Water hyacinth (*Eichhornia crassipes*) as a phytoremediator for organochlorine pollutants in Lake Tondano

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Abstract. The aim of this research was to assess the absorption capacity of water hyacinth *Eichhornia crassipes* to organochlorine pollutants. Samples of water hyacinth taken were the whole plants consisting of roots, leaves and stems from Lake Tondano. Samples obtained were placed in plastic containers and then transported to the Pharmacy Laboratory of the Faculty of Mathematics and Natural Sciences (MIPA UNSRAT) for analysis. The samples namely root, leaves and stems each were ground and then put into 2 Erlenmeyer flasks, each containing 10 g. The sample in the first Erlenmeyer was not added with a standard solution, while in the second Erlenmeyer, 1 mL of 60 ppm NaCl standard solution was added and then filtered. Afterwards, a total of 100 mL of filtrate of each sample was added with 25 mL of HCl, then destructed for 2 hours with 5 mL of nitric acid repeatedly until the solution was clear, then filtered. Then, 0.1 mL of the sample solution was taken and 10 mL of reagent was added. The solution was mixed, and heated at 37^{o}C for 5 minutes, and measured its absorbance using a UV−Vis 1800 spectrophotometer at maximum wavelength. Then, the absorbance data was used to create a standard curve to obtain the line equation of $y = a + bx$, which was then used to measure the absorbance capacity of water hyacinth. This research proved that water hyacinth was able to adapt and absorb organochlorine pollutant in water. The highest absorption capacity of water hyacinth to organochlorine pollutant was found in roots. As conclusion, the water hyacinth plant is capable of absorbing persistent organic pollutants (POPs) in waters.
Key Words: absorption capacity, environmentally friendly, organochlorine, phytoremediation.

Introduction. *Eichhornia crassipes*, commonly known as water hyacinth, is a very fast-growing aquatic plant and very difficult to control. This plant originates from South America, and then has spread to Africa, Asia, the South Pacific, North America and Europe, where it became invasive (Kriticos et al 2016; Jones et al 2018). Water hyacinth is one of the aquatic plants that has attracted the most scientific interest in the last decade. This plant is able to absorb various pollutants that pollute water, such as toxic metals, organic pollutants, industrial waste, agricultural waste, and domestic and household waste (Misbahuddin & Fariduddin 2002; Ghabbour et al 2004). Its great ability to reproduce has become a real problem in tropical areas, where high temperatures and a lack of predators cause its development to go uncontrolled (De Laet et al 2019). In Europe, it was recently included in the list of invasive alien species through Regulation No 2016/1141 13 July 2016 JOUE No L 189, 14 July (Piria et al 2017; De Laet et al 2019). One hundred and nine scientific articles have described this problem (De Laet et al 2019). Water hyacinths thrive in polluted waters and actually consume a lot of water and take over entire ecosystems. Water hyacinth is used as a phytoremediator agent because this plant has the ability to absorb nutrients, organic compounds and other chemicals from wastewater in large quantities (Slak et al 2005).

These chemical pollutants are referred to as persistent organic pollutants (POPs) (Ashraf et al 2015). Terrestrial and aquatic systems are usually exposed to such pollution, probably due to run-off of contaminated effluent from agricultural and industrial activities (Anasco et al 2010; Olisah et al 2019).

POPs have a long half-life in soil, sediment, air and biota. There is no consensus about how long the half-life in a particular medium is for the term persistent to be applied, however, the half-life of POPs can be years or decades in soil/sediments and several days in the atmosphere (Ashraf 2017). The carbon-chlorine bond is very stable against hydrolysis and a greater amount of chlorine substitutions and/or functional groups causes greater resistance to biological and photolytic degradation because POPs decompose very slowly (Chu et al 2006). POPs in the environment are transported at low concentrations through the movement of fresh and marine water. In addition, because they are semi volatile, POPs are transported long distances in the atmosphere. The result is a widespread distribution of POPs throughout the world, including regions where POPs have never been used (Buccini 2003). The levels of POPs observed in the Arctic region surprised many people because some of these pollutants have been banned from the US and Canada for years. POPs travel to colder areas such as Alaska and then sink due to colder temperatures. These contaminants remain in the area for a long time because the temperature does not allow them to decompose easily (Muir & de Wit 2010). As a result, they move from air and water to soil and plants, then to animals and humans easily (Hung et al 2016). The persistence of contaminants in the Arctic from distant sources was first revealed in the late 1970s when pesticides were discovered in the fatty tissue of polar bears. The reality of atmospheric POPs and their effects on wildlife and human health then became evident. In addition to the Arctic, researchers have begun looking for evidence of airborne POPs in cold ecosystems and environments (Devi 2020).

