing or converting environmental pollutants into harmless substances [1]. This method has garnered increasing attention for remediating severely contaminated soil and water, particularly when harnessed with highly efficient indigenous microorganisms. Microbes residing in polluted soils display an incredible ability to endure by altering their genetic makeup and enzymatic processes, reducing the toxicity of their surroundings [2]. Consequently, these microorganisms emerge as a promising resource for advancing bioremediation applications, boasting advantages such as environmental friendliness, cost-effectiveness, minimal energy requirements, and remarkable efficacy in breaking down or transforming a wide range of hazardous compounds, including hydrocarbons, polychlorinated biphenyls (PCBs), polyaromatic hydrocarbons (PAH), pharmaceuticals, radionuclides, and heavy metals (Cr, Cd, As, Hg, etc.) [3]. The process of microbial bioremediation involves intricate mechanisms such as biodegradation, biotransformation, and biosorption/bioaccumulation [3]. From a cellular metabolism perspective, this process can be categorized into two main approaches: metabolism-dependent (active method) and metabolism-non-dependent (passive method), depending on whether pollutants are transformed during microbial cell metabolism or through physicochemical interactions with cell wall ligands [3], [4]. One specific area of bioremediation focuses on petroleum contamination, where numerous microorganisms have demonstrated significant potential for degrading petroleum-derived substances, including various hydrocarbons, with specific genes and enzymes playing crucial roles [5]. Additionally, specialized bacterial strains have shown remarkable proficiency in degrading specific chemical components of petroleum [6]. Another facet of bioremediation pertains to sludge management, encompassing sewage sludge, ash sludge, pond sludge, and petroleum-contaminated sludge [7].
Innovative microbial-driven approaches are emerging as effective means for the bioremediation of these diverse sludge types, offering sustainable solutions for environmental and waste management challenges [2].

2. Bioremediation of petroleum

Sources of hydrocarbons including petroleum, pesticides, and other hazardous organic matter are one of the main pollutants in soil, surface water, and groundwater [8][9]. Various chemical compounds in crude oil, oil products, and petroleum consist of different weights of hydrocarbons such as saturated and branches alkanes, mono- and poly-cyclic aromatics, homo- and hetero-cyclic aromatic and large aromatic molecules, and these compounds seriously affect the health of soil and purity of water [10][8]. The soil degradation in Mongolia is caused by excessive mining results in contaminating the soil with heavy metals, further causing 77% of soil degradation and desertification nationwide [11]. Petroleum pollution is mainly from gas stations, railroad stations, car repair centers, oil fields, mining, and transportation of petroleum-derived products. Hydrocarbons in petroleum are very dangerous to living organisms such as plants, animals, and humans, and it has carcinogenic, mutagenic, and neurotoxic properties [10][9]. Microbial bioremediation degrades complex organic compounds to simple inorganic compounds like CO\(_2\) and H\(_2\)O [9]. Several microorganisms have been isolated from petroleum-derived contaminated soils and these organisms showed a high potential for bioremediation application. Common microbial species that can remediate petroleum-derived products are listed in Table 1, and some of them could work at less than 25\(^\circ\)C [12][3][5]. Some special genes include alkB and nahAC code for enzymes that can break down alkane and naphthalene [5]. Moreover, other enzymes such as hydrolases, oxygenase, demethylase, dehalogenases, transferases, and oxidoreductases contribute to pollutants’ aerobic and anaerobic degradation [12]. Some special microbes produce biosurfactants that contribute to the main role of reduction of bacterial surface tension and degradation of pollutants [6].

