# Identification of Riparian Plants Potential for Remediation and Water Quality Monitoring in The Downstream of Brantas River, East Java

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**Abstract**

Indonesia is home to an extraordinarily diverse range of plant and animal species, particularly in vital wetland, riparian, and aquatic areas crucial for watershed ecosystems. For example, the Brantas River system, located in East Java, plays a pivotal role in sustaining regional biodiversity. However, the river system is currently under threat from degradation and escalating river pollution. This underscores the pressing need to document and inventory its plant diversity. This study specifically focuses on the downstream area of the Brantas River, aiming to identify riparian seed-plants and assess their potential in remediating pollutants. Additionally, the research evaluates water quality in the downstream region. Conducted from November 2020 to February 2021 using an observational method with a descriptive explorative approach, the study identified 14 seed-bearing plant species in the downstream area. Although certain water quality parameters met established standards, elevated levels of heavy metals such as lead, copper, and chromium exceeded permissible limits. Notably, 12 out of the 14 identified plant species demonstrated the ability to absorb heavy metals from the environment

**Keywords**: Brantas River, conservation, phytoremediation, plant, riparian.

## Introduction

Water is one of the most essential natural resources for human and ecosystem's life around the world. A healthy water is an important prerequisite for protecting public health and environmental sustainability (Li & Wu, 2019). Unfortunately, the problem of water pollution is currently massive and has become a deepening global concern. Water pollution can be caused by various sources, such as industrial waste, intensive agriculture, and domestic waste (Yunasfi & Singh, 2019). Water pollution may threaten the existence of aquatic ecosystems, and even human health and well-being (Madhav et al., 2020). One of the ecosystems that is vulnerable to water pollution is the river's ecosystem, particularly in the downstream (Suresh Raj & Mohan Viswanathan, 2023). Whereases, in alignment with the 3rd and 6th point of Sustainable Development Goals (SDGs), which respectively focus on good health and well-being, and clean water and sanitation, it is the most important to addressing water pollution in river's ecosystems.

The Brantas River is the longest river in the province of East Java in Indonesia. The reason why it called the longest river is because the Brantas River passes through several cities, including Malang, Blitar, Tulungagung, Kediri, Jombang, Mojokerto, Sidoarjo, and Surabaya (Mariyanto *et al.*, 2019). This river has an important role in providing water for various purposes such as agricultural irrigation, industrial irrigation, and water supply for the people who live near the river (Roestamy & Fulazzaky, 2021). According to the Regulation of the Minister of Public Works and Public Housing regarding the Pattern of Management of Water Resources in the Brantas River Basin in 2020, by the year of 2015, there were 18,166 million people residing on this river basin, which was counted as 46.7% of the total of East Java Population. Furthermore, Brantas River plays a significant role in supporting East Java's status as the national rice granary. In 2015, the rice production's total reached 1.69 million tons and representing 2.24% of Indonesia's total rice production.

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However, along with the rapid of industrial and agricultural development throughout the Brantas River, its water quality continues to decrease. Previous studies have reported that the Brantas River is currently polluted by various pollutants, including domestic and industrial waste (Roosmini *et al*., 2018). Furthermore, the results of the analysis of heavy metal levels in the Brantas river showed average values of Pb (2.63); Cd (1.09); Cu (0.74); Ni (0.40); Fe (0.26); Cr (0.10); and Mn (0.02) (Handayani et al., 2023). Therefore, it is important to selected the effective solutions of water pollution in the Brantas River.

One of the methods or techniques that can be used to overcome the water pollution is by using plants. This method is commonly known as the Phytoremediation method. The phytoremediation method refers to the ability of plants to accumulate pollutants in their bodies (Afifudin & Irawanto, 2022). It is because some types of plants have been proven to accumulate high levels of pollutants. These plants can be categorized as hyperaccumulator plants (Hidayati, 2020). However, one of the challenges of applying phytoremediation is the lack of information related to the potential and ability of each plant to remediate pollutants (Singh *et al*., 2022). In fact, information on potential plants is important in the further development of phytoremediation methods.

