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Utilization of *Pistia stratiotes* L. and *Hydrilla verticillata* (L.f.) Royle as Phytoremediators for LAS Detergents

Pemanfaatan Pistia stratiotes L. dan Hydrilla verticillata (L.f.) Royle sebagai Fitoremediator LAS Deterjen

Yeremia Ajijaya Putra Ritiau*, Herlina Fitrihidajati
Study Program of Biology, Faculty of Mathematics and Natural Sciences
Universitas Negeri Surabaya
*e-mail: yeremia.nio@gmail.com

Abstract. The increase in human population causes water pollution to increase. One of the water pollutants used is wastewater washing which contains Linear Alkylbenzene Sulfonate (LAS) detergent that can threaten the balance of the aquatic ecosystem. This research aims to describe the effect of a combination of Kayu Apu (*Pistia stratiotes* L.) and Ganggeng (*Hydrilla verticillata* (L.f.) Royle) on reducing LAS, pH, and BOD content. The research was carried out experimentally using a randomized block design (RBD) with one treatment factor, namely the level of detergent used (3 ppm, 9 ppm, and 15 ppm). The research was carried out 4 times in repetition so that there were 24 treatment units. The parameters measured in this research include LAS levels of planting media detergent, BOD levels, and degree of acidity (pH). The LAS data obtained were analyzed using the T-test with an accuracy level of 0.05. Water quality data in the form of BOD and pH were analyzed descriptively and qualitatively and then compared with quality standards. The results showed that there was an effect of plant combinations on reducing LAS, pH, and BOD at various detergent concentrations. The highest decrease in LAS occurred at a concentration of 9 ppm. The highest reduction in BOD levels occurred at a concentration of 15 ppm, and the combination of plants changed the pH to acid at various detergent concentrations. Thus, there is an influence of the combination of *Pistia stratiotes* L. and *Hydrilla verticillata* (L.f.) Royle plants on reducing LAS, pH, and BOD.
Keywords: Phytoremediation; water quality; water management; pollution remediation

Abstrak. *Peningkatan populasi manusia menyebabkan pencemaran perairan semakin tinggi. Salah satu pencemar perairan adalah air bekas cucian yang mengandung deterjen Linear Alkylbenzene Sulfonate (LAS) yang dapat mengancam keseimbangan ekosistem perairan. Penelitian ini bertujuan untuk mendeskripsikan pengaruh kombinasi tanaman kayu apu (Pistia stratiotes L.) dan ganggeng (Hydrilla verticillata (L.f.) Royle) terhadap penurunan kandungan LAS, pH, dan BOD. Penelitian dilakukan secara eksperimental menggunakan rancangan acak kelompok (RAK) dengan satu faktor perlakuan yaitu kadar deterjen yang digunakan (3 ppm, 9 ppm, dan 15 ppm). Dalam penelitian dilakukan 4 kali pengulangan sehingga terdapat 24 unit perlakuan. Parameter yang diukur dalam penelitian ini meliputi kadar LAS deterjen media tanam, kadar BOD, derajat keasaman (pH). Data LAS yang diperoleh dianalisis menggunakan uji T dengan taraf ketelitian 0,05. Data kimia air berupa BOD dan pH dianalisis secara deskriptif kualitatif dan dibandingkan dengan baku mutu. Hasil penelitian menunjukkan bahwa terdapat pengaruh kombinasi tanaman terhadap penurunan LAS, pH, dan BOD pada berbagai konsentrasi deterjen. Penurunan tertinggi LAS terjadi pada konsentrasi 9 ppm. Penurunan kadar BOD tertinggi terjadi pada konsentrasi 15 ppm, dan kombinasi tanaman merubah pH menjadi asam pada berbagai konsentrasi deterjen. Dengan demikian terdapat pengaruh kombinasi tanaman kayu apu dan ganggeng terhadap penurunan LAS, pH, dan BOD.*
Kata kunci: *Fitoremediasi; kualitas air; pengelolaan air; remediasi polusi*

INTRODUCTION

The increasing human population will also increase human living needs. This will also be directly proportional to the increase in negative impacts which take effect on lowering the environmental quality (Yudo and Said, 2017). The higher the human population, the more water waste there will be in the environment, causing air pollution levels to increase (Fitrihidajati *et al*., 2020). Domestic wastewater is known to have merely high organic material content because it comes from various sources such as used washing water, food waste, and bathroom waste (Ryanita *et al*.,

