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A Comprehensive Study on Water Hyacinth (*Eichhornia Crassipes*) as a Biofiltration Solution for Water Purification

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Abstract: *The study involves transplanting water hyacinth in six different water samples. Water quality analysis was conducted periodically in every hyacinth- water sample to monitor plant health and evaluate changes in water quality parameters (including alkalinity, hardness, calcium hardness, calcium, chloride, ammonia, phosphate, nitrite, nitrate, pH) and heavy metal contaminants (including arsenic, lead, chromium and mercury).An ANOVA (Analysis of Variance) was conducted between different hyacinth- water samples to compare changes in the mean levels of the selected water quality parameter. Results revealed significant variations in water hyacinth's health between different water samples, and the water hyacinth had accumulated 0.2 µg/Kg of lead and 35.3 µg/Kg of mercury from its lake water source containing 17.5 µg/L of lead and 57.7 µg/L of mercury respectively. ANOVA results showed statistically significant differences in the mean levels of alkalinity, hardness, calcium hardness, calcium, chloride and phosphate between different hyacinth- water samples. The findings underscore the significance of tailored strategies for utilizing water hyacinth in diverse aquatic ecosystems, paving the way for informed decision-making in sustainable water resource management and ecosystem conservation efforts.*

Keywords: *Biofiltration;Heavy metal accumulation;Hyacinth (Eichhornia crassipes);Hyacinth-water samples;Periodic water quality analysis;Water quality parameters.*

1. Introduction

Water contamination causes a significant risk to both aquatic environments and human well-being. Therefore, the need for innovative and sustainable methods in water quality management is necessary. Among these methods, phytoremediation has emerged as a promising approach, utilizing aquatic plants to control water pollution. One such plant called as the Hyacinth (*Eichhornia crassipes*), is classified as an invasive species in many areas, but the Hyacinth has a substantial potential in purifying polluted aquatic ecosystems through its biofiltration processes.

Figure 1: Hyacinth in Adambakkam Lake

Background

Singhal & Mahto (2004) had conducted a studyon the environmental condition of Jabalpur's urban Robertson Lake, which was contaminated by sewage and overgrowth of Hyacinth. Their findings revealed that the lake had low oxygen levels, a neutral pH, and an elevated concentration of carbon, ammonia, organic nitrogen and phosphorus. Despite the ability of Hyacinth to absorb significant quantities of carbon, nitrogen, and phosphorus, it released these nutrients back into the water at a rapid rate than it absorbed them, disturbing the nutrient balance.[1]In a study by Liu et al. (2011) on the effects of Hyacinth cultivation on water quality in Zhushan Bay, it was observed that Hyacinth contributed to prevent the condition of oxygen depletion and maintained oxygen levels by its altering wave patterns and facilitating water circulation. However, areas where Hyacinth was grown showed high levels of total nitrogen and total phosphorus, indicating pollution, although the plants absorbed nutrients.[2]Wu et al. (2015) investigated the response of Hyacinth to varying concentrations of algal species at 25°C to explore its potential in controlling adverse effects and increasing the water quality. Their findings demonstrated that as algae density increased, dissolved oxygen and pH levels decreased, leading to hypoxic conditions. Hyacinth responded to moderate algae densities by increasing levels of leaf soluble protein, soluble sugar, and MDA content, indicating an adaptive response.[3] Madikizela (2021) proposed the utilization of Hyacinth for pollution remediation and its capability to remove organic pollutants through phytoremediation and adsorption processes. Current research primarily focuses on the plant's efficiency in eliminating organic dyes, investigating the intricate mechanisms involved in pollutant absorption.[4]Xu et al. (2022) had explored diverse methods in physical, chemical, and biological approaches to manage Hyacinth. Hyacinth holds promise in mitigating pollution and yielding valuableproducts. Utilizing these resources not only offers a sustainable avenue for its control but also yields more benefits.[5]In a study by Kiyemba et al. (2023) investigating the growth patterns and impact of Hyacinth on Lake Victoria in Uganda, it was revealed that as the lake's surface area decreased, the Hyacinth multiplied. Many factors, including the shape of bays, discharge of wastewater, wind patterns, water velocity, fluctuations in water levels, movement of ferries, and construction alongthe shoreline, contributed to its multiplication. Its presence notably affected water quality indicators such as pH, total phosphorus (TP), biochemical oxygen demand (BOD), chemical oxygen demand (COD), dissolved oxygen (DO), turbidity, and transparency.[6]

Riddle et al. (2002) had conducted an examination on the capacity of Hyacinths to absorb mercury with their roots and shoots, both in controlled laboratory environments and in closeto the Big Break Region. Their findings indicated that mercury initially absorbs oxygen with the roots and sulfur with the shoots of Hyacinths. Through laboratory experiments, they observed the gradual accumulation of mercury in Hyacinths, with peak levels had reached within approximately 16 days. Also, the study assessed mercury concentrations in both water and sediment surrounding the Big Break area, suggesting that employing physical removal techniques instead of herbicides could aid Hyacinths in

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mercury accumulation.[7]Skinner et al. (2007) had conducted a comparative investigation involving four aquatic plant species, including Hyacinth, water lettuce, zebra rush, and taro, to assess their efficiency in removing mercury from water. Over a month-long period, these plants were exposed to varying concentrations of mercury (0.0, 0.5, 2.0 mg/L). The results indicated that all the plant species were capable of reducing mercury levels in water with higher concentrations observed in plant roots compared to water samples.[8]Rajan et al. (2008) had conducted a studyof the potential of Hyacinth regarding mercury contamination, while also investigating the effects of plant disintegration and oxygen levels on mercury accumulation. Their field observations revealed significant mercury accumulation inHyacinth, indicating sediment pollution. Laboratory experiments indicated that plants cultivated in aerated conditions had lower methylmercury levels compared to those grown under stagnant conditions or with fragmented plants.[9]

Mishra & Tripathi (2009) evaluated the capacity of Hyacinth (*Eichhornia crassipes*) to eliminate chromium (Cr) and zinc (Zn) from metal-contaminated solutions. Results showed that Hyacinth efficiently removed up to 95% of zinc and 84% of chromium during an 11-day period.Additionally, Hyacinth safely extracted zinc across various concentrations (1.0, 5.0, 10.0, and 20.0 mg/L) without revealing signs of toxicity.[10]Govindaswamy et al. (2011) investigated the capability of dried Hyacinth roots (DHR) of*Eichhornia crassipes* to eliminate heavy metals, particularly evaluating their efficiency in removing 90% of arsenic from artificially contaminated drinking water samples. They highlighted the potential of Hyacinth roots as an efficient agent for arsenic removal in drinking water treatment.[11]In a study by Peng et al. (2020), Fourier Transform Infrared (FTIR) Spectroscopy and Inductive Coupled Plasma-Optical Emission Spectroscopy (ICP-OES) were employed to evaluate Hyacinth's capacity to eliminate lead, copper, cadmium, and arsenic from aqueous solutions. Their results showed rapid metal uptake, with Hyacinth removing over 80% of all heavy metals tested.[12]

Aim of Work

The investigation of Hyacinth's impact on aquatic condition and its efficiency in reducing heavy metal concentrations involved a series of experiments. These experiments included the transplantation of Hyacinth into various water samples, followed by the observation of its biosorption activity. This observation was conducted through several methods:

1. Steady analysis of Hyacinth-water samples to monitor deviations in water quality parameters such as alkalinity, hardness, calcium hardness, calcium, chloride, ammonia, phosphate, nitrite, nitrate and pH continuing till any deterioration in the Hyacinth health was observed.