Therefore, this study aims to inventory Riparian plants in the downstream of the Brantas River and assess their ability to remediate pollutants. It is because the success of phytoremediation depends on the selection of suitable plants and wild plants may play an important role (Prabakaran *et al*., 2019; Singh & Fulzele, 2021). Native plants of the contaminated area have been found to have tolerance to a number of heavy metals/metalloids and accumulate them in significant quantities (Afifudin & Irawanto, 2023; Chandra et al., 2018; Vijaya Kumar & Kumara, 2014). In addition, this study also aim to evaluate water quality in the downstream of the Brantas River, East Java.

## Methods

### *Study Area*

This study was using observational method with descriptive explorative approach. The exploration conducted at several locations in the downstream of the Brantas River, East Java, Indonesia. from November 2020 until February 2021. In this study, the observed plants were restricted to only type of plants that produce seeds along the observation lines. For species identification purposes, the photographs of each plants that ecountered were taken by using a digital camera. Water sampling was conducted at multiple locations, including: 1. Kali Surabaya (-7.351324, 112.662447) 2. Kali Wonorejo (-7.307167, 112.822992) 3. Kali Gununganyar (-7.334110, 112.829239) 4. Kali Kalanganyar (-7.405224, 112.831004), and 5. Kali Porong (-7.534811, 112.851110). The selection of these locations was based on the various pathways of the Brantas River, as illustrated in Figure 1.

### *Analysis*

Water quality tests are carried out with the ROOBON water test kid instrument. The use of this instrument is considered sufficient to serve as an initial presumptive test of water quality in the downstream of the Brantas River. While the parameters were tested in this study include alkalinity, pH, Hardness, Lead, Copper, Chrome, and Sulfide. Then, the identification of plants began with guidance from experts and was subsequently confirmed using reference books to further characterize their morphology. The identification results, including the scientific names of the plants, then were validated by using an online database from the Plant of the World Online (POWO) website. To assess the potential of each plant for phytoremediation purposes, a literature review was conducted using various scientific platforms over the past ten years, which included Google Scholar, ScienceDirect, and Springer, among others.

The data about the types of plant, conservation statuses, water quality and plants phytoremediation ability, then

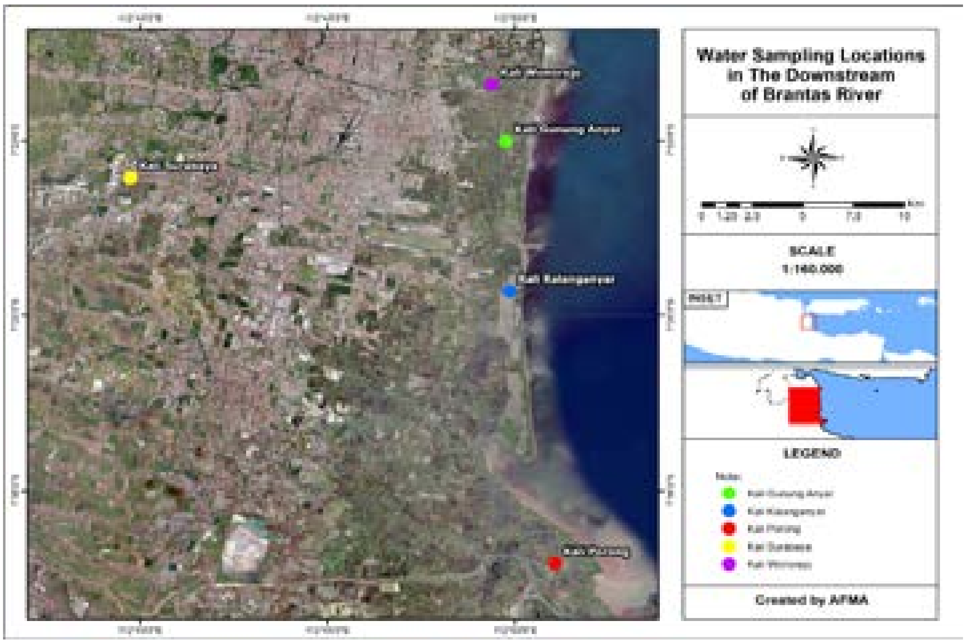


Figure 1. Location of water sampling

compared and presented in subsequent figures and tables, and analyzed using a descriptive qualitative method.

