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REVIEW ARTICLE

The Ability of Aquatic Carnivorous Plants *Utricularia vulgaris L.* as Heavy Metal Bioremediators

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A B S T R A C T

Utricularia vulgaris is one of the aquatic carnivorous plants that is able to grow in low-nutrient environmental conditions. This unique plant is also a macrophytic plant whose entire body, except for the flowers, is submerged in water. *Utricularia vulgaris* also has no roots, so it grows to float in water. The plant was found growing in an environment polluted by heavy metals. Several studies have shown that *U. vulgaris* is able to absorb several kinds of heavy metals effectively, namely Cu, Fe, Mn, and Zn. These heavy metals are needed in small amounts by organisms, but in high amounts, they can inhibit the growth of aquatic organisms. This plant has also posed its potential to absorb heavy metals, making it a subject of interest for phytoremediation.

K E Y W O R D S

Common bladderwort, Water contaminants, Phytoremediation

H I G H L I G H T S

- Freshwater, essential for organisms, is being contaminated with heavy metals, causing concern due to its harmful effects on organisms.
- Heavy metals such as Cu, Fe, Mn, and Zn in water are not easily broken down, posing a potential threat to water quality, inhibiting growth, being toxic, and harming aquatic organisms.
- Among the various bioremediation agents, aquatic plants become the most dependable option for degrading heavy metals.
- *Utricularia vulgaris* is an aquatic carnivorous plant that can act as a phytoremediation agent, absorbing heavy metals in high concentrations.

INTRODUCTION

Freshwater is an essential source of water needs for humans, animals, and plants. Apart from being a necessity, it is an important ecosystem for some organisms, especially aquatic organisms. Freshwater is estimated to be only about 3% of the 70% of the earth's water. However, along with population growth and development, freshwater sources experienced a decline in quality, one of which is due to contaminants (Mushtaq et al., 2020). Contaminants in freshwater sources come from various sources and forms. Heavy metals and nanoplastics are toxic and disturbing contaminants in freshwater (Blair et al., 2017; Maksimović et al., 2019). The content of pollutants in an ecosystem will be very detrimental to aquatic organisms and water quality.

Contaminants in freshwater are usually caused by the disposal of industrial waste and the use of pesticides on plantations and rice fields, which are then carried away by water flow. Heavy metals have properties that are tough to decompose, making them gather in sediments and waters. Heavy metals content in water negatively impacts organisms, although some are needed only in small amounts (Azizah et al., 2018). Industry players have also tried to deal with the problem of waste generated. However, handling the waste requires a high cost. Therefore, some companies are looking for other alternatives so that their waste disposal does not harm the environment. The high content of contaminants in the waters can provide a low life expectancy for organisms, one of which is aquatic plants that live in the waters.

Aquatic plants, such as *Nelumbonaceae*, *Hydrilla sp.*, and many others, have an entire life cycle in water. There are also aquatic carnivorous plants. Generally, carnivorous plants consist of 700 species, 20 genera from 12 families, and 220 species in the Genus *Utricularia* scattered throughout the world (Mishra & Kumar, 2020; Adamec, 2013). Fifty species are aquatic plants, including Utricularia (Adamec, 2013). One species in *Utricularia* is *U. vulgaris*, a species native to Europe that can be found in freshwater bodies and environments threatened by human activities. Moreover, it is included in the Red List as a species with Least Concern (LC) status in Europe (Astuti & Peruzzi, 2018). This plant can live in an environment that is low in nutrients, making it able to obtain its nutrition from small animals and insects, in addition to the photosynthesis process for supplying its nutritional needs (Freund et al., 2022).

Several studies have shown that *U. vulgaris* has a positive potential for heavy metals contained in water (Alias et al., 2009; Azeez, 2021; Maksimović et al., 2019). Therefore, in this article, we discuss the ability of *U. vulgaris* to degrade heavy metals and how much *U. vulgaris* can be used as a bioremediation agent in freshwater sources.

THE MORPHOLOGY OF *UTRICULARIA VULGARIS L.*

Utricularia vulgaris, commonly known as Common Bladderwort, is an aquatic carnivorous plant (Prausová et al., 2022). It is part of a genus of plants without roots, mainly rootless, that forms floating shoots (Sirová et al., 2009). This plant grows to float under the water's surface and has no roots. Water and minerals are absorbed on the plant's surface (Irina & Constantin, 2007).

