Potential of local plant Eleocharis dulcis for wastewater treatment in constructed wetlands system: review

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Abstract. Plants have a vital role in constructed wetlands because they provide oxygen in removing pollutants, as a medium of microorganisms, as absorbers of nutrients and other pollutants, must be resistant to high levels of pollutant loads and stressful conditions. Several plants have potential for constructed wetland, namely Phragmites sp., Typha sp., Canna indica, Colocasia esculenta, Eichornia crassipes, Eleocharis dulcis, and others. Eleocharis dulcis is a local plant commonly found in South Kalimantan. Eleocharis dulcis in the local, namely Purun tikus, grows in tidal swamps and grows in areas of high soil acidity (pH 2.5 – 3.5). Eleocharis dulcis can be used in tackling reclamation waste of acid sulfate soil which can absorb 1.45% of N elements; Cu 15 ppm; P 0.08%; Zn 48 ppm; Mg 0.16%; Fe 1.386 ppm; S 0.18%; Mn 923 ppm; K 2.05%; and Ca 0.22%. According to several studies that have been carried out, Eleocharis dulcis have been shown to reduce several pollutant loads such as Hg 99.84%; Pb; Cd; Fe 85.68%; SO₄; Mn 78.94%; BOD 98.74%; COD 98.73%; and turbidity 80% also. The local plant Eleocharis dulcis can be potentially used as wastewater treatment, especially in a constructed wetland systems.

1. Introduction

Nowadays, constructed wetlands are not foreign to several industries to treat wastewater such as domestic waste, acid mine drainage, agricultural waste, landfill leachate, and others. Several factors can affect the method of constructed wetlands, such as media, microorganisms, temperature, and plants. Plants are one of the critical factors in the success of this method because they have several functions as a provider of oxygen in the process of decomposition of pollutants, as a supporting factor for the growth of microorganisms, restraining flow rates, absorbing nutrients and other pollutants and others [1]. To choose materials for revegetation, a basic rule is to use plants or seeds obtained from their original or surrounding environment so that these plants can adapt well if transferred to plants from different or distant environments [2]. Not all plants can be used for constructed wetlands systems; only plants can survive and have macrophyte roots that can grow even in extreme environments. According to several studies that have been carried out, several plants can absorb heavy metals, nitrogen, phosphorus, and others. The content of heavy metals and others absorbed by plants will accumulate in the roots, stems, and leaves [3].
The relationship between the absorption of heavy metals by plants and the decomposition of contaminants in wastewater by microorganisms in a system to meet quality standards is called the phytoremediation method. [4]. Microbes not only affect the phytoremediation system but also directly affect plant growth and biomass [5]. Based on several studies that have been carried out, constructed wetlands or phytoremediation is an environmentally friendly wastewater treatment technology [6].

2. Methodology

Constructive wetlands utilize aquatic macrophytic vegetation. Plants of this species live on the surface, bottom, and edge of waters; these plants are commonly used for wastewater treatment. Macrophytes in artificial wetlands are divided into four groups: emergent macrophytes grow in submerged soil and have parts that protrude above the water surface so that stems, leaves, and flowers are visible above the water surface examples such as Carex rostrata, Typha latifolia, and others. Floating-leaved macrophytes are plants with submerged roots in the soil at a depth of 0.5-3.0 m floating with leaves above the water surface examples such as Nuphar lutea and Nymphaea odorata. Submerged macrophytes grow well in water with all tissues submerged in water (below the water surface). Examples such as Ceratophyllum demersum, Egeria densa, Stuckenia pectinata, and others. Free-floating macrophytes are plants that grow well in water that float freely on the surface of the water) Examples include Pistia stratiotes, Eichhornia crassipes, Lemna minor, and others [7,8].

Based on several studies, there are about ± 150 species commonly used in constructed wetlands that are Iris pseudacorus, Phragmites australis, Glyceria maxima, Juncus effusus, Typha latifolia [9], Cyperus papyrus, Eichhornia crassipes, Typha angustifolia, Phragmites Mauritianus, Cyperus husband, Limnocharis Flava [10], cattail, narrow-leaf cattail, Scirpus (Schoenolectus) laeustris, Scirpus californicus, Canna indica, Colocasia esculenta, Eichornia crassipes, Eleocharis dulcis, Phalaris arundinacea, reed canary grass. Another common genus is Eleocharis, spike rush. While Scirpus Validus (S. tabernaemontani), Typha domingensis, southern cattail, Phragmites australis, soft-stem bulrush, and others [11]. Inaccessible water surface wetlands, plants are often grouped according to the average water depth. Common deep marsh species that thrive in water 12–30 inches deep (30–76 cm) include Typha, Scirpus, Phragmites [12,13], Scirpus validus, Scirpus lectures, Eleocharis sphacelata, and Scirpus fluviatilis [14], P. karka, Eleocharis dulcis, S. grossus, S. mucronatus, Lepironia articulate and Phylidrium lanuginosum [15]. Plants that are usually used in subsurface flow constructed wetland systems are Phragmites australis [13]. Aquatic plants often used in horizontal subsurface flow constructed wetland systems are Typha, Scirpus, Phragmites, Phalaris arundinacea, and Iris [16].