## Result

### *Riparian Plants in Downstream of Brantas River*

Table 1 represents the results of an exploration of seed-bearing plant species in the downstream area of the Brantas River, East Java. In this study, our focus lies on the selection of seed-bearing plant species. This is because seed-bearing plants are often easy to propagate, either through seeds or vegetative propagation, allowing for a more extensive application in phytoremediation to cover larger areas. Our identification have revealed a total of 14 seed-bearing plant species present in the downstream area of the Brantas River. The majority of the plant species we encountered belong to the herbaceous type. Moreover, of the five sampling locations conducted, the 5th location (Kali Porong) has the largest number of plant species with 10, while the 1st location (Kali Surabaya) has the lowest number, with only 3 species. Additionally, the images of each plant are showed in Figure 1.

### *Water Quality*

This study serves as preliminary research with the aim of assessing water quality at several locations situated downstream of the Brantas River in East Java. The analysis results are expected to represent two regencies and cities that are downstream of the Brantas River, Surabaya and Sidoarjo. Several parameters were tested, encompassing chemical parameters such as pH, hardness, alkalinity, sulfide, and heavy metals including copper (Cu), chromium (Cr), and lead (Pb). Overall, the water quality met the standards for several parameters, except for the heavy metal parameters. Detailed results of the water quality analysis can be found in Table 2.

### *Phytoremediation Ability*

Riparian plants, which are plants that grow along the banks of rivers and streams, have the ability to remove pollutants from water environments through a process called phytoremediation. This is because riparian plants have several characteristics that make them effective in phytoremediation, including rapid growth, high biomass, profound root systems, and the ability to accumulate high levels of pollutants in their

Table 1. List of Plants in the Downstream of Brantas River and Their Conservation

| No | Type of Plants | Local Name | Sampling location | | | | | Conservation status (IUCN) |
|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | |
| 1 | *Acacia farnesiana* | *Akasia manis, Bunga siam* | | | | **V** | **V** | Least Concern |
| 2 | *Acanthus ilicifolius* | *Jeruju, Daruju* | | **V** | **V** | | **V** | Least Concern |
| 3 | *Coix lacryma-jobi* | *Jali* | **V** | | | | | - |
| 4 | *Crotalaria juncea* | *Orok-rok* | | **V** | | **V** | | - |
| 5 | *Cyathula prostrata* | *Bayam pasir* | | | | **V** | **V** | - |
| 6 | *Dolichandrone spathacea* | *Mangrove terompet* | | | | | **V** | - |
| 7 | *Ipomoea carnea* | *Kangkung pagar* | **V** | | | | **V** | - |
| 8 | *Lannea coromandelica* | *Pohon kuda, Kayu jawa* | | **V** | | | **V** | - |
| 9 | *Neptunia plena* | *Mimosa air* | | | | **V** | | Least Concern |
| 10 | *Ruellia tuberosa* | *Kenvaca ungu, Pletekan* | **V** | **V** | | | | - |
| 11 | *Senna hirsuta* | *Sena berbulu* | | | **V** | | **V** | - |
| 12 | *Sonneratia caseolaris* | *Pidada merah, Perepat merah* | | **V** | **V** | | **V** | Least Concern |
| 13 | *Sesuvium portulacastrum* | *Krokot laut* | | **V** | **V** | **V** | **V** | Least Concern |
| 14 | *Thespesia populnea* | *Waru laut, Baru laut* | | | | | **V** | Least Concern |
| | Total | | **3** | **6** | **4** | **5** | **10** | |