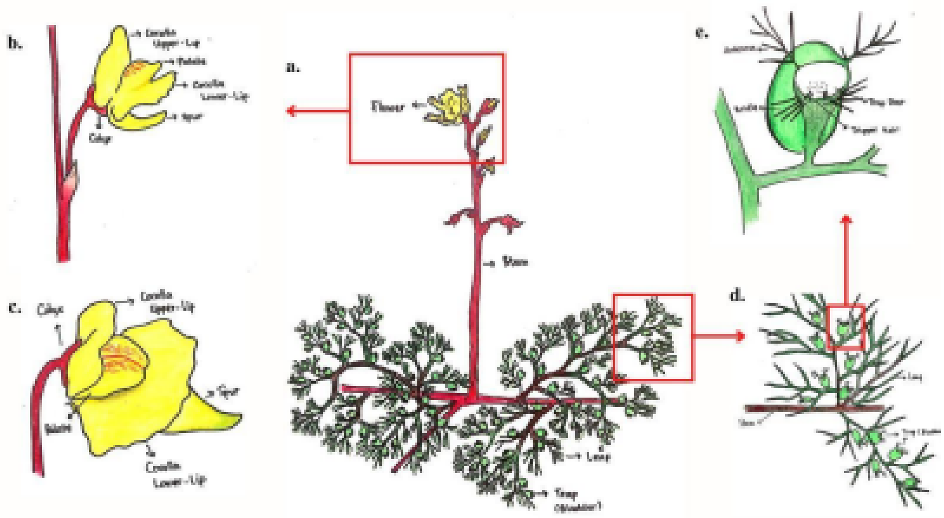

Figure 1. a) Overall morphology of *Utricularia vulgaris*; b) flower morphology looks lateral; c) top view; d) leaves; e) Trap (bladder)

Utricularia vulgaris leaves have normal filiform leaves, but some leaves are modified in insect traps as a characteristic of carnivorous plant groups. These modified leaves, commonly called 'bladder,' have a bladder-like shape with very thin semi-transparent walls (**Figure 1**). The aperture is equipped with a small lid, and a funnel-shaped, sensitive, and long trichome is present at the edge of the aperture. The bladder cover acts as an entrance, and the trichomes guide small animals toward the bladder opening. In addition, these two parts also play a role in avoiding big animals that can damage the bladder (Irina & Constantin, 2007; Reifenrath et al., 2006). Generally, traps in the *Utricularia* group capture prey and produce hydrolytic enzymes to digest prey. The prey are usually aquatic insects and other small arthropods (Miranda et al., 2021).

Utricularia vulgaris is considered a flowering carnivorous plant. As seen in **Figure 1**, its flowers appear and grow upright. The *U. vulgaris* flower consists of two petals: the top (Corolla upper-lip) and the bottom (Corolla lower-lip). Both are yellow and have reddish-brown tufts on the upper crown palate and palate (lower crown). The lower crown forms a platform with a U-shaped margin. Meanwhile, the lower lip is not tightly pressed against the upper lip, and there is a slit that contains the generative structure of the flower (pistil and stamen). The flowers are also equipped with a spur below the lower crown and a spur-like shape with a tapered tip. The spur of this flower is one of the differences between species in the genus Utriculria (Płachno et al., 2018).

IMPACT OF HEAVY METALS IN POLLUTED WATERS

Heavy metals can pollute water and are very difficult to decompose. These heavy metals come from human activities, such as mining and industrial waste. Heavy metals can be stored in columnar waters and sediments at the bottom of rivers (Audry et al., 2004). Heavy metals commonly found in sediments and waters are Zn, Fe, Mn, and Cu. Fe, Mn, Zn, and Cu are essential nutrient metals living organisms need. Low concentrations of this element can lead to a shortage of essential metals in the environment. However, the concentrations required by living organisms are very low. Heavy metals that exceed normal limits in the aquatic environment can reduce water quality and become toxic to all living organisms, including aquatic organisms (Gawad, 2018).

Table 1. Quality standards and their impact on heavy metal levels in freshwater sources

Heavy metal	Quality standard (mg/L)	Heavy metals examples	Content impact
Fe	0.03	0,371 mg/L (Supriyantini & Endrawati, 2015)	Increase mortality of organisms, reduce environmental quality, disrupt the life cycle of organisms (Gemaque et al., 2019; Gawad, 2018)
Mn	0.5	35,6 mg/kg (Ujianti & Andova, 2021)	Causes a change in the colour of the water, turning it reddish, yellow, and black, giving it an unpleasant taste (Ujianti & Andova, 2021)
Zn	5	16,69 mg/kg (Ujianti & Andova, 2021)	Poisoning the bodies of aquatic organisms

			(Ujianti & Andova, 2021)
Cu	2.25	2.547 mg/kg (Ujianti & Andova, 2021)	Being toxic and inhibits the growth of organisms (Amoatey & Bawaain, 2019; Ujianti & Andova, 2021)

Iron (Fe) is an active metal that acts as a medium to transport contaminants (such as As, Cr, and Pb) (Gontijo et al., 2017). Iron is also an important component of hemoglobin in the blood (Gawad, 2018). However, the amount of Fe that exceeds the normal limit can cause an increase in the permeability of the capillary blood vessel walls, allowing blood plasma to leak out and reducing blood volume (Pratama et al., 2017) and various other disturbances (**Table 1**). Fe is also an active metal produced through the Fenton reaction and leads to highly reactive hydroxyl radicals forming, which can cause damage and death of plant cells (Maksimović et al., 2019).

