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PHYTOREMEDIATION AS PHYTOTECHNOLOGY APPROACH FOR WASTEWATER TREATMENT: AN ISLAMIC PERSPECTIVES

(Fitoremediasi Sebagai Pendekatan Fitoteknologi untuk Rawatan Air Sisa: Perspektif Islam)

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ABSTRACT

Wastewater contamination is one of the critical environmental issues that is becoming worse daily due to the development of human activities mainly produced from domestic, heavy metals, oil, agricultural, and industrial waste. From the Islamic perspective, Muslims play essential roles as khalifah on earth responsible for taking care of and preserving the balanced relationship between man and the environment. As such, phytotechnology, which applies plants and associated microorganisms-based technologies, has been emerging to examine the problems and provide sustainable solutions for this issue. In the 1980's, the concept of phytoremediation was born

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when the ability of plant species to accumulate high amounts of heavy metals in their tissue and organs was proved. There are several advantages of using aquatic plants for the remediation process, such as being very cost-effective, eco-friendly and safe. Selecting suitable aquatic plant species helps safely remediate the wastewater contamination without producing any toxic substances. This article summarises recent facts on phytoremediation by using aquatic plants as the best approach to remediate wastewater contaminants. Furthermore, some sustainability principles have been highlighted in the Quran and Sunnah, which can guide stakeholders and serve as a basis for any institution to introduce better environmental conservation and management policies through Islamic perspectives, particularly in the practice of phytoremediation for wastewater management.

Keywords: Wastewater; phytoremediation; heavy metal; aquatic plants; Islamic views

ABSTRAK

Pencemaran air sisa adalah salah satu masalah persekitaran yang semakin kritikal dari hari ke hari disebabkan oleh perkembangan aktiviti manusia yang kebanyakannya terhasil daripada sisa domestik, logam berat, minyak, pertanian, dan sisa industri. Dari perspektif Islam, Muslim memainkan peranan penting sebagai khalifah di bumi yang bertanggungjawab menjaga dan memelihara keseimbangan hubungan antara manusia dan persekitaran. Oleh itu, fitoteknologi, iaitu teknologi berasaskan tumbuhan dan mikroorganisma telah digunapakai bagi meneliti masalah dan memberikan penyelesaian yang lestari kepada isu pencemaran ini. Pada tahun 1980-an, konsep fitoremediasi diperkenalkan apabila tumbuhan terbukti mampu mengumpul logam berat dalam jumlah yang tinggi di dalam tisu dan organnya. Terdapat beberapa kelebihan menggunakan tumbuhan akuatik dalam proses remediasi seperti kos yang efektif, mesra alam, dan selamat. Pemilihan spesies tumbuhan akuatik yang bersesuaian dapat membantu mengatasi pencemaran air sisa dengan selamat tanpa menghasilkan bahan toksik. Tinjauan ini merangkumi fakta terkini mengenai fitoremediasi dengan menggunakan tumbuhan akuatik sebagai pendekatan terbaik untuk merawat pencemaran air sisa. Selanjutnya, beberapa prinsip kelestarian telah diketengahkan dalam al-Quran dan Sunnah, yang dapat membimbing pihak berkepentingan dan menjadi asas bagi mana-mana institusi untuk memperkenalkan dasar yang lebih baik dalam pemeliharaan dan pengurusan alam sekitar melalui perspektif Islam, terutama dalam praktik fitoremediasi dalam pengurusan air sisa.

Kata Kunci: *Air sisa; fitoremediasi; fitoteknologi; logam berat; tumbuhan akuatik*

INTRODUCTION

Currently, the ecological condition of the biosphere is gradually unstable due to natural and human activities (Pleto et al. 2018). Economic and industrial activities mainly cause air, soil and water pollution (El-Ramady et al. 2020). Water pollution usually faces critical and uncontrollable issues since water bodies are widely covered on the earth's surface (Besseling 2018). Focusing on improper waste management, residential and industrial waste vastly dumped at the improper landfill has caused the leachate to flow into water bodies. On the other hand, the wastewater from the aquaculture industry, usually located in the coastal area is directly discharged into water bodies (Mojiri et al. 2021). Contamination occurs when waste's organic or inorganic elements are released into the surroundings (Mojiri et al. 2021). As a result, surrounding ecosystems are disturbed and degraded due to high concentrations of toxic compounds, chemicals, salts, radioactive materials or disease-causing agents (Yuvaraj & Mahendran 2020; Weldeslassie et al. 2017).