2. Assessment of changes in the amount of heavy metal contaminants such asArsenic (As), Lead (Pb), Chromium (Cr), and Mercury (Hg).

3. Application of statistical analysis, specifically ANOVA: Single Factor, to compare the dissimilarities in water quality parameter levels between different Hyacinth-water samples.

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[9]Rajan, M., Darrow, J., Hua, M., Barnett, B., Mendoza, M., Greenfield, B.K., & Andrews, J.C. (2008). Hg L3 XANES study of mercury methylation in shredded *Eichhornia crassipes*. *Journal of Environmental Science & Technology*, ;42(15), 5568-73.

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2. MATERIALS

Hyacinth (*Eichhornia crassipes*) specimens were sourced from Adambakkam Lake, exhibiting well-established growth. For experimental purposes, healthy and uniform Hyacinth plants were carefully chosen to maintain consistency throughout the study.Water samples were collected from different water samples such as those from Puzhuthivakkam Lake (lake water 1), Madipakkam Lake (lake water 2), Adambakkam Lake ((lake water 3), Pallikaranai Lake (lake water 4), groundwater and RO-water.Care was taken to collect these samples in sanitized containers to avoid any contamination. Samples held in reserve for heavy metal contaminant analysis were stored under refrigeration until laboratory analysis.The experiment was conducted in a controlled environment with adequate lighting and temperature control.Hyacinth plants were transplanted in individual containersofeach 6-litre capacityand filled with the respective water samples.The water samples were not replaced or refilled to not to induce any change in the mineral or nutrient or other physiochemical contents of the initially filled water samples.Control group was the Hyacinth transplanted in distilled water, which provided a baseline comparison.Water quality was analyzed until the Hyacinth plant showed a complete decline in health.Ethical considerations, including adherence to relevant regulations and guidelines for handling experimental materials and disposal of waste, were ensured throughout the experiment.

Methods

The health of the Hyacinthin every water sample was monitored regularly.Physiochemical parameters of the water, such as alkalinity, hardness, calcium hardness, calcium, chloride, ammonia, phosphate, nitrite, nitrate andpHwere measured in the Hyacinth - Water samples using appropriate instrumentation (Royal field water testing kit – ISO 9001:2015 certified, CSIR & NEERI lab evaluated).Water quality parameters were monitored periodically throughout the experiment, including alkalinity, hardness, calcium hardness, calcium, chloride, ammonia, phosphate, nitrite, nitrate andpHandheavy metal concentrations (arsenic, lead, chromium andmercury).Water quality analysis (including alkalinity, hardness, calcium hardness, calcium, chloride, ammonia, phosphate, nitrite, nitrate andpH) was conducted periodicallyin every Hyacinth - Water sample and observed for any change in their levels. The analysis was performed using appropriate instrumentationin accordance with ISO standards (Royal field water testing kit – ISO 9001:2015 certified, CSIR & NEERI lab evaluated).Heavy metal analysis was conductedin Hyacinth leaves along-with its lake water source (Adambakkam Lake) and the water samples,using inductively coupled plasma mass spectrometry (ICP-MS),in accordance with Indian Standard IS: 3025 Part 65:2014 (Reaff:2019), methods of sampling and testing for total arsenic, lead, total chromium(Bureau of Indian Standards, 2014)and for total mercury using USEPA Method 200.8 (U.S. Environmental Protection Agency, 1994).

An ANOVA (Analysis of Variance) was conducted between different Hyacinth - Water samples, such as those from Puzhuthivakkam Lake (lake water 1), Madipakkam Lake (lake water 2), Adambakkam Lake (lake water 3), Pallikaranai Lake (lake water 4), groundwater and RO-waterto compare changes in the mean levels of theselected water quality parameter (including alkalinity, hardness, calcium hardness, calcium, chloride, ammonia, phosphate, nitrite and nitrate).

<u>Assumptions of ANOVA: Single Factor for Hyacinth-Water Quality Analysis:</u>

Observations within each group (each Hyacinth-water sample) are independent of each other.The data within each group should follow a normal distribution.The variance of the data in each group should be roughly equal.The residuals (the differences between the observed and predicted values) should be independent of each other. The samples should be randomly selected from the population of interest. The dependent variables are the water quality parameters andthere is a meaningful difference between the values and ratios of values.

<u>Statement of Hypothesis:</u>

Null Hypothesis (H_0): There was no significant difference in thelevel of the selected water quality parameter between the Hyacinth - Water samples.

H_0: $\mu_1 = \mu_2 = \mu_3 = \mu_4 = \mu_5 = \mu_6$

where μ_1, $\mu_2, \mu_3, \mu_4, \mu_5, \mu_6$ were the mean levels of the selected water quality parameter of six different Hyacinth - Water samples respectively.

Alternative Hypothesis (H_1): There was at least one pair of Hyacinth - Watersamples where the level of the selected water quality parameter differs significantly.

$H_1: \mu i \neq \mu j, (i \neq j)$

where μi and μj were the mean levels of the selected water quality parameter of two different Hyacinth - Water samples, i and j respectively.

Result of Hypothesis:

In case where the null hypothesis could not be rejected ($p > 0.05$):

The ANOVA results showed that the differences in the levels of specified water quality parameter between the Hyacinth - Water samples were not statistically significant (F (df1, df2) = F- statistical value, $p > 0.05$). Therefore, the null hypothesis could not be rejected, indicating that the variation between the group could likely be attributed to random chance rather than systematic differences between the groups.

In case where the null hypothesis was rejected ($p < 0.05$):

The ANOVA results revealed statistically significant differences in the levels of the specified water quality parameter between the Hyacinth - Water samples (F (df1, df2) = F-statistical value, $p < 0.05$). Therefore, the null hypothesis was rejected, indicating that at least one pair of sampled groups showed significant differences in the level of the specified water quality parameter.

3. RESULTS AND DISCUSSION

The outcomes of this studyreveal the complicated dynamics between Hyacinth and water quality, offering valuable insights into the plant's efficiency as a biofiltration agent and its potential in controlling water pollution.The Hyacinthspecimens weretransplanted in six different water sources: Puzhuthivakkam Lake (lake water 1), Madipakkam Lake (lake water 2), Adambakkam Lake (lake water 3), Pallikaranai Lake (lake water 4), groundwaterand RO-waterand the water quality was analyzed until the Hyacinth plant showed a complete decline in health.

