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Solutions to Mitigate Agrotoxics in Drinking Water using Plants

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Abstract

This study focuses on drinking water problems, sustaining environmental conditions in river basins, and heavy metals concentration reduction, using selected plants as a nature-based solution for degraded wetland ecosystems. Unconventional water treatments are increasingly tested as phytoremediation assists effluent treatment systems or sanitary waste, which eliminate or mitigate toxic molecules in water. Selected plants are intensively used for revegetation of degraded river basins and water amelioration systems throughout small-scale constructed wetlands in water bodies near to factories. Large-scale constructed wetlands include several plants occurring in natural wetlands and used in constructed ones. Those plants associate with Arbuscular Mycorrhizae Fungi (AMF) Among these plants, vetiver grass (*Chrysopogon zizanioides*) and *Urochloa* brizantha, having vigorous deep roots, used for revegetation and for AMF multiplication, developing infective propagules. *Typha* and Cyperaceae species are cultivated for sustainable water systems. In the present study, recent reports on drinking water characteristics and amelioration were compiled for water quality treatment. Among vegetation, the best candidate is Vetiver grass, resistant to pests, diseases, and climatic variations, with efficient absorption of nutrients also associated with Glomeraceae. Due to its environmental services, as promoters of soil health in wetlands, detailed research is needed on biotic interactions and AMF inoculant production.

Keywords: Grass; Arbuscular Mycorrhizae; Wetland; Soil; Grasses, Vetiver Grass.

Abbreviations: AMF: Arbuscular Mycorrhizae Fungi; HQ: Hazard Quotients; AMF: Arbuscular Mycorrhizal Fungi; HM: Heavy Metals.

Introduction

Due to the increasing interest in wetlands to obtain better water production and treatment besides reducing environmentally unfavourable emissions, the decrease in use of pesticides and fertilizers was proposed to improve ecosystem health and sustainability [1]. Human exposure to heavy metals through ingestion of contaminated food or uptake of drinking water can lead to their accumulation in plants, animals and humans. The excessive use of fertilizers and waste inputs has deteriorated soil and environment. However, the deleterious effects of pesticides are not totally examined and controlled [2]. By chance, the effect of plants, manures, waste, compost, and biochar amendments to the soils and water is increasingly studied worldwide, as organic and natural ecosystems gained space. Thus, experiments on the implementation of plants by agriculture are rapidly increasing, in parallel selected plants and organic or regenerative agriculture adopted the addition of natural residues on horticultural plants and crops. Furthermore, the compatibility among biofertilizers and soil conditioners is also more investigated to support sustainable agricultural systems and to deal with the effects of global and especially climatic change. Thus, the mycorrhizal symbiosis, application of compost of selected waste Hu et al. [3], phosphate solubilizing microorganisms, microbial inoculants, and biochar are increasingly explored. Selected plants compiled by Lopes and Duarte [4] are intensively indicated for revegetation of degraded river basins and water amelioration systems throughout small-scale constructed wetlands in water bodies near to factories.

Thus, large-scale constructed wetlands were also proposed. Among commonly used plants, vetiver grass (*Chrysopogon zizanioides*) *Urochloa brizantha, Pennisetum purpureum, Urochloa* decumbens and Pennisetum graucum are of particular interest for sewage research [4] *Atriplex numularia, Azolla Carolinian, Salvinia minima* and *Spirodela polyrhiza, Guadua angustifolia, Phyllostachys aurea, Phyllostachys bambusoides, Chrysopogon zizanioides, Zantedeschia aethiopica*, were also selected for this purpose. Wetlands can purify water and help treat wastewater by removing pollutants, surplus of nutrients, and sediments from water, however little is known about the occurrence and function of AMF inhabiting wetland ecosystems besides the creation of ecological floating beds created for the remediation of polluted water bodies Xu et al. [5]. As Plant-fungal ecological studies are increasing, more root samples of selected plants are examined. Among indicated plants, *Canna generalis, Cyperus alternifolius* and *Eichhornia crassipes* were mentioned. Vetiver grass stans outs due to its resistance to pests and diseases being tolerant of climatic variations, probably due to efficient absorption of nutrients as described by Santos [6], and Siqueira [7], proposed experiments to evaluate the development of vetiver grass in constructed wetland systems. The morphological and anatomical development of its roots were affected by dissolved oxygen concentrations in effluent lagoons.; however, this plant species is tolerant and resilient in diverse adverse conditions of sludge treatment, pointed out by Filho [8] in various environments with adverse conditions, including sewage treatment lagoons.