Therefore, phytoremediation is thought of as an efficient approach since it provides eco-friendly and cost-effective solutions for the rehabilitation and restoration of polluted areas, food safety improvement, and global warming mitigation by applying carbon sequestration (Mojiri et al. 2021). The ability of plant species to measure environmental conditions is called a biological indicator or phytoindicator. The plant has many roles in various features, such as serving as an indicator for agriculture, forest, soil, minerals and pollution. Numerous sensitive plant species can indicate specific contaminants which cause pollution since each plant has its specialities and benefits as written in the Quran (Luqman 31: 10):

He created the heavens without pillars that you see and has cast into the earth firmly set mountains, lest it should shift with you, and dispersed therein from every creature. And We sent down rain from the sky and made grow therein [plants] of every noble kind.

Therefore, phytotechnology should be explored further by various disciplinary in order to attain our role as vicegerent (khalifah) on earth, as mentioned in the Quran (al-Fatir 35: 39):

It is He who has made you successors upon the earth. And whoever disbelieves - upon him will be [the consequence of] his disbelief. And the disbelief of the disbelievers does not increase them in the sight of their Lord except in hatred; and the disbelief of the disbelievers does not increase them except in loss.

As a result, continued research into this technology has a strong link between one's faith (iman) and the environment and achieving the Islamic objective of sustainable development.

SOURCE OF WASTEWATER

Globalization and anthropogenic activities have resulted in severe environmental pollution due to improper waste management, which has resulted in waste being released into bodies of water. The wastewater produced by landfill leachate and the aquaculture sector will be the emphasis of this article.

Landfill Leachate

Besides recycling, composting waste is also little practised in Malaysia. Waste composting is a suitable and functional method for reprocessing biodegradable waste into compost, where this practice may help reduce the waste disposed at landfills (Nawaz et al. 2020). Usually, municipal solid waste in Malaysia contains high organic waste. Subsequently, it produces high moisture due to the hot and humid weather, and this will generate leachate through precipitation and moisture that exists in the waste when disposed of (Aziz & Ramli 2018). The common issues arising from open dumpsites that harm the environment are direct waste that produces leachate (Abbas et al. 2019). Leachate will take suspended and soluble materials from the degradable waste disposed of, transfer them into the surrounding groundwater and surface water regimes, and collect them as wastewater (Nawaz et al. 2020).

The contaminants in the leachate vary between areas depending on the climatic condition at the sites, age of waste and landfill, depth of landfill, types and density of waste disposed of, degree of decomposition that has taken place, moisture content, rate of water movement, and physical modification of the waste such as shredding (Daud et al. 2018). Leachate can be categorised by the concentration of biodegradable or non-biodegradable organic matter, ammonia nitrogen, chlorinated organic and inorganic salts and heavy metals or trace elements. In contrast, the characteristics of leachate are influenced by the composition of waste, precipitation amount, the hydrology pattern of the site, waste compaction level, design of landfill cover and interaction of leachate with the surrounding environment (Ngoc et al. 2019; Daud et al. 2018; Mojiri et al. 2021). Moreover, organic matter in leachate contaminants is generally measured by the chemical oxygen demand (COD) and biological oxygen demand (BOD) combined with ammonia, salt and other inorganic matters. These compounds' high concentrations potentially result in landfill contamination and pollution to the surrounding soil and water bodies (Xu et al. 2020; Daud et al. 2018).

