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# Effectiveness of *Sagittaria lancifolia* as Detergent Phytoremediator

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## ABSTRACT

The extensive use of detergent causes a high level of it to contaminate water body. This study was aimed to determine the effectiveness of the *Sagittaria lancifolia* plant as a phytoremediator for water contaminated with detergents. *Sagittaria lancifolia* was planted in medium exposed to detergent at various levels (10, 50, 75 ppm) with two different detention times (7 and 14 days). Remediated water was tested of its toxicity using *Xiphophorus maculatus*. LAS removal rate, BOD, plant morphology, and mortality of *X. maculatus* were recorded. The result showed that *S. lancifolia* had a high level of LAS removal rate, the longer detention time (81.53 ± 0.37% at 14 days) with significantly lower BOD (27.48 ± 0.78mg/L). Plant leaves showed signs of necrosis and chlorosis during detergent exposure. Detergent water remediated for 14 days induced the lowest rate of mortality in *Xiphophorus maculatus*. Thus, *Sagittaria lancifolia* can be applied to remove the organic contaminant from the water body.

## INTRODUCTION

Water pollution is generally caused by anthropomorphic activities around water bodies. The higher human population leads to more waste disposed to the environment, causing pollution level to be increased. Waste can be originated from domestic or industrial activities. The domestic activities result in waste with high organic content. Without proper management, this type of waste can potentially contaminate water and endanger the aquatic organisms in ecosystems.

One of the causing factors of water pollution is detergent waste from domestic areas. Detergent is a soap compound formed through chemical processes. Generally, the main component composing detergent is natrium dodecyl benzene sulfonate (NaDBS) and sodium tripolyphosphate (STPP), both of which are difficult to be degraded naturally. NaDBS and STPP can form a precipitate with alkaline soil and transitional metals (Herlambang & Hendriyanto 2015). Surfactant types commonly used in detergent are anionic surfactant Alkyl Benzene Sulfonate (ABS) or Linear Alkylbenzene Sulfonate (LAS).

Detergent is a synthetic cleaner composed of petroleum derivative materials. Detergent is widely used due to its better cleaning ability compared to soap and not affected by water salinity. Generally, detergent contains surfactants, builders, fillers, and additives. Overuse of detergents can be dangerous to humans as it is a skin irritant. It can also endanger the environment; the decrease of water quality due to LAS affects the aquatic organisms living in it (Kamiswari 2013).

High level of detergent in water can lower oxygen level. At a concentration of 0.5 mg/L, detergent was found to form suds that inhibited oxygen diffusion to the water surface (Rochman 2016). Previous findings reported that average surfactant concentration in domestic wastewater could reach up to 10 mg/L (Scott & Jones 2000). The presence of excessive detergent is signified with soap foams on the water surface (Rochman 2009).

Phytoremediation is the application of plant to extract, accumulate, or detoxify pollutants. This technique is considered as a novel technique to cleanse the environment. Plants are ideal agent to improve land and water, because of their unique genetic properties, both form biochemical and physiological facets (Sidauruk & Sipayung 2015). The ability of aquatic plants to reduce water pollution has been studied extensively, including *Sagittaria lancifolia* (Melinda Paz-Alberto & Sigua 2013). *Sagittaria lancifolia* is a species of aquatic plants endemic to tropical regions, including Indonesia. A previous study found that this species was able to survive detergent-polluted water up to concentration 0.15 g/L (Adistiara et al. 2019) thus *S. lancifolia* was hypothesized to have potential in phytoremediation of detergent.

The safety of water after remediation using plants is rarely examined, whether it has become safe for water organisms or not. As fishes can show response to the presence of pollutants in water, they can be used as a bioindicator of safe water. *Xiphophorus maculatus*, a species of tropical fish, was previously shown to have sensitivity towards contaminant potassium chloride (Santos Oliveira et al. 2018), but no previous study had examined the response of this species towards detergent. Thus, we examined the ability of *Sagittaria lancifolia* to remediate detergent-contaminated water and the safety of remediated water using *Xiphophorus maculatus* in this study.