Cu, also known as copper, is also a heavy metal that has an impact on survival, feeding activity, and inhibiting growth. In addition, the presence of Cu in waters becomes a high concentration with increasing water temperature, as the effects of climate change can also increase pollutant concentrations (Amoatey & Baawain, 2019). Krayem et al. (2018) revealed that copper accumulation was higher in plants' root and shoot systems. The concentration of Cu in waters of 0.01 ppm can kill phytoplankton because Cu inhibits enzyme activity in cell division, and in the range of 2.5–3.0 ppm, it can kill the fish (Pratama et al., 2017).

Manganese (Mn) is a heavy metal related to the pH and alkalinity of water. The high concentration of Mn in the waters can be indicated by changes in the colour of the water and the low pH in the aquatic environment (**Table 1**). According to research conducted by Harford et al. (2015), the calculated hazardous concentration of Mn can affect about 5% of organisms. This is because several organisms still tolerate low pH, including *U. aurea.* Kumar et al. (2019) research noted how *U. aurea* is often found in aquatic environments that have low pH.

Another heavy metal often found in waste disposal is zinc (Zn). In small amounts, Zn is an essential metal needed by living organisms. Plants need zinc for the biosynthesis of nucleic acids and polypeptides. However, like other heavy metals, large amounts of Zn can be toxic to plants (Bakar et al., 2019) (**Table 1**).

HEAVY METALS IN *U. VULGARIS*

The high level of heavy metals in an aquatic environment can disrupt its organisms. However, some organisms, such as plants, were found to be able to live in the environment because they have a high tolerance level for aquatic pollutants, one of which is *U. vulgaris* (Maksimović *et al.,* 2019). This plant tends to accumulate heavy metals in its body. Several studies have revealed that *Utricularia vulgaris* has the ability to absorb heavy metal content in water. The ability of *U. vulgaris* was proven in both research conducted by Maksimović et al. (2019) and Azeez (2021).

Table 2. Heavy metal content in *Utricularia vulgaris*/kg (Maksimović et al., 2019)

Heavy metal	Unit	Heavy metal content	Absorbed heavy metal
Fe	mg/kg	616.66-620	1.184

Mn	mg/kg	189.99-355.83	620
Zn	mg/kg	51.66-71.66	39-55
Cu	mg/kg	2.83-17.72	1.70-1.18

Research conducted by Maksimović et al. (2019) reported that 1 kg of *U. vulgaris* has the highest absorption capability of up to 1.184 mg/kg Fe in the environment, with a total contamination of 616.66-620 mg/kg, as well as other heavy metal content (Mn, Zn, and Cu) (**Table 2**). Heavy metal absorption by *U. vulgaris* also showed quite high results in other heavy metal content, namely Zn, Mn, and Cu, as evidenced by research performed by Azeez (2021). The results of this study also encompassed the ability of *U. vulgaris* to absorb heavy metal content in the waters. This is emphasized by the presence of each heavy metal in *U. vulgaris* tissue. According to the results obtained, *U. vulgaris* can reduce 68.49% of heavy metal content within 21 days. This result is higher than the reduction ability of other plants, which in this study used *Lemna minor L.* Other members of the genus *Utricularia* are also known to have the potential to be bioaccumulators of heavy metals, such as *U. aurea*. Similar studies also showed that *U. aurea* could absorb up to 90% Cu^{2+} (Akbar et al., 2017).

The ability of *U. vulgaris* to absorb heavy metals is due to the transfer of heavy metals into the organism's body, cells, tissues, and organs. This transfer mechanism can occur directly in an organism with a polluted environment. Heavy metals can be absorbed through heavy metals to cell walls or metal precipitation so that metals can accumulate in plant tissues (Kurniawan & Mustikasari, 2019). There are several mechanisms for absorbing environmental heavy metals in plants, such as the phytoremediation mechanism. One of the mechanisms is phytoaccumulation, which is carried out by aquatic macrophytes, such as *U. vulgaris* (Rezania et al., 2016). Heavy metals will be absorbed by plant surfaces, such as roots, stems, and leaves. Each plant has the ability to tolerate certain types of contaminants, but there are also those that have tolerance to several types of contaminants, such as *U. vulgaris*, which has tolerance to several types of contaminants (Zhang et al., 2020), making it reckoned as potential bioaccumulators.

CONCLUSION

Utricularia vulgaris has the ability to absorb heavy metals in a very high environment. Heavy metals, comprising zinc (Zn), iron (Fe), copper (Cu), and manganese (Mn), have the potential to disrupt water quality and harm aquatic organisms. The impact of heavy metals on organisms varies, from changing water colour to causing toxicity and inhibiting growth. *U. vulgaris* can be an alternative and potential in freshwater remediation efforts that are getting longer and minimize environmental impact. *U. vulgaris*, a flowering carnivorous plant, has shown a positive potential to absorb heavy metals, especially in aquatic environments. Studies have shown that *U. vulgaris* can accumulate heavy metals, such as Mn, Zn, Fe, and Cu. *U. vulgaris* shows a high level of tolerance to these pollutants. The phytoaccumulation mechanism in *U. vulgaris* offers potential applications in phytoremediation to absorb these metals.

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