

## Review Article

# Phytoaccumulation of Nitrate Loads from Drinking Water by Using Different Aromatic Grasses: Green Technology

## ABSTRACT

The rapid increase in population needs a vast amount of food energy to survive. This review paper reveals the potential of aromatic grasses to remove nitrate loads from different sources of contaminated water. A sustainable development approach for growing food energy needed pure water for irrigation and drinking purposes. These days, farmers are using chemical fertilisers to increase the quantity of food energy without knowing its harmful effect: our challenge is to be aware of them with green technology and teach them how to use it sustainably. Currently, many countries are experimenting with the green approach with the help of plants; they are trying to eliminate harmful elements from contaminated water. This method of removing pollutants by plants use is known as phytoremediation. So, many countries are using it to accumulate and extract toxic substances like heavy metals and higher nutrients load from water with the help of this approach. These aromatic grasses have identified most photo-stabiliser, hyper-accumulator, and hyper-extractor of the toxic substance and nutrient loads at contaminated sites without harming or negatively impacting these toxics to other parts of the plant. Aromatic grasses cost-effectively have higher economic value. Many studies observe that toxicity enhances the essential oil quality of these grasses and increases the, which results in higher quality and quantity of oil. Thus, grasses are very suitable for removing nitrate from different contaminated water sites and ideal sustainable development options.

*Keywords:* Aromatic grasses, Contaminated, Environment, Phyto-Remediation, Sustainable, Wastewater.

## 1,INTRODUCTION

Pure water scarcity is a significant problem to national and international constancy, natural health, food supply, and even becoming a water war in the upcoming future for the universe level. The population of India is the second-highest in all over the world. Rapid population increases required a higher amount of agricultural land to fulfil the need for food energy. Indian farmers are under heavy pressure to grow a massive quantity of yield; for this, they use a higher amount of chemical fertiliser and pesticide (shown in figure1) to increase the yield, making harvest easy to equaling the need for food energy.

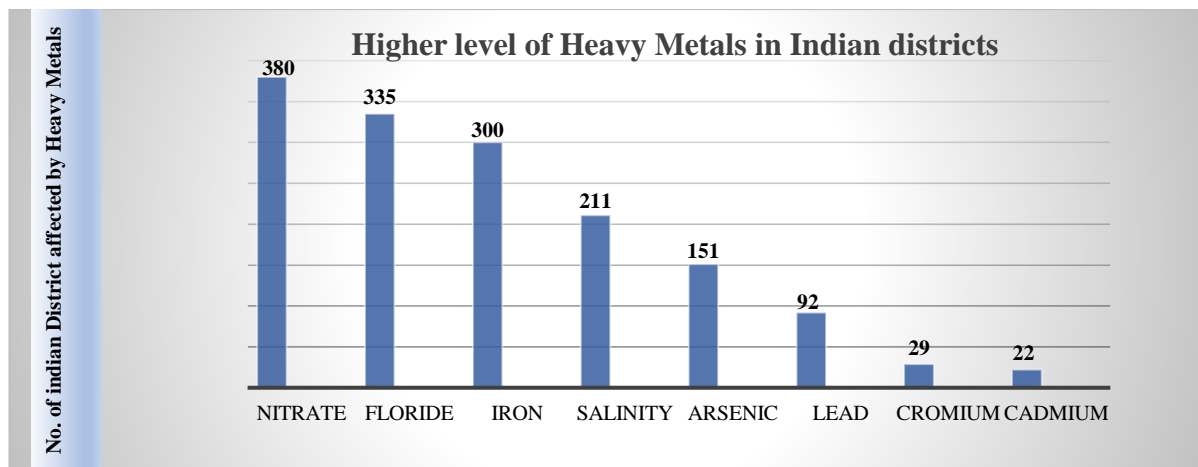
However, using these chemicals for an extended period resulted in declining water sources (like a river, lake, surface water, and groundwater) quality and increasing the level of nitrogen and phosphorous in water bodies of the Indian district. Researchers revealed that more than 50 per cent of Indian districts exceed the permissible level of nitrogen in water Times of India [1]. More than 350 districts of the Indian