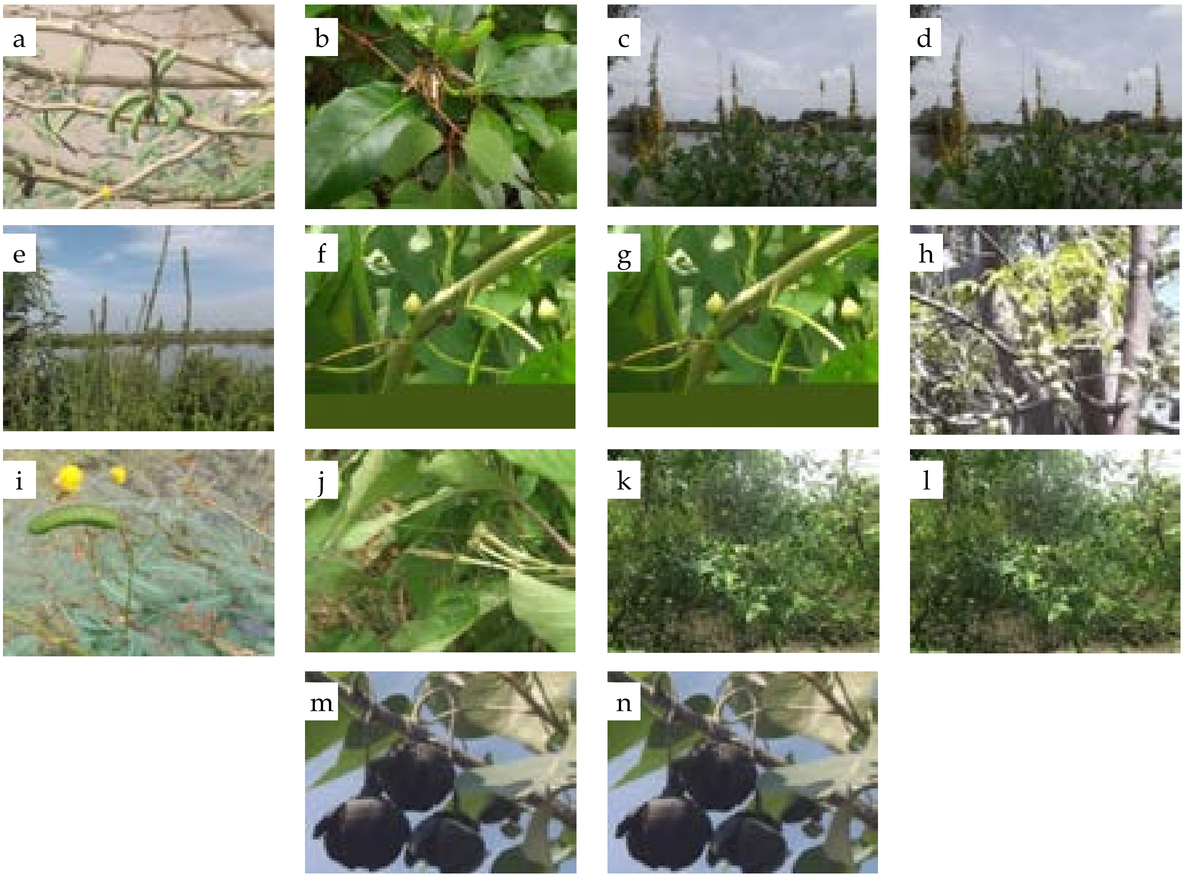


Figure 2. Riparian Plants in the Downstream of Brantas River (Private documentation, 2021): a. *Acacia farneciana*; b. *Acanthus ilicifolius*; c. *Coix Lacryma-jobi*; d. *Crotalaria juncea*; e. *Cyathula prostata*; f. *Dolichandrone spathaceae*; g. *Ipomoea carnea*; h. *Lannea coromandelica*; i. *Neptunia plena*; j. *Ruellia tuberosa*; k. *Senna hirsuta*; l. *Sonneratia caseolaris*; m. *Sesuvium portulacastrum*; n. *Thespesia populnea*.

