Journal of Environmental Science and Technology

ISSN 1994-7887

science alert

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OPEN ACCESS Journal of Environmental Science and Technology

ISSN 1994-7887
DOI: 10.3923/jest.2017.139.146

Research Article

Affectivity Dose of *Acorus calamus* (Sweet Flag) to Reduce the Ammonia in Hospital Wastewater

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Abstract

Background and Objective: Some applicable traditional technologies to clean up contaminated soil and water have been proven to be efficient but they are usually very expensive and need to control continuously. The aim of the study was to determine the rate at which the ammonia (NH_3) content in hospital wastewater decreased using the sweet flag plant (*Acorus calamus*). **Materials and Methods:** The research was quasi-experimental with a time series design conducted in a special PVC (polyvinyl chloride) container with a medium volume of 45 L tub^{-1} and a glass container equipped with a water pump. The data were processed using a statistical regression test with a significance level of $p<0.05$. **Results:** The research results revealed that the ammonia level decreased to 0.003 mg L^{-1} or by 99.48% in a container growing a sweet flag plant. The level in the container without a sweet flag plant was 0.317 mg L^{-1} and the ammonia level only decreased by 45.63%. Meanwhile, the level in a pool with a water stream decreased to 0.007 mg L^{-1} over 8 h. **Conclusion:** It was concluded that sweet flag plants can be used to reduce the levels of ammonia by 99.48% compared to that without the use of a sweet flag plant (45.63%). In addition, the use of the system water flow more quickly reduced the levels of ammonia and BOD values and raised the level of DO required by the biota. Information on the use of sweet flag should be promoted by the government as a method to reduce the ammonia content (NH_3) in the hospital environment.

Key words: Sweet flag, *Acorus calamus*, ammonia content, phytoremediation and polyvinyl chloride container

Received: January 13, 2017 Accepted: March 14, 2017 Published: April 15, 2017

Citation: Noer Bahry Noor, Anwar Daud, Munawir Amansyah and Anwar Mallongi, 2017. Affectivity dose of *Acorus calamus* (Sweet flag) to reduce the ammonia in hospital wastewater. J. Environ. Sci. Technol., 10: 139-146.

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

The application of *Acorus calamus* (sweet flag) in reducing the ammonia pollutant content in hospital wastewater was frequently selected method in the developing countries. This method can be affective way in term of hospital money spending and pollution control continually. Hospital is considered as a health care institution, whose activity is likely to cause positive and negative impacts on society and the environment. The positive impacts of hospitals include improving public health, while the negative impact of hospitals comes in the form of the waste generated by the hospital[1]. This phytoremediation method introduces a hospital wastewater treatment system with simple operation procedure for multi-layer artificial in wastewater treatment with short process, fast speed, good water quality, big ratio of enrichment, low cost and less consumption of energy.

The purpose of this phytoremediation by using *Acorus calamus* is to eliminate the ammonia content in the hospital waste that will be released to the environment. It is expected that by adding the *Acorus calamus* the waste will meet the requirement to be reused after treatment.

The waste produced by hospitals is certainly not the type of waste that is common in the community and industry. The waste produced by hospitals is more complex and can be a blend of industrial waste, household and infectious wastes. Hospital waste with characteristics almost identical to those of household waste can be categorized as waste containing various organic materials, such as ammonia. One of the challenges that arises in the treatment of wastewater is achieving a total nitrogen concentration in the effluent that is in accordance with the quality standards[2].

The results of the research conducted by Djaja and Maniksulistya[3] showed that the waste treatment results at X Hospital in Jakarta in February 2006 indicated that the chemical parameters passed the quality standard, except for the ammonia parameter. The equalization basin has high ammonia levels, which decrease in the aeration basin but the levels increase in the tub. The tub clarifier effluent is equal to 19 and 19.5 mg L^{-1}. In addition, the average results from routine processing done by Hospital X during 2005 obtained ammonia levels of 11.4 mg L^{-1}, which exceeded the quality standards set out in the Decree of the Minister of Environment, 58/MenLH/12/1995 or 0.1 mg L^{-1}.

The use of plants, including trees, grasses and aquatic plants, to eliminate or reduce hazardous materials, both organic and inorganic, in the environment is called phytoremediation[4]. Application of this technology has been performed commercially in the USA and Europe but Indonesia is still relatively new to this technology[5]. Some ornamental plants reduce the levels of total nitrogen and have a high market value in Mexico. In addition, ornamental plants, such as *Acorus calamus*, are considered capable of adapting well in wastewater[6]. *Acorus calamus* (sweet flag) is distributed in wetlands and in temperate and subtropical regions in the world[7].