Researchers have been paying much attention to investigating new microbial species that have efficient remediation activity [12]. Mycobacterium austroafricancum was isolated and identified from a gasoline-contaminated aquifer, and the result of the study revealed that bacteria degraded 86% of gasoline in 28 days [42]. Rhodococcus sp. is able to survive and work under low temperatures and high salt conditions, moreover, bacteria degrade 65% of crude oil in 9 days [6]. Bacillus subtilis-27 can survive and work under different ranges of temperature and salinity, and degrade 65% of crude oil in 5 days in laboratory conditions [43]. A mixture of bacterial consortiums including Raoultella ornithinolytica strain PS, Bacillus subtilis strain BJ11, Acinetobacter lwofii strain BJ10, Acinetobacter pittii strain BJ16, and Serratia marcescens strain PL degraded more than 94% of crude oil in 10 days in a liquid medium and 65% of crude oil in 40 days in soil [44]. A selected bacterium consortium degraded 80–82% of BTEX (benzene, toluene, ethylbenzene, and xylene) in a liquid medium in 7 days [45]. Flavobacterium petrolei sp. nov which was isolated and identified from oil-contaminated Arctic soil degraded 60% of diesel oil in a liquid medium within 14 days [46]. Also, some special bacterial strains have been shown to efficiently degrade of chemical compounds of petroleum. For instance, the Pseudomonas aeruginosa L10 strain efficiently degrades some chemical components of diesel oil including C10-C26 n-alkanes, naphthalene, phenanthrene, and pyrene [47]. Both Delftia sp. and Achromobacter sp. have shown a potential to degrade polyaromatic carbon (naphthalene, phenanthrene, fluoranthene, and pyrene) and aliphatic hydrocarbons (C12, C16, C20, and C32) [48].

3. Bioremediation of sludge

Waste sludges, such as sewage and ash sludge, pond sludge, and petroleum-contaminated sludge, are raising environmental concerns in the context of waste management [3]. These sludges, generated from various sources, require sustainable disposal solutions. Bioleaching, bioremediation, and biodegradation methods play a pivotal role in addressing the ecological impact and promoting environmentally friendly waste management practices [7]. These diverse sludge categories represent critical areas of research in environmental science, encompassing municipal and industrial waste as well as hydrocarbon-related activities.

After industrial and municipal wastewater treatment, massive amounts of primary and secondary sludge are produced. The primary sludge is produced from the mechanical treatment of the wastewater, and the secondary sludge is from the biological treatment [7]. The most common method of removing sludge is burning it until it becomes fly ash [3]. Coal and fuel oil are traditional energy resources in developing countries. In Mongolia, all the thermal power plants, industries, and civilians living in Ger burn coal for energy. Because of these reasons, massive amounts of fly ash and bottom ash are continuously produced. Different inorganic materials and metals like Al, Cd, Cr, Cu, Ni, Pb, and Zn are compromised in the sludge and fly ash [7][48]. Several anthropogenic pollutants including nonylphenol are usually found in sewage sludge [49]. Therefore, environmentally friendly methods such as bioleaching,
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Table 1. Common microbial species isolated from contaminated place

<table>
<thead>
<tr>
<th>Microbial species</th>
<th>Source of isolation</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arthrobacter spp.</td>
<td>Nuclear waste contaminated sediment, Diesel contaminated soil</td>
<td>[13][14]</td>
</tr>
<tr>
<td>Achromobacter sp.</td>
<td>Crude oil-contaminated seawater</td>
<td>[15]</td>
</tr>
<tr>
<td>Alcaligenes sp.</td>
<td>Petroleum oil-contaminated sites</td>
<td>[16]</td>
</tr>
<tr>
<td>Enterobacter sp.</td>
<td>Petroleum oil-contaminated sites</td>
<td>[16]</td>
</tr>
<tr>
<td>Brevibacterium sp.</td>
<td>Crude oil-contaminated soil</td>
<td>[17]</td>
</tr>
<tr>
<td>Planococcus sp.</td>
<td>Diesel contaminated ocean</td>
<td>[18]</td>
</tr>
<tr>
<td>Pseudomonas sp.</td>
<td>Oil contaminated soil, Heavy metals contaminated soil, Hydrocarbon contaminated soil</td>
<td>[18][19][20][21]</td>
</tr>
<tr>
<td>Phenyllobacterium sp.</td>
<td>PAHs contaminated soil</td>
<td>[22]</td>
</tr>
<tr>
<td>Collimonas sp.</td>
<td>Oil contaminated soil</td>
<td>[23]</td>
</tr>
<tr>
<td>Corynebacterium sp.</td>
<td>Oil contaminated soil</td>
<td>[24]</td>
</tr>
<tr>
<td>Rhodococcus sp.</td>
<td>Oil contaminated soil, Nuclear waste contaminated sediment</td>
<td>[23][25][26][14]</td>
</tr>
<tr>
<td>Bacillus sp.</td>
<td>Hydrocarbon contaminated soil, PAHs contaminated soil</td>
<td>[27][28]</td>
</tr>
<tr>
<td>Nocardioides sp.</td>
<td>Oil contaminated soil</td>
<td>[29]</td>
</tr>
<tr>
<td>Nocardia sp.</td>
<td>Nuclear waste contaminated sediment</td>
<td>[30]</td>
</tr>
<tr>
<td>Marinobacter sp.</td>
<td>Sediment, Oil-producing well</td>
<td>[31][32]</td>
</tr>
<tr>
<td>Mycobacterium sp.</td>
<td>PAH contaminated soil</td>
<td>[33]</td>
</tr>
<tr>
<td>Micrococcus sp.</td>
<td>Hydrocarbons contaminated soil</td>
<td>[34]</td>
</tr>
<tr>
<td>Methylobacterium sp.</td>
<td>Hydrocarbons contaminated soil</td>
<td>[34]</td>
</tr>
<tr>
<td>Sphingomonas sp.</td>
<td>PAHs contaminated soil, heavy metals contaminated soil</td>
<td>[35][36][37]</td>
</tr>
<tr>
<td>Sphingobium sp.</td>
<td>Aromatic fraction of crude oil, jet fuel and diesel contaminated soil</td>
<td></td>
</tr>
<tr>
<td>Shewanella sp.</td>
<td>Phenanthrene contaminated soil</td>
<td>[38]</td>
</tr>
<tr>
<td>Stenotrophomonas sp.</td>
<td>Diesel contaminated ocean</td>
<td>[18]</td>
</tr>
<tr>
<td>Stenotrophomonas sp.</td>
<td>Oil contaminated sites</td>
<td>[39]</td>
</tr>
<tr>
<td>Flavobacteria sp.</td>
<td>Oil-contaminated arctic soil</td>
<td>[40]</td>
</tr>
</tbody>
</table>