Table 2. Water quality in the downstream of Brants river

| Parameters | Sampling location | | | | | Standard |
|---|---|---|---|---|---|---|
| | Main Surabaya | Wonorejo | Gununganyar | Porong | Kalanganyar | |
| Alkali (mg/L) | 120 | 120 | 120 | 120 | 130 | 500 |
| pH | 7,5 | 7,6 | 7,6 | 7,2 | 8,5 | 6-9 |
| Hardness (mg/L) | 125 | 250 | 250 | 250 | 250 | 500 |
| Lead (mg/L) | 50 | 20 | 20 | 50 | 20 | 0,03 |
| Copper (mg/L) | 8 | 10 | 1 | 1 | 10 | 0,02 |
| Chrom (mg/L) | 2 | 0 | 2 | 2 | 2 | 0,05 |
| Sulfide (mg/L) | 10 | 10 | 10 | 10 | 10 | 300 |

tissues (Nedjimi, 2021). Phytoremediation using riparian plants can be an effective and sustainable solution for removing pollutants from water environments in the downstream of a river. By using specific plant species and ecohydrological approaches, phytoremediation can help to improve water quality and protect the health of the ecosystem and human populations that depend on it. Therefore, table 3 below show the phytoremediation ability of riparian plants in the downstream of Brantas river.

**Discussion**

The Brantas River, located in East Java, Indonesia, is the longest river in the region, stretching for a total length of 320 kilometers. It originates from the southern slopes of Mount Kawi-Kelud-Butak, Mount Wilis, and the northern slopes of Mount Liman-Limas, Mount Welirang, and Mount Anjasmoro, covering a drainage area spanning over 11,000 square kilometers. The course of this river takes on a semi-circular or spiral pattern: starting at its source, it initially flows southeastward but gradually changes direction, curving south, then southwest, followed by a westward turn, a northern course, and ultimately meandering eastward as it divides into the Kalimas and Porong River.

Based on the table 1 above, it represents the results of an exploration of seed-bearing plant species in the downstream area of the Brantas River, East Java. In this study, our focus lies on the selection of seed-bearing plant species. This is because seed-bearing plants are often easy to propagate, either through seeds or vegetative propagation, allowing for a more extensive application in phytoremediation to cover larger areas. Our identification efforts have revealed a total of 14 seed-bearing plant species present in the downstream area of the Brantas River. The majority of the plant species we encountered belong to the herbaceous type.

In the Table 1 also shows the conservation status analysis results of each plant species. As observed in the table, several plant species have been documented in the International Union for Conservation of Nature (IUCN) database. Furthermore, if a species of plant is included in IUCN's work, it will be monitored and evaluated for its conservation status and vice versa. However, this does not mean that the species is not important for maintaining the biodiversity of the planet. All species, including plants, play a crucial role in the ecosystem and contribute to the health of the plane. Furthermore, Based in the table 1, it can be seen that six of fourteen plants in the downstream of Brantas river are included on the IUCN's database with "Least Concern" status. Refer on IUCN's website, if a species of plant is included in the IUCN Red List as "Least Concern," it means that the species has been evaluated against the Red List criteria and does not qualify for Critically Endangered, Endangered, or Vulnerable status. However, although Least Concern species have a lower risk of extinction, they are still important in maintaining the biodiversity of the planet, for example to environment remediation effort.

Next, in the table 2 presents the results of the analysis of several water quality parameters at various locations downstream of the Brantas River, then compared to the water quality standards that referenced from the Indonesian Government Regulation No.