Traditional technologies that used to clean up contaminated soil and water have been proven to be efficient but they are usually vulnerable and require intensive preparation[8]. Based on this, the authors conducted research to study the ability of sweet flag (*A. calamus*) to lower ammonia levels in hospital effluents. This study was necessary to meet the administrative procedure standard of the hospital and to protect the environment from the waste pollutant released by the hospital activities.

MATERIALS AND METHODS

Location and research design: The study was carried out on 2016 in a special PVC (polyvinyl chloride) container that was 50 cm long, 30 cm wide and 30 cm high with a medium volume of 45 L tub^{-1}. The water flow system container was glass and was 50 cm long, 40 cm high and 30 cm wide. Sweet flag plants were placed in the containers and adapted for 1 week. The examination was conducted in a laboratory. This type of research was a quasi-experimental study/pseudo-experiment with a circuit design time.

Population and sample: This study was conducted to determine changes in the levels of ammonia (NH_3).The dissolved oxygen content, Biological Oxygen Demand, temperature, pH, turbidity and the amount of MPN coliform in the hospital wastewater samples before and at the time of treatment were recorded.

The population in this study was obtained from the wastewater sewage treatment plants at General Hospital and Syekh Yusuf Kab. The Gowa sweet flag plants were obtained from swamp/paddy fields. The sample in this study was wastewater containing ammonia obtained from a hospital and it was used as a medium to grow sweet flag plants. The water was sampled on days 1, 5 10 and 15 and the initial concentration was compared with the samples obtained from the hospital effluent pond.

Materials and research methods: The *Acorus calamus* used in this study was collected and the average height and average length of the roots were measured. The plants used as much as 2/3 of the volume of the artificial pond.