2020). In this case, air pollution is a circumstance when an aquatic environment changes for the worse (Fatikasari and Purnomo, 2022). Air pollution in Indonesia is generally caused by the overflow of industrial waste, household activities, and agricultural waste (Rismawati *et al*., 2020). If the amount of pollution is excessive, it can cause environmental contamination (Fitrihidajati *et al*., 2020). One of the causes of air pollution as a general problem is the increasing use of detergent by people because people's daily activities cannot be avoided from using detergent, for example when washing. The outworn detergent will be immediately thrown into surrounding waters such as rivers so that it can cause pollution and has an impact on air biota such as fish (Lestari, 2022). This event will trigger the liver to work excessively, resulting in swelling and inflammation, as well as reducing the fertility of the gonads for reproduction (Yuliani *et al*., 2015). This stands because detergent waste that was thrown into the waters was unable to cover the surface of the air, which results in an inadequate supply of oxygen to the waters (Magfirah *et al*., 2015).

Detergent is a compound made from synthetic organic chemicals, especially surfactants, and has sufficient cleaning power (El-Gawad, 2014). Detergent has the advantage of being able to have excellent washing power. Based on the degradation of the active substance, detergents are divided into two, namely soft and hard detergents. Soft detergents are detergents that are easily broken down by microorganisms because they have unbranched carbon chains, for example, *Linear Alkylbenzene sulfonate* (LAS), while hard detergents mean that these detergents are difficult for microorganisms to break down when they are thrown away, so they are not degraded and able to pollute the environment, an example is *Alkylbenzene sulfonate* (ABS) (Tefa *et al*., 2018).

According to Herlambang and Hendriyanto (2015), *linear Alkylbenzene Sulfonate* (LAS) is an anionic surfactant that can reduce surface tension and at the same time emulsify dirt that is carried in water. According to Setyawati *et al*. (2021), detergents containing LAS can foam 10-13% of active organic elements and polyphosphate ingredients. The presence of phosphate in water creates the potential for eutrophication events (Zairinayati and Shatriadi, 2019). Eutrophication event causes water to have low level of oxygen and impacts the quality of these waters (Mirwan and Puspita, 2021). Lack of oxygen in waters will cause high level of Biological Oxygen Demand (BOD).

Most daily water needs come from groundwater and rivers, including water availability from Drinking Water Companies (DWC), therefore the quantity and quality of water sources must always be maintained (Kospa and Rahmadi, 2019). One of them is to carry out phytoremediation, it is to reduce contaminants that are considered dangerous to the environment to be converted into safer concentrations using green plants (Sharma *et al*., 2015; Emmanuel and Patience, 2011). In a research report, it's said that aquatic plants are known to have quite optimal abilities in improving water quality (Ramadhania and Rachmadiarti, 2021). In accordance with Ramadhania and Rachmadiarti (2021), several aquatic plants that can be used as phytoremediators are *Eichornia crassipes*, *Ipomea aquatica*, *Alternanthera philoxeroides*, *Hymneachne amplexicaulis*, *Lemna minor*. Apart from that, according to Fatikasari and Purnomo (2022), *Hydrilla verticillata* can be used as a LAS detergent phytoremediator. According to Setyawati *et al* (2021), *Pistia stratiotes* or known as water lettuce are able to reduce detergent LAS levels in the water.

Water lettuce or *Pistia stratiotes* L. is a high-level aquatic plant and is classified as a weed that is often found in swamps and rice fields but can grow and develop well even in an environment with low water quality. According to Wirawan *et al* (2014), *P. stratiotes* can efficiently reduce COD levels by 65%, TSS by 20%, and oil and fat by 37%. It lives by floating on the surface of the water with its roots completely submerged in the water.

Hydrilla verticillata (L.f) Royle is an aquatic plant that lives by submerging or the entire plant body is submerged (Mutmainnah, 2015). According to Shrivastava dan Srivastava (2021), *H. verticillata* has a fairly extensive root system and is useful for storing carbohydrates. Several previous studies stated that *H. verticillata* can live with a fairly high level of tolerance to contaminants. In research conducted by Fatikasari and Purnomo (2022), *H. verticillata* was proven to be effective in reducing detergent LAS levels by 95%.

This research aims to combine *H. verticillata* plants with *P. stratiotes* plants because of their ability as phytoremediators also their sinking and floating ability in the hope of reducing detergent LAS levels by testing the water chemical parameters Methylene Blue Anionic Surfactant (MBAS), Biological Oxygen Demand (BOD), and Potential Hydrogen (pH).