In Brazil, the water pollution of rivers leads to drinking water control of main Agrotoxics used in the region by municipalities (Table 2). In India, the concentrations of metals in rivers showed significant spatial variation between some metals like As, Mn, Fe, Cu and Se exceeding the drinking water standards at some sites. As described by Giri and Singh [9]. In South America, the perennial grass *Urochloa brizantha*, a tropical forage, associated with Arbuscular mycorrhizae fungi (AMF), which highly colonize its roots [10]. developing infective propagules. *Urochloa decumbens* is also used for arbuscular mycorrhizae multiplication, besides its cultivation for ensuring the sustainability of wetland systems. Moreover, these grass species are increasingly used as cover crops [5,6]. Some grass species actively propagate benefice microsymbionts, among them, *Urochloa* species. are frequently selected for intercropping to improve land use due to their high residue content [7]. Thus, the occurrence and life cycle of relevant symbionts such as the AMF in wetlands were previously investigated worldwide, Vetiver grass is utilized in pest management and its growth was studied when inoculated vs. non-inoculated, being intensively used for revegetation of degraded lands, *Urochloa* is also used for AMF taxonomic and plant fungi ecological studies. Reports on AMF inoculation, and on AMF root colonization by Filho [8] indicated differences between the AMF species symbionts of wetland species. However, due to the lack of detailed data on this topic, more detailed research is needed to better understand the interactions with soil microbiota in this ecosystem. In the present study, with the purpose of examining the AMF associated with wetland plants, the AMF reports were compiled.

The current study reviews the latest reports on vetiver-grass among other plant species used for removing pollutants from unconventional water. Regarding AMF-based inoculants at field conditions in the soil/ substrate, high values of spores were observed in the *U. brizantha* inoculated with *Acaulospora longula*, followed by plants inoculated with *Acaulospora colombiana* (and *Acaulospora morrowiae* (grasses in wetland ecosystems, with focus on its ecology including reports on their symbiosis. We searched the databases Scopus, and Google Scholar, with special attention to the most recent articles. In the Subarnarekha River Basin, India, the risk of metals on human health was evaluated using Hazard Quotients (HQ) and cancer risk by ingestion (adults and child), indicating that Mn was the most important pollutant leading to non-carcinogenic troubles. The carcinogenic risk of arsenic (As) for adults and children was within the acceptable cancer risk value of 1×10^{-4}. The largest contributors to chronic risks were Mn, Co and As, informed by Giri and Singh [9].

Materials and Methods

We searched for recent reports on unconventional water treatment. (GOOGLE Academic, SCOPUS, including the keywords: wetland, mycorrhizae as criteria for selecting studies. As an example, Figure 1 shows an artificial lake (depth of 5 to 16 m), which receive domestic wastewater in Belo Horizonte, Brazil. The lake is fed by 8 small streams, like Sarandi and Ressaca.in a hilly area, within the plants growing grasses and mainly *Typha* vegetation rapidly occupied a border being used for pasture by the local cattle, and in other border a waste treatment station was installed. The lake tolerates the (rainy period (in February) and (dry period in (September). In the reports on wetland, the efficiency of treatment of experimental systems was considered by some authors varying from medium to good for most of the parameters analysed by Lopes and Duarte [4].

Figure 1: Polluted wetland at Pampulha lake, Minas Gerais, Brazil.

Soil Characterization

Natural plant species from wetlands are adapted to nutrient poor acid soils subjected to frequent flooding, therefore, wetland soils depend on hydrology, which influences soil genesis and characteristics.

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Results

AMF associated to wetland plants

Wetlands presented the occurrence of AMF, most Glomeraceae, associated with *vetiver* grass. Compared to other reports, *Claroideoglomus etunicatum* was dominant among the isolated species of Glomeromycotan (Table 2). Cultivated soils show exclusive characteristics such as high amount of K due to commonly applied fertilization as reported previously by Pagano et al. [10]. This study showed the AMF species associated with grass and wetland plants, as well as potential for AMF inoculant formulation. Different AMF species (*Acaulospora longula* and *Acaulospora colombiana*) were previously reported by Barbosa et al. [11] as associated to *U. brizantha* in greenhouse, Brazil; however, vetiver grass was the favourite, considered a miracle plant. As described by Machado et al. [12] who highlighted that the thin roots of vetiver grass showed high shear strength, which contributed to a reduction in erosion processes.

Thus, controlling soil erosive processes Table 1 shows some recent available reports on wetland species. Plant-fungal ecological studies pointed out that aquatic, wetland and terrestrial plants harbour arbuscular mycorrhizae Xu et al. [5] [11]. Table 2 shows some standards of Agrotoxics evaluated in drinking water from the municipalities of Santa Catarina state, Brazil. The drinking water samples are monitored for some common Agrotoxics used in regional agriculture (Figure 2), which implies the number of exogenous intoxication cases found Setyaningsih et al. [13]. investigated *Typha angustifolia* growing on waterlogged areas such as a tailing dam, inoculated with Arbuscular Mycorrhizal Fungi (AMF) plus compost and soil from gold mining tailings. Experiments were conducted in greenhouse by inoculating two AMF isolates (*Claroideglomus etunicatum* and *Glomus manihotis*) to *Typha* seedlings, which increased AMF colonization of *Typha* roots besides plant growth.