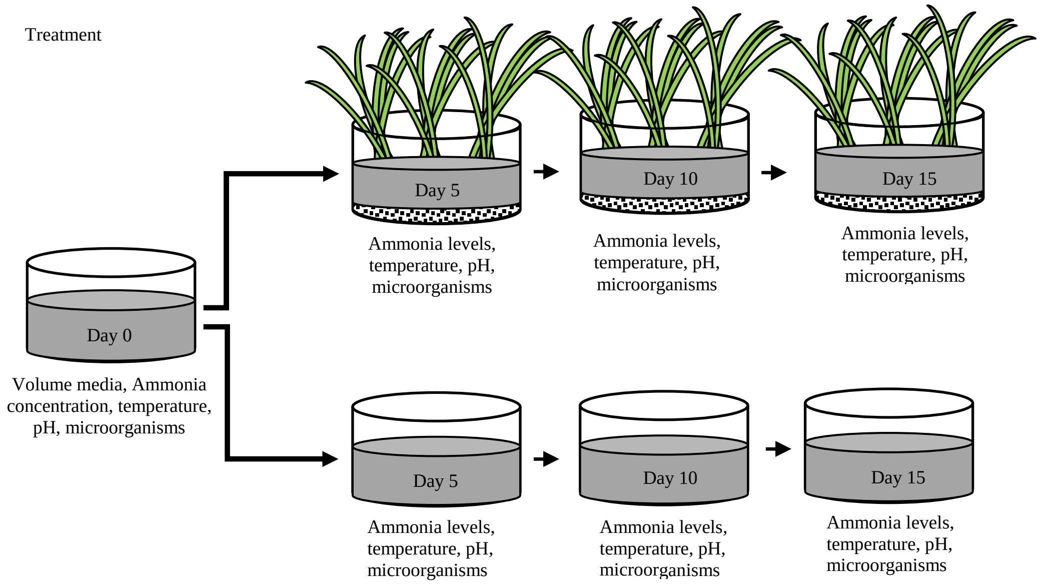

Fig. 1: Schematic representation of the operational research

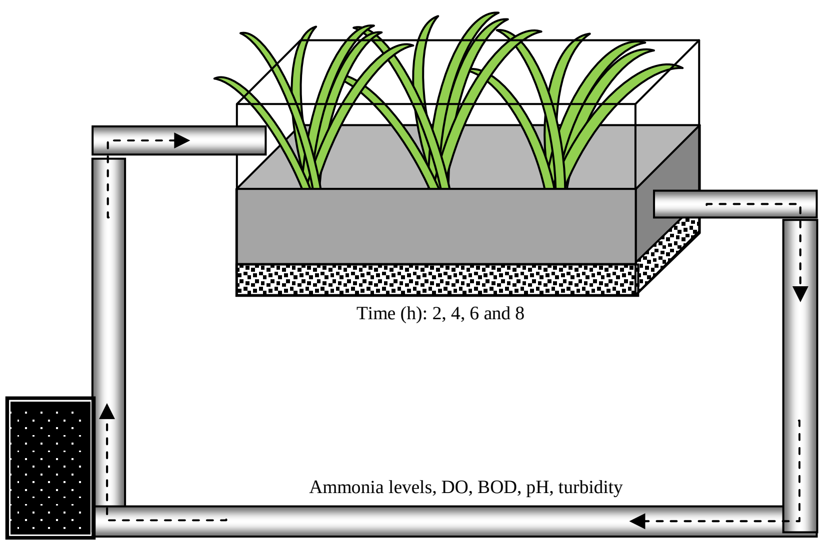

Fig. 2: Study design to measure the concentration based on the water flow

The sweet flag plants taken from a river were cleaned using distilled water to remove any particles or chemical compounds, which can affect the ammonia level measurements. Once the plants were adapted, they were grown in a special container with a certain size and as many as 6 clumps were used for each treatment and control with a spacing of 10 cm.

The wastewater was obtained from the hospital waste storage before it was processed and from the waste treatment prior to entering water bodies using sample bottles, plastic samples, scales and scoops.

The container used in this study consisted of 3 sections to divide the experiments sample. Two sections were with the sweet flag plants and without the plants (Fig. 1) and another section of the container was designed to control the flow of the water to the sweet flag plant (Fig. 2).

Data collection: The primary data were obtained from the laboratory results from testing the influent wastewater before and after use as a medium to grow plants and as the hospital wastewater effluent pond. The secondary data were obtained from the literature, such as journals, scientific papers and books.

Statistical analysis: Data were obtained based on the 0-15 days test results using the spectrometer Photometric

(Shimadzu, Spectr. AA 6200) tools in laboratories. Then, to determine the rate of decline in the ammonia levels (removal rate), the following formula was used[9].

$$R = \frac{(S-S_o)}{S} \tag{1}$$

S is the value in the wastewater samples before treatment and S_o is the initial value of the wastewater samples. To predict the daily decline in the levels of ammonia, a linear regression analysis of the formula was used.[10]

$$Y = a+bX \tag{2}$$

Y is the concentration of ammonia, a is the intercept (initial concentration), b is the slope and X is the day. The data is presented in the form of tables and graphs that are equipped with the narrative.

RESULTS

Based on the results of the wastewater samples, as shown in Table 1, the levels of ammonia in the wastewater decreased by 99.48%. The ammonia levels in the wastewater samples were down to 0.003 mg L^{-1} after the sweet flag plants grew for 15 days.

The wastewater samples that were used as controls, shown in Table 2, had 45.63% decreased levels of ammonia. The ammonia levels in the wastewater samples were down to 0.266 mg L^{-1} without sweet flag in 15 days.

The results for the wastewater samples in the pond prototype, as shown in Table 3, indicated that the levels of ammonia in the wastewater decreased by 98.80%. The ammonia levels in the wastewater samples were down to 0.007 mg L^{-1} with the sweet flag plant growth and aid of the flow of water for 8 h.

Table 1: Changes in the levels of ammonia in wastewater using sweet flag plants for 15 days

	Concentration in wastewater					
	Time				Changes in concentration	
Parameters	Day 0	Day 5	Day 10	Day 15	mg L^{-1}	(%)
Ammonia	0.583	0.387	0.263	0.003	0.580	99.48
MPN coliform	3,500,000	20,000	7,000	400	3,499,600	99.9
Temperature	27	27	27	26		
pH	7.1	7.2	7.4	7.4		

Table 2: Changes in the levels of ammonia in wastewater without the use of sweet flag plants, i.e., the control pond, for 15 days

	Concentration in wastewater (mg L^{-1})					
	Time				Changes in concentration	
Parameters	Day 0	Day 5	Day 10	Day 15	mg L^{-1}	(%)
Ammonia	0.583	0.433	0.353	0.317	0.266	45.63
MPN coliform	3,500,000	40,000	23,000	0.33	3,500,000	99.99
Temperature	27	27	27	0.33		
pH	7.1	7.4	7.4	0.33		