**Figure 1** Excess amount of chemical fertilizers used in agriculture fields

**Source:** [1]

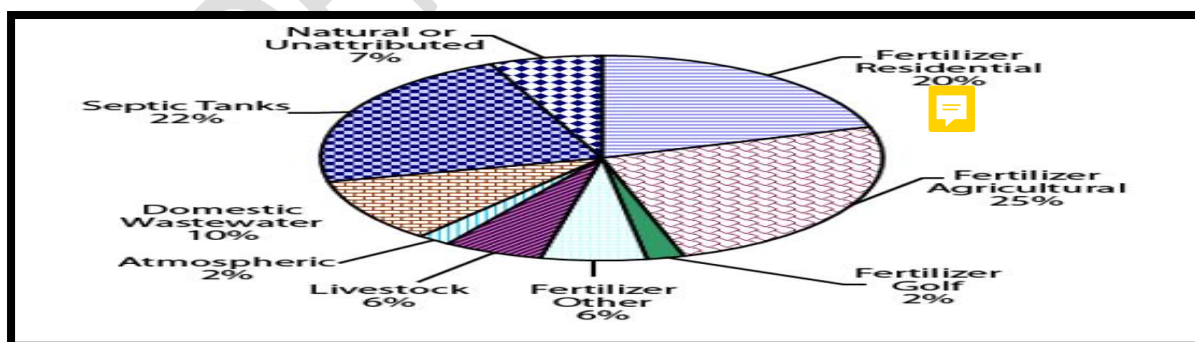
community were affected by nitrate pollution in drinking water followed by fluoride, Iron, Salinity, Arsenic Lead, Cr, and Cd, data given in figure 2.



**Figure 2** Sophisticated load of nitrate and other polluted found in different districts of India.

**Source:** Times of India

The natural composition of water, like groundwater and surface water, has become degraded by anthropogenic activities. Because of the rapid growth of urbanization, industrialization, and overpopulation, the generation rate of municipal, industrial, and sewage wastewater is very high. Due to India's lack of treatment facilities, social workers were forced to shed this untreated wastewater to direct discharge into an aquifer. This untreated wastewater is a leading cause of water pollution and becomes a significant source of organic and inorganic pollutants. The process by which this contaminated water reaches into the groundwater and surface water may be by drainage, leaching, leakage, and agriculture runoff during monsoon, affecting water quality and increasing nitrate and phosphorus loads in water. Approximately more than 23% nitrogenous compound discharge from agriculture runoff this data was (shown in figure 3). Compared to other causes of nitrate pollution, farmers and self-owner employees use nitrate-bearing chemical fertilizer for their fields; they apply various pesticides, fungicides, and herbicides that may migrate and reach groundwater. Nitrogenous compounds are highly soluble and mobile in water; by this nature, nitrate and nitrites are found most common pollutants of groundwater in the rural and suburban areas of Indian communities.



**Figure 3** Significant sources of nitrogen generation from different areas.

Unpolluted water for drinking is the primary requirement for every human being. Surface water is blue water present on the top of the earth surface, such as rivers, lakes and wetlands. The water precipitation and evaporation process is the primary producer of surface water by this water cycle moving into the ground, becoming groundwater. In India rural population largely depends upon groundwater sources for drinking. However, these days' groundwater resources are not fit for safe drinking purposes. All of these have been highly contaminated by nitrate, fluoride, iron, manganese, salinity and other toxic metals. If all existing sources in the village have such problems, the selected water sources need suitable treatment,

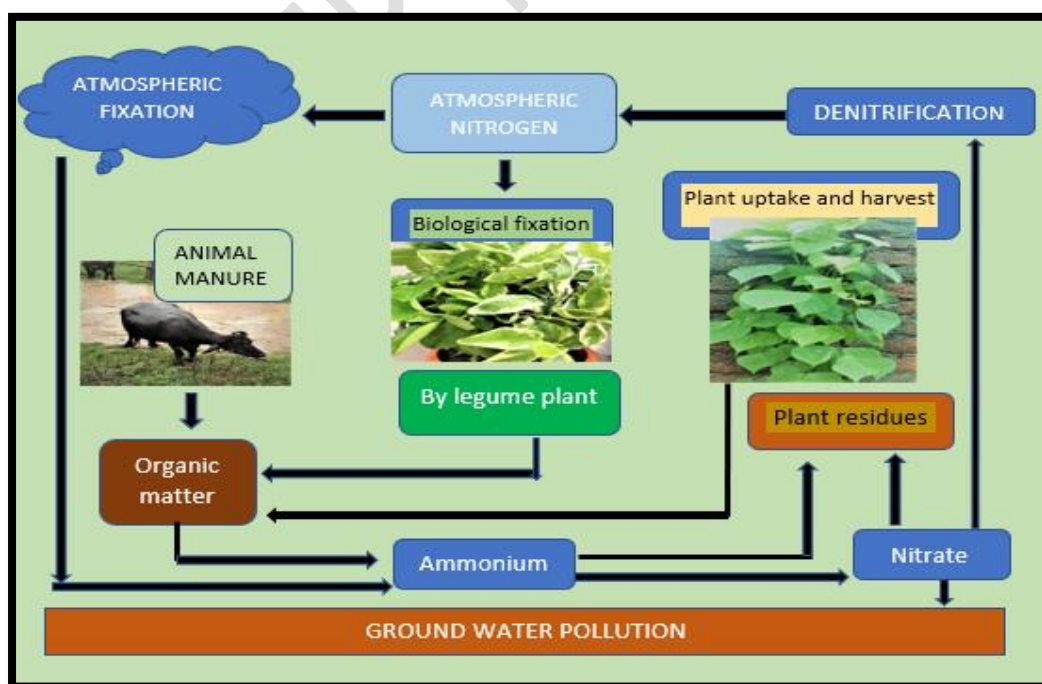
depending upon the nature of problem parameters. Not only rural area but the urban area also depends on groundwater for irrigation and drinking purpose. Indian urbanization is growing fast, approximately more than 33.40 % from 2010 to 2020 [2].