Effect of Hyacinth on Lake Water 1 (PuzhuthivakkamLake):

From Figure 2(a),it was observed that the Hyacinthpartially deteriorated between 1st week and 2nd week and was completely deteriorated between 2ndweek and 3rd week in the Hyacinth-lake water 1 sample.The water quality was analyzed in Hyacinth - lake water 1 sample for a period of 2 weeks on a daily basis. The control sample was the Hyacinth transplanted in distilled water sample for the same period of time (3 weeks), which provided a baseline comparison. Week 0 represents the initial water quality of lake water 1 sample without the Hyacinth. Week 1 and Week 2 represents the impact of Hyacinth on the water quality of lake water 1.Table 1(a)represents the analysis of water quality in the Hyacinth -lake water 1 sample:

Figure 2(a): Health of Hyacinth in Lake Water 1 (Puzhuthivakkam Lake) over 3 weeks

Table1(a). *Analysisof Water Quality in Hyacinth - Lake Water 1 (Puzhuthivakkam Lake) Sample*

Parameters (mg/L)	Control	Week 0	Week 1	Week 2
Alkalinity	0	110	115	120
Hardness	0	120	130	150
Calcium Hardness	0	150	85	90
Calcium	0	60	34	36
Chloride	0	80	90	100
Ammonia	0	0.2	0.2	3
Phosphate	0	0	0.5	3
Nitrite	0	0	0.5	0.5
Nitrate	0	0	45	45
pH	7	7.5	7.5	7.5

From Table 1(a), it indicates that during the two-week period in Hyacinth - lake water 1 sample, there were changes in several parameters. Calcium hardness decreased from an initial concentration of 150 to 90 mg/L, while calcium dropped from 60 to 36 mg/L. Alkalinity rose from 110 to 120 mg/L, whereas hardness increased from 120 to 150 mg/L. Chloride levels elevated from 80 to 100 mg/L. Ammonia, phosphate, nitrite, and nitrate concentrations all showed an upward trend, with ammonia going from 0.2 to 3 mg/L, phosphate from 0 to 3 mg/L, nitrite from 0 to 0.5 mg/L, and nitrate from 0 to 45 mg/L. pH, however, remained stable at 7.5.

Effect of Hyacinth on Lake Water 2 (Madipakkam Lake):

From Figure 2(b),it was observed that the Hyacinth partially deteriorated between 1st week and 2nd week and was completely deteriorated between 2ndweek and 3rd week in the Hyacinth -lake water 2 sample.The water quality was analyzed in Hyacinth - lake water 2 sample for a period of 2 weeks on a daily basis. The control sample was the Hyacinth transplanted in distilled water sample for the same period of time (3 weeks), which provided a baseline comparison. Week 0 represents the initial water quality of lake water 2 sample without the Hyacinth. Week 1 and Week 2 represents the impact of Hyacinth on the water quality of lake water 2.Table 1(b)represents the analysis of water quality in the Hyacinth -lake water 2 sample:

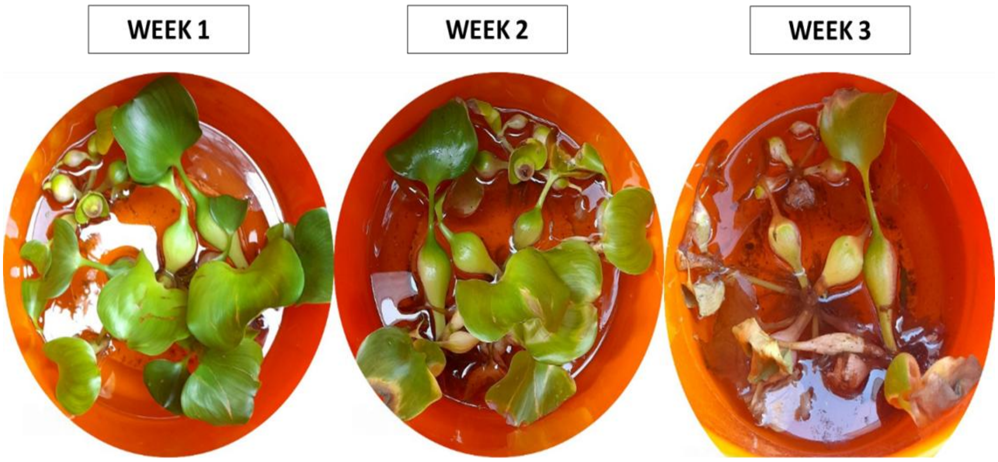

Figure 2(b): Health of Hyacinth in Lake Water 2 (Madipakkam Lake) over 3 weeks

Table1(b). *Analysisof Water Quality in Hyacinth - Lake Water 2 (Madipakkam Lake)Sample*

Parameters(mg/L)	Control	Week 0	Week 1	Week 2
Alkalinity	0	130	135	130
Hardness	0	160	130	150
Calcium Hardness	0	100	95	85
Calcium	0	40	38	34
Chloride	0	80	80	100
Ammonia	0	0.2	0.2	0.5

Phosphate	0	0	0.5	1
Nitrite	0	0	0.5	0.5
Nitrate	0	0	45	45
pH	7	7.5	7.5	7.5

From Table 1(b), it was observed that during the two-week monitoring period of Hyacinth - lake water 2 sample, alterations were noted in various parameters. Calcium hardness decreased from 100 to 85 mg/L, alongside a decrease in calcium from 40 to 34 mg/L. Hardness also experienced a reduction from 160 to 150 mg/L. Chloride levels saw an increase from 80 to 100 mg/L. Ammonia levels rose from 0.2 to 0.5 mg/L, while phosphate increased from 0 to 1 mg/L. Nitrite concentrations increased from 0 to 0.5 mg/L, and nitrate levels climbed from 0 to 45 mg/L. Alkalinity remained steady at 130 mg/L, and pH stayed constant at 7.5.

Effect of Hyacinth on Lake Water 3 (Adambakkam Lake):

From Figure 2(c),it was observed that the Hyacinth partially deteriorated between 1st week and 2nd week and was completely deteriorated between 2ndweek and 3rd week in the Hyacinth -lake water 3 sample.The water quality was analyzed in Hyacinth - lake water 3 sample for a period of 2 weeks on a daily basis. The control sample was the Hyacinth transplanted in distilled water sample for the same period of time (3 weeks), which provided a baseline comparison. Week 0 represents the initial water quality of lake water 3 sample without the Hyacinth. Week 1 and Week 2 represents the impact of Hyacinth on the water quality of lake water 3.Table 1(c)represents the analysis of water quality in the Hyacinth -lake water 3 (Adambakkam Lake)sample:

Figure 2(c): Health of Hyacinth in Lake Water 3 (Adambakkam Lake) over 3 weeks

Table1(c). *Analysisof Water Quality in Hyacinth - Lake Water 3 (Adambakkam Lake)Sample*

Parameters(mg/L)	**Control**	**Week 0**	**Week 1**	**Week 2**
Alkalinity	0	340	340	325
Hardness	0	350	340	345
Calcium Hardness	0	220	210	200
Calcium	0	88	84	80
Chloride	0	130	140	170
Ammonia	0	3	0.2	0.5
Phosphate	0	3	2	3
Nitrite	0	0.5	0.5	0.5
Nitrate	0	45	45	45
pH	7	9	9	9

From Table 1(c), it was observed that during the two-week monitoring period of Hyacinth - lake water 3 sample, changes were observed in various parameters. Alkalinity decreased from 340 to 325 mg/L, while calcium hardness decreased from 220 to 200 mg/L. Calcium levels decreased from 88 to 80 mg/L, and hardness decreased from 350 to 345 mg/L. Ammonia levels dropped from 3 to 0.5 mg/L. Chloride levels increased from 130 to 170 mg/L. Phosphate remained stable at 3 mg/L, while nitrite and nitrate concentrations remained constant at 0.5 and 45 mg/L respectively. pH remained steady at 9.