Table 3: Changes in the levels of ammonia (NH_3) with a water flow system in a prototype for 8 h in 2012

	Concentration in wastewater						
	Time					Changes in concentration	
Parameters	0	2	4	6	8	mg L^{-1}	(%)
Ammonia	0.583	0.450	0.180	0.015	0.007	0.576	98.80
DO	0	0	1.9	2.4	3.6	3.6	100
BOD	154.97	99.16	62.38	36.77	17.73	137.24	88.56
Turbidity	189	97	91	52	46	143	75.66
Temperature	27	27	27	27	27		
pH	7.1	7.2	7.2	7.4	7.4		

Table 4: Differences in the levels of ammonia (NH_3) in a time-based wastewater treatment

Time (days)	Using sweet flag plants	Without sweet flag plants (treatment)	Difference
0	0.583	0.583	0.00
5	0.386	0.433	0.047
10	0.263	0.353	0.090
15	0.003	0.317	0.314

Table 5: Results of the bivariate correlation analysis to determine the spread of the data

		Treatment	Control
Treatment	Pearson correlation	1	0.933
	Sig. (2-tailed)	.	0.067
	N	4	4
Control	Pearson correlation	0.933	1
	Sig. (2-tailed)	.067	.
	N	4	4

Table 4 shows the differences in the levels of ammonia in the wastewater on day 5 using sweet flag (0.047 mg L^{-1}) compared with the levels of ammonia in wastewater without the use of sweet flag. Day 10 showed a difference of 0.090 mg L^{-1} and day 15 showed a difference of 0.314 mg L^{-1}.

The bivariate correlation test results obtained a value of $p = 0.067$, which is a value of $p<0.250$ and explained the normal spread of the data. Further testing was done, as shown in Table 5.

In addition, Results of a one-way ANOVA test that shows the value of $p = 0.009$, which means the value of $p<0.05$ and the equation obtained from the regression is fit for use.

The test results of regression coefficient constant value were 0.174 and the residual value was 0.0003 with an F of 109.014, means that the equation formed from the two values of the correlation coefficient will have a value of 99.1%.

DISCUSSION

Levels of ammonia (NH_3) in wastewater: The hospital wastewater flows in or beneath surface layer of groundmass at the wetland and decomposes ammonia, sulphuric and nutritive materials in water through such a serial processes as attachment microbe system. The results of the examination of the ammonia levels in wastewater samples with sweet flag plants showed a large decrease in the concentration, as presented in Table 3. Based on the observations, the concentration of ammonia in the media using sweet flag plants within a period of 15 days decreased up to 0.003 mg L^{-1} from 0.583 mg L^{-1} (99.48%) (Table 2).

Decreased levels of ammonia also occurred in wastewater without using sweet flag plants during the period of 15 days observation but the decline was only amounted to 45.63% of the concentration, as shown in Table 3. The difference in the media concentration between the wastewater treatment and the control after 15 days was 0.313 mg L^{-1}, as shown in Table 4.

These results indicated that there are differences in the concentration of ammonia in wastewater with sweet flag plants versus wastewater without sweet flag plants. The use of sweet flag plants is an effort to reduce the levels of ammonia in a hospital effluent for 15 days was highly effective.

Compared with the result of research using the same plan by Sutrisno and Suciastuti[11], revealed that the effective dose in this research was 5 g L^{-1}, that dose can reduce the ammonia level of 96.769%, which is less effective than this study with 99.48 ammonia reduction. Another research conducted by Prihananto[12] at Roemani Hospital Semarang, showed dose of chlor tablet use only effective in lowering levels Ammonia with 30 g L^{-1} at 65.39%, that show a lower reduction of ammonia. An increase in ammonia levels occurs because of the presence of volatile materials, dissolved gases and byproducts from decomposition of organic matter. Protein organics present in wastewater decomposed by bacteria microorganisms grow on waste Liquid[13].

In addition, result of study by Amansyah[14] the results of the study indicate that decreased levels of ammonia reached of 99.48% use the *Acorus calamus* plant, which has exactly the same results of ammonia reduction with this research finding. However, study from Dewi[15] indicated that the use of *Acorus calamus* L. in wastewater can decrease the value of COD by 42.5% by *Acorus calamus* L plants and with kangkung plants by 41.3%, respectively. In the case of phosphate and Ammonia *Acorus calamus* L slightly better with a decreased efficiency of only 53.7%.

