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Development of Phosphorus and Ammonium-Nitrogen Concentration Calibration Curve Using Laboratory Resistivity Method at Alkaline pH Condition

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Abstract: Phosphorus and ammonium nitrogen are typically an essential part of the living ecosystem, but the amount needs to be at the optimum level. The high concentration level can impact the nature of the water and the environment around it. Water resistivity method can be applied in-situ to obtain the resistivity value of the water body. This study was proposed to develop the phosphorus and ammonium nitrogen concentration calibration curve using laboratory resistivity method at alkaline pH condition. A laboratory experiment was conducted to obtain the resistivity value of different concentration of phosphorus and ammonium nitrogen at alkaline condition range from 7.8 to 11.0. The resistivity value was obtained using electrical resistivity box and analysed to obtain the calibration curve. The concentration of phosphorus was divided into three ranges which is low range covers from 1 mg/L to 99 mg/L, medium range covers from 100 mg/L to 999 mg/L and high range covers from 1000 mg/L to 2000 mg/L while the concentrations of ammonium-nitrogen standard are divided into three major groups which is low range covers from 1 mg/L to 99 mg/L, medium range covers from 100 mg/L to 99 mg/L and high range covers from 1000 mg/L to 5000 mg/L .The results in this lab experiment showed that the concentration of the phosphorus and ammonium nitrogen was inversely proportional to the resistivity value. This is because the high number of ions will results in the high conductivity and low resistivity. The calibration curves that have been obtained including R^2 value can be used as the references to determinte the water quality by measuring the resistivity in-situ of the water body.

Keywords: Ammonium Nitrogen, Phosphorus, Calibration Curve, Alkaline

1. Introduction

The accessible supply of water should be adequate and safe for everyone. Significant amounts of benefits on health can be obtained as the result of improving access to safe drinking-water. Safe-drinking water means the water is free from pollution. Water pollution can happen when hazardous

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substances in which chemicals or microorganisms contaminate and degrade the quality of water in a particular water body for instance river, ocean, lake and aquifer. It is the water nature acting as the universal solvent since it has the ability to dissolve numerous amounts of substances. Nevertheless, this can be a problem as water will be vulnerable in exposure to pollution. Hence, this study is going to investigate the possibility of water being polluted with the presence of certain substances in a water body.

In a condition where too much nutrients, mostly contributed from nitrogen will cause nutrient pollution. Nutrient pollution usually happens in areas where there are agriculture industry conducted. Based on UN-Water (2017), one of the main sources of nitrogen pollution is ammonia [1]. Ammonia pollution is potentially possible to affect biodiversity by having an impact of nitrogen accumulation on plant species diversity and composition among affected habitats. Species composition can be affected by ammonia through soil, direct toxic which leads to the damage of leaves, drought and pathogens. If this continues to happen, changes in composition would increase and extinction could happen. Furthermore, freshwater ecosystem can be contaminated causing from a direct agricultural run-off which will lead to eutrophication. Eutrophication will give a negative impact on the aquatic livings since it contains an excessive amount of nutrients in a water body which will increase the growth of algae and in the meantime, eutrophication also will deteriorate the water quality [2].

Wood *et al*., (2017) claims that aquatic animals and plants, as well as the health of the environment are significantly affected by the health of water bodies [3]. Environmentalists can determine the factors that affecting the water quality either based on natural or human factors with the help of the effective water quality monitoring strategies. There are several methods of measuring and monitoring the water quality in order to create a decent and healthy aquatic ecosystem. One of the methods is to study the resistivity of a water body. Ibrahim (2013) describes the measure of water ability in resisting electrical current as water resistivity [4]. The amounts of dissolved salts in a water body affects directly on its water resistivity. Low resistivity of water contains high concentration of dissolved salts. Meanwhile, high resistivity of water contains low concentration of dissolved salts. Free ions will be created if the salts dissolved in the water and the ions created will be able to produce electrical current. Thus, the purity of a water sample can be indicated if there is less dissolved salts in the water body.