Due to which they generate a higher amount of wastewater, the urban society of India produced point and nonpoint sources, mainly contaminated groundwater and nonpoint sources from different areas [3] with lack of water and sanitation system contamination become much higher. The physiological importance of trace elements in agriculture is well known. Some stuff like B, Fe, Cu, and Mn are considered essential micronutrients. Still, if the concentration level of these micro and micronutrients increased, it shows the opposite effect on water, soil, and air. The groundwater quality was maintained by different ions such as carbonate, bicarbonate, chloride, sulphate, nitrate, phosphate, and fluoride. These ions are present in the form of the anion. Both cations and anions are responsible for maintaining the quality of water.

Nitrate ( $\text{NO}_3$ ) is made of nitrogen and oxygen, a naturally occurring chemical compound. It is highly soluble in water and naturally found in nitrate salt on earth at large deposits known as sodium nitrate. It may be fixed from the atmosphere by nitrifying bacteria in nitrites more than 78% nitrogen reserved in the atmosphere. Nitrate nitrogen is of prime importance for plants, and it is naturally found in soil and water (shown in figure 5). The most important source of nitrate-nitrogen is the fertilizer and manure used in the nearby fields, along with the dead animals and plants decomposing therein. Many nitrogen-bearing compounds, like ammonium, ammonia, nitrite, and nitrate, are commonly present in consumption water and also found these compounds in various agricultural, domestic, and industrial wastewaters [4, 5]. These pollutants, which were directly discharged into water bodies, increased loads of macronutrients in surface water which trends to a higher amount of nitrogen and phosphorus, are the main factor causing eutrophication in aquatic bodies.



Figure 4 Grasses have the potential to accumulate various adverse environmental effects.



**Figure 5** Nitrogen cycle—a gaseous cycle with the major reserve in the atmosphere (N<sub>2</sub>: 78%).

**Source:** Independent (self-created)

Researchers observed a large amount of nutrient discharge in water bodies by nonpoint sources, such as agriculture activities responsible for eutrophication which affects aquatic life [6].

This is a challenging situation for surface water quality because excess nutrients **discharge** in water is a food source for microorganisms and algae. A higher population of algae will create a problem where sunlight is unable to enter **into** the water, which disturbs the balance of dissolved oxygen devastatingly. At the same time, an aquatic organism will die off. This condition increases the volume of decaying organic material and increases the population of microorganisms and bacteria; these organisms will consume more oxygen, leading to the decline of the total amount of dissolved oxygen in the water. This condition **lowest** the level of oxygen, this state of water is called eutrophication; at this level, many aquatic insects and fish are unable to survive [7].

Nitrogen is essential for all living things in lower concentrations, but high nitrate-nitrogen levels in water are not suitable **for** potable. Nitrate is **the** life-threatening compound of nitrogen found in water and soil. Nitrates are inorganic **compound** whose flexibility and constancy make them highly hazardous in aerobic systems **as** underground water. Nitrate levels up to 3 parts per million (ppm) are found naturally in healthy water **indicate** a lower risk of water contamination. Still, a water test with a high nitrate concentration is not recommended for families with newborns, expecting women, nursing **moms**, or older people because these groups are the most vulnerable to nitrate. **Nitrate polluted** water supplies have also been connected with outbreaks of infectious diseases [8].

Different health monitoring authorities like WHO, EPA agency, **ICMR** set the safe limit **of** nitrate consumption in drinking water; it is also called a permissible limit. Thus, the researchers can check water quality and decrease adverse effects on health [9]. According to water quality standards set by World Health Organization (WHO) [9], the guideline value for nitrate is ten ppm. The Indian Council of Medical Research (ICMR) [10] has suggested the highest desirable level of 20 ppm of nitrate in drinking water. The maximum permissible level recommended is 50 ppm data given in Table 1. High nitrate may cause methemoglobinemia, gastric cancer, thyroid disorder, miscarriages, congenital disabilities, and the development of some cancers in adults. Methemoglobinemia or blue baby syndromes was **found** predominant compared to other **problem** in all age **group** in many districts of India. Due to higher consumption of nitrate in the body, which **oxidize** the iron in haemoglobin (**act** as a carrier of oxygen in the blood) from ferrous iron (2+) to ferric iron (3+). this oxidation of iron reduces the transportation capacity of oxygen in the blood. This process decreases the oxygen level in the blood and causes severe respiratory tract infections-infants of six months old or younger mainly come at higher risk **with** this disease. The sequential condition is methemoglobinemia or "blue baby syndrome" [8, 11-12].