From the advantages of aquatic plants *P. stratiotes* and *H. verticillata* as an alternative solution to the problem of LAS detergent waste as a phytoremediator. According to Patrick and Florentine

(2021), *H. verticillata* can adapt and survive even in conditions of low light intensity, and the *P. stratiotes* plant can live floating above *H. verticillata* plants and is a phytoremediator plant.

MATERIALS AND METHODS

The type of research carried out is experimental research because there are control treatment groups, repeated tests, and response results from manipulation. The parameters observed were water quality, namely final LAS levels, DO levels, BOD, and pH. This research was carried out for 4 months, from September to December 2023 at the Greenhouse, Biology Department, State University of Surabaya. This research used a randomized block design (RBD) method with one factor, it is LAS detergent concentration. The dosage of LAS detergent concentration was based on East Java Governor Regulation Number 52 of 2004 with a detergent quality limit of 3 ppm so that the LAS detergent content used is 3 ppm (same to quality standards), 9 ppm (> quality standards), and 15 ppm (> standards quality). The type of plant used in this research is a combination of two plants, namely *Pistia stratiotes* L., and *Hydrilla verticillata* (L.f.) Royle. Each treatment in this study was repeated 4 times, so this research contained 24 experimental treatment units (Table 1). The plants, *P. stratiotes* and *H. verticillata* were obtained from Mas River, Taman, Sidoarjo.

This research began with preparing tools and materials. The tools used are nets, container tubs, glass beakers, balances, large bottles, DO meter Milwauke Mi 605, pH meter, lux meter, and Winkler bottles. The following materials used in this research are *P. stratiotes* plants, *H. verticillata* plants, LAS detergent, and distilled water. Next, plant samples were taken in Mas River, Taman, Sidoarjo then acclimated for three days. After going through an acclimatization process for three days, *P. stratiotes* and *H. verticillata* were placed in a large bottle filled with 5 liters of water. After that, continue with labeling large bottles according to the treatment code. The LAS detergent was weighed according to the treatment dosage, specifically 3 ppm, 9 ppm, and 15 ppm. The LAS detergent concentration was carried out by homogenizing the detergent with water according to the dosage used for each plant. Once everything is prepared, it is poured into each large bottles according to the treatment code label. This research used 4 repetitions and the phytoremediation process was carried out for 7 days.

Table 1. Research Design

Type of Plants	LAS Concentration (ppm)	Repetition in Research Number-			
		1	2	3	4
K0	3	$K0_{A1}$	$K0_{A2}$	$K0_{A3}$	$K0_{A4}$
	9	$K0_{B1}$	$K0_{B2}$	$K0_{B3}$	$K0_{B4}$
	15	$K0_{C1}$	$K0_{C2}$	$K0_{C3}$	$K0_{C4}$
K1	3	$K1_{A1}$	$K1_{A2}$	$K1_{A3}$	$K1_{A4}$
	9	$K1_{B1}$	$K1_{B2}$	$K1_{B3}$	$K1_{B4}$
	15	$K1_{C1}$	$K1_{C2}$	$K1_{C3}$	$K1_{C4}$

Note: K0 = Control without plants, K1 = Combination between *P. stratiotes* and *H. verticillata*, A = 3 ppm detergent LAS level, B = 9 ppm detergent LAS level, and C = 15 ppm detergent LAS level.

The examination of LAS detergent levels was carried out at PDAM Surya Sembada, Surabaya using the Methylene Blue Anionic Surfactant (MBAS) parameters referring to SNI 06-6989.51-2005. Potential hydrogen (pH) as a supporting parameter for the quality of the water used will be measured directly in the Greenhouse of the Biology Department every day using a pH meter. Biological Oxygen Demand (BOD) was measured using the calculation method from DO_0 – DO_5. The BOD levels were measured on day 0 and day 7 of observation. BOD levels were obtained through dissolved oxygen (DO) using an electrometric method because a DO meter was used in the research. The BOD measurements begin with calculating DO_0 and DO_5 samples are stored in the refrigerator for 5 days.

The LAS data obtained were analyzed using the t-test with an accuracy level of 0.05. Supporting data in the form of BOD and pH were analyzed descriptively and qualitatively and compared with East Java Governor Regulation Number 52 of 2014.