Effect of Hyacinth on Lake Water 4 (Pallikaranai Lake):

From Figure 2(d),it was observed that the Hyacinth partially deteriorated between 1^{st} week and 2^{nd} week and was completely deteriorated between 2^{nd}week and 3^{rd} week in the Hyacinth -lake water 4 sample.The water quality was analyzed in Hyacinth - lake water 4 sample for a period of 2 weeks on a daily basis. The control sample was the Hyacinth transplanted in distilled water sample for the same period of time (3 weeks), which provided a baseline comparison. Week 0 represents the initial water quality of lake water 4 sample without the Hyacinth. Week 1 and Week 2 represents the impact of Hyacinth on the water quality of lake water 4.Table 1(d)represents the analysis of water quality in the Hyacinth -lake water 4 sample:

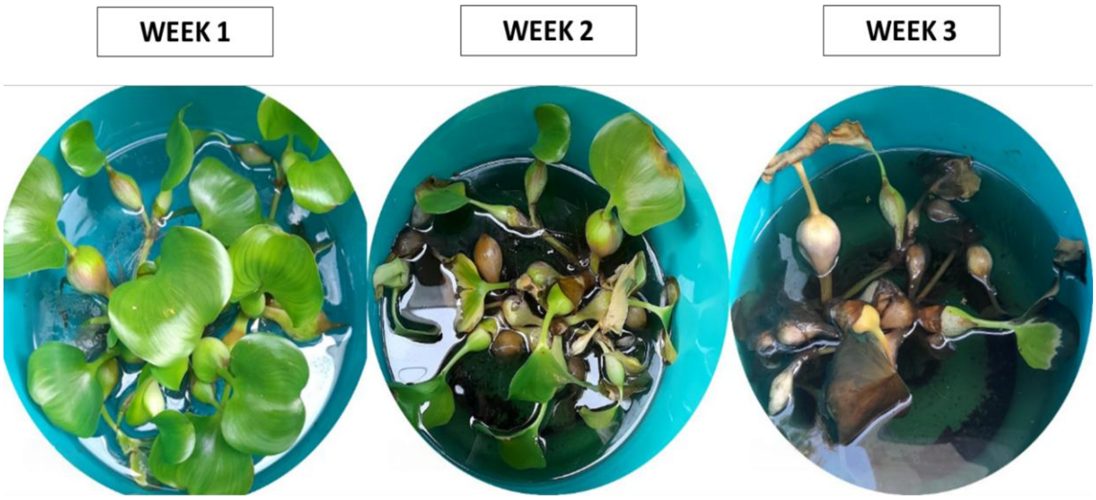

Figure 2(d): Health of Hyacinth in Lake Water 4 (Pallikaranai Lake) over 3 weeks

Table1(d). *Analysis of Water Quality in Hyacinth - Lake Water 4 (Pallikaranai Lake)Sample*

Parameters (mg/L)	Control	Week 0	Week 1	Week 2
Alkalinity	0	360	330	340
Hardness	0	360	300	300
Calcium Hardness	0	200	200	185
Calcium	0	80	80	74
Chloride	0	110	110	135
Ammonia	0	0.2	0.2	0.5
Phosphate	0	0.5	0.5	1
Nitrite	0	0	0.5	0.5
Nitrate	0	15	45	45
Ph	7	8.5	8.5	8.5

From Table 1(d), it was observed that during the two-week monitoring period of Hyacinth - lake water 4 sample, alterations were observed in several parameters. Alkalinity decreased from an initial concentration of 360 to 340 mg/L. Hardness experienced a reduction from 360 to 300 mg/L, while calcium hardness decreased from 200 to 185 mg/L. Calcium levels dropped from 80 to 74 mg/L. Chloride levels increased from 110 to 135 mg/L. Ammonia concentrations rose from 0.2 to 0.5 mg/L. Phosphate levels increased from 0.5 to 1 mg/L. Nitrite concentrations increased from 0 to 0.5 mg/L, and nitrate levels climbed from 15 to 45 mg/L. pH remained constant at 8.5.

Effect of Hyacinth on Groundwater:

From Figure 2(e),it was observed that the Hyacinth partially deteriorated between 1st week and 2nd week and was completely deteriorated between 2ndweek and 3rd week in the Hyacinth-groundwatersample.The water quality was analyzed in Hyacinth - groundwater sample for a period of 2 weeks on a daily basis. The control sample was the Hyacinth transplanted in distilled water sample for the same period of time (3 weeks), which provided a baseline comparison. Week 0 represents the initial water quality of groundwatersample without the Hyacinth. Week 1 and Week 2 represents the impact of Hyacinth on the water quality of groundwater.Table 1(e)represents the analysis of water quality in the Hyacinth -groundwater sample:

Figure 2(e): Health of Hyacinth in groundwater over 3 weeks

Table1(e). *Analysis of Water Quality in Hyacinth -Groundwater Sample*

Parameters (mg/L)	Control	Week 0	Week 1	Week 2
Alkalinity	0	380	350	310
Hardness	0	340	285	280
Calcium Hardness	0	250	140	160
Calcium	0	100	56	64
Chloride	0	120	115	135
Ammonia	0	0.2	0.2	0.5
Phosphate	0	0.5	0.5	1
Nitrite	0	0	0.5	0.5
Nitrate	0	15	45	45
pH	7	8.5	8.5	8.5

From Table 1(e), it was observed that during the two-week monitoring period in the Hyacinth -groundwater sample, changes were noted in various parameters. Alkalinity decreased from 380 to 310 mg/L, while hardness decreased from 340 to 280 mg/L. Calcium hardness also showed a decrease from 250 to 160 mg/L, alongside a decrease in calcium from 100 to 64 mg/L. Chloride levels increased from 120 to 135 mg/L. Ammonia concentrations rose from 0.2 to 0.5 mg/L. Phosphate levels increased from 0.5 to 1 mg/L. Nitrite concentrations increased from 0 to 0.5 mg/L, and nitrate levels climbed from 15 to 45 mg/L. pH remained constant at 8.5 throughout the monitoring period.

<u>Effect of Hyacinth on RO-Water:</u>

From Figure 2(f),it was observed that the Hyacinth was not deteriorated from 1stweek to 3rd week in the Hyacinth -RO-water sample.The water quality was analyzed in Hyacinth - RO-water sample for a period of 2 weeks on a daily basis. The control sample was the Hyacinth transplanted in distilled water sample for the same period of time (3 weeks), which provided a baseline comparison. Week 0 represents the initial water quality of RO-water sample without the Hyacinth. Week 1 and Week 2 represents the impact of Hyacinth on the water quality of RO-water.Table 1(f)represents the analysis of water quality in the Hyacinth - RO-water sample:

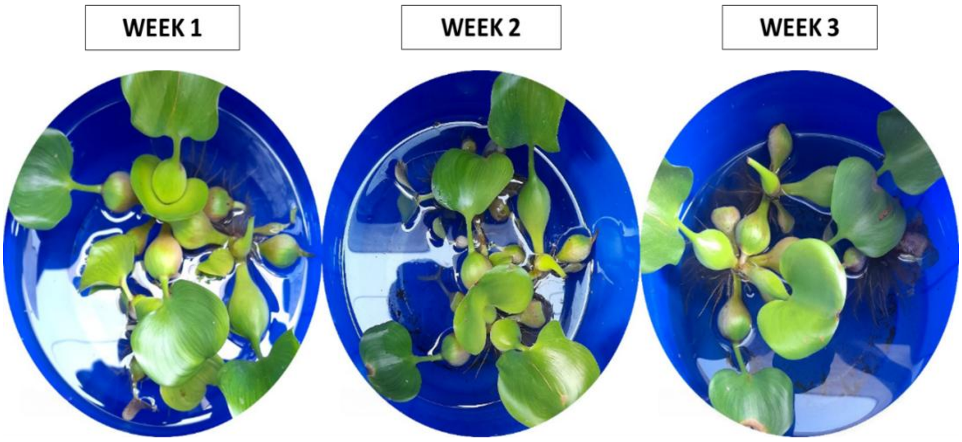

Figure 2(f): Health of Hyacinth in RO-water over 3 weeks

Table1(f). *Analysisof Water Quality in Hyacinth-RO-Water Sample*

Parameters (mg/L)	Control	Week 0	Week 1	Week 2
Alkalinity	0	30	35	30
Hardness	0	20	20	15
Calcium Hardness	0	20	20	20
Calcium	0	8	8	8
Chloride	0	20	25	30
Ammonia	0	0.2	0.2	0.5
Phosphate	0	0	0	0
Nitrite	0	0	0.5	1
Nitrate	0	15	45	45
pH	7	6.5	6.5	6.5

From Table 1(f), it was observed that over the course of two weeks in the Hyacinth - RO-water sample, there were changes in several parameters. Hardness decreased from 20 to 15 mg/L, while alkalinity remained stable at 30 mg/L. Calcium hardness and calcium levels stayed constant at 20 and 64 mg/L respectively. Chloride levels increased from 20 to 30 mg/L. Ammonia concentrations rose from 0.2 to 0.5 mg/L. Phosphate remained consistent at 0 mg/L. Nitrite concentrations increased from 0 to 1 mg/L, and nitrate levels climbed from 15 to 45 mg/L. pH remained steady at 6.5 throughout the monitoring period.

Analysis of Heavy Metal Contaminants in Water Samples:

Table 2(a)represents the heavy metal analysis conducted on all the water samples:

Table 2(a). *Heavy Metal Analysis of Water Samples*

Heavy Metals	Maximum Permissible Limit for Safe Drinking Water - IS 10500:2012 (mg/L)	Water Samples (mg/L)
Total Arsenic as As	Not more than 0.01	Less than 0.005
Lead as Pb	Not more than 0.01	Less than 0.005
Total Chromium as Cr	Not more than 0.05	Less than 0.02
Mercury as Hg	Not more than 0.001	Less than 0.0005

From Table 2(a),it was observed that the heavy metal contaminants like arsenic (As), lead (Pb), chromium (Cr) and mercury (Hg) in all the water samples were below the instrument detection limit. The amount ofarsenic was less than 0.005 mg/L; the amount of lead was less than 0.005 mg/L; the amount of chromium was less than 0.02 mg/L and the amount of mercury was less than 0.0005 mg/L.

Comparison of Absorption of Heavy Metals by Hyacinth Leaves from its Lake Water Source (Adambakkam Lake):

Table 2(b) represents the heavy metal analysis conducted on both Hyacinth leaves and the corresponding water from Adambakkam Lake:

Table 2(b): Heavy Metal Absorption of Hyacinth Leaves from its Lake Water Source

Heavy Metals	**Lake Water Source (µg/L)**	**HyacinthLeaves (µg/Kg)**
Total Arsenic as As	1.1	Not Detected
Lead as Pb	17.5	0.2
Total Chromium as Cr	32.2	Not Detected
Mercury as Hg	57.7	35.3

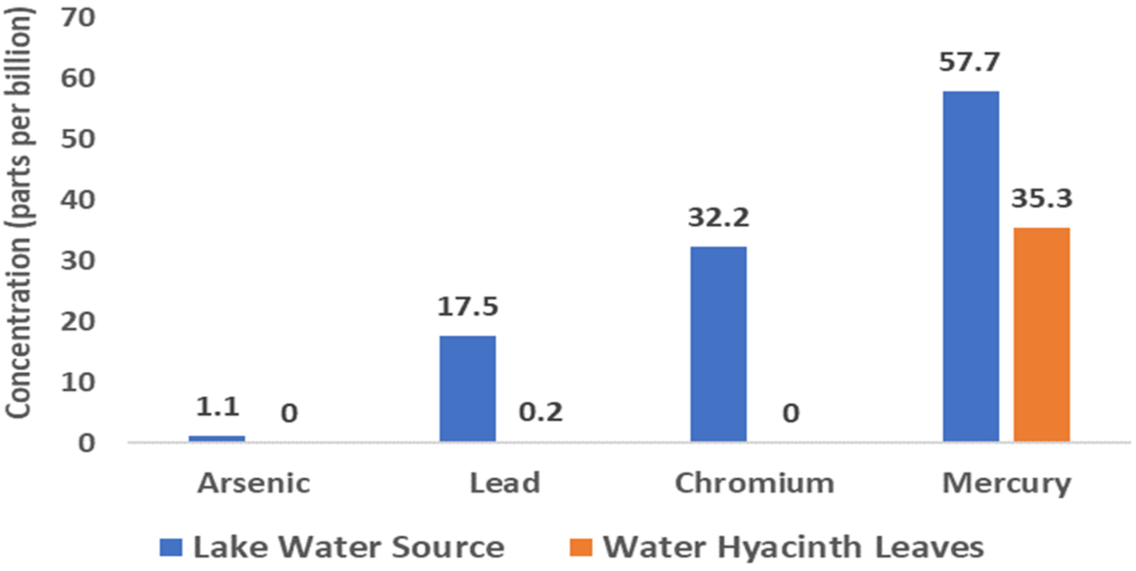

Figure 3: Comparison of Heavy Metal Absorption Between Hyacinth Leaves and its Lake Water Source (Adambakkam Lake)

From Figure 3, it was observed that the Hyacinth leaves did not absorb arsenic and chromium from the lake water and was not detected, but it had accumulated 0.2 µg/Kg of lead and 35.3 µg/Kg of mercury from its lake water source (Adambakkam Lake) containing 17.5 µg/L of lead and 57.7 µg/L of mercury respectively.

<u>Comparative Analysis of the Levels of the Water Quality Parameters Between Different Hyacinth - Water Samples Using ANOVA (Analysis of Variance):</u>

An ANOVA (Analysis of Variance) was conducted between different Hyacinth - Water samples, such as those from Puzhuthivakkam Lake (lake water 1), Madipakkam Lake (lake water 2), Adambakkam Lake (lake water 3), Pallikaranai Lake (lake water 4), groundwater and RO-waterto compare changes in the levels of the water quality parameters (including alkalinity, hardness, calcium hardness, calcium, chloride, ammonia, phosphate, nitrite and nitrate). The threshold for significance was set at $\alpha = 0.05$ during the entire process.

<u>Comparative Analysis of Alkalinity Levels Between Different Hyacinth - Water Samples Using ANOVA:</u>

The aim of ANOVA was to determine whether there were significant differences in alkalinity levels between different Hyacinth - Water samples. An ANOVA: Single Factor analysis was performed to evaluate the alkalinity levels across the sampled groups.