## MATERIALS AND METHODS

This study was an experimental laboratory study. *Sagittaria lancifolia* used was taken from the original collection of Purwodadi Botanical Garden, Indonesia. The plants were acclimatized first for 14 days in an aquarium filled with 4 L of distilled water medium with additional nutrients. After that, plants were rinsed before put into the aquarium filled with 4 L aquatic planting medium added with various levels of detergent (10 ppm, 50 ppm, 75 ppm). Planting medium was first measured for its LAS level to ensure the detergent level. Control was planting medium without *S. lancifolia*. Each concentration of detergent was replicated thrice. Level of LAS was examined at two different detention times; 7 and 14 days. Water quality parameters like temperature and acidity were recorded at the end of the experiment.

Resulting water after phytoremediation using *S. lancifolia* was tested of its safety by performing toxicity test on *X. maculatus*. Fish sized ± 4-6 cm were first acclimatized in 10 L aquarium filled with 5 L water for three days. Fish were given commercial feed daily during acclimatization and then fasted for two days during the pre-treatment period. For treatment, as much as 10 fishes were put into a plastic container filled with 1.5 L water resulted from phytoremediation at various concentrations of the detergent. Each treatment was replicated three times. Mortality of fish was evaluated at 24 h, 48 h and 72 h.

Level of LAS removal and BOD were analysed statistically using one-way ANOVA and continued using the Duncan test. Leaf morphological change and fish mortality were analysed descriptively.

## RESULTS AND DISCUSSION

### Phytoremediation of the Detergent Using *Sagittaria lancifolia*

Results showed that *S. lancifolia* was able to remove LAS significantly compared to control (Table 1). Level of detergent in control did not change, but different initial detergent level resulted in significantly different LAS removal rate using *S. lancifolia*. The higher the detergent concentration at the start and the longer the detention time, the higher the rate of LAS removal by *S. lancifolia*. The temperature did not show much difference between phytoremediated and non-phytoremediated water, but pH was lowered slightly, from the range of 7 to 8 in phytoremediated water, both at 7 and 14 days detention time.

*Sagittaria lancifolia* was able to remove LAS from planting medium. At 75 ppm, *S. lancifolia* was able to

Table 1: Rate of LAS removal and BOD of detergent-contaminated water.

| Group | Detergent level (ppm) | LAS removal rate (%) | BOD (mg/L) |
|---|---|---|---|
| Control 7 days | 10 | $1.14 \pm 0.01^{a}$ | $29.37 \pm 0.38^{a}$ |
| | 50 | $1.27 \pm 0.02^{a}$ | $29.40 \pm 0.25^{a}$ |
| | 75 | $1.33 \pm 0.01^{a}$ | $29.57 \pm 0.16^{a}$ |
| Plant 7 days | 10 | $71.65 \pm 0.21^{b}$ | $26.90 \pm 0.69^{bc}$ |
| | 50 | $73.44 \pm 0.17^{c}$ | $28.08 \pm 0.42^{d}$ |
| | 75 | $77.43 \pm 0.85^{e}$ | $28.10 \pm 0.79^{d}$ |
| Control 14 days | 10 | $1.20 \pm 0.01^{a}$ | $29.22 \pm 0.15^{a}$ |
| | 50 | $1.61 \pm 0.01^{a}$ | $29.48 \pm 0.25^{a}$ |
| | 75 | $2.63 \pm 0.01^{a}$ | $29.60 \pm 0.44^{a}$ |
| Plant 14 days | 10 | $75.57 \pm 0.31^{d}$ | $25.55 \pm 0.94^{e}$ |
| | 50 | $76.53 \pm 0.56^{e}$ | $26.18 \pm 0.99^{be}$ |
| | 75 | $81.53 \pm 0.37^{f}$ | $27.48 \pm 0.78^{cd}$ |
| Standard* | | - | 100 |

(*) Standard based on Regulation of East Java Governor No. 72 year 2013.
Different letters indicated statistical difference based on Duncan test ($\alpha = 0.05$).

remove up to 77.43% of LAS at 7 days and 81.53% at 14 days of detention time. Similarly, BOD was also lowered significantly after using plants compared to control. LAS was taken from the medium by plant roots, which would then be translocated to the upper part of the plants (Grøn et al. 2000). Besides, LAS was also lowered through microorganism activity in roots of plants, which degraded LAS in the medium. Thus, a longer period of detention time, microorganisms could degrade the higher level of LAS, decreasing LAS in the medium. Aquatic plants also can effectively absorb various pollutants, such as heavy metals and organic contaminants, due to their hairy roots (Rachmadiati et al. 2018).