RESULT

The results of measuring detergent LAS levels in the planting media (water) after being treated for 7 days showed that there was a decrease in detergent LAS levels in each treatment with the largest decrease in detergent LAS levels of 9 ppm with phytoremediation which is presented in the following reduction percentage (Table 2):

Tabel 2. Decrease of LAS Detergent on Planting Media Used

Treatment Code	LAS Concentration (ppm)		Decreasing Percentage of LAS Level (%)
	Initial	Finale	
$K0_A$	3	1,31 ± 0,27	57 ± 0,09
$K0_B$	9	1,56 ± 0,54	83 ± 0,06
$K0_C$	15	1,26 ± 0,25	92 ± 0,02
$K1_A$	3	0,32 ± 0,07	90 ± 0,03
$K1_B$	9	0,35 ± 0,09	96 ± 0,01
$K1_C$	15	0,43 ± 0,17	94 ± 0,01

Notes: Types of plants K0 (Control without plants) and K1 (Combination between *P. stratiotes* L. and *H. verticillate* (L.f.) Royle). Notation $_A$ means 3 ppm of LAS detergents, $_B$ means 9 ppm of LAS detergents, and $_C$ 15 ppm of LAS detergents. The quality standard used was based on East Java Governor Regulation Number 52 of 2014

These results were analyzed using the t-test by paying attention to the "t" and "Sig" values (Table 3) and showed that there was an effect on reducing LAS levels in each treatment. The significant value shown is 0.000; 0.004; and 0.001. These results shows that the significance value is smaller than 0.05 which means treatments with or without phytoremediation are stated to affect on reducing the various LAS levels of detergents used in the research. Therefore, the amount of reduction is presented with the percentage reduction in detergent LAS in each treatment. In the treatment with phytoremediation, if seen from the percentage reduction in detergent LAS levels, it is more effective than without phytoremediation with the largest reduction occurring in the phytoremediation treatment by detergent LAS levels of 9 ppm with a percentage of 96%.

Table 3. Result of t-test Analysis on LAS Detergent

Treatments	T value	Sig.
Concentration 3 ppm	6,995	0,000
Concentration 9 ppm	4,440	0,004
Concentration 15 ppm	5,555	0,001

The following are the results of research that has been carried out at various concentrations with BOD test parameters with the calculation formula BOD = DO_0 – DO_5. The BOD value was calculated on day 0 of treatment and day 7 to determine the difference in initial and final BOD values. The results obtained that a decrease in BOD occurred in each treatment with the highest decrease happens at LAS levels of 15 ppm which is presented as follows (Table 4).

Table 4. Average Decrease on BOD Level

Treatments	LAS Detergent Level (ppm)	Average Decrease (ppm)	Quality Standard (ppm)
K0	3	13,93 ± 4,06	75
	9	9,76 ± 2,69	
	15	21,58 ± 1,99	
K1	3	17,11 ± 1,79	
	9	18,05 ± 3,01	
	15	23,14 ± 0,89	

Notes: Types of plants K0 (Control without plants) and K1 (Combination between *P. stratiotes* L. and *H. verticillate* (L.f.) Royle). The quality standard used was based on East Java Governor Regulation Number 52 of 2014

Based on the data that has been obtained, the Biological Oxygen Demand (BOD) results from day 0 to day 7 always decrease. The final BOD level with the highest average reduction was obtained in the phytoremediation treatment at a concentration of 15 ppm, with a BOD value of 23.14 ppm. The final BOD level with the lowest average reduction was obtained in the treatment without phytoremediation at a concentration of 9 ppm, with a BOD value of 9.76 ppm. Based on the average

BOD results above, these results do not exceed the quality standards of East Java Governor Regulation Number 52 of 2014 on 75 ppm.

The following is the pH value for each treatment on the planting media with various concentrations used in the research. The results obtained were that the phytoremediation treatment tended to be acidic and the treatment without phytoremediation tended to be neutral, which is presented as follows (Table 5).

Table 5. Average pH Values at Various LAS Detergent Concentrations

Treatments	LAS Detergent Level (ppm)	Average	Quality Standards
K0	3	7,19 ± 0,16	6-9
	9	7.09 ± 0,08	
	15	6,81 ± 0,15	
K1	3	6,41 ± 0,11	
	9	6,03 ± 0,19	
	15	**5,90** ± 0,18	

Notes: Types of plants K0 (Control without plants) and K1 (Combination between *P. stratiotes* L. and *H. verticillate* (L.f.) Royle). The quality standard used was based on East Java Governor Regulation Number 52 of 2014. The averages in bold does not meet the quality standards.