The statistical analysis showed that the average alkalinity levels varied among the different sources. Groundwater exhibited the highest mean alkalinity level, measured at 346.7 ± 35.1 mg/L, followed by lake water 4 at 343.3 ± 15.3 mg/L, lake water 3 at 335 ± 8.7 mg/L, lake water 2 at 131.7 ± 2.9 mg/L, and lake water 1 at 115 ± 5 mg/L. While, RO-water displayed the lowest alkalinity level, recorded at 31.7 ± 2.9 mg/L.

Result of Hypothesis:

The results of the ANOVArevealed notable differences in alkalinity levels among the Hyacinth - Water samples (F (5,12) = 224.5, p = 2 x 10^{-11}). As $p < 0.05$, the null hypothesis (H_0) was dismissed in favor of the alternative hypothesis (H_1), indicating substantial variations in alkalinity levels among at least one pair of sampled groups.

Comparative Analysis of Hardness Levels Between Different Hyacinth - Water Samples Using ANOVA:

The aim of ANOVA was to determine whether there were significant differences in hardness levels between different Hyacinth - Water samples. An ANOVA: Single Factor analysis was performed to evaluate the hardness levels across the sampled groups.

The statistical analysis indicated that the average hardness level varied across different sources. Lake water 3 displayed the highest mean hardness level, measured at 345 ± 5 mg/L, followed by lake water 4 at 320 ± 34.6 mg/L, lake water 2 at 146.7 ± 15.3 mg/L, and lake water 1 at 133.3 ± 15.3 mg/L. While, RO-water exhibited the lowest hardness level, recorded at 18.3 ± 2.9 mg/L.

Result of Hypothesis:

The results of the ANOVA analysis indicated significant differences in the hardness levels among the Hyacinth - Water samples (F (5,12) = 109.4, p = 1.4 x 10^{-9}). As $p < 0.05$, the null hypothesis (H_0) was refuted in favor of the alternative hypothesis (H_1), indicating notable variations in hardness levels among at least one pair of sampled groups.

Comparative Analysis of Calcium Hardness Levels Between Different Hyacinth - Water Samples Using ANOVA:

The aim of ANOVA was to determine whether there were significant differences in calcium hardness levels between different Hyacinth - Water samples. An ANOVA: Single Factor analysis was performed to evaluate the calcium hardness levels across the sampled groups.

The statistical analysis showed that the average calcium hardness level varied across different sources. Lake water 3 exhibited the highest mean calcium hardness level, measured at 210 ± 10 mg/L, followed by lake water 4 at 195 ± 8.7 mg/L, groundwater at 183.3 ± 58.6 mg/L, lake water 1 at 108.3 ± 36.2 mg/L, and lake water 2 at 93.3 ± 7.6 mg/L. And, the lowest calcium hardness level was found in RO water, at 20 mg/L.

Result of Hypothesis:

The results of the ANOVA analysis indicated significant differences in the calcium hardness levels among the Hyacinth - Water samples (F (5,12) = 19.7, p = 2.1 x 10^{-5}). As $p < 0.05$, the null hypothesis (H_0) was dismissed in favor of the alternative hypothesis (H_1), suggesting notable variations in calcium hardness levels among at least one pair of sampled groups.

Comparative Analysis of Calcium Levels Between Different Hyacinth - Water Samples Using ANOVA:

The aim of ANOVA was to determine whether there were significant differences in calcium levels between different Hyacinth - Water samples. An ANOVA: Single Factor analysis was performed to evaluate the calcium levels across the sampled groups.

The statistical analysis showed that the average calcium level varied across different sources. Lake water 3 exhibited the highest mean calcium level, measured at 84 ± 4 mg/L, followed by lake water 4 at 78 ± 3.5 mg/L, groundwater at 73.3 ± 23.4 mg/L, lake water 1 at 43.3 ± 14.5 mg/L, and lake water 2 at 37.3 ± 3.1 mg/L. And, the lowest calcium level was found in RO-water, at 8 mg/L.

Result of Hypothesis:

The ANOVA results unveiled notable differences in calcium levels among the Hyacinth - Water samples ($F (5,12) = 19.7$, $p = 2.1 \times 10^{-5}$). As $p < 0.05$, the null hypothesis (H_0) was dismissed in favor of the alternative hypothesis (H_1), indicating significant variations in calcium levels between at least one pair of sampled groups.

Comparative Analysis of Chloride Levels Between Different Hyacinth - Water Samples Using ANOVA:

The aim of ANOVA was to determine whether there were significant differences in chloride levels between different Hyacinth - Water samples. An ANOVA: Single Factor analysis was performed to evaluate the chloride levels across the sampled groups.

The statistical analysis indicated that the average chloride level varied among different sources. Lake water 3 exhibited the highest mean chloride level, measured at 146.7 ± 20.8 mg/L, followed by groundwater at 123.3 ± 10.4 mg/L, lake water 4 at 118.3 ± 14.4 mg/L, lake water 1 at 90 ± 10 mg/L, and lake water 2 at 86.7 ± 11.5 mg/L. And, the lowest chloride level was found in RO-water, at 25 ± 5 mg/L.

Result of Hypothesis:

The ANOVA results uncovered notable differences in chloride levels among the Hyacinth - Water samples ($F (5,12) = 31.9$, $p = 1.6 \times 10^{-6}$). As $p < 0.05$, the null hypothesis (H_0) was refuted in favor of the alternative hypothesis (H_1), suggesting significant variations in chloride levels between at least one pair of sampled groups.

Comparative Analysis of Ammonia Levels Between Different Hyacinth - Water Samples Using ANOVA:

The aim of ANOVA was to determine whether there were significant differences in ammonia levels between different Hyacinth - Water samples. An ANOVA: Single Factor analysis was performed to evaluate the ammonia levels across the sampled groups.

The statistical analysis showed that the average ammonia level varied among different sources. Lake water 3 exhibited the highest mean ammonia level, measured at 1.2 ± 1.5 mg/L, followed by lake water 1 at 1.1 ± 1.6 mg/L. Meanwhile, lake water 2, lake water 4, and groundwater displayed similar mean levels of 0.3 ± 0.2 mg/L. While, the lowest ammonia level was found in RO-water, at 0.3 ± 0.2 mg/L.

Result of Hypothesis:

The results of the ANOVA analysis indicated that the differences in ammonia levels among the Hyacinth - Water samples were not statistically significant ($F (5,12) = 0.7$, $p = 0.6$). As $p > 0.05$, the null hypothesis (H_0) could not be refuted, implying that the discrepancies among the groups might be attributed to random chance rather than systematic variations between them.

Comparative Analysis of Phosphate Levels Between Different Hyacinth - Water Samples Using ANOVA:

The aim of ANOVA was to determine whether there were significant differences in phosphate levels between different Hyacinth - Water samples. An ANOVA: Single Factor analysis was performed to evaluate the phosphate levels across the sampled groups.

The statistical analysis indicated that the average phosphate level varied among different sources. Lake water 3 displayed the highest mean phosphate level, measured at 2.7 ± 0.6 mg/L, followed by lake water 1 at 1.2 ± 1.6 mg/L. Meanwhile, lake water 4 and groundwater showed similar mean levels of 0.7 ± 0.3 mg/L, and lake water 2 had a mean level of 0.5 ± 0.5 mg/L. While, phosphate was not detected in RO-water, with a recorded level of 0 mg/L.