As LAS translocated to the upper part of the plant body, this resulted in alteration of plant organs. During the experiment period, morphological changes could also be observed from the leaves of *S. lancifolia.* Alteration of leaves morphology from 7 and 14 days course from 75 ppm detergent exposure is presented in Fig. 1.

The toxicity of LAS on *S. lancifolia* induced senescence to leaves, as indicated by chlorosis and necrosis. This change could be particularly clearly observed in 75 ppm detergent concentration. Leaf colour was turned from green to yellow to brown, while leaf surface was gradually shrivelled. LAS accumulation to leaf caused the change of lipid composition, resulting in lowered production of chlorophyll, plastoquinone, and carotenoid, as well as $NADP^+$ activity. This decrease would decrease electron transport to chloroplast and the disruption of the Calvin cycle, lowered metabolism and slowed plant growth (Sharma & Dubey 2005).

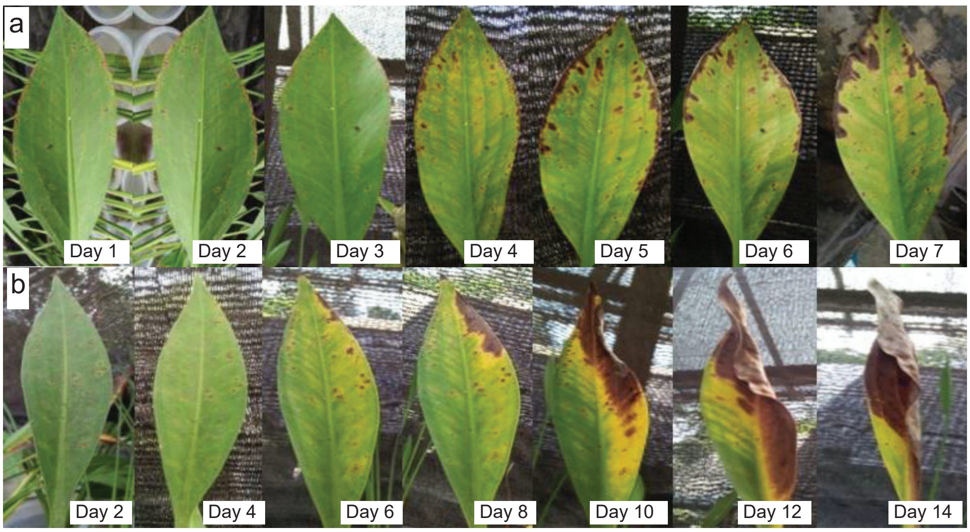


Fig. 1: Morphological change in *Sagittaria lancifolia* leaf during exposure to 75 ppm detergent for (a) 7 days and (b) 14 days.

Table 2: Mortality level of *X. maculate* in remediated detergent-contaminated water.

| Group | Detergent concentration (ppm) | Mortality (%) | | |
|---|---|---|---|---|
| | | 24 h | 48 h | 72 h |
| Control 7 days | 10 | 0 | 40 | 60 |
| | 50 | 0 | 60 | 40 |
| | 75 | 100 | 0 | 0 |
| Plant 7 days | 10 | 0 | 0 | 0 |
| | 50 | 0 | 20 | 0 |
| | 75 | 40 | 0 | 0 |
| Control 14 days | 10 | 0 | 40 | 60 |
| | 50 | 0 | 60 | 40 |
| | 75 | 100 | 0 | 0 |
| Plant 14 days | 10 | 0 | 0 | 0 |
| | 50 | 0 | 0 | 10 |
| | 75 | 0 | 20 | 0 |