Based on the measurement data obtained, the pH value in the phytoremediation treatment tends to decrease towards acidic values. The lowest average pH level after 7 days of treatment was obtained in the phytoremediation treatment with a detergent content of 15 ppm, an average value of 5.90. Apart from that, the highest average pH value after 7 days of treatment was given to the treatment without phytoremediation with a detergent content of 3 ppm, an average value of 7.19. Of all the pH measurements, there were treatments where the average pH value did not meet the quality standards, they were in the phytoremediation treatment with a level of 15 ppm. Apart from that, the average pH value still met the quality standards of East Java Governor Regulation Number 52 of 2014, with a pH level of 6-9.

DISCUSSION

The results of the analysis showed that the phytoremediation process using a combination of *H. verticillata* and *P. stratiotes* or without using a combination of plants was able to reduce the levels of LAS detergent in the growing media used. However, treatment with phytoremediators showed a better level of phytoremediation than without using phytoremediators. This is proven by the T-test analysis in Table 3 which shows that each treatment shows a significance value of <0.05, specifically 0.000; 0.004; and 0.001. This means that all treatments with phytoremediation and without phytoremediation both affect reducing detergent LAS levels. However, treatment with phytoremediation had a higher percentage reduction in LAS levels. These results are shown in Table 2 which shows the average reduction in detergent LAS levels with phytoremediation at a LAS detergent concentration of 3 ppm showing a 90% reduction compared to treatment without phytoremediation which only showed a 57% reduction. This also happened in the phytoremediation treatment, LAS detergent concentrations of 9 ppm and 15 ppm showed a 96% and 94% reduction compared to the treatment without phytoremediation, namely 83% and 92% reduction. However, treatments with or without phytoremediation do not exceed the quality standard limit according to East Java Governor Regulation Number 52 of 2014, namely 3 ppm.

LAS detergent as a contaminant has decreased levels due to phytoaccumulation, namely the process of plants attracting contaminants until they accumulate around the roots of plants (Irhamni *et al*., 2017). LAS detergent containing sulfate ions (SO_4^{2-}) found around the roots will be absorbed into the root cells and converted into sulfite (SO_3^{2-}) (Susanto *et al*., 2021). Plant roots not only absorb essential ions but also absorb non-essential ions and organic materials or compounds (Fitrihidajati *et al*., 2020). These ions will be passed into the cortex and the xylem tissue (Advinda, 2018). The incoming LAS detergent will accumulate in the vacuole so as not to inhibit metabolism. However, if the amount of LAS detergent that accumulates in the vacuole is too much, the vacuole will burst and mix into the cytoplasm and damage the plasma membrane (Fitrihidajati *et al*., 2020). Damaged plasma membranes will affect chlorophyll function.

BOD measurements as supporting data for water quality parameters were carried out to determine the amount of dissolved oxygen in the water needed by microorganisms to decompose

organic matter. In this study, the reduction in BOD levels was caused by phytoremediation. The presence of plants in the phytoremediation process can absorb organic substances contained in wastewater. According to Khaer and Nursyafitri (2019), the more plants there are, the more organic material will be absorbed and the less organic material will be degraded by microorganisms. The decrease in organic matter will increase the amount of dissolved oxygen in the water (Pulungan and Inggriani, 2014.). Microorganisms can decompose organic substances assisted by oxygen produced from the photosynthesis process of plants which also increases the supply of dissolved oxygen in water (Sumarta and Muntu, 2023).

The results of measuring the BOD that was contaminated with LAS detergent after the phytoremediation process can be seen in Table 4, which shows that the BOD value in the phytoremediation treatment experienced a greater decrease compared to planting media without the phytoremediation process. This was proven by the average decrease in planting media with phytoremediation being greater than the average decrease in BOD values in planting media without phytoremediation. At a LAS detergent concentration of 3 ppm, the planting media with phytoremediation experienced an average decrease greater than the planting media without phytoremediation, 17.11 ppm compared to 13.93 ppm. At a LAS detergent concentration of 9 ppm, the phytoremediation planting media experienced an average decrease which was also greater than the planting media without phytoremediation, 18.05 ppm compared to 9.76 ppm. Apart from that, at a LAS detergent concentration of 15 ppm, the phytoremediation planting media experienced an average decrease which was also greater than the planting media without phytoremediation, 23.14 ppm compared to 21.58 ppm. The final results of this research show that the BOD value in treatments with and without phytoremediation does not exceed the quality standard limit according to East Java Governor Regulation Number 52 of 2014, 75 ppm. However, this study shows that there is an effect of giving a combination of plants on the average reduction in initial and final BOD levels. These results are also directly proportional to the decrease in LAS levels in the planting media.