In Malaysia, most landfills are non-sanitary, whereby the leachate collection and treatment system are not adequately designed, with some lacking such infrastructure. Many landfills in Malaysia are situated near water bodies without proper wastewater

treatment plans (Aziz & Ramli 2018). This contamination may prolong and affects the others as this water body is a significant water supply for industries such as agriculture.

Aquaculture Industry

Significant aspects that influence the amount of the aquaculture water ponds discharged are the size of the farm, the quantity of food given and chemicals added, and the cycles and periods of cultivation (Yunus et al. 2020; Eid et al. 2019). Nutrient loads and suspended solids are major by-products generated from aquaculture ponds, consequently degrading receiving water and coastal environments (Yunus et al. 2020). The entire pond water will be discharged during the harvest period, which causes a sudden increase in water pond loads on receiving waters (Lai et al. 2018). During a culture cycle, physicochemical parameters such as pH and salinity have no significant differences because pH will be controlled by adding dolomite and quick lime, whereas the water source quality will determine the salinity of water (Eid et al. 2019; Ariadi et al. 2019). In contrast, biological oxygen demand (BOD) levels, total suspended solids (TSS), and turbidity will increase within this period (Pleto et al. 2018; Ariadi et al. 2019).

Shrimp aquaculture is among the critical marine industries that produce large amounts of waste comprising shrimp heads, shells, and tails (Othman, Hatta, and Shafiai 2021; Ariadi et al. 2019). Moreover, half of a shrimp's total weight is a waste product that may cause environmental contaminants. Nowadays, many researchers are paying attention to the effects of intensive shrimp aquaculture on coastal environment pollution as its requirements for water are the highest rather than other forms of aquaculture and its dependence on large inputs quantity of synthetic feeds, fertilisers, and several chemical additives (Eid et al. 2019). Typically, wastes from the aquaculture have increased the nutrients excess, especially nitrogen (N) and phosphorus (P) (Lai et al. 2018). Generally, in semi-intensive and intensive shrimp aquaculture, phosphate concentration was very high, especially when the water was not exchanged. Subsequently, a significant amount of P was released to the surrounding environment or accumulated in the sediment from the shrimp pond (Othman et al. 2021; Gao et al. 2019). For fish aquaculture, organic contaminants and inorganic contaminants such as ammonium (NH_4) and phosphate (PO_4) were released by fish. Uneaten feed also produced an emission of nitrogen (N) and phosphorus (P) (Othman et al. 2021). Different parts of the aquatic ecosystem would be affected by the different elements released. For example, the small particles and dissolved nutrients would affect the condition of the euphotic zone; meanwhile, the large particles of wastes would accumulate and affect the benthic zone of the aquatic ecosystem (Bergmann et al. 2015)

PHYTOTECHNOLOGY

Phytotechnology is an approach to landscape ecology that uses sciences and engineering to solve environmental problems by using plants as living technology. The term "*phyto*" refers to plants, whereas phytotechnology means uses plants in technology (Chrismadha 2020). This technology proves that plants can benefit society and natural systems. In line with advancing technology, numerous authors have mentioned several purposes of phytotechnology (Mustafa et al. 2021; Zaman et al. 2020; Bansal, Shinde, and Sarkar 2018; Gatliff et al. 2016), which are:

1. To solve or decrease environmental pollution issues by using constructed ecosystem or wetland for wastewater treatment;
2. To assist the ecosystem retrieval after being disturbed, for example, the restoration of rivers and lakes;
3. To improve socio-economic benefits within the ecosystem management context;
4. To reduce climate change effects as a sink for carbon dioxide by reforestation; and
5. To soften and inject the urban areas with the natural element to mitigate pollution, such as green roofs.

To achieve a successful phytotechnology application, researchers must understand the prospects and limits of the technology as insufficient knowledge may lead to failed application. Moreover, the plant's capacity is a crucial factor in determining the efficiency of this technology (Yachnin 2019). This technology must meet environmental goals and reduce any risks to human health (Henry et al. 2013).