Table 3. Ability of Riparian Plants for Phytoremediation

| No | Type of Plants | Phytoremediation Ability | References |
|---|---|---|---|
| 1 | *Acacia farnesiana* | Heavy metals Pb: 51.9 mg/L; and As: shoot 940 mg/L and root 4380 mg/L | (Alcantara-Martinez *et al.*, 2016; Maldonado-Magaña *et al.*, 2011) |
| 2 | *Acanthus ilicifolius* | Heavy metals Zn: 107 mg/L; Pb: 28.7 mg/L; Cu: 16.9 mg/L; As: 11.2 mg/L; Cr: 4.99 mg/L in leaves and Zn: 104.32 mg/L; Pb: 27.02 mg/L; Cu 15.29 mg/L; As: 10.39 mg/L; Cr: 3.80 mg/L in roots. In other reseacrh Cu roots has an average of 20.68 mg/L; in stem has an average of 8.51 mg/L ; and in leaves has an average of 5.75 mg/L. | (Rahman *et al.*, 2021) |
| 3 | *Coix lacryma-jobi* | Heavy metals Cr 280.94 ± 13.88 mg/L in roots, 67.05 ± 0.66 mg/L in stems and 78.85 ± 5.88 mg/L in leaves; Pb 8.197 mg/L in roots, 242.8 mg/L in stems, and 274.5 mg/L in leaves; Cd 194.1 mg/L in roots, 2.93 mg/L, and 18.1 mg/L in leaves. | (Fang *et al.*, 2022; Irawanto *et al.*, 2015) |
| 4 | *Crotalaria juncea* | Heavy metals Cd 73.82±2.20 mg/L; and Pb 25.333±0.034 mg/L | (Brito *et al.*, 2021; Thooppeng *et al.*, 2023) |
| 5 | *Cyathula prostrata* | Heavy metals Zn: 2.2 mg/L; Cu: 0.026 mg/L; Fe: 11.67 mg/L; and Pb: 0.59 mg/L. | (Adesuyi *et al.*, 2015) |
| 6 | *Dolichandrone spathacea* | - | |
| 7 | *Ipomoea carnea* | Heavy metals Fe: 741 mg/L; Mn: 154.05 mg/L; Cu: 20.75 mg/L; Pb: 6.75 mg/L; Ni: 4.0 mg/L; Cr: 3.3 mg/L; Cd: 0.05 mg/L. | (Pandey, 2020) |
| 8 | *Lannea coromandelica* | - | |
| 9 | *Neptunia plena* | Heavy metals As 30–60 mg/L; Cd roots 7.76 mg/L, stems 1.59 mg/L, and shoots 0.22 mg/L. Petroleum Liquid Waste. | (Atabaki *et al.*, 2020; Hardestyariki & Fitria, 2023; Syuhaida *et al.*, 2014) |
| 10 | *Ruellia tuberosa* | Heavy metals Hg leaves 0.107 mg/L; root 0.053 mg/L; and shoot 0.066 mg/L. | (Jameer Ahammad *et al.*, 2018) |
| 11 | *Senna hirsuta* | Heavy metals Pb in roots 72.71±2.18 mg/L; in stems 124.60±2.27 mg/L; and in leaves 282.40±3.79 mg/L. | (Udiba *et al.*, 2020) |
| 12 | *Sonneratia caseolaris* | Heavy metal Pb in root 4.83 mg/L, in stems 3.37 mg/L; in leaves 15.57 mg/L. In other study Pb 3.4 mg/L. | (Luthansa *et al.*, 2021; Rumanta, 2019) |
| 13 | *Sesuvium portulacastrum* | Heavy metals Cr 49.82 mg/L; Cd 22.10 mg/L, Cu: 35.10 mg/L and Zn 70.10 mg/L. | (Ayyappan *et al.*, 2016) |
| 14 | *Thespesia populnea* | Cu Zn Ni Mn Cr Cd Pb, Cu 4.5 mg/L; Zn 13.8 mg/L; Ni 42.5 mg/L; Mn 11.4 mg/L; Cr 0.5 mg/L; Cd 0.2 mg/L; Pb 21.5 mg/L. | (Kaewtubtim *et al.*, 2016) |

22 of 2021 concerning the Implementation of Environmental Protection and Management and the Guidelines for the Restoration of Contaminated Land with Hazardous Waste of 2018 issued by the Indonesian Ministry of Environment and Forestry. The analysis shows that the alkalinity values at all locations meet the standards well, remaining below the established threshold of 500 mg/L. Similarly, parameters such as pH, hardness, and sulfide at all research locations show results that conform to the established water quality standards. However, it is important to note that for all heavy metal parameters, all observation stations exceed the water quality standards, especially in the case of lead (Pb).