Furthermore, water sample will have low resistivity if the conductivity is high. This happens since the relationship of water resistivity is reciprocal with conductivity. In order to measure the purity of water sample, both methods either resistivity or conductivity, can be applied. For this study, the main focus is the solution in alkaline pH range. A strong alkaline solution will have high conductivity. This happens due to low concentration of ion in the alkaline solution. High concentration of hydroxide ion will result in higher pH which also will bring in high conductivity and low resistivity in the alkaline solution. The pH of a solution will significantly change when there is an addition of acid or base to pure water. The flow of ions can be measured to determine the resistivity of fluid as well as to determine the concentration of ions in solution [5].

To measure the electrical resistivity of liquid, a soil box resistivity meter can be utilized. When choosing a resistance meter, extra care should be taken due to the fact that the equipment involved is highly sensitive in order of obtaining accuracy. The electrical current in a solution can be produced since there will be a source of voltage applied. The resistivity value can be obtained based on the amounts of ions contained in a solution. Electrons are known to be flowing through in a solution by ions. Hence, the greater amounts of ions in an alkaline solution will result in a low resistivity.

2. Materials and Methods

There were laboratory work required for prepation of phosporus and ammonium nitrogen solution,. The ammonium nitrogen and phosphorus solution were prepared in separate way in the Environmental Laboratory, and its resistivity value were measured in the Geology and Geophysics Laboratory.

Before doing an experiment, there are various apparatus must be prepared such as beakers, burets, pH metres, ambers bottle,durren, droppers and vials. The material for ammonium nitrogen solution prepration that being used was ammoinium sulphate while for phosphorus solution prepration that being used was potassium phosphate monobasic, KH_2PO_4. After these two solution prepared, both of it were mix together at specific ratio to determine the solution's resistivity. A MILLER-400A resistivity metre and a soil box were utilized to measure resisvitiy value. Sulphuric acid, H_2SO_4, and sodium hydroxide, NaOH were the chemicals used as pH adjuster as shown in Table 1.

Table 1: The solution involved for pH adjuster.

Solution used	Concentration (M)	Purposes
Sulfuric acid	1, 2	pH adjuster
Sodium hydroxide	1, 2	pH adjuster

Eq. 1 wass used in order to prepare the Ammonium Sulphate and Standard Solution with various concentration:-

$$M_1V_1 = M_2V_2 \quad \text{(Eq.1)}$$

Where

M_1 = Phosphorus or ammonium nitrogen concentration– stock solution (mg/L)

V_1 =Volume of solution taken from the phosphorus or ammonium nitrogen concentration (L)

M_2 = Required phosphorus or ammonium nitrogen concentration (mg/L)

V_2 = Volume of volumetric flask (L)

A 1000 ml of volumetric flask was filled with 2 ml of 1000 mg/L of ammonium nitrogen then filled with ultra pure water until reached the mark. The concentration of ammonium nitrogen solution will become 2 mg/L. The same method was applied for variable concentration of phosphorus solution.

Table 2 shows the volume of stock concentration required for the preparation of the various solutions concentration

Ammonium-Nitrogen or Phosphorus stock solution (1000mg/L)	2	4	6	8	10
Concentration of dilution solution (mg/L)	2	4	6	8	10

In order to evaluate the resistivity, this study utilised a soil sample on a liquid measurement. In this application, four electrodes are employed. This investigation will fill the electrolyte box with the aquatic solution. In the typical resistivity measurement, the MILLER-400A electrolyte cage is commonly known as the soil box. One of the elements in measuring resistance is the geometry of the electrolyte box, and the MILLER-400 using the formula can be calculated by utilising the resistance value:

$$\rho = RA/L \quad \text{(Eq.2)}$$

Where

ρ = Resistivity (ohm.cm)

R = Resistance (ohms)

A = Cross-sectional area of the current electrodes (cm)

L = Separation between the potential electrodes (cm)