Result of Hypothesis:

The ANOVA examination unveiled significant distinctions in the phosphate levels among the Hyacinth - Water samples ($F(5,12) = 4.6$, $p = 0.01$). As $p < 0.05$, the null hypothesis (H_0) was dismissed in favor of the alternative hypothesis (H_1), suggesting noteworthy variations in phosphate levels across the sampled groups.

Comparative Analysis of Nitrite Levels Between Different Hyacinth - Water Samples Using ANOVA:

The aim of ANOVA was to determine whether there were significant differences in nitrite levels between different Hyacinth - Water samples. An ANOVA: Single Factor analysis was performed to evaluate the nitrite levels across the sampled groups.

The statistical analysis indicated that the average nitrite level was highest in both RO water, measured at 0.5 ± 0.5 mg/L, and lake water 3, also at 0.5 mg/L. While, it was lowest in lake water 1, lake water 2, lake water 4, and groundwater, showing comparable mean levels of 0.3 ± 0.3 mg/L.

Result of Hypothesis:

The results of the ANOVA analysis indicated that the differences in nitrite levels among the Hyacinth - Water samples did not exhibit statistical significance ($F(5,12) = 0.2$, $p = 0.9$). As $p > 0.05$, the null hypothesis (H_0) could not be dismissed, implying that the variation among the groups might be attributed to random chance rather than systematic differences.

Comparative Analysis of Nitrate Levels Between Different Hyacinth - Water Samples Using ANOVA:

The aim of ANOVA was to determine whether there were significant differences in nitrate levels between different Hyacinth - Water samples. An ANOVA: Single Factor analysis was performed to evaluate the nitrate levels across the sampled groups.

The statistical analysis indicated that the average nitrate level was observed to be highest in lake water 3 at 45 mg/L, followed by lake water 4, groundwater, and RO-water, all showing similar mean levels of 35 ± 17.3 mg/L. And, the lowest mean levels were found in lake water 1 and lake water 2, both displaying comparable mean levels of 30 ± 26 mg/L.

Result of Hypothesis:

The results of the ANOVA analysis indicated that the differences in nitrate levels among the Hyacinth-Water samples were not statistically significant ($F(5,12) = 0.2$, $p = 0.9$). As $p > 0.05$, the null hypothesis (H_0) could not be refuted, suggesting that the variances observed among the groups might be attributed to random chance rather than systematic differences.

Comparative Analysis of pH Levels Between Different Hyacinth - Water Samples Using ANOVA:

The aim of ANOVA was to determine whether there were significant differences in pH levels between different Hyacinth - Water samples. An ANOVA: Single Factor analysis was performed to evaluate the pH levels across the sampled groups.

The statistical analysis revealed that the mean pH level was highest in lake water 3, recorded at 9 units, followed by lake water 4 and groundwater, both with similar mean levels of 8.5 units. Lake water 1 and lake water 2 exhibited comparable mean levels, both at 7.5 units. The lowest mean pH level was observed in RO-water, measuring 6.5 units.

Result of Hypothesis:

The results of the ANOVA analysis indicated that the differences in the pH levels among the Hyacinth - Water samples were not statistically significant ($F(5,12) = 65535$, p value was not defined, and it was assumed that $p > 0.05$). Therefore, the null hypothesis (H_0) could not be dismissed, suggesting that the variation among the groups might be primarily due to random chance rather than systematic differences.

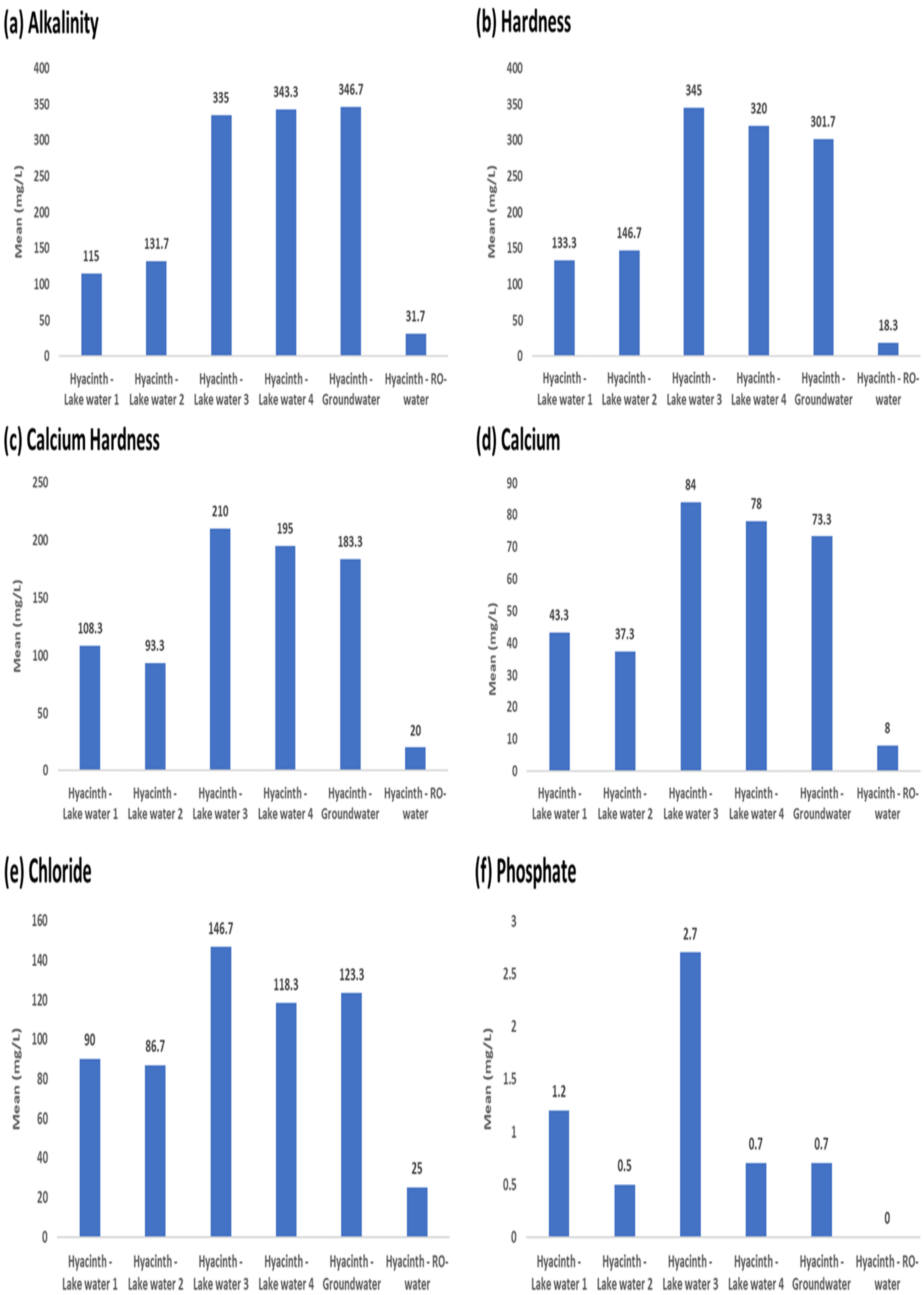

Figure 4: Mean levels of (a) Alkalinity (b) Hardness (c) Calcium Hardness (d) Calcium (e) Chloride (f) Phosphate between different Hyacinth – Water samples. (Data was analyzed using ANOVA: Single Factor using Microsoft Excel. Data obtained were significantly different, $p < 0.05$)