Measurements of the degree of water acidity/potential hydrogen (pH) to support water quality data on chemical parameters are carried out every day during treatment, showing significant fluctuations or changes. This indicates that there is a chemical change in the planting medium, such as increasing CO_2, because in general the acidity level (pH) of water is influenced by CO_2 (Supriatna *et al*., 2020). However, changes in pH values can also be caused by the respiration activity of microorganisms and the absorption of nutrients by plants. When plant roots absorb positive ions, they will release an excrete in the form of positive ions (H^+) into the environment, and vice versa, if a plant absorbs negative ions it will also release an excrete in the form of negative ions (OH^-). In this case, if more positive ions are absorbed, the pH value or degree of acidity of the water will increase (Fitriana and Kuntjoro, 2020). In addition, a decrease in pH can be caused by the absorption of large amounts of elements in waste by plants (Rulitasari *et al*., 2020). This was also supported by the research from Imtiyaz and Rachmadiarti (2020) and Silviana and Rachmadiarti (2023) which states that the presence of plants can reduce the pH of detergent LAS. According to Fatikasari dan Purnomo (2022), a decrease and increase in pH can occur due to the processes of respiration and photosynthesis. The photosynthesis process will reduce CO_2 levels and cause the pH to increase. However, if the CO_2 level in the water is high, it will cause a decrease in pH because CO_2 reacts with the water so that it turns into carbonic acid.

The data presented in Table 5 shows that the average degree of acidity of the water in the phytoremediation treatment with a combination of H. verticillata and P. stratiotes plants has an acidic pH value. The highest increase in pH until the 7th day of treatment occurred without phytoremediation when LAS detergent was given a concentration of 15 ppm with a pH of 7.36. All averages for treatment without phytoremediation show that they do not exceed the quality standard limit according to East Java Governor Regulation Number 52 of 2014, namely 6-9 ppm. On the other hand, the pH value in the planting media with phytoremediation decreased towards acid with the pH value on day 7 being the lowest at LAS detergent levels of 15 ppm with a pH value of 4.41. This can be due to the activity of microorganisms that emit CO_2 and can reduce the oxygen concentration and pH value of the water (Supriatna *et al*., 2020). The condition of the roots of aquatic plants is an ideal place for microorganisms to attach and live (Susanto *et al*., 2021).

Based on the results and discussion that have been presented, phytoremediation treatment using a combination of *H. verticillata* plants and *P. stratiotes* has a good impact on water quality compared to treatment without phytoremediation. This was proven by the phytoremediation treatment which had a greater effect in reducing detergent LAS levels in the study. Apart from that,

phytoremediation treatment also shows a good impact on water quality, which is shown by a decrease in biological oxygen demand (BOD) levels. Other than that, phytoremediation treatment using a combination of *H. verticillata* plants and *P. stratiotes* was proven to be more effective in reducing detergent LAS levels compared to when the two plants underwent phytoremediation separately. In Fatikasari and Purnomo (2022), *H. verticillata* plants separately were able to reduce LAS levels of detergent by 95%, while in Setyawati *et al*. (2021) *P. stratiotes* plants separately were able to reduce 94% of detergent LAS levels. In this study, the combination of the two plants had a higher effectiveness value for reducing detergent LAS levels 96% at a concentration of 9 ppm. However, the results of research using phytoremediation treatment show that the degree of water acidity/potential hydrogen (pH) has changed towards acid. The test results for LAS, BOD, and pH parameters with phytoremediation treatment show that they can be implemented in social life because they meet the quality standards of East Java Governor Regulation Number 52 of 2014.

CONCLUSION

The combination of *Pistia stratiotes* L. and *Hydrilla verticillata* (L.f.) Royle can reduce LAS, BOD, and pH levels effectively. The highest combination of plants in reducing detergent LAS levels occurred at a concentration of 9 ppm. The highest reduction in BOD levels occurred at a LAS detergent concentration of 15 ppm and changed the pH to acidic.

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Authors:
Yeremia Ajijaya Putra Ritiau, Study Program of Biology, Faculty of Mathematics and Natural Sciences, Universitas Negeri Surabaya, Ketintang, C2 Building Lvl. 2 Surabaya 60231, Indonesia, e-mail: yeremia.nio@gmail.com
Herlina Fitrihidajati, Study Program of Biology, Faculty of Mathematics and Natural Sciences, Universitas Negeri Surabaya, Ketintang, C2 Building Lvl. 2 Surabaya 60231, Indonesia, e-mail: herlinafitrihidajati@unesa.ac.id

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