3. Results and Discussion

This study was focused on developing the calibration graph curve between the mixture of ammonium nitrogen and phosphorus concentration to the resistivity value at alkaline condition started from pH 7.8 to pH 11.0. The mixture of ammonium nitrogen and phosphorus solutions were tested and analyzed at different concentration and pH value. Figure 1 shows the calibration curve that represent the relationship between the mixture of ammonium-nitrogen and phosphorus concentration to the resistivity at pH 7.8. The x-axis representing the resistivity value and for y-axis represent phosphorus and ammonium-nitrogen.. The data shows if the concentration of ammonium nitrogen and phosphrus is increasing, the resistivity value is decreasing gradually. The graph shows the minimum value of resistivity was 0.624 Ωm at 1000mg/L phosphorus and 2000mg/L ammonium-nitrogen, while the maximum value of resistivity was 56.5 Ωm at 2mg/L phosphorus and 20mg/L ammonium-nitrogen. The relationship of phosphorus with resistivity inside the of mixture phosphorus and ammonium-nitrogen at pH 7.8 were phosphorus [P] = 302.86r-1.513 and R^2 = 0.9567.While the relationship of ammonium-nitrogen with resistivity inside the of mixture phosphorus and ammonium-nitrogen at pH 7.8 were ammonium-nitrogen [NH_4^+] = 1362r-1.169 and R^2 = 0.9825.

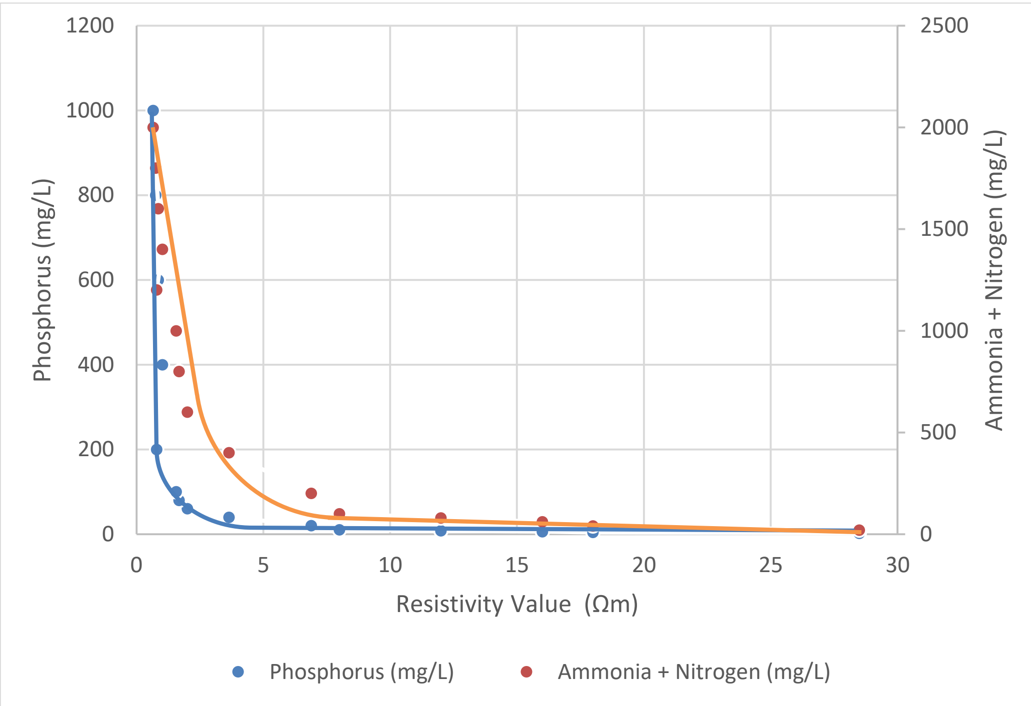

Figure 1: Calibration curve of ammonium nitrogen and phosphorus concentration to the resistivity at pH 7.8

Figure 2 shows the calibration curve that represent the relationship between the mixture of ammonium-nitrogen and phosphorus concentration to the resistivity at pH 9.8. The x-axis representing the resistivity value and for y-axis represent phosphorus and ammonium-nitrogen.. The data shows if the concentration of ammonium nitrogen and phosphrus is decreasing, the resistivity value is increasing gradually. The graph shows the minimum value of resistivity is 0.651 Ωm at 1000mg/L phosphorus and 2000mg/L ammonium-nitrogen, while the maximum value of resistivity is 49.0 Ωm at 2mg/L phosphorus and 20mg/L ammonium-nitrogen. The relationship of phosphorus with resistivity inside the of mixture phosphorus and ammonium-nitrogen at pH 9.8 were phosphorus [P] = 302.86r-1.513 and R^2 = 0.8343.While the relationship of ammonium-nitrogen with resistivity inside the of mixture phosphorus and ammonium-nitrogen at pH 9.8 were ammonium-nitrogen [$NH_4{}^+$]= 1362r-1.169 and R^2 = 0.9546.