Phytoremediation

Phytoremediation is the use of plants and their associated soil and water conditions, rhizospheric microorganisms, and agronomic methods to remediate and sequester organic and inorganic contaminants in soil and water without harming the environment (Mojiri et al. 2021). The main requirements for plants that are suitable for phytoremediation include having deep roots, fast-growing, high biomass, easily harvested on above-ground portion and have the capability to sequester large amounts of metals in above-ground biomass (DalCorso et al. 2019; Yang et al. 2019). Some of the advantages of phytoremediation are the ability to perform in minimal environmental disruption, applicable to a wide range of pollutants, including several metals with limited different options and radionuclides (DalCorso et al. 2019). It also can degrade the organic contaminants to oxygen and carbon dioxide and remove environmental toxicity (Bansal et al. 2018). In addition, it does not use heavy devices or vehicles to

operate, which can prevent the soil from damage so that soil can remain at the site after pollutants are eliminated (Batool & Saleh 2020).

However, there are several limitations of phytoremediation. For instance, it requires a long period for remediation, the treatment is limited to soils at one meter from the ground surface, and groundwater within a few meters of the ground surface, and the growth rate of the utilised plants may be affected by climate conditions and hydrology (Pandey et al. 2021). Even though plants can remove the pollutants, they still can enter the food chain through animals that eat the polluted or contaminated plants (Mishra et al. 2019).

Phytoremediation should be acknowledged as a tool in planting selection and design which focuses on on-site recovery and remediation (Pandey et al. 2021). Nowadays, the concept of sustainability is emphasised in landscape development. Thus, phytoremediation can fulfill a sustainable landscape ecological approach by improving the ecosystem through soil and water, mitigating environmental problems (Pandey et al. 2021).

Aquatic Plants as Phytoremediation Agent

Aquatic plants are defined as any plant that grows partly or wholly in water, whether rooted in the mud or floating without anchorage, which is growing in or closely associated with an aquatic environment (Hauwa M. Mustafa & Hayder 2021). Aquatic plants have prominent taxonomic, morphological, and ecological diversity, which have unique growth systems and pervasive existence wherever wetland habitats are extant. The plants are divided into algae, floating, emerged and submerged (Chrismadha 2020). There are several benefits of aquatic plants. Indigenous aquatic plant species can provide wildlife habitat, including water quality protection and shoreline stabilisation (Cheng and Zhang 2020). Algae are primitive plants divided into microalgae and macroalgae. Microalgae are defined as small microscopic aquatic photosynthetic plants, also known as planktonic algae such as *Spirulina* sp., *Chlorella* sp., *Dunaliella* sp., *Haematococcus* sp., *Schizochytrium* sp., *Aphanizomerion flos-aquae, Botryococcus braunii* and *Nannochloropsis* sp. (Vidyashankar & Ravishankar 2016).

Macroalgae were defined as large aquatic photosynthetic plants that can be seen without a microscope. Macroalgae have many colours, such as green, red, brown and blue, and in various forms, growing tall and growing as mats (Lesiv, Polishchuk, and Antonyak 2020). The commonly known types can be divided into three groups by colour which are Green (Chlorophyta), Red (Rhodophyta), and Brown-Kelps (Phaeophyta) (Lee & Ryu 2021).

Submerged plants such as pondweed (*Potamogeton Crispus*) and hornwort (*Ceratophyllum demersum, C. submersum*) are rooted aquatic plants with most of their vegetative crowd below the water surface, even though some segments will attach above the water. One of the features of submerged plants is their soft stems which prevent them from rising above the water surface, and they used leaves to accumulate metals from water and sediments such as Fe, Cu, Zn, Cr, Ni, Pb and Hg (Ali et al. 2020).

Emergent plants are rooted aquatic plants habitually along the water's edge or riverbank that stand above the water's surface with firm stem, for example, cattails (*Typha latifolia*) and common reed (*Phragmites australis*). They have the ability to accumulate metals such as Cu, Fe, Cd, Pb, Zn and Ni by using leaves and tolerate most heavy metal loads in the roots (Ali et al. 2020).