**Table 1** The acceptable limit of nitrate in potable water given by different authorities.

Organization	Conc.* as NO <sub>3</sub> -N (mg/l)	Conc.* NO <sub>3</sub> (mg/l)	Source
WHO <sup>a</sup>	10	45	Latest guideline (1987)
US Environmental Protection <sup>b</sup>	10	45	Max. Conc. Level
ICMR (India) <sup>c</sup>	20	50	IS:10500 (1983)

**Notes:** <sup>a</sup>WHO -World health organization, <sup>b</sup>US-United states, <sup>c</sup>ICMR- Indian Council of Medical Research, Conc.\* - concentration **Source:** [13]

Many countries are making efforts to reduce nitrate removal from water and wastewater. The task of environmentalists, engineers, and scientists is to develop effective and simple ways to treat contaminated groundwater and surface water; different accessible to all methods are trying to reduce the level of nitrate from dirty water and soil. Adsorption is a widespread removal process from contaminated water; it is an ascent process of gathering soluble substances present in the solution using different tricks and techniques. Many data showed that adsorption methods are not up till now used in wastewater decontamination. Still, demands for an improved superior method for treating wastewater runoff have led to an intensive examination and use of the procedure of adsorption by activated carbon. Activated carbon is a very luxurious adsorbent material to remove impurities, so other adsorbents must be investigated [14, 15]. **Pomegranate** extracts have started an improved range of applications in the arena of pollution

control, based on their extraordinary selectivity in adsorption, but it required massive amounts of contaminated areas, which are tough to manage. Many other biological and chemical processes are there, such as natural treatment by using denitrifying bacteria, in this reaction oxidation process takes place and nitrate convert into nitrogen gas, chemical methods have a list of forms of removal of nitrate from water by reverse osmosis, distillation, electro dialysis, catalytic denitrification ion exchange process and so on. These removal technics are very expensive and required higher energy, chemicals, equipment's, human power etc., to show the results in a reduction in nitrate concentration. Therefore, we have to think and develop some cost-effective and easy to use for everyone methods out of these. Nowadays, phytoremediation as green technology is one of the primaries of ecologically friendly technologies scientists practice in their research.

## 2. Phytoremediation

"Phyto" means "plant", and "remediation" means "restoration" or "removal of contamination with the help of plant". In this process, no chemicals, no machine power are used for the removal of pollutants, but only suitable plants spices are used directly to clean up contaminated water, soil and air; phytoremediation is a new, easy, simple, affordable, fascinating pleasing and cheap suitable solution for many surroundings problems. Landmeyer [16] define "phytoremediation is the application of plant in a controlled environment and their interactions with contaminated groundwater, organic and inorganic substances to achieve site definite remedial areas". Plants can reduce, absorb, extract, volatile, and translocate certain toxic substances and heavy loads of nutrients in their root, leaves, and shoots in less harmful forms in various parts [17]. Across the world, there are many countries like China, Vietnam, Australia, and other parts of the world using green technology (phytoremediation) to clean contaminated water and land [18].

The environmental condition is stable at the time of using phytoremediation methods because in this actual condition is not affected, and in natural conditions, all the processes sustainably take place. When growing in contaminated sites, most plants convert their morphology, physiology, and anatomy according to the environment to stay alive; this mechanism of a plant is called a defence mechanism and dilution phenomenon [19]. They can convert complex toxic compounds into more minor or simple compounds that lead to challenging situations explaining why different plants can grow in different environments. Remediation through plants is one of the fundamental approaches compared to various other methods of removing pollutants from soil and water; it cannot show any harm to the composition of the soil, and with time it enhances the superiority and fertility of the soil. In this methods removal of pollutants depend on selection and identification of suitable crop. The study was done by [20] that more than twenty plant species suggested that the nitrogen and phosphorous subtraction capacity depends on species selection.

### 2.1 Selection of crop required these points

- It cannot be used as a food crop.
- It should be surviving in adverse conditions.
- High production in biomass and removal efficiency will be increased.
- The bioaccumulation and adsorption value are high for that plant.

Many types of grass can accumulate and extract organic and inorganic pollutants from contaminated water and land. For example, according to many studies, grass blades effectively remove a higher amount of nitrogen and phosphorus from dirty water and land [21].

## 3. Using Aromatic plants in the race of phytoremediation

Aromatic plants have a unique aroma and flavors; many of them are used as medicinal crops. These crops are not eatables crops, but numerous plant species are cultured for their additional characters of aroma and flavors. As this plant is not straight to the food chain, they are more feasible than food crops for phytoremediation. Moreover, they have high economic value due to their precise production of essential oil used in perfumes, cosmetics, small-scale agarbatti and doorbatti, industries, mosquito liquid, pain balm, and other fragmented products formation. Many aquatic plants and aromatics plants are in this phytoremediation race. Long ago, different aquatic plants are using for the removal of nutrient load from wastewater; they are water lettuce (*Pistia stratiotes*) [22], duckweed (*Lemna spp.*), water hyacinth (*Eichhornia crassipes*), and others [22, 23–24].