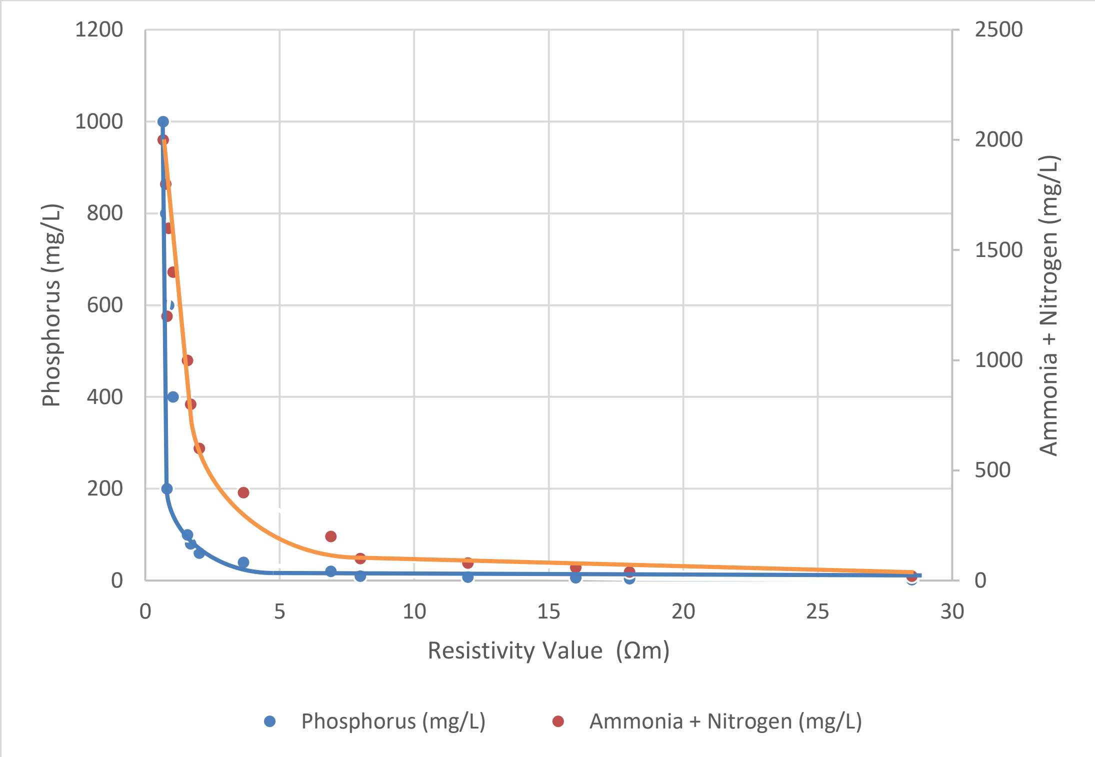

Figure 2: Calibration curve ammonium nitrogen and phosphorus concentration to the resistivity at pH 9.8

Figure 3 shows the calibration curve that represent the relationship between the mixture of ammonium nitrogen and phosphorus concentration to the resistivity at pH 11. The x-axis representing the resistivity value and for y-axis represent phosphorus and ammonium-nitrogen. The data shows if the concentration of ammonium-nitrogen and phosphorus increasing, the resistivity value decreasing gradually. The graph shows the minimum value of resistivity is 0.657 Ωm at 1000mg/L phosphorus and 2000mg/L ammonium-nitrogen, while the maximum value of resistivity is 28.5 Ωm at 2mg/L phosphorus and 20mg/L ammonium-nitrogen. The relationship of phosphorus with resistivity inside the of mixture phosphorus and ammonium-nitrogen at pH 11.0 were phosphrous[P] = 302.86r-1.513 and R^2 = 0.8343. While the relationship of ammonium-nitrogen with resistivity inside the of mixture phosphorus and ammonium-nitrogen at pH 11.0 were ammonium-nitrogen [$NH_4{}^+$] = 1362r-1.169 and R^2 = 0.9546.