Floating plants are aquatic plants not attached to the bottom with the roots hanging and submerged in the water. There are various sizes of floating plants from very small to over a foot in diameter, for example, water lily (*Nymphaea odorata*), duckweeds (*Lemna minor*), water hyacinth (*Eichhornia crassipes*), water ferns (*Salvinia minima*), and water lettuce (*Pistia stratoites*) (Ali et al. 2020). They have the potential to accumulate As, Cr, Ni, Mn, Fe, Zn, and Cd in two conditions since they do not attach to the ground. During active transportation, heavy metals arise from roots and are transferred to the plant body, whereas during passive transport, heavy metals are accumulated mainly by the upper body (Ali et al. 2020). As a whole, passive treatment systems, such as floating aquatic plant systems, are ideal for treating wastewater (Abbas et al. 2019).

The ecological approach to remediate contaminated or polluted water and soil by removing heavy metals and radionuclides from polluted water and soil proved successful by using aquatic plants (Daud et al. 2018; Bansal, Shinde, and Sarkar 2018). The aerial organ of plants' roots plays a vital role in absorbing and concentrating the contaminants and then precipitating them as carbonated and phosphates (Liu et al. 2018).

Factors of Heavy Metal Accumulation by Aquatic Plants

Numerous studies discovered that aquatic plant species could sequester or accumulate heavy metals as nutrients from the rhizosphere through their root system before being stored in plant tissues to be used (Annapurna et al. 2016; Leblebici et al. 2019).

The root can also precipitate the pollutants from contaminated effluents through the rhizofiltration process since the different elemental compositions in plants with soil composition make their growth taken for granted (Annapurna et al. 2016; Leblebici et al. 2019; DalCorso et al. 2019). This character was credited to the ability of plants to absorb necessary macronutrients and micronutrients from soil or water and fix carbon from the air. Some characteristics of an excellent phytoremediator are high tolerance to the concentration of heavy metal accumulated, high biomass and rapid growth, have root systems that are highly widespread, easy to be harvested and usually non-consumable by humans and animals (DalCorso et al. 2019; Favas et al. 2016). However, not all characteristics were fulfilled by plants as some rare plant species have a high capability to accumulate heavy metals with slow growth and are small (Bhat et al. 2019).

Next, heavy metals characters were among the factors that affected the bioavailability of the metals. There are three groups of heavy metal availability which are in high (As, Se, Cd, Cu, Ni, Zn,); moderate (Mn, Fe, Co,) and low (Pb, U, Cr) (Yunus et al. 2020; Mishra et al. 2019). The availability of metals for plant uptake is influenced by metal oxidation as it regulates their solubility (Bhat et al. 2019). Generally, metals contain two or more oxidation states in an environment which makes them less available for uptake as most of the metals in the oxidised form are less soluble (Mishra et al. 2019; Vardhan et al. 2019). Besides, metals are also classified into two groups which were essential heavy metals that are also known as trace elements (Fe, Cu, Mn, Zn, Ni), and non-essential heavy metals (Cd, Cr, As, Hg, Pb) (Dibofori-Orji et al. 2019). These non-essential elements do not typically contribute to plants' growth and development, whereas plants require trace elements for physiology and biochemical roles (Dibofori-Orji et al. 2019). So, the existence of trace elements might help plant growth and successively enhance the plant's bioavailability to uptake the metals from the contaminated site (Bhat et al. 2019; Dibofori-Orji et al. 2019). Plants can also develop a group of cytoplasmic mechanisms that can regulate and respond to the toxicity of both essential and non-essential heavy metals.