But unique space is occupied by aromatic grasses, just a while ago, aromatic plants have been verified for their potential of phytoremediation because it survives in harsh conditions, cannot be a part of the food chain, and potential to stabilise, accumulate, extract, and volatile toxic metals and nutrients loads from polluted sites and produce higher biomass, which enhances the essential oil quantity and quality—

aromatic grasses day by day increasing attention in the removal of nitrogen and phosphorous (shown in the table. 2) from contaminated water and soil [25, 26].

**Table 2** Potential of aromatic grasses for removal of nitrate and other pollutants from the different contaminated sources of water

Aromatic Grasses	Source of Pollutant	Nitrate Removal Efficacy	Other Pollutants	Economic benefit, extraction % of essential oil	Source
Lemongrass	from contaminated water and soil	reduce nitrogen and phosphorus	accumulate Cr <sup>+6</sup> and As <sup>+3</sup>	0.36 to 1% on fresh weight	[30]
Citronella grass	from contaminated water and soil	reduce nitrogen and phosphorus	multi-metals removal	0.4 to 1.1% on fresh weight	[32]
Palmarosa grass	from contaminated water and sewage sludge soil	reduce nitrogen and phosphorus	toxic elements, Ni, Pt Cd and Cr, are absorbed in the upper and lower parts of a crop	0.7- 1.1 % on fresh weight	[31]
	water contaminated by organic pollutants	reduce 27.5 mg/l 9.8 mg/l	BOD, phosphorus, TSS,	to 1.50 % on dry weight	[27]
	water contaminated by sewage effluents	reduce N 40-70% and other pollutants	multi metals removal		[6]
Vetiver grass	wastewater from a pig farm	reduce N 93.50%			[29]
	contaminated water by overuse of chemicals	tolerate N load up to 5500 kg nitrogen ha <sup>-1</sup> year <sup>-1</sup>			[36]
	contaminated water and soil by industrial effluents	reduce N up to 93.90%			[34]

There are many species of aromatic grasses with high potential of biomass grown in adverse environmental conditions; more than 50 species are found of lemongrass (*Cymbopogon Flexuosus*); it has a quality to survive with toxic stress conditions if this cultivates for a lengthier period. A study investigated by [27] revealed that lemongrass herb stays healthy if irrigated with wastewater and produce higher essential oil yield.

The experiment done by [28] studied that *Cymbopogon Citratus* stem can adsorb Pb<sup>+2</sup> ions from contaminated waters. Thus, it will be used as an effective adsorbent for wastewater containing a higher concentration of Pb ions. Another experiment reveals lemongrass's capacity to eliminate higher toxic elements from industrial effluents [29]. Studied completed by [30] *Cymbopogon Flexuosus* can accumulate Cr<sup>+6</sup> and As<sup>+3</sup> in satisfying amounts. Therefore, studies concluded that lemongrass could be used as a good crop for cultivating in polluted sites shown in Table 2.

Palmarosa (*Cymbopogon Martinii*), studied completed by [31], reveal the potential of Palmarosa for phytostabilisation in the removal of toxic substances from tannery sludge amended soil shown in Table 2.

Citronella (*Cymbopogon Winterianus*); these grasses are using in higher contaminated areas for photo stabiliser of heavy metals such as Cd and Cr from polluted water. Studies were done by [32] disclose the removal ability of Cadmium by Citronella, and [33] also studied the removal capacity of chromium by *Cymbopogon Winterianus*. More experiments have to be done in the future to examine the absorption and uptake capacity of citronella and palmarosa grasses.

Among all grasses, Vetiver grass (*Chrysopogon Zizanioides* L.) has been observed more suitable for the removal of nitrogen from wastewater. Australia and China, after the nineties, started the application of vetiver grass for the disposal of contaminated wastewater. Vetiver was used to absorb effluent and leachate from toxic landfills by different pollutants in Australia [34]; also, China effectively purified polluted river water using vetiver [35, 36]. Experiments have also revealed that vetiver shows higher potential for absorption of nutrients such as nitrogen (N) and phosphorus (P) in polluted water bodies [37]. After using vetiver in dirty river water, they show more than 70 per cent removal of nitrogen in 35 days and 98 per cent removal of phosphorous in 30 days observed by [35, 36].

The remarkable result shown in the hydroponic system by using vetiver with sewage effluent removes more than 90 per cent of N and P and reduces algal growth and faecal coliform [38]. Many studies are focusing on the reduction of nutrient using vetiver grass has been achieved higher growth in respect to the efficiency of the refurbishment of waste generated from sewage, industrial wastewater [39] iron ore mine soil [40], municipal solid waste leachate [41]. Scientists [39] experimented that vetiver grass reduces all pollutants by (62-100%) and mainly nitrogen was recorded less from 27.5 mg/l to 9.8 mg/l, from sewage effluent. More evidence observed that 40-70% of total nitrogen was removed within 2 to 4 days [6] using vetiver grass in contaminated water. Various studies explore the potential of vetiver grass for a suitable candidate to remove higher loads of nutrients from contaminated drinking water.