bioremediation, and biodegradation are needed to investigate the disposal of the sludge. There are several studies related to bacterial bioleaching or bioremediation have been published. Among them, *Acidithiobacillus ferrooxidans* is one of the most important species because they get energy from the oxidation of sulfur and from ferric ions (Fe³⁺) to ferrous ions (Fe²⁺) oxidation [7]. *A. ferrooxidans* and *A. thiooxidans* successfully degrade sludge by removing 10–100% of heavy metals such as Cu, Cr, Cd, Pb, Mn, Ni, and Zn under anaerobic conditions [3]. Moreover, *A. ferrooxidans* and *A. thiooxidans* reduced 74% and 96.4% of V in fuel oil ash, respectively [50][51]. *A. thiooxidans* removed 25% of Al and 22% of Fe in coal ash [52]. There is another species *Leptospirillum ferrooxidans* also uses Fe²⁺ as an energy source and can tolerate lower pH, and higher concentrations of uranium, molybdenum, and silver than *A. ferrooxidans*, but they have lower tolerance against copper and sulfur [7]. *Bacillus safensis* CN12 is able to degrade extracted nonylphenol solution from sewage sludge after applying cyclodextrin [49]. Interestingly, Mongolian researchers have successfully transformed sewage sludge into the soil by using a mixture of several microorganisms including bacteria, yeast, and fungi, after applying fortified preparation of humin to the sludge [53]. According to this study’s result, the treated soil had absence of pathogenic microorganisms, and was odorless.

On the other hand, amounts of surplus organic materials from organic degradation and leftover feed
build sludge. Sewage waste from ponds is divided into 4 forms including gases, liquid, semi-solid, and solid or sludge [54]. Furthermore, sludge is categorized into suspended and settled solids [55]. Among them, suspended solids are difficult to remove from water, because of the remaining suspension of small particles in water [56]. By contrast, big particles make settled solids easy to remove [57]. Microbial bioremediation is one of the effective approaches for cleaning pond sludge. Ammonia-oxidizing bacteria and nitrite-oxidizing bacteria from autotrophs contribute to nitrification and denitrification. Microorganisms from heterotrophs convert ammonia nitrogen into harmless substances and they use organic waste as nutrient sources. Nitrite-oxidizing bacteria from genera of *Nitrobacter*, *Nitrooccus*, and *Nitrospira* convert nitrate to a harmless form of nitrogen. Several genera of denitrifiers, including *Bacillus* have been identified [54]. *Bacillus* sp. has shown a potential to decrease the amounts of ammonia, nitrogen, phosphorus, nitrite, nitrate, phosphate ions, and chemical oxygen [58][59][60][61][62]. A mixture of *Bacillus subtilis*, *Nitrobacter*, and yeast reduced 99.74% of total nitrogen and nitrate [63]. *Marichromatium gracile* YL28 discharged 99.96% of nitrite in pond sludge within 7 days [64]. Bacteria with special enzymes such as phosphatases and phytases can produce phosphorus from organic compounds such as PO₄. Sulfur bacteria from the Chromatiaceae and Chlorobiaceae families consume hydrogen sulfide in anaerobic conditions under sunlight [54].