The analysis of lead (Pb) levels at all monitoring stations shows values that exceed the established threshold, with concentrations of 50 mg/L, 20 mg/L, 20 mg/L, 50 mg/L, and 20 mg/L, respectively. Similarly, the copper (Cu) levels at the observation stations also surpass the permissible limit, registering concentrations of 8 mg/L, 10 mg/L, 1 mg/L, 1 mg/L, and 10 mg/L, respectively. However, for chromium (Cr), the analysis results reveal lower values, specifically 2 mg/L, 0 mg/L, 2 mg/L, 2 mg/L, and 2 mg/L, respectively. Therefore, based on these findings, it can be inferred that there is no heavy metal contamination in the form of chromium in Wonorejo, while heavy metal pollution, including lead, copper, and chromium is present at all locations.

Based on the several research, heavy metals such as Pb, Cu, and Cr can come from various sources, including mining and smelting activities, waste disposal, and anthropogenic pollutants (Rong *et al*., 2023; Sudarningsih *et al*., 2023). When heavy metals such as Pb, Cu, and Cr pollute water environments, they can have detrimental effects on the ecosystem and human health. In the downstream of the river, heavy metals can accumulate in sediments and aquatic organisms, which can lead to bioaccumulation and biomagnification in the food chain (Kadim & Risjani, 2022). This can result in the contamination of fish and other aquatic organisms, which can pose a risk to human health if consumed. Heavy metals can also cause damage to the liver, kidneys, and other organs in humans and animals, as well as affect the growth and reproduction of aquatic organisms (Yap & Al-Mutairi, 2022).

Then, on the table 3 that have been mentioned above, it shows the remediation ability of each riparian plants in the downstream of Brantas river. From 14 types of plants that collected, just 2 two plants that haven't ability for environment remediation, those plants are *Dolichandrone spathacea* and *Lannea coromandelica*. This result shows that almost riparian plants have the ability of environment remediation. In Table 3 we also can see that almost pollutants that found in the downstream ecosystem are heavy metals.

The result of this study was shows that heavy metals are a common type of pollution that is discovered in the downstream of rivers. This is due to several factors, including natural resource, human activities, and urbanization (He *et al*., 2020; United States Environmental Protection Agency, 2023). Furthermore, when heavy metals pollute water environments, they can have detrimental effects on the ecosystem and human health. In the downstream of the river, heavy metals can accumulate in sediments and aquatic organisms, which can lead to bioaccumulation and biomagnification in the food chain (Jin *et al*., 2022). This can result in the contamination of fish and other aquatic organisms, which can pose a risk to human health if consumed (Abotalib *et al*., 2023). Heavy metals can also cause damage to the liver, kidneys, and other organs in humans and animals, as well as affect the growth and reproduction of aquatic organisms (United States Environmental Protection Agency, 2023).

Therefore, it is important to monitor and control the sources of heavy metal pollution in water environments, especially in the downstream of the river. This can be done through the implementation of regulations and policies to reduce waste disposal and control mining and smelting activities. Additionally, regular monitoring of water quality and the health of aquatic organisms can help to identify and mitigate the effects of heavy metal pollution in water environments.

**Conclusion**

Following observations conducted in the downstream area of the Brantas River in East Java, 14 seed-bearing plant species were identified. The analysis of water quality revealed that most parameters such as alkalinity, pH, hardness, and sulfide met the established water quality standards. However, there were excessive levels of heavy metals, including lead (Pb), copper (Cu), and chromium (Cd), exceeding the standard limits. Furthermore, among the 14 seed-bearing plant species identified, 12 of them are known to possess the capability to absorb heavy metals in the environment.

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