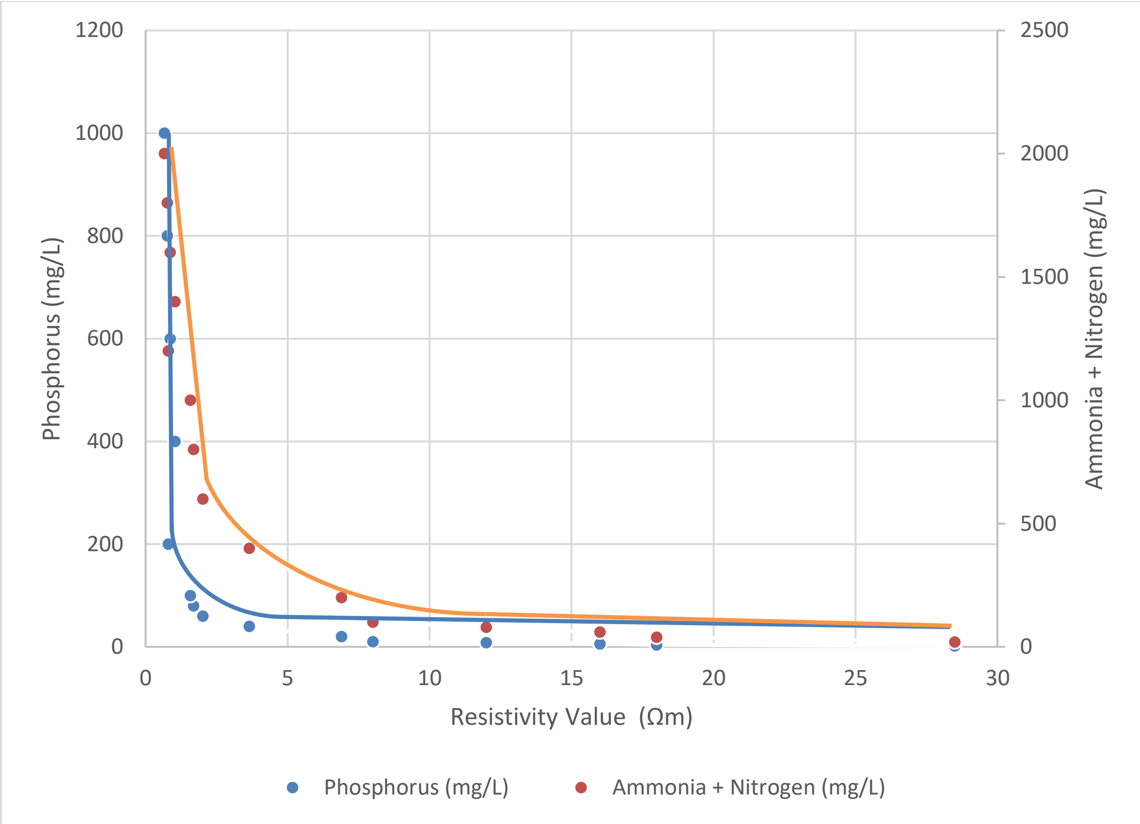

Figure 3: Calibration curve of ammonium nitrogen and phosphorus concentration to the resistivity at pH 11.0

In general, the higher pH value of solution, the higher resistivity value at alkaline conditions. The higher the concentration of the phosphorus and ammonium-nitrogen, the lower the resistivity value in the solution.

4. Conclusions

The study of the relationship between the mixture of ammonium-nitrogen and phosphorus to the electrical resistivity in alkaline condition was succesfully conducted. The presences of ion significantly affect the electrical resistivity. Various concentration of ammonium nitrogen and phosphorus were prepared and the resistivity value have been determined by the laboratory experiment that conducted in environmental laboratory and geophysical laboratory. The developments of calibration graph were based on the relationship between the concentration of ammonium-nitrogen and the value of electrical resistivity. The data result can be used on site in future to determine the concentration of phosphorus and ammonium-nitrogen immediately based on calibration curved.

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References

[1] UN-Water. (2017). Gobal analysis and assessment of sanitation and drinking-water (GLAAS) 2017 report: financing universal water, sanitation and hygiene under the sustainable development goals. In World Health Organization. https://doi.org/CC BY-NC-SA 3.0 IGO.