Furthermore, high-efficiency petroleum degrading microorganisms have been studied and used for the bioremediation of petroleum oily sludge. Indigenous microbial consortium successfully degraded more than 80% of total petroleum hydrocarbon in oil sludge-contaminated soil within 90 days [65]. A mixture of bacterial communities including *Lettimonas huabeiensis*, *Chelatococcus daeguensis*, *Pseudomonas aeruginosa*, *Bacillus subtilis*, and indigenous microorganisms showed high potential to degrade 97% of total petroleum hydrocarbons and to reduce 93% of chemical oxygen demand (COD) from petroleum sludge [66]. The combination of bacterial consortium and wheat bran bulking agent degrades 76% of hydrocarbon in petroleum oily sludge [67].

**Summary**

In the realm of environmental conservation, bioremediation stands as a powerful natural process led by microorganisms, serving as a beacon of hope in tackling environmental contamination concerns. These microorganisms, particularly when native to the polluted soil, exhibit remarkable resilience by adjusting their genetic composition and enzymatic functions to mitigate the toxicity of their surroundings [2]. Microbial bioremediation showcases its mettle in addressing a wide array of environmental pollutants, ranging from hydrocarbons, polyaromatic hydrocarbons and heavy metals, with the potential to transform these harmful substances into harmless compounds [3]. This process is multifaceted, with metabolic-dependent and metabolic-independent mechanisms, adding layers of complexity to this eco-friendly approach [4].

The bioremediation of petroleum-contaminated soil represents a crucial facet, given the prevalence of hydrocarbon pollutants in various ecosystems [10]. This endeavor has led to the discovery of numerous microorganisms with the capacity to break down petroleum-derived substances efficiently. Specific genes and enzymes are key players in the biodegradation process, contributing to the mitigation of pollutants [5]. Furthermore, researchers are continually exploring novel microbial species with the potential for efficient remediation.

In addition to petroleum-contaminated soil, the management of different types of waste sludge, including sewage and ash sludge, pond sludge, and petroleum-contaminated sludge, presents significant environmental challenges [3]. These waste products result from a variety of industrial and municipal processes and necessitate sustainable disposal solutions [8]. Bioleaching, bioremediation, and biodegradation methods are emerging as pivotal tools to address these challenges, promoting eco-friendly waste management practices and mitigating the environmental impact [7]. These distinct areas of bioremediation research underscore the ongoing efforts to address pollution concerns and promote sustainable environmental stewardship.

**References**


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Neftiyin bytetgrzwhhun, lagiyin bohirldy bychil biyetn aishgian byuruulan sudalgaany toym ogyulul

Dorjzhutdor Nasangjargal*, Baldorj Pamyadulam, Mendeihaar Yuuriinhtuy*, Mendeihaar Mend-Amar, Rentchinjargal Uyjihilham, Hannda Ouyuxan, Zerreinmad Rentschand

Monhog Ulaa, Ulaanbaatar, Shingzel insha hana akademi, Biologiyin xurzehi, Mikrobiiyin nийgelshii laboratori

*Holbo barik zoixovoc: uniriinuvey@mas.ac.mn, https://orcid.org/0009-0009-5858-2705