#### 4. Benefit of aromatic grasses

The farming of uneatable aroma plants always is suggested for cultivation in polluted areas because they are beneficial, feasible, easy to grow and workable crops. The advantage of using aromatic plants for phytoremediation resolve can be considered under three main titles a health benefit, environmental view and economic view.

##### 4.1 Health benefit

Aromatic plants have a significant health benefit if these crops are used in the phytoremediation process as a green technology. They decrease the health issues generated by a higher concentration of nitrogen, phosphorus, and toxic metals present in contaminated water and soil. These plants do not come in the food chain that is the most beneficial quality of these plants. Untreated wastewater direct discharged into water bodies, and this toxic water leached out and reduced the rate of surface and groundwater, which humans consumed and other living organisms and causes many diseases like methemoglobinemia, blue baby syndromes mainly cause by excess nitrate in drinking water and also increased the risk of gastric cancer, heart, kidney, lungs problems, congenital disabilities, and many others. Many studies confirmed that vetiver grass decreased the concentration of heavy metals and nitrogen, such as Cu by [42] Cr, [43] Pb, Zn, Cd [44], and nitrate up to 93.90% [45] from contaminated water. Therefore, if we use these plants in the contaminated area or discharge them into water bodies, they should be treated with these grasses. It will sustainably reduce health risks.

##### 4.2 Environmental View

The aromatic plant is very effective in the environmental aspect because it can survive in adverse or harsh environmental conditions without harming soil, water, air, and other parts of plants. Toxic metal and higher nutrient concentrations can't affect essential oil quality and increase their biomass when cultivated in contaminated water or soil. Many studies revealed that vetiver and lemongrass could tolerate toxic environmental conditions, reduce soil erosion, pest control, and termite control, increase water quality and air quality, and enhance soil fertility [46]. Vetiver was most effective in tolerating a higher load of nitrogen. It shows the positive impact at the high level of nitrogen supply equal to 5500 kg Nitrogen ha<sup>-1</sup> year<sup>-1</sup>, without showing any adverse effect on crop development and quality of essential oil more than 9000 kg Nitrogen ha<sup>-1</sup> year<sup>-1</sup>. These qualities make vetiver highly appropriate candidates for treating contaminated water and other wastewater highly polluted by nitrogen [37]. The morphology and physiology feature of vetiver and lemongrass is unique. They have a long and thick root with a higher penetration system, rigid and inflexible stem, high tolerance range of toxic water and soil, and survive best in adverse conditions [47]. It proved that it is one of the easy, cost-effective, and straightforward methods of many surrounded ecological problems [48].

##### 4.3 Economic View

Aromatic plants produce an essential oil that contains aroma and flavour; its demand is very high worldwide, expected to reach up to the US \$4 trillion in upcoming years [49]. Aromatic plants and grasses can mainly fulfil this demand. Aroma grasses can grow in polluted water and soil without any harm to

essential oil. This feature of grass repairs the environment and **increase** the **economics** of our country [50]. Aroma crops are easy to grow, low maintenance, **needless** fertiliser, survive in any metrological condition, and also farmers are free from farm maintenance by which with insufficient **efforts** they earn more. Moreover, scientists revealed that it is suitable for sustainably treating waste and polluted water.

## 5. Future Aspect

Restoration and reclamation of contaminated sites by aromatic grasses need more research and review to monitor the impact of phytoremediation methods on water, soil, air, and the environment. By using fragrant grasses for recovery of contamination, sites show an increased cost-benefit ratio and decreased risk of going hazardous substances in the food chain. But together with this, **long term** investigation in the field is essential to check the improvement in soil quality along with other risk features. Besides, multifaceted efforts must be taken to judge the impact of these aromatic grasses to recognize the removal and accumulation mechanism of toxic elements and nutrients loads from contaminated sites. These crops have incalculable economic values; they can gain financial profits and other remunerative weight by growing them in polluted areas instead of eatable crops. Using these methods for an extended period enhance the drinking water quality with sustainable technique.

## 6. Conclusions

It is verified that aromatic grasses are an appropriate candidate for use in a contaminated **site** such as sewage, domestic, municipal, and industries wastewater to remove nutrients loads and toxic heavy metals in an enviro-friendly **method** cost-effectively. Aromatic plants have the countless potential for phytoremediation of polluted, infected sites. Using aroma grasses reduces poisonous chemicals, nitrogen, and phosphorus from dirty water, leading to increased quality of wastewater, reducing health impact, cutting a load of direct discharge of untreated waste **in** river bodies, and improving water quality through which it can improve surface and groundwater and many other benefits **soon**.