Research results have shown that sweet flag has the ability to absorb some types of heavy metals found in some areas of Pakistan, including Fe 16.16 mg kg^{-1}, Cr 44.20 mg kg^{-1}, Zn 39.20 mg kg^{-1}, Mn 51.40 mg kg^{-1}, Cu 10.00 mg kg^{-1}, Co 0.200 mg kg^{-1}, Ni 24.20 mg kg^{-1}, Na 148 mg kg^{-1}, K 19000 mg kg^{-1}, Cd 0.20 mg kg^{-1} and Pb 2.20 mg kg^{-1} [2,16].

Furthermore, the application of *Cornus alternifolia* in monoethanolamine-contaminated wastewater revealed that plant could completely uptake MEA at day 5 from an initial MEA concentration of 18 mM. The result indicated that *C. alternifolius* has the potential to remove ethanolamines and can be applied to ethanolamine-contaminated wastewater[17].

This was also supported by research conducted by Zhang *et al.*[6] in a study that described the use of a crop of sweet flag to reduce the total nitrogen in the effluent drainage from a factory in Jinhua, China. On the 5th day, the content was reduced by 66.5%, with 84.9% reduction on the 10th day and 88.3% reduction on the 15th day.

The decrease in the concentration of ammonia in wastewater with sweet flag plants can be considered a bioremoval biotechnology. A bioremoval process is a process of accumulation and concentration of pollutants from a liquid by biological materials using microorganisms, such as algae, bacteria, fungi and aquatic plants, that can remove pollutants so that the wastewater can be disposed of and is friendly to the environment[6].

According to Haberl[18] the process of photosynthesis in aquatic plants (hydrophyta) allows the release of oxygen to the area around the roots (rhizosphere zone). Because the rhizosphere zones are rich in oxygen, they lead to the development of aerobic bacteria in the zone.

The group of microorganisms that are in the rhizosphere are often called the microbial rhizosphere and they belong to bacteria and some belong to fungi groups. These microbes live in symbiosis with the rhizosphere around the roots of the plant and their presence typically depends on the plant roots.

Based on the above, the main role of microorganisms in degrading organic matter may explain the trend/tendency of decrease in the organic material in the experimental results. The plant acclimatization process at the beginning of the experiment provides opportunities for the rhizosphere bacteria that are present to grow and adapt. Thus, at the beginning of the study, the bacterial growth has achieved the exponential growth phase.

Differences in the decreased levels of ammonia (NH_3) in wastewater: By using wastewater samples with the same initial ammonia levels of 0.583 mg L^{-1} were compared by the media treatment and control. On day 5, the wastewater samples showed decreased levels of ammonia but the media plant treatment sample was able to reduce the levels of ammonia to 0.047 mg L^{-1}, which was a greater decrease than the control media. Similarly, on the 10th and 15th day, the levels of ammonia decreased in comparison to the two media with reduced levels of ammonia 0.090 and 0.313 mg L^{-1}, respectively.

This shows that the use of sweet flag plants as an alternative to decrease the levels of ammonia in the wastewater was more effective based on the reduced levels of ammonia on the 15th day, 0.003 mg L^{-1}.

The results of another study conducted by Zhao *et al.*[19] showed that a water flow system with the sweet flag plant reduced the total nitrogen from 78.37-84.27-15.87-43.89 mg L^{-1}, or by 63.25%, in 24 h. In this study, the value of the dissolved oxygen increased from 3.08-6.02 mg L^{-1}.

To determine whether the data obtained by linear regression could be tested, the bivariate correlation was tested using the SPSS program. The results show a value of $p = 0.067$ or $p<0.250$, which means that the data in this study had a normal spread, as explained in Table 5. From the test results, the linear regression equation was obtained.

$$Y = 0.589-0.037 \text{ (day)} \tag{3}$$

These equations show that the levels of ammonia in wastewater will experience a reduction of 0.037 mg L^{-1} every day for initial ammonia levels of 0.583 mg L^{-1}. In the equation, the value of Y represents the decreased levels of ammonia per day (mg L^{-1}) using the sweet flag plant and R was -0.991, i.e., the data has a correlation value of 99.1%.