1. Udirtgal

Biologiyin noxn sэрэгэлт нь ундсэндээ бичил биетний тусламжтай явагддаг байгалийн уйл явц богоодхурулэлний бүйрэчлэлийг хоргоосгогчлол мөн хэрэгцээд бичил биетний генетикийн бөлөн ферментийн дасан зохиолч чадвартай байдаг [1]. Ялангуяа биологийн идэвх зорчигчийн болон бичил биетний бодисын солилцооны явцад эсвэл эсийн ханын лигандуудтай физик-химийн харилцаны дүнд бохирдуулагч бодисын солилцооны бүтэнгүй бодис бий болгоно [3]. Хураангуй. Бичил биетнээр биологийн наохон сэрэгэлт хийх нь хүрээлэн буй орчны бохирдлыг буцаж авах, бохирдол ихээхэн бүтэнгүй бохирдлыг бууруулах давуу талтай. Бохирдолтын орчноос ялган авсан бичил биетний генетикийн бөлөн ферментийн дасан зохиолч чадвартай ашгынс бий болохдоод, энэ нь биологийн хэрэгцээд бичил биетний механизм, бодисын сонын ашиглан, байгаль орчны ээлгүй багтавт, зорчил багтавна нөхон сэргээл эрдэүүд арга замын бий болгодог. Улмаар байгаль орчны хөгжлөө, хөргөн улмаар нөхөрлөөгийн асуудлын асуудлын шийдэлээлзэц хүйлэс.

Түлхүүр үгс: Биологийн наохон сэрэгэлт, бичил биет, нефтийн буэтгэдххүүн, лаг

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бохирдсан лагийг болохон буулган юм [7]. Бичил биетнэр болохийг нөхөрлөлөөс жирийн нь байгаль орчны, хөрсний менежментийн асуудлыг шийдвэрлэх одор үр дүнгээ агуулах нэг юм [2].

2. Нефтийн бүтээгдэхүүний бохирдлыг бичил биетэн ашиглан бууруулах

Нүүрсустоговор агуулсан нефтийн бүтээгдэхүүн, нөлөөлдөг болон амьддаг организм бууруулах болсон микроорганизмийг бичил биетныг "энэд" нь орж ирээд. Нүүрсустоговор нь амьдарч буй нэгэн бичил биетний температурдаас 10 - 25°C болсон газар болсон авдонд цэвэрлэгээр хэрэгжийтэй тэнцүүдийн үр дүн санал болгогдсон [8].

3. Лагийн бохирдлыг бичил биетэн ашиглан бууруулах

Бохир усны үснэг үсэн нь, үсэн нь, бохирдын биетэн бууруулах болсон зэрэгт хяналтын усны арга болон байгаль орчны үеийн хугацааны бичил биетныг ашиглалттай байна [3]. Лагийн бохирдлыг бууруулахад бичил биетныг ашиглана учраас бохирдлын нөлөөлөгчдийн нөлөөллөгчдийн амьдралд бичил биетнэр бохирддаг. Бичил биетнын нөлөөлөгчдийн нөлөөллөгчдийн шийдвэрлэлт болсон зэрэгт хяналтын усны арга болон байгаль орчны үеийн хугацааны бичил биетныг ашиглалаа.
### Хүснэгт 1. Бөхирдлтой газраас ялгасан бичил биетний зүйлүүд

<table>
<thead>
<tr>
<th>Бичил биетний төрөл</th>
<th>Дүүрэн асан эх үүсвэр</th>
<th>Эх сурвалж</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arthrobacter spp.</td>
<td>Цомийн хаягдаал бөхирдсэн хөрс</td>
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<tr>
<td>Achromobacter spp.</td>
<td>Түүхий нефтээр бөхирдсэн даян ус</td>
<td>[15]</td>
</tr>
<tr>
<td>Alcaligenes sp.</td>
<td>Нефтээр бөхирдсэн газрууц</td>
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<td>Enterobacter sp.</td>
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<td>Planococcus sp.</td>
<td>Дийл ялгах бөхирдсэн даян</td>
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<tr>
<td>Pseudomonas sp.</td>
<td>Нефтээр бөхирдсэн хөрс, Хүнд металлаар бөхирдсэн хөрс, Нүүрсустөрөгчөөр бөхирдсэн хөрс</td>
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<td>Collimonas sp.</td>
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<td>[23]</td>
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<td>Corynebacterium sp.</td>
<td>Түүхий нефтээр бөхирдсэн хөрс</td>
<td>[24]</td>
</tr>
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<td>Rhodococcus sp.</td>
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</tr>
<tr>
<td>Bacillus sp.</td>
<td>Нүүрсустөрөгчөөр бөхирдсэн хөрс, РАН болсноор хөрс</td>
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<td>Nocardiales sp.</td>
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<td>Marinobacter sp.</td>
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<td>Mycobacterium sp.</td>
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<td>Micrococcus sp.</td>
<td>Нүүрсустөрөгчөөр бөхирдсэн хөрс</td>
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<td>РАН болсноор хөрс, Хүнд металлаар бөхирдсэн хөрс</td>
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<td>Фенантренээр бөхирдсэн хөрс</td>
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<tr>
<td>Shewanella sp.</td>
<td>Дийл ялгах бөхирдсэн даян</td>
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<td>Streptococcus sp.</td>
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<td>Stenotrophomonas sp.</td>
<td>Хүнд металлаар бөхирдсэн газар тарналангийн талбай</td>
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<td>Flavobacteria sp.</td>
<td>Түүхий нефтээр бөхирдсэн хойд туйлын хөрс</td>
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</tbody>
</table>