DalCorso et al. (2019) have listed the factors affecting heavy metals accumulation, which are pH and toxicology interactions. The uptake of metals cation by plant root was also significant for substantial pH changes in the rhizosphere as the pH changes were influenced by the inequality between absorption of cations and anions. The respiration of the rhizosphere contributes to the generation of carbon dioxide and the emission of organic acids and other chemical components from roots (DalCorso et al. 2019). However, the different chemical properties of heavy metals may influence

the pH, metals mobility, and plants sequestration rate. The next one is the toxicology interactions. This interaction has four effects: additive effect, potentiation, antagonism, and synergism (Shahbazi et al. 2021; Bhattacharya et al. 2020). The additive effect occurs when two or more chemicals have been combined and produced an impact equal to the amount of each agent given alone. They do not interact or affect each other directly due to the hybrid metal (Shahbazi et al. 2021; Bhattacharya et al. 2020).

The biogeochemistry of metals was different based on diverse environmental conditions. Temperature, pH, and salinity, are the ecological factors affecting the plants' uptake effectiveness (DalCorso et al. 2019; Pleto et al. 2018). Temperature is a crucial aspect of living things' physiological processes, such as plant development or other purposes concerning energy metabolism. At the same time, the declination of salinity contributed to the increased plants' capability to accumulate some metal ions (Pleto et al. 2018). Thus, metals concentration in plant tissues may increase when temperature rises and higher temperature with lower salinity may contribute to increased metals accumulation.

ECOLOGICAL BENEFITS OF PHYTOREMEDIATION

Over the past few years, the aquatic plant culture systems have been used for wastewater treatment due to their efficiency in solving environmental pollution and contributing towards economic benefits (Ali et al. 2020; Daud et al. 2018; Handajani et al. 2018). Besides lower operational costs than conventional technologies, this technology can produce other beneficial by-products (Hauptvogl et al. 2020). For example, for agricultural purposes, the by-products of this approach can be utilised as nitrogen and phosphorus supplements (Nizam et al. 2020; Trang et al. 2018). Besides that, through photosynthesis, the large number of contaminants absorbed can be turned into biomass. Subsequently, the biomass can be converted into useful material such as compost and animal feed (Ali et al. 2020; DalCorso et al. 2019). Regarding landscape ecology, plants used as phytoremediators can enhance the visual aesthetics of the underwater garden, create new habitat, improve the soil structure, and consequently provide ecology restoration and revitalisation (Astorino et al. 2020).

Their exceptional capability is to sustain the environment, especially as a regulator for the level of hazardous compounds and to remove or at least expressively help reduce pollution (Christian Ebere et al. 2019). The ecological benefits and potential of plants as remediators and protectors of the environment include the concurrently interacting with three different environments by using roots to contact with soil and water and leaves to get with air; interaction between soil, plants and microbial (Kumar and Verma 2018).

These characters give advantages to plants and determine their capability to accumulate most contaminants from the air, soil and water (Kumar & Verma 2018). However, a significant limitation of these green technologies is that they strongly rely on the climate as an essential feature for growth, development, and survival (Gunarathne et al. 2021). One of the approaches is focusing on several growing seasons, which may help obtain the effective age of the plants for optimum utilisation in green technology, such as in phytoremediation.

ISLAMIC PERSPECTIVE ON ENVIRONMENTAL MANAGEMENT

Humans require nature or environs to continue their daily lives since this biosphere provides all necessities for development, growth, and survival in living places, variety and quality of life, and economic resources (Ashtankar 2016). According to the Quran, Allah created the universe with perfect wisdom (hikmah) for essential purposes that serve as a sign for those who believe (Sad 38: 27):

And We did not create the heaven and the earth and that between them aimlessly. That is the assumption of those who disbelieve, so woe to those who disbelieve from the Fire.

and (Al-Anbiya' 21:16),

And We did not create the heaven and earth and that between them in play.

However, the overuse and the neglect of environmental welfare has resulted in this biosphere being stressed, and environmental issues such as air, water and soil contamination, ecosystem loss, reduction of natural sources and others have occurred (Ashtankar 2016). The deterioration of the ecosystem is the result of people's unrestrained greed. Allah says in Quran (ar-Rum 30: 41):

Corruption has appeared throughout the land and sea by [reason of] what the hands of people have earned so He [i.e., Allah] may let them taste part of [the consequence of] what they have done that perhaps they will return [to righteousness].