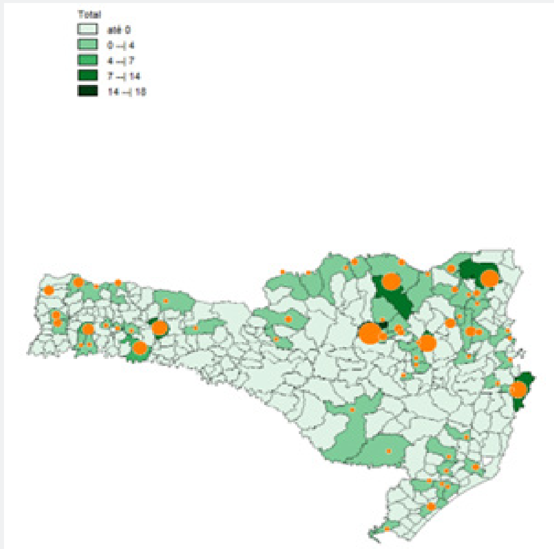

Figure 2: Map of the monitored region in Santa Catarina state, Brazil, showing cases of exogenous intoxication by agrotoxics. Number of notified cases of exogenous intoxication by agrotoxics, Source: SINAN, 2018.

Table 1: Reports on AMF species in wetlands.

Field/ greenhouse	Plant species	Root colonization (%)	AMF species	Reference
Greenhouse	*Typha*		Claroideoglomus etunicatum, Glomus manihotis	[12]
Greenhouse	Vetiver	>10	Native inoculum, 200 spores per plant	[16]
	U. brizantha		Claroideoglomus	[17]
	U. brizantha	16	Acaulospora colombiana, A. longula, A. morrowiae Gigaspora margarita; Paraglomus occultum	[10]
Constructed wetland	*Canna generalis, Cyperus alternifolius, and Eichhornia crassipes*		Glomus, Acaulospora	[5]

The number of notified cases of exogenous Agrotoxics intoxication is monitored by the SINAN system. As a result, municipalities with the highest incidence of intoxication by Agrotoxics in Santa Catarina state (Figure 2) was in the municipalities: Rio do Campo, Joinville and Grande Florianopolis (Figure 2, red circles) showing the relationship between agriculture and cases of intoxication. Source: SINAN, 2018.

Regulatory aspects

Brazil's pesticide regulations are supervised by three governmental agencies, the Brazilian Health Regulatory Agency (ANVISA) and the Ministry of the Environment the Ministry of Agriculture (MAPA). Under Brazil's 1989 pesticide old law No. 7802, The country incorporated a more protective "hazard assessment" to ban carcinogenic, teratogenic, mutagenic and hormone disrupting pesticides. However, limited effectiveness of human and environmental health protections are barriers to how often pesticides can be reevaluated, the aggressive protection of the agrochemical industry. Despite this, some hazardous pesticides were banned. However, in recent years, this

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changed. In 2023, Brazil implemented a new pesticide law (Law 14,785/2023) that significantly changed the regulatory structure for pesticides, including registration, commercialization, and use. The regulatory agencies can increase the protections for some pesticides, including limiting where the pesticide can be used in crop management practices, the most effective and reliable option is to ban a pesticide entirely if the potential for dangerous exposure cannot be feasibly mitigated, as compiled by Donley [14].

Table 2: Agrotoxics evaluated in drinking water from the municipalities of Santa Catarina state, Brazil.

2.4D-2.4ST	Active principle	MVP
	Glyphosate+ AMPA	500
Alachlor	Lindane	20
Chlordane	Metolachlor	0.03
DDT+DDE	Molinate	6.0
Pendimenthalin	Trifluralin	20.0
Available P mg·kg^{-1}		1.8
Endosulfan (αβsis)	Endosulfan	
Chlorpyrifos#	(= Same)	30.0
Lindane	2.0	2.0
Aldrin	0.03	
Atrazine	-	-
Heptachlor Methoxychlor	Methylic Parathion	20.0

NA: Not available. # concentration in water samples. Maximum value permitted (MVP (µg L^{-1}). Source: Brazil. Ministry of Health. Health Surveillance Secretariat. Department of Environmental Health Surveillance and Workers' Health. Quality of Drinking Water: A Guide for the Promotion and Protection of Health, Brasília: Health Ministry, Brazil, 2018.