Уис болтол нь шатаа аядал юм [3]. Нүүрс болон шатагаан нь хожиж буй орнуудын эрхийн хуучны гол нэрэн эх үүсвэр. Монголд бүх дулааны цахилгаан станц, үйлдвэр, гэр хороолд амьдардаг иргэд нүүрс түлж эрчим хүчээ авдаг. Энэ шалтгааны улмаас их хэмжээний уис болон ёроолын уис тасралтгүй уусдэг. Янз бүрийн органик бус материал болон Al, Cd, Cr, Cu, Ni, Pb, Zn гэх мэт металдуулагдаг бол болон агаарт дүгнэлт үнэхээ агууллагддаг[7][48]. Бөхирхүс нийц тугантай нефтээр хүндийн уис эхлээд ажиллагааны цөмийн хаягдаалд бөхирдсэн

Иймд лагийг байгаль орчинд элтгэй бичил биетэн ашигласан био-усуустаа, био-нохон сэрэгээр, био-нахай бүрэн агуулагдох (Fe³⁺-с Fe²⁺) [7]. A. Ferrooxidans, A. Thiobrixoides омго нь амьдардаг болохгүй металлд ногогдсон Cu, Cr, Cd, Pb, Mn, Ni, Zn эхээр хүнд металлыг 10-100% зайлжлаж лагийг амжилттай
Цаашилбал, нефтийг задалдаг өндөр үр ашигтай нефтийн тосны лаг дахь нүүрсустөрөгчийн 80% гаруйг амжилттай задалсан [65]. Leteimonas huabeiensis, Chelatococcus daeguensis, Pseudomonas aeruginosa, Bacillus subtilis болон нутгийн омгуудын биобэлдмэл нь газрын тосны нийт нүүрсустөрөгчийн 97%-ийг задалж, химийн хэрэгцээт хүчилтөрөгчийн (COD) 93%-ийг бууруулах оидер чадамжтай болохыг харуулсан [66]. Бактерийн биобэлдмэл болон улаан буудайг хивгийг хослуулах хэрэгцээт нутгийн лаг дахь нүүрсустөрөгчийн 76%-ийг задалдаг нь нөгөөтээгүүр [67].

Дүгээр

Бичил биетүүдийг судалж, нефтийн тосны лаг дахь нүүрсустөрөгчийн 80% гаруйг амжилттай задалсанд биологийн, химийн, био-нөхөн сэргээлтийн 93%-ийг задалж, химийн хэрэгцээт хүчилтөрөгчийн (COD) 93%-ийг бууруулах оидер чадамжтай болохыг харуулсан [66]. Бактерийн биобэлдмэл болон улаан буудайг хивгийг хослуулах хэрэгцээт нутгийн лаг дахь нүүрсустөрөгчийн 76%-ийг задалдаг нь нөгөөтээгүүр [67].

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Дүгээр
орчинд үзүүлэх нөлөөллүүг бүүрүүлэхад иээхэн
измэр оруулал бол өлөө гүлсэн жана үүл байна [7]. Биологоон нөхөн сэрээлтын
судалгааланы эгээр тодорхой чиглээлүүд нь багардлын
асуулгыг шийдээлэн байгааг орны тэгтвээрт
менежментийн хангахад чиглээлн хүчн дээдлэлэн
үзээсэн хэсэг юм.

Ашиглалсан бүтээл