To create phytoremediation technology and be environmentally friendly, plants must have characteristics such as fast growth rates, high biomass yields, uptake of large amounts of pollutants, the ability to transport pollutants above the soil surface, and mechanisms to tolerate pollutant toxicity (Arslan et al 2017; Burges et al 2018). Research reports showed water hyacinth is used to remove pollutants because of its ability to grow in highly polluted water (Roy & Hänninen 1994; Ebel et al 2007; Sarkar et al 2017; Mahalakshmi et al 2019; Singh & Balomajumder 2021). In water hyacinth plants, biochemical parameters such as chlorophyll, protein and sugar content are indicated to experience a decreasing trend due to the uptake of phenol and cyanide during cultivation. Toxicity to 100-1000 mg L^{-1} phenol and 10-100 mg L^{-1} cyanide was measured by measuring relative transpiration over 13 days. At 100 mg L^{-1} phenol and 10 mg L^{-1} cyanide, there was only a slight decrease in transpiration but no morphological changes were seen. Both pollutants were absorbed through the roots of water hyacinth plants by the plasmalemma and accumulated into plant root and stem cells (Singh & Balomajumder 2021). The aim of this research was to assess the absorption capacity of water hyacinth to organochlorine pollutants.

Material and Method

Research location. The research location was Lake Tondano, Lelejo village, Remboken District, Minahasa Regency, North Sulawesi Province (Figure 1).

Sample collection. Water hyacinth samples were taken in July 2023 from the waters of Lake Tondano. This species was found abundantly in this lake. The samples taken were the whole plants consisting of roots, leaves and stems, with a height of 30 cm and a weight of 500 g. Total number of samples collected was 25 specimens. Samples obtained were placed in plastic containers and then transported to the Pharmacy Laboratory of the Faculty of Mathematics and Natural Sciences (MIPA UNSRAT) for analysis.

Research procedure and analysis of pesticide. The water hyacinth was acclimatized in a container for 1 day and then transferred into 18 containers containing different organochlorine concentrations, namely 0, 1, 2, 4, 6, and 8 ppm, each with 3 replications (U1, U2, U3). The exposure time was 12 days, after which samples were taken and the roots, leaves, and stems were separated to analyze their absorption capacity for organochlorine pollutants exposed.

The sample of roots was ground and then put into 2 Erlenmeyer flasks, each with 10 g of root powder. The sample in the first Erlenmeyer was not added with a standard solution, while in the second Erlenmeyer, 1 mL of 60 ppm NaCl standard solution was added. Afterward, a desired solution was taken and then filtered. A similar procedure was conducted for leave and stem samples.

Afterward, a total of 100 mL of filtrate of each sample was added with 25 mL of HCl, then destructed for 2 hours with 5 mL of nitric acid repeatedly until the solution was clear, then filtered. Then, 0.1 mL of the sample solution was taken and 10 mL of reagent was added. The solution was mixed, and heated at 37^{o}C for 5 minutes, and measured its absorbance. The absorbance of each sample was read at 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, and 10 minutes using a UV−Vis 1800 spectrophotometer at maximum wavelength. Then, the absorbance data was used to create a standard curve to obtain the line equation:

The simple linear regression formula is as follows:

$$y = a + bx$$

where: y = dependent variable;
x = independent variable;
a = constant;
b = regression coefficient.

The pesticide content of each sample was then calculated using this equation (Rahayu et al 2009).