Several constructed wetlands have been studied and applied, most of them using one plant species native to their habitat, but there are also various types of plant species. Based on the study results, it is stated to use plant species native to their habitat or use plants that can grow throughout the area [3].

3. Results and discussion

Based on several studies carried out, not all plants can be used in the constructed wetland system; only plants with special abilities can be used because plants play a role in the waste treatment process in the constructed wetland system. It is known that several types of plants can accumulate some heavy metals and other substances in wastewater so that these plants can be used in the constructed wetland system in the future. The following will summarize several types of plants and their ability to accumulate heavy metals and others in Table 1.
Table 1. The ability of some plants to accumulate heavy metals.

| Reference                          | Plants                        | Classification              | Accumulation       |
|------------------------------------|-------------------------------|-----------------------------|--------------------|
| IFAS [17]                          | *Limnocharis Flava*           | Emergent plant              | Fe & Mn            |
| PDF [18]                           | *Canna indica*                | Emergent plant              | Co, Ni, Cr, Zn, and Cu |
| Chen et al. [19]                   | *Cyperus alternifolius*       | Emergent plant              | Cu, Fe, and Zn     |
| IFAS [17]                          | *Alligator weed*              | Floating leaved plant       | Pb, Cd, and Zn     |
| Global Invasive Species Database [20]| *Zizania latifolia*          | Emergent plant              | Pb, Cd, and Zn     |
| Queensland Government [21]         | *Echinochloa crus-galli*      | Emergent plant              | Pb, Cd, and Zn     |
| PDF [18]                           | *Polygonum hydropiper*        | Emergent plant              | Pb, Cd, and Zn     |
| CABI [22]                          | *Monochoria vaginalis*        | Emergent plant              | Pb and Cd          |
| NZPCN [23]                         | *Machine globosa*             | Emergent plant              | Zn and Cd          |
| Chu [24]                           | *Digitaria sanguinialis*      | Emergent plant              | Zn                 |
| EOL [25]                           | *Fimbristylis miliacea*       | Emergent plant              | Zn                 |
| IFAS [17]                          | *Eichhornia crassipes*        | Floating leaved plant       | Cd, Cu, Cr, Ni, and Pb |
| PDF [18]                           | *Type domingensis*            | Emergent plant              | Ni, Cd, and Pb     |
| IFAS [17]                          | *Juncus effusus*              | Emergent plant              | Fe, Cr, Ni, Pb, Zn, Mn, and Cd |
| Zhuang [26]                        | *Lemna minor*                 | Free-floating plant         | Cu, Cr, Pb, Ni, and Cd |

In South Kalimantan, local weeds are commonly found in acid sulfate tidal swamp areas or in swampy areas that are inundated with water at an altitude of 0-1,350 m above sea level that is *Eleocharis dulcis* in its local name Purun tikus. In addition, this plant is also commonly found in rice fields, lakes, or waterlogged. Based on several studies, it turns out that this plant can be used as a hyperaccumulator in constructed wetlands systems [17]. Based on the taxonomic position, *Eleocharis dulcis* is included in the family Cyperaceae or the puzzle group. The stem of this plant is cylindrical or obtuse square and 2-3 mm in diameter with a plant height of up to 150 cm. This plant is unbranched and green, so photosynthesis is carried out through the stem. The leaves of this plant are reduced to a reed-shaped midrib that covers the base of the stem and sometimes with rudimentary leaf blades. The flowers of this plant are found at the end of the stem. The roots of this plant are in the form of rhizomes standing vertically or tightly tilted with long creeping shoots, and when the rhizome roots are 6-8 weeks old, new tillers will form. Flowers are formed after the saplings appear above the water surface, which is approximately 15 cm high. After flowering, this plant will form a new rhizome at the end of the stolon, approximately 12.5 cm long. After the plant is 7-8 months old, the rhizomes are no longer productive, so the stems of the plants begin to dry up and die slowly [18].