Discussion

The urgent acceptance of green infrastructure, nature-based arrangement of spaces, and attention to ecosystem services of artificial water bodies has enhanced the quality of urban surroundings with environmentally friendly measures such as reclaimed water (treated wastewater). The AMF community structure in the studied wetlands showed dominance of Glomeraceae. AMF (were previously reported associated with wetland plants by the compilation of Wang and Qiu. The present study showed the AMF communities associated with wetlands listed in recent reports, and thus the potential for AMF inoculant formulation. However, to understanding the wetland ecology it is necessary to analyse the associated AMF species, the time of symbiosis establishment, root colonization and spore multiplication under different abiotic and biotic conditions. The hypothesis of this study is that wetland plants associate with diverse AMF species, which have different behaviors when colonizing this host plant. We examined the arbuscular mycorrhizae reported associated with wetland grass. The AMF community structure was studied in a U. brizantha grassland in Brazil (Figure 2a), which showed a greater diversity of AMF compared to previous reports. Moreover, around 50 % of unviable AMF spores were estimated. Four genera of *Glomeromycota* and five species were detected (Table 2).

Wetland soil tolerates inundation showing exclusive characteristics, such as high amounts of soil organic matter. Wetlands in which herbs were planted had a high removal efficiency of indicator pathogens, organic matter, LAS detergent in comparison to a control wetland (without canes) and could improve physicochemical parameters (DO, ammonia, nitrate, electrical conductivity, and pH) of wastewater [15,13]. Most studies were conducted at field conditions , the present study is the first to show in detail the AMF community associated to wetland plants besides previous reports on root colonization [4,18], and to point out the potential for AMF inoculant formulation to improve sustainable plant cultivation at field conditions. Wetland ecology requires the use of efficient and economically viable strategies and techniques. Arbuscular Mycorrhizal Fungi (AMF) have been widely reported to occur in wetland plants [15,19]. However, the factors that affect AMF colonization in wetland plants and its physiological functions in AMF inoculated plants were inadequately studied as pointed out by Hu et al. [3]. Vetiver grass presented mycorrhizal colonization besides septate melanized hyphae from dark septate endophytic fungi as informed by Machado et al. [12]. The association of the vetiver grass with Glomus was reported in soils contaminated with arsenic by Caporale et al. [20].

Also, the effect of *Glomus mosseae* in vetiver grass growing in cadmium-contaminated soils was registered by Karimi et al. [19]. using various plants, including common weeds *Phragmites australis* [14], water hyacinth *Eichhornia crasspies*, water *lettuce Pistia stratiotes*, bulrush (Typha), duckweed (Lemna, pampas grass Cortaderia selloana and Quinoa *Chenopodium quinoa* wild, could be also investigated as they were proposed as a supplementary approach for unconventional water phytoremediation by Dorafshan et al. [15] Among the vegetation associated with natural wetlands, some grass communities predominate. These plants associate with AMF, which provide tolerance to environmental stress. One of the most used plants is vetiver grass, an aromatic *Poaceae* plant, which can tolerate extreme climatic variations such as prolonged drought flood, and submergence. understanding wetland ecology important characteristics must be studied, such as soil properties, plant species, wet and dry periods, plant symbioses, and thus the potential for AMF inoculant formulation for this vegetation type. However, understanding the wetland ecology is important not only for environmental issues, but also for human life quality. *Glomus* was the most dominant and *Acaulospora*, the second dominant genera of AMF, found in the three ecological floating beds investigated by Xu et al. [5].

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Vetiver, a perennial grass with a great height(2m) and depth (3 m) is highly explored for restoring degraded lands acting as a natural barrier against erosion and pollution, due to a massive odorous root system, also is considered a Hyperaccumulator plant, as it can take up one or two specific metals in high concentrations into their tissues as reported by Khan [2]. Most Plants growing on degraded and Heavy Metals (HM) contaminated soils including vetiver grass, possess arbuscular mycorrhizae, indicating that these AMF tolerate HM and that they play an important role in the mycorrhizoremediation of stressed wetland soils [2]. Viana Barbosa et al. [11] investigated the Arbuscular mycorrhizal fungi in *Urochloa brizantha* its symbiosis and spore multiplication. We summarized here the plant species associated with wetlands and their reported symbiosis. Vetiver grass is preferred for artificial wetlands.

Conclusion

This is the first report to compile native and exotic plants for using in unconventional water treatment, especially in Brazil, a tropical and subtropical country; however, it serves to be used in other countries with similar vegetation and climate. Additionally, we show which Agrotoxics are evaluated in drinking water from the municipalities of Santa Catarina state, Brazil, explaining how the cases of exogenous intoxication by Agrotoxics are registered in the SINAN national monitoring system of notified cases. Finally, we mentioned which plants used in unconventional water treatment are associated with arbuscular mycorrhizae.

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