## References

- [1] <https://timesofindia.indiatimes.com/india/govt-body-finds-high-levels-of-groundwater-contamination-across-india/articleshow/65204273.cms>
- [2] Aaron ON. Urbanization in India 2021; Statista.com.
- [3] Jha R, Singh VP, Vatsa V. Analysis of urban development of Haridwar, India, using entropy approach. *KSCE Journal of Civil Engineering*.2008;12: 281–288.
- [4] Peavy HS, Rowe DR, Tchobanoglous G. *Environmental engineering*, McGraw–hill book company, Vol. 696 New York. 1985.
- [5] Lin SH, Wu CL. 1996 Removal of nitrogenous compounds from aqueous solution by ozonation and ion – exchange. *Water Res.* 1996; 30:1851.
- [6] Kao C, Wang J, Lee H, Wen C. Application of a constructed wetland for nonpoint source pollution control. *Wat. Sci. Tech.* 2001;44(11- 12): 585-590.
- [7] Akbarzadeh A, Jamshidi S, Vakhshouri M. Nutrient uptake rate and removal efficiency of *Vetiveria zizanioides* in contaminated waters. *Pollution Winter* 2015;1(1): 1-8.
- [8] Barber WP, Stuckey DC. Nitrogen removal in a modified anaerobic baffled reactor (ABR). *Water Res.*2000; 34: 4867.
- [9] World Health Organization. Health hazards from nitrates in drinking water Report on a WHO meeting, Copenhagen: WHO; 1985.
- [10] Indian Council of Medical Research Manual of standards of quality for drinking water supplies ICMR, New Delhi;1975.
- [11] Feleke Z, Sakakalibara Y. A bio- electrochemical reactor coupled with adsorber for the removal of nitrate and inhibitory pesticide. *Water Res.* 2002;36: 3092.
- [12] Mena-Dura CJ, Sun Kou MR, Lopez T, Aquilar DH, Dominguez, MI, Odriozola JA, Quintana P 2007 Nitrate removal using natural clays modified by acid thermo activation. *Applied Surface Science*.2007;253: 5762.
- [13] Lunkad SK. Rising levels in groundwater and increasing N-fertilizer consumption (Bhu-Jal News; 1994;4-10.
- [14] Weber WJ. *Physicochemical processes for water quality control* (Wiley, New York). 1972;638.
- [15] Noll KE, Gounari V, Hou WS. 1992 Adsorption technology for air and water pollution control Lewis Publishers Inc. 1992;347.
- [16] Landmeyer JE. Introduction to phytoremediation of contaminated groundwater: Historical foundation, hydrologic control and contaminant remediation Springer. Science and Business Media. 2011.