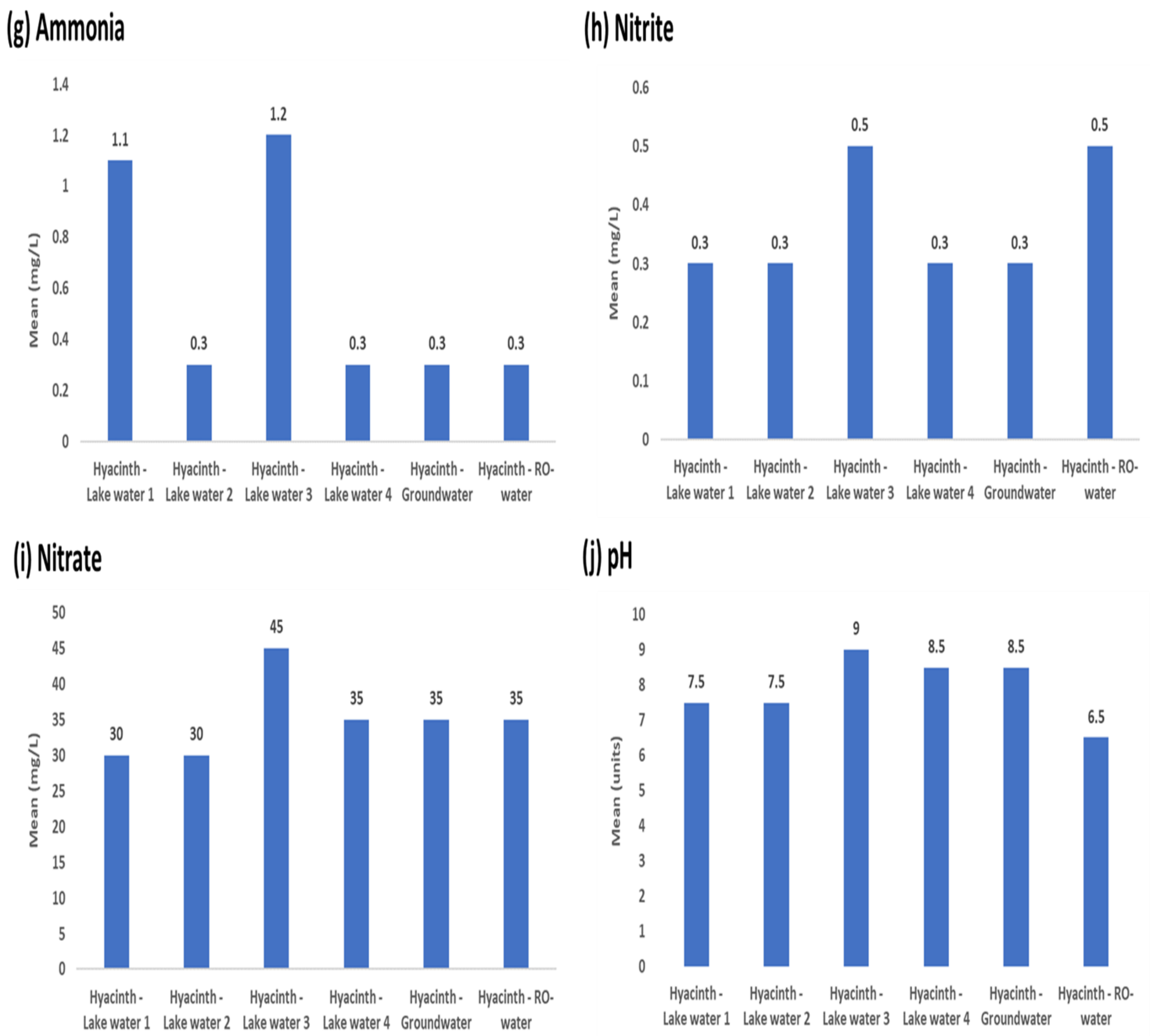

Figure 4: Mean levels of (g) Ammonia (h) Nitrite (i) Nitrate (j) pH between different Hyacinth – Water samples (Data was analyzed using ANOVA: Single Factor using Microsoft Excel. Data obtained were not significantly different, $p > 0.05$)

Significance inthe Levels of Water Quality Parameters Between Different Hyacinth - Water Samples:

Based on the ANOVA (Analysis of Variance) between different Hyacinth - Water samples, such as those from Puzhuthivakkam Lake (lake water 1), Madipakkam Lake (lake water 2), Adambakkam Lake (lake water 3), Pallikaranai Lake (lake water 4), groundwater and RO-waterto compare changes in the level of theselected water quality parameter (including alkalinity, hardness, calcium hardness, calcium, chloride, ammonia, phosphate, nitrite and nitrate).Table 3 represents the significance in the levels of every water quality parameter:

Table3. *Significance in the Levels ofWater Quality Parameters*

Parameters	**F-value**	**p-value**	**Significanceif ($p < 0.05$)**
Alkalinity	224.5	2×10^{-11}	Significant
Hardness	109.4	1.4×10^{-9}	Significant
Calcium Hardness	19.7	2.1×10^{-5}	Significant
Calcium	19.7	2.1×10^{-5}	Significant
Chloride	31.9	1.6×10^{-6}	Significant
Phosphate	4.6	0.01	Significant
Ammonia	0.7	0.6	Non-significant

Nitrite	0.2	0.9	Non-significant
Nitrate	0.2	0.9	Non-significant
pH	65535	Not defined	Non-significant

From the analysis of water quality parameters across various Hyacinth - Water samples using ANOVA: Single Factor as listed in Table 3, it was noted that significant differences existed in the levels of alkalinity, hardness, calcium hardness, calcium, chloride, and phosphate. However, no statistically significant differences were observed in the levels of ammonia, nitrite, nitrate, and pH.

4. CONCLUSIONS

This study investigated the effect of Hyacinth on changes in water quality across different water samples. Six different water samples were used for this experimentsuch as those from Puzhuthivakkam Lake (lake water 1), Madipakkam Lake (lake water 2), Adambakkam Lake (lake water 3), Pallikaranai Lake (lake water 4), groundwater and RO-water. The Hyacinth was transplanted in every water sample and the water quality parameters (including alkalinity, hardness, calcium hardness, calcium, chloride, ammonia, phosphate, nitrate, nitrite and pH) were analyzed until the Hyacinth plant showed complete decline in health (until two weeks).

Based on the heavy metal analysis of Hyacinth leaves and its lake water source (Adambakkam Lake), it was observed that the Hyacinth leaves did not absorb arsenic and chromium from the lake water and was not detected; but it had accumulated 0.2 µg/Kg of lead and 35.3 µg/Kg of mercury from its lake water source (Adambakkam Lake) containing 17.5 µg/L of lead and 57.7 µg/L of mercury respectively.

Upon conducting a comparative analysis of water quality parameters across various Hyacinth - Water samples using ANOVA: Single Factor, significant differences were noted in the levels of alkalinity, hardness, calcium hardness, calcium, chloride, and phosphate. However, no statistically significant differences were observed in the levels of ammonia, nitrite, and nitrate between the different Hyacinth - Water samples.

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