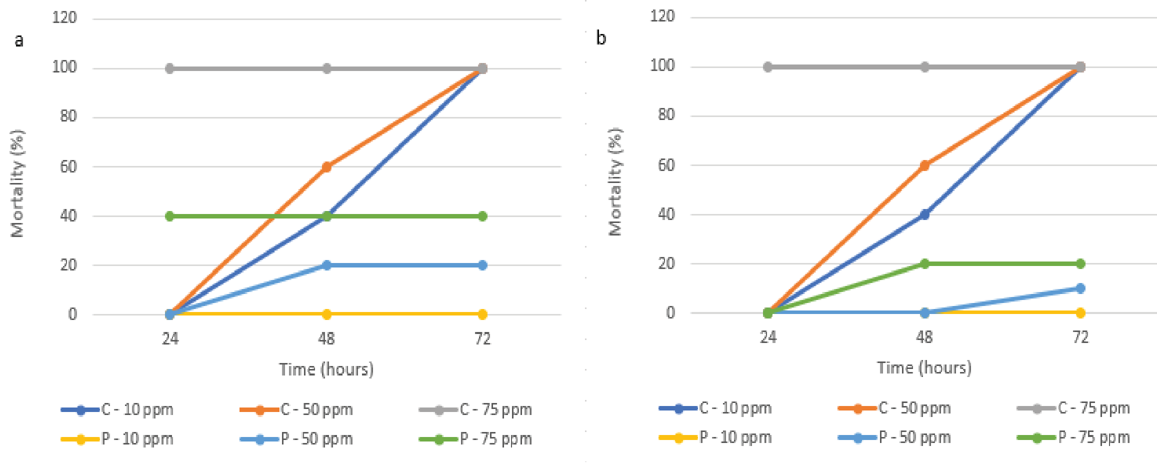


Fig. 2: Trends of *Xiphophorus maculatus* mortality in remediated water after (a) 7 days and (b) 14 days of detention time. C: control group, P: plants group.

### Toxicity Test of Remediated Water

Post-phytoremediation contaminated water was evaluated of its safety based on the mortality of *X. maculate*. Mortality level of *X. maculate* was varied based on the detergent level in the water and whether phytoremediation was performed or not. Level of *X. maculate* mortality in water after various treatments is presented in Table 2, while the trend of mortality is presented in Fig. 2.

*Xiphophorus maculatus* was found to have a higher mortality rate at the higher level of detergent concentration and shorter period of phytoremediation. Fish in control water had 100% mortality rate at 24 hours. Fish mortality in control water took longer time in the lower detergent concentration. This was in line with a previous study, in which 18 ppm detergent induced the mortality of *X. maculatus* longer than 54 ppm (Kamiswari et al. 2013).

In contrast with control, the mortality of *X. maculatus* was lower in water with phytoremediation of *S. lancifolia*. No mortality was found in 10 ppm detergent with phytoremediation for both 7 and 14 days. Contaminated water at initial detergent water of 75 ppm remediated for 7 days resulted in 40% mortality in the first 24 hours and no additional mortality during the next 48 hours. However, the same level of detergent remediated for 14 days resulted in 20% mortality at 48 hours and no additional mortality thereafter. This shows that the longer the phytoremediation period, the lower the detergent level remained in the water, as well as safer water.

Suds and foam caused by detergent could cause oxygen level in the water to reduce. This would in turn induce hypoxia in various water organisms, such as phytoplankton, aquatic plants and fishes. In fishes, hypoxia causes stress that disrupts physiological homeostasis, resulting in a complex process of physiological and biochemical changes to help fishes to cope with the stress. Hypoxia also affects nutrient metabolism (Abdel-Tawwab et al. 2019). When oxygen in water is below the level sufficient for aerobic glycolysis, fishes fail to maintain normal physiological function and metabolism (Richard 2011).

In addition to hypoxia, the surfactant can also induce stress if it enters fish metabolism. Fishes will mobilize triglycerides and protein to meet increased energy demand from stress-induced physiological changes and xenobiotic excretion (Alkahem et al. 1998). Behavioural abnormality can also indicate nervous impairment due to blocked nervous transmission, enzyme dysfunction, and/or disruption of the metabolic pathways (Siddiqui & Arifa, 2011). This change was found in the *X. maculatus* used in this study, as fish experienced stress from detergent. The failure to adapt to detergent-induced stress caused mortality to *X. maculatus*. Thus, this species could also be used as an indicator of organic pollutant.

## CONCLUSIONS

Based on the present study, it could be concluded that *Sagittaria lancifolia* has an ability of phytoremediation, as indicated by a high rate of LAS removal. At high concentration of detergent, phytoremediation for 14 days resulted in the lowest mortality. The plant could survive until detention time of 14 days, however, leaves showed signs of chlorosis and necrosis.

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