[2] Shaban, M., AbuKhadra, M. R., Nasief, F. M., & Abd El-Salam, H. M. (2017). Removal of ammonia from aqueous solutions, ground water, and wastewater using mechanically activated clinoptilolite and synthetic zeolite-a: kinetic and equilibrium studies. Water, Air, & Soil Pollution, 228(11), 450

[3] Wood, K. A., O'hare, M. T., McDonald, C., Searle, K. R., Daunt, F., & Stillman, R. A. (2017). Herbivore regulation of plant abundance in aquatic ecosystems. Biological Reviews. https://doi.org/10.1111/brv.12272

[4] Ibrahim, E. (2013). Geoelectric resistivity survey for site investigation in East Matruh Area, North Western Desert, Egypt. World Applied Sciences Journalhttps://doi.org/10.5829/idosi.wasj.2013.21.7.2871

[5] Paul Glover (2017). *Resistivity Theory*. Petrophysics MSc Course Notes

[6] Purwono, Rezagama, A., Hibbaan, M., & Arief Budihardjo, M. (2017). Ammonia Nitrogen (NH_3‾N) and Ammonium-Nitrogen (NH_4^+‾N) equilibrium on the process of removing Nitrogen by using tubular plastic media. Journal of Materials and Environmental Sciences

[7] Rodell, M., Famiglietti, J. S., Wiese, D. N., Reager, J. T., Beaudoing, H. K., Landerer, F. W., & Lo, M. H. (2018). Emerging trends in global freshwater availability. Nature. https://doi.org/10.1038/s41586-018-0123-1

[8] Wrage-Mönnig, N., Horn, M. A., Well, R., Müller, C., Velthof, G., & Oenema, O. (2018). The role of nitrifier denitrification in the production of nitrous oxide revisited. Soil Biology and Biochemistry. https://doi.org/10.1016/j.soilbio.2018.03.020

[9] Bertagnolli, A. D., McCalmont, D., Meinhardt, K. A., Fransen, S. C., Strand, S., Brown, S., & Stahl, D. A. (2016). Agricultural land usage transforms nitrifier population ecology. Environmental Microbiology. https://doi.org/10.1111/1462-2920.13114

[10] Cabello, P., Luque-Almagro, V. M., Roldán, M. D., & Moreno-Vivián, C. (2019). Nitrogen cycle. In Encyclopedia of Microbiology. https://doi.org/10.1016/B978-0-12-809633-8.20706-1

[11] Clement, R., & Moreau, S. (2016). How should an electrical resistivity tomography laboratory test cell be designed? Numerical investigation of error on electrical resistivity measurement. Journal of Applied Geophysics. https://doi.org/10.1016/j.jappgeo.2016.02.008

[12] Dincer, I., & Bicer, Y. (2017). Comprehensive evaluation of NH_3 production and utilization options for clean energy applications. Liaison Functions 2017 - Core Programming Area at the 2017 AIChE Annual Meeting.

[13] Dodds, W. K., & Smith, V. H. (2016). Nitrogen, phosphorus, and eutrophication in streams. Inland Waters. https://doi.org/10.5268/IW-6.2.909

[14] Francis, J. D. (2019). Water. In Rural Society in the U.S.: Issues for the 1980s. https://doi.org/10.4324/9780429305153-43

[15] Karastogianni, S., Girousi, S., & Sotiropoulos, S. (2015). pH: Principles and Measurement. In Encyclopedia of Food and Health. https://doi.org/10.1016/B978-0-12-384947-2.00538-9

[16] Lemley, D. A., & Adams, J. B. (2018). Eutrophication. In Encyclopedia of Ecology. https://doi.org/10.1016/B978-0-12-409548-9.10957-1

[17] Liu, Y., & Von Wirén, N. (2017). Ammonium as a signal for physiological and morphological responses in plants. Journal of Experimental Botany. https://doi.org/10.1093/jxb/erx086

[18] Islam, S., Reza, M. N., Jeong, J.-T., & Lee, K.-H. (2016). Sensing Technology for Rapid Detection of Phosphorus in Water: A Review. Journal of Biosystems Engineering, 41(2), 138–144. https://doi.org/10.5307/jbe.2016.41.2.138

[19] Körner, S., Das, S. K., Veenstra, S., and Vermaat, J. E. (2001). The effect of pH variation at the ammonium_ammonia equilibrium in wastewater and its toxicity to Lemna gibba. Aquat. Bot. 71, 71–78.doi: 10.1016/S0304-3770(01)00158-9