Figure 1. *Eleocharis dulcis*’s structure; A. flower, B. leaf, C. Stem, D. root, E. corm.
Eleocharis dulcis can grow well at a temperature of 30-35°C, with 98-100% soil moisture. The soil suitable for the growth of this plant is loam or humus soil with a pH of 6.9-7.3 but can also grow well in acidic soils [19]. This plant is specific for acid sulfate soils because it is resistant to high soil acidity (pH 2.5–3.5), so that it becomes indicator vegetation for acid sulfate soils [17]. Also, this plant can grow in conditions of extreme soil chemical properties, such as low pH and high Al, SO$_4^{2-}$ (content that other compounds can exchange), and high soluble Fe. The vegetation of this plant can grow at pH 3, with an aluminum (Al) content of 5.35 me/100 g, a soluble sulfate (SO$_4^{2-}$) content of 0.90 me/100 g, and a soluble iron (Fe$^{2+}$) content of 1.017 ppm [20].

Figure 2. Eleocharis dulcis in South Kalimantan.

Eleocharis dulcis has several abilities to be used as a hyperaccumulator plant with uses for improving water quality [20-21]. The results of this study indicate that this plant is used as a biofilter to improve water quality in the dry season by absorbing dissolved toxic compounds such as Fe and SO$_4$ in the water inlet (irrigation) and water outlet (drainage). This plant is also able to absorb lead from palm oil industry wastewater at the roots of 0.32-0.54 ppm and 0.24-0.27 ppm in the stems [20], and can overcome the reclamation waste of acid sulfate soil, which can absorb the element N by 1.45%; Cu 15 ppm; P 0.08%; Zn 48 ppm; Mg 0.16%; Fe 1.386 ppm; S 0.18%; Mn 923 ppm; K 2.05%; and Ca 0.22% [22]. Another study explained that this plant can also absorb 4263 ppm Fe in 5 days [23].

Prihatini et al. [24] reported that the ability of Eleocharis dulcis to absorb Pb in wastewater. The accumulation of Pb was primarily found in the roots rather than the stems; it was explained that plant roots interacted directly with wastewater and sediment. Roots can absorb most of the nutrients from the soil. Plant genetic traits can control the root system, but several other factors can influence it, such as soil conditions, aeration, nutrient availability, and others. The ability of Eleocharis dulcis to absorb Fe is not yet known. Based on the assumption, this plant is like other monocot plants which use chelation-based ability to absorb Fe. This ability is called phytosiderophores, which releases chelates into the rhizosphere to bind Fe$^{3+}$ until it accumulates in plants [25]. Sulthoni et al. [26] reported that the finding of a relatively high concentration of Fe in the plant organs of Eleocharis dulcis indicates that this plant has the potential as a hyperaccumulator plant for ferrous metal because it can absorb and accumulate more than 0.1% of the metal in its organs. Phenolic compounds are found in the root and leaf cells of Eleocharis dulcis so that this plant has a high tolerance for iron. This study indicates that this plant accumulates excess Fe in its body at the roots and then the top of the plant or leaves. Besides
Fe, this plant can also absorb dissolved toxic compounds such as SO₄ and absorb heavy metal mercury with a high amount of biomass in a short time because this plant has a high tolerance level for heavy metals such as mercury and others. The mechanism of Eleocharis dulcis in accumulating Fe and Mn metals is called phytoremediation [20]. The plant process to absorb and accumulate heavy metals is divided into three continuous processes that are the roots will absorb through a chelating substance called phytosiderophores which functions to bind metals and then carry them into root cells through active transport, the next stage, the metal will be translocated from the roots to the parts of the plant others through transport networks (xylem and phloem). The metal will be in certain parts of the cells to inhibit plant metabolism [27].

According to several studies that have been carried out, a local plant in South Kalimantan that is Eleocharis dulcis has been proven to be used as a hyperaccumulator plant in a constructed wetland system to removal some pollutant loads such as Hg 99.84% [21]; Pb; SO₄; Cd [28]; Fe 85.68% [29-31]; Mn 78.94% [32]; BOD 98.74%; COD 98.73%; and turbidity 80% also [33,34].

4. Conclusion
Based on several studies, local plants in South Kalimantan Eleocharis dulcis have proven to have the ability to proliferate in extreme environments as a hyperaccumulator plant, have the tolerance to heavy metals. They can produce large amounts of biomass, so that Eleocharis dulcis has a high potential for phytoremediation.

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