As *khalifah*, human has been trusted with the responsibility to manage this earth. They have been endowed with an *'aql* to determine whether to take care of, preserve, and maintain or destroy the animals, plants, and whole environment (Mikdar et al. 2017). Allah has mentioned in Quranic (al-A'raf 7:56):

And cause not corruption upon the earth after its reformation. And invoke Him in fear and aspiration. Indeed, the mercy of Allah is near to the doers of good.

Moreover, Allah has sent guidance through the Prophets as the best *khalifah* on earth for humans to follow his good deeds and avoid wrongdoings. On the authority of Abu Sa'eed al-Khudree (may Allah be pleased with him), that the Messenger of Allah (peace and blessings of Allah be upon him) said (Forty Hadith of an-Nawawi: Hadith 32):

There should be neither harming (darar) nor reciprocating harm (dirar).

According to Zabariah Matali (2011) and Rashidi Othman et al. (2016), the following are some of the sustainability principles that have been highlighted in the Quran and Sunnah:

1. Trusteeship (amanah): The concept of stewardship or vicegerency is closely linked to the responsibility of conserving and managing the earth wisely (khilafah). Hence, knowledge, wisdom ('aql), and skill should be applied while making the best option to handle environmental challenges.
2. Environmental degradation induced by anthropogenic activity could be termed injustice (zalim) because it is a type of action that causes harm to the natural environment for the sake of profit and economic benefit. To fulfil Allah's creatures' rights (huquq al- ibad), sustainable wastewater management, such as phytoremediation, should be appropriately practised.
3. Balance (mizan): Everything created by Allah was made in harmony with significant purposes. Humankind is taught not to disturb this balance. Not only socially and economically, but also environmentally, Islam urges us to be fair and balanced. The use of plants as a phytoremediation agent for wastewater treatment is a good example. To minimize pollution of receiving water and avoid the discharge of toxic substances that would degrade water quality and harm subsequent users, this practise would also provide economic benefits (e.g., by-product production and low-cost maintenance, health and safety). As a result, this cycle as a whole can meet the Islamic notion of environmental planning, which is to maximise overall benefits (masalih) while reducing total expenditures (mafasid).
4. Middleness or the best (wasat): As previously said, phytoremediation is a more effective strategy than traditional approaches since excessive use of energy, money, and other resources may be avoided, resulting in less waste and overspending (israf). As a result, as vicegerents, we must be cautious and adhere to the highest standards when it comes to wastewater management.
5. Spiritual and physical cleanliness (taharah): Muslims have a great connection with the concept of purification. Polluting and wasting water is seen as disrespectful to the environment and other living beings, who have the right to live a healthy life. As a result, phytoremediation strategies for wastewater treatment are highly

recommended because they are a natural water purification process that has no harmful effects on humans, animals, or plants.

6. Knowledge and science practicality ('ilm nafi'): Henceforth, phytoremediation is a part of scientific and technological advancement that can contribute to the betterment of communities and future generations.

More effective and practical methods should be considered to achieve the notion of balance, which is to ensure the equilibrium of the environment while managing its resources. As a result, selecting an effective solution in planning and developing the alternatives is critical. It is because natural resources should be used for economic advantage in a fair and just manner. Any environmental issues that arise due to human activities indicate that people are failed to fulfil their responsibilities and trust.

CONCLUSION

Aquatic plants' ability to act as phytoremediation agents can be explored further, and the results of certain prospective aquatic plants can be used to assist wastewater treatment technologies for future environmental protection initiatives. The research on wastewater treatment using the phytoremediation approach is critical to provide significant support to the related industry and field to strike a balance between environmental preservation and the development of sectors that contribute significantly to sustainable economic growth. Poor wastewater management, on the other hand, has harmed environmental quality. Although numerous options have been proposed to address this issue, they are deemed inefficient in terms of energy, cost and maintenance. Therefore, a thorough investigation of the efficacy of this technology could contribute to long-term wastewater management in terms of ecological, economic and social benefits.

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