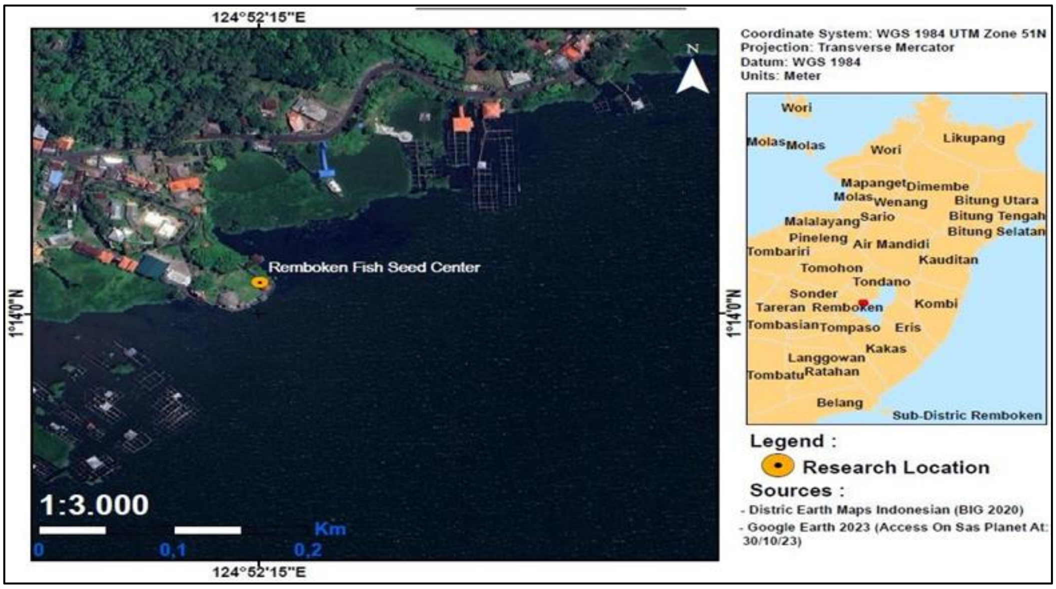

Figure 1. Map of sampling locations.

Results and Discussion. The absorbance values of root, leave and stem of water hyacinth measured using a spectrophotometer are presented in Tables 1, 2 and 3.

Table 1

Absorbance value of water hyacinth root exposed to organochlorine pollutants at different concentration

Organochlorine concentration (ppm)	*Absorbance*		
	U1	*U2*	*U3*
1	0.066	0.069	0.067
2	0.069	0.071	0.069
4	0.078	0.077	0.071
6	0.076	0.079	0.077
8	0.079	0.081	0.085
Control	0	0	0

U1, U2, U3: replications.

Table 2

Absorbance value of water hyacinth leave exposed to organochlorine pollutants at different concentration

Organochlorine concentration (ppm)	*Absorbance*		
	U1	*U2*	*U3*
1	0.031	0.032	0.032
2	0.033	0.035	0.036
4	0.036	0.037	0.035
6	0.039	0.039	0.041
8	0.042	0.045	0.043
Control	0	0	0

U1, U2, U3: replications.

Table 3

Absorbance value of water hyacinth stem exposed to organochlorine pollutants at different concentration

Organochlorine concentration (ppm)	*Absorbance*		
	U1	*U2*	*U3*
1	0.041	0.044	0.044
2	0.046	0.048	0.051
4	0.053	0.054	0.057
6	0.059	0.061	0.063
8	0.066	0.069	0.041
Control	0	0	0

U1, U2, U3: replications.

Based on the absorbance values, a standard curve was created to calculate the organochlorine levels in roots, stems and leaves. The organochlorine levels obtained were then used as a measure of absorption capacity the water hyacinth to organochlorine pollutants. The organochlorine levels in roots, leaves and stems were presented respectively in Tables 4, 5 and 6.

The highest absorption capacity value was found in the 8-ppm organochlorine treatment with a value of 1.12103 ppm (Table 4). It seemed that the higher the organochlorine concentration exposed to the water hyacinth plant, the higher the absorption capacity value of the root.

Table 4

Organochlorine pollutants levels in roots

Organochlorine concentration (ppm)	*Replications*			*Mean absorption (ppm)*
	U1	*U2*	*U3*	
1	0.88000	0.92615	0.89538	0.90051
2	0.92615	0.95692	0.92615	0.93641
4	1.06462	1.04923	0.95692	1.02359
6	1.03385	1.08000	1.04923	1.05436
8	1.08000	1.11077	1.17231	1.12103
Control	-0.13538	-0.13538	-0.13538	-0.13538

U1, U2, U3: replications.