- [17] Schnoor JL, Licht LA, McCutcheon SC, Wolfe NL, Carreira LH. Phytoremediation of organic and nutrient contaminants. *Environ Sci Technol.*1995; 29(7): 318–323.
- [18] Truong P. Vetiver system technology for prevention and treatment of polluted water and contaminated land (Proceeding of the Second International Vetiver Conference, Thailand).2002; 46-57.
- [19] Akhter A, Inam A. Response of mustard and linseed to thermal power plant wastewater supplemented with nitrogen and phosphorus. *African Journal of Plant Sciences.*2018; 2: 67-71.
- [20] Lamchaturapatr J, Yi SW, Rhee JS. Nutrient removals by 21 aquatic plants for vertical free surface-flow (VFS) constructed wetland. *Ecol. Eng.*2007; 29: 287–293.
- [21] De La MOC, Gonzalez-Acuna IJ, Saucedo TRA, Flores LHG, Rubii-Aruas HO, Ochoa -Rivero J. Removing organic matter and nutrients from big farm wastewater with a constructed bed plant system. *International Journal of Environmental Research and Public Health.*2018;15(5): 1031.
- [22] Lu B, Xu ZS, Li JG, Chai XL. Removal of water nutrients by different aquatic plant species an alternative way to remediate polluted rural rivers. *Ecol. Eng.* 2018;110:18–26.
- [23] Petrucio MM, Esteves FA. Uptake rates of nitrogen and phosphorus in the water by *Eichhornia crassipes* and *Salvinia auriculata*. *Rev. Bras. Biol.* 2000;60: 373–379.
- [24] Valipour A, Raman VK, Ghole VS. Phytoremediation of domestic wastewater using *Eichhornia crassipes*. *J. Environ. Sci. Eng.* 2011;53:183–190.
- [25] Sooknah RD, Wilkie AC. Nutrient removal by floating aquatic macrophytes cultured in anaerobically digested flushed dairy manure wastewater. *Ecol. Eng.* 2004;22: 27–42.
- [26] Moore MT, Locke MA, Kroger R. Using aquatic vegetation to remediate nitrate, ammonium, and soluble reactive phosphorus in simulated runoff. *Chemosphere* 2016;160:149–154.
- [27] Lal K, Yadav RK, Kaur R, Bundela DS, Khan MI, Chaudhary M, Meena RL, Dar SR, Singh G. Productivity, essential oil yield, and heavy metal accumulation in lemon grass (*Cymbopogon flexuosus*) under varied wastewater–groundwater irrigation regimes. *Ind Crops Prod.* 2013;45:270–278.
- [28] Sobh M, Moussawi MA, Rammal W, Hijazi A, Rammal H, Reda M and Hamieh T. Removal of lead (II) ions from waste water by using *Lebanese Cymbopogon citratus* (lemon grass) stem as adsorbent. *Am J Phytomed Clin Ther.* 2014;2(9):1070–1080.
- [29] Hassan E. Comparative study on the biosorption of Pb (II), Cd (II) and Zn (II) using Lemon grass (*Cymbopogon citratus*) kinetics, isotherms and thermodynamics. *Chem Int.*2016; 2(2):89–102.
- [30] Jha AK, Kumar U. Studies on removal of heavy metals by *cymbopogon flexuosus*. *Int J Agric Environ Biotechnol* 2017;10(1):89.
- [31] Pandey J, Chand S, Pandey S, Patra D. Palmarosa [*Cymbopogon martinii* (Roxb.) Wats.] as a putative crop for phytoremediation, in tannery sludge polluted soil. *Ecotoxicol Environ Saf.* 2015;122:296–302.
- [32] Boruah HPD, Handique AK, Borah GC. Response of Java citronella (*Cymbopogon winterianus Jowitt*) to toxic heavy metal cadmium. *Indian J Exp Biol.*2000;38(12):1267–1269.
- [33] Sinha S, Mishra RK, Sinam G, Mallick S, Gupta AK. Comparative evaluation of metal phytoremediation potential of trees, grasses, and flowering plants from tannery-wastewater-contaminated soil in relation with physicochemical properties. *Soil Sediment Contamin.* 2013;22(8):958–983.
- [34] Truong PN, Stone R. *Vetiver grass for landfill rehabilitation: Erosion and leachate control*. Report to DNR and Redland Shire Council.1996.
- [35] Anon. A consideration and preliminary test of using vetiver for water eutrophication control in Taihu Lake in China. (Proc. International Vetiver Workshop, Fuzhou, China).1997.
- [36] Zheng CR, Tu C, Chen HM. Preliminary study on purification of eutrophic water with vetiver. (Proc. International Vetiver Workshop, Fuzhou, China).1997.
- [37] Truong P. The global impact of vetiver grass technology on the environment. (Proceedings of the second international conference on vetiver office of the royal development projects board, Bangkok).2000; 48-61.
- [38] Truong PN, Hart B. Vetiver system for wastewater treatment poster paper presented at the International Fresh Water Conference, (Bonn, Germany).2001.
- [39] Mudhiriza T, Mapanda F, Mvumi BM, Wuta M. 2015 Removal of nutrient and heavy metal loads from sewage effluent using vetiver grass, *Chrysopogon zizanioides* (L.) roberly. Published under a Creative Commons Attribution Licence.2015;41:1816-7950.
- [40] Banerjeea R, Goswami P, Pathak K, Mukherjeea A. Vetiver grass an environment clean-up tool for heavy metal contaminated iron ore mine-soil. *Ecological Engineering* 2016;90;25-34.

- [41] Muhammad HM, Noor H, Anwar BM, Yousuf J. Phytoaccumulation of heavy metals from municipal solid waste leachate using different grasses under hydroponic condition. *Scientific Reports* 2020;10:15802.
- [42] Chen KF, Yeh TY, Lin CF. Phytoextraction of Cu, Zn, and Pb enhanced by chelators with vetiver (*Vetiveria zizanioides*) hydroponic and pot experiments. *ISRN Ecol.*2012.
- [43] Sinha S, Mishra RK, Sinam G, Mallick S, Gupta AK. Comparative evaluation of metal phytoremediation potential of trees, grasses, and flowering plants from tannery-wastewater-contaminated soil in relation with physicochemical properties. *Soil Sediment Contamin.*2013; 22(8):958–983.
- [44] Adigun M, Are K. Comparatives effectiveness of two vetiveria grasses species *Chrysopogon zizanioides* and *Chrysopogon nigritana* for the remediation of soils contaminated with heavy metals. *Am J Exper Agric.*2015;8(6):361–366.
- [45] Maharjan A, Pradhanang S. Potential of vetiver grass for wastewater treatment. *Environment and Ecology Research.*2017;5(7):489-494.
- [46] Edgard G, Catarina MA, Jegannathan KR. Multiple applications of vetiver grass – a review. *International Journal of Environmental Science.*2017;2: 2367-8941.
- [47] Truong PN, Baker D. Vetiver grass system for environmental protection. (Bulletin No./1. pacific rim vetiver network office of the royal development projects board, Bangkok).1998.
- [48] Greenfield JC. Vetiver grass – an essential grass for the conservation of planet earth. (Infinity Publishing, Haverford).2002.
- [49] Verma SK, Singh K, Gupta AK, Pandey VC, Trivedi P, Verma RK, Patra DD. Aromatic grasses for phytomanagement of coal fly ash hazards. *Ecol Eng.* 2014;73:425–428.
- [50] Pandey J, Verma RK, Singh S. Suitability of aromatic plants for phytoremediation of heavy metal contaminated areas: a review. *International Journal of Phytoremediation.* 2019; ISSN: 1522-6514 (Print 1549-7879).
- [51]