From the results of the wastewater samples at an outlet hospital, the data indicated the value of the ammonia level in the hospital wastewater was 0.15 mg L^{-1}. This means that the levels of ammonia in the hospital exceed the value of the effluent standards for hospitals according to Ministry of Environment Decision 58/MENLH/12/1999 regarding the levels of ammonia in wastewater, which is equal to 0.1 mg L^{-1}. The levels of ammonia (NH_3) will easily diffuse and pass through the network if present in high concentrations and are potentially toxic to aquatic biota. Ammonia will result in an acute concentration at 1.0-1.5 mg L^{-1} in types of tilapia and 0.5-0.8 mg L^{-1} in salmon. However, ammonia can still be tolerated at a concentration of 0.05 mg L^{-1} by tilapia and 0.0125 mg L^{-1} by salmon. Ammonia in shrimp should be less than 0.003 ppm and will cause death at concentrations greater than 0.1 ppm. Study from Tang *et al.*[20] indicated that the use of sweet flag plant and the removal rate reduces with the decrease in NO_3-N/NH_4-N ratio. When the ratio of NH_4-N/NO_3-N was 1:1, there was little impact on NH_4-N removal, a possible reason was which being that an insufficient amount of oxygen in the subsurface wetlands limits these processes.

Concentrations of ammonia (NH_3) in wastewater with an air flow system: The rate of the water velocity and volume were set according to the average volume of the wastewater effluent at the hospital. At the hospital, the average speed of the hospital wastewater in the equalization pool is 20 m sec^{-1} with a volume of 416 L of wastewater room^{-1} day^{-1} [21]. The volume of wastewater in the pond is approximately 45 L with a cross-sectional area of the pipe (d = 3 cm, length = 2 m) of 0.7543 m^2.

The rate of change in the levels of ammonia for 8 h was used sweet flag plants and water flow systems shown in Table 3. The initial concentration of ammonia was 0.576 mg L^{-1} and decreased after 8 h to 0.007 mg L^{-1}, or by 98.80%.

Treatment of hospital waste with a water flow system relies heavily on the ability of bacteria and plants to treat the wastewater, so the performance of this waste treatment system will be greatly influenced by the temperature and pH of the waste solution because these two parameters are the limiting factors for living microorganisms in water. The results showed that the temperature of the wastewater at the time of the study was 27°C at pH 7.1 (morning wastewater). The condition of a relatively neutral pH in the waste supports processing by microorganisms because a neutralization process is not needed to obtain the ideal pH conditions for the growth of the microorganisms, which can reduce the cost of the wastewater treatment.

The temperature conditions of the wastewater were relatively higher than the average temperature of tropical waters (25°C); although this water temperature is relatively higher than average, it is actually an ideal condition for the growth of mesophilic bacteria, which grow optimally at temperatures between 25-37°C and at a minimum temperature of 15°C.

The results showed that the water flow system can reduce the amount of BOD in the wastewater samples by up to 88.56% and increase the amount of Dissolved Oxygen (DO) from 0-3.6 mg L^{-1}. This is because of the process of aeration or contacting water with air through the flow of water, thus increasing the number of droplets and decreasing the amount of BOD in a water flow pool. The increase in the dissolved oxygen in water is needed for microbial life, especially to oxidize ammonia through nitrification[22,23].

A waste processing system with a water flow system only requires simple tanks (pool), so it is not costly to install them in buildings. Sewage treatment plants and microbes rely on the natural performance, so they do not require a complicated operating system and can reduce the cost of operations. Another advantage of this system is that it is relatively resistant to variations in the flow of the waste, making it suitable for wastewater treatment in industrial environments, hospitals and residential/housing complexes[24].

CONCLUSIONS AND RECOMMENDATIONS

Sweet flag plants can be used to reduce the levels of ammonia by 99.48% compared to that without the use of a sweet flag plant (45.63%). In addition, the use of the system water flow more quickly reduced the levels of ammonia and BOD values and raised the level of DO required by the biota. This plant can also be used in industrial and residential environments, so the public health and presence of aquatic biota can be protected. It is expected that hospital could use them as an alternative, late-stage treatment before hospital waste is dumped into water bodies.

SIGNIFICANCE STATEMENTS

This study discovers the possible sweet flag as an alternative for the final processing of hospital wastewater before it is released into a water body. This study will help the researcher to uncover the critical problem of hospital wastewater that the use of sweet flag can decrease the ammonia content in wastewater.

ACKNOWLEDGMENTS

Authors give our gratitude to all Wahidin Sudirohusodo Hospital staffs who have supported this study. Our thanks are also for all laboratory staffs, Hasanuddin University who have conducted the analysis accordingly.

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