Based on Table 5, the highest absorption capacity value was achieved at a concentration of 8 ppm with a value of 0.53128 ppm. As in the root, the higher the organochlorine concentration exposed to the water hyacinth plant, the higher the absorption capacity value of the leave.

Table 5

Organochlorine pollutants levels in leaves

Organochlorine concentration (ppm)	*Replications*			*Mean absorption (ppm)*
	U1	*U2*	*U3*	
1	0.34154	0.35692	0.35692	0.35179
2	0.37231	0.40308	0.41846	0.39795
4	0.41846	0.43385	0.40308	0.41846
6	0.46462	0.46462	0.49538	0.47487
8	0.51077	0.55692	0.52615	0.53128
Control	-0.13538	-0.13538	-0.13538	-0.13538

U1, U2, U3: replications.

Based on Table 6, the highest absorption capacity value shown by the highest organochlorine concentration was found at 6 ppm treatment with a value of 0.80308 ppm. At higher concentration that was at 8 ppm, the absorption capacity value tended to decrease slightly.

Table 6

Organochlorine pollutants levels in stems

Organochlorine concentration (ppm)	*Replications*			*Mean absorption (ppm)*
	U1	*U2*	*U3*	
1	0.49538	0.54154	0.541538	0.52615
2	0.57231	0.60308	0.649231	0.60821
4	0.68000	0.69538	0.741538	0.70564
6	0.77231	0.80308	0.833846	0.80308
8	0.88000	0.92615	0.495385	0.76718
Control	-0.13538	-0.13538	-0.135385	-0.13538

U1, U2, U3: replications.

This research proved that water hyacinth was able to adapt and absorb organochlorine pollutant in water. The results of this study showed that the highest absorption capacity of water hyacinth to organochlorine pollutant was found in roots (Table 4) while the lowest capacity was found in leaves (Table 5). Plants absorbed POPs from the environment and translocated them into different tissues (Chu et al 2006; Germaine et al 2006; Arslan et al 2017). The uptake of POPs in plants depends on a number of physicochemical characteristics of the compounds (Campanella et al 2002; Admire et al 2015; Zhan et al 2015). Unyimadu et al (2018) stated the pollutant levels in aquatic biota should reflect concentrations in their environment, therefore it is important to be investigated to ensure safe water bodies.

The main pathways for POP absorption can be direct absorption by plant roots, evaporation from the soil and absorption by leaves, or directly from the surrounding atmosphere (Smith & Jones 2000; Arslan et al 2017). Although POPs can enter plants through roots and leaves (Wang & Liu 2007), most of them are taken up by roots and translocated to the aboveground parts (Chen et al 2010; Sarkar et al 2017). Because POPs are man-made chemicals, protein-specific transporters for their transport do not exist in plants, hence, their uptake by roots occurs by simple diffusion through the cell walls from where they enter the xylem stream (Chekroun et al 2014). Different plant species can differentially absorb POPs at different rates (Mikes et al 2009). According to Ficko et al (2010), factors to be considered when assessing plants to determine their potential as phytoremediators include the contaminant type, availability and concentration in the soil, the ability of the plant to transport the contaminant from the soil or water into different tissues, and the plant biomass production in a given area and within a given time period. Organochlorine pesticides are POPs which have slow biodegradation and mobility in biotic and abiotic environments (Burkow & Kallenborn 2000; El Nemr & El-Sadaawy 2016; Mwevura et al 2020). Organochlorine insecticides were widely used in the mid-1940s to mid-1960s to control malaria-carrying mosquitoes and termites. Since organochlorines were discovered to persist in the environment and accumulate in large quantities in various organisms, including humans, their use has been drastically reduced. Many organochlorine compounds have been banned for use in the United States, and the Environmental Protection Agency has restricted their use. Apart from that, the possibility of experiencing bioaccumulation and biomagnification in the environment is also large (Zhao et al 2009; Wang et al 2015; Olisah et al 2019).

Conclusions. Based on the results obtained, it can be concluded that the water hyacinth plant (*Eichhornia crassipes*) is capable of absorbing organochlorine pollutants with the highest absorption being in the water hyacinth roots while the lowest capacity was found in leaves. The pollutant levels in water hyacinth should reflect concentrations in their environment, therefore it is important to be investigated to ensure safe water bodies.

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Conflict of interest. The authors declare that there is no conflict of interest.

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