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A Concise Study on Essential Parameters for the Sustainability of Lagoon Waters in Terms of Scientific Literature

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Abstract: Lagoons are becoming sporadically utilised albeit they are equipped with high potential for the outsourcing of environmental and industrial benefits. It leads to the endangered pollution of lagoon water aquatic system. The prime reason is the lack of knowledge among stakeholders and researchers regarding the influential parameters in establishing the lagoon water quality. The optimal quality for lagoon water is critical for the longevity of aquatic ecosystem. This study focuses on using bibliographic references to find the most influential factors determining the water quality in lagoons for deriving a comprehensive long-term water quality monitoring plan to ensure the sustainability of the lagoon water ecosystem. The lagoon water quality was classified in this study into biological, physical, and chemical parameters and studied for their importance upon enhancing the water quality. Experiments were conducted on selected parameters using the water samples from the selected Sri Lankan lagoons with available facilities to observe the water quality. The overall findings on physiochemical and biological characteristics using the experiments temperature, turbidity, pH, salinity, DO, BOD, COD, phosphates, nitrates, ammonia content and faecal coliforms in water specimens suggest that the selected Sri Lankan lagoons are heavily polluted due to their distinctive variations from the allowable threshold limits specified in the literature sources. To increase such increased risks associated with lagoon water systems, a long-term monitoring strategy is recommended to be incorporated at lagoon waters in order to assure their sustainability.

Keywords: water quality; sri lankan lagoons; threshold limits; lagoon water pollution; physiochemical characteristics; sustainability

1. Introduction

A Lagoon is a type of shallow water body that is reinforced from the oceans by coral reefs, sandbars, and islands, which formed about 6000–7000 years ago due to Holocene sea level rise and marine transgressions, which covered about 13% of the worldwide coastal regions (Kjerfve, 1994). Many economic activities on transportation and industrial progress, such as tourism, aquaculture, and fishing are being conducted based on lagoons. It provides habitat for a number of fauna and flora and serves as a breeding site and nursery for aquatic organisms (Silva, Katupotha, Amarasinghe, Manthrithilake, & Ariyaratna, 2013, Okoyen et al., 2020, Raimi et al., 2022a). Lagoons, on the other hand, are polluted by a variety of pollution sources, including industrial, domestic, and agricultural waste, which contributes to water quality deterioration and has an impact on aquatic organisms and communities that rely on lagoon ecosystems (Afolabi & Raimi, 2021; Raimi et al., 2022b, c; Olalekan et al., 2022a, b; Raimi & Sawyerr, 2022). In particular to Sri Lankan lagoons, more swamps of eutrophication, floating of dead aquatic species, and the advent of waterborne diseases constantly prevail in the surrounding community (Silva et al., 2013; Raimi et al., 2017; Olalekan et al., 2020). Therefore, it is necessary to obtain a systematic approach regarding the processes, functions, and structure of lagoons to facilitate environmental sustainability during utilisation for human wellbeing.

Optimum features of lagoon water for accommodate the ecological demands would viable the breeding sources for fisheries, shrimp farming, habitat for fauna and flora, useful for the surrounding community and even for drinking purposes. Therefore, the utilisation of lagoons for human needs and other requirements largely depends on water quality parameters (Afolabi & Raimi, 2021; Raimi et al., 2022b, c; Olalekan et al., 2022a, b; Raimi & Sawyerr, 2022; Stephen et al., 2023). Therefore, this study includes biological, chemical, and physical parameters of lagoon water under its scope. Based on previous studies, it was identified that the most influential parameters on the dynamic nature of lagoons are comprehensively elaborated in Table 1. The purpose of this study is to collect the relevant information from the authentic scientific literature regarding the important parameters influencing the attributes of lagoon water, to investigate the nature of Sri Lnakan lagoon waters in accordance to identified literature sources, and to provide the researchers with a comprehensive idea for a long-term monitoring plan to withstand the risks of physicochemical and biological contamination of lagoon waters. The selected parameters were tested on water samples from five Sri Lankan lagoons: Jaffna, Negombo, Batticaloa and Koggala lagoons and the results were compared with the allowable ranges found in scientific literature. The trends of pollution were briefly discussed in this paper under relevant subtopics along with their corresponding protective measures and a comprehensive monitoring plan for lagoons was proposed for the long-term establishment of sustainability.

Table 1. Classification of water quality parameters (Spellman, 2008).

Water Quality Parameters		
Physical	**Chemical**	**Biological**
Temperature	pH	Bacteria (Fecal contamination)
Turbidity	Salinity	Virus
Total Dissolved Solids	Dissolved Oxygen	Algae
Total Suspended Solids	Biological Oxygen Demand and Chemical Oxygen Demand	
	Alkalinity	
	Hardness	
	Oil and grease	
	Sulphate	
	Phosphate	
	Nitrate	
	Ammonia	
	Potentially Toxic Elements	

2. Literature Review

Water quality is a measure of the definite state of water in terms of the requirements of several aquatic biota for optimal human use (Shah, 2017; Olalekan et al., 2022a, b; Raimi et al., 2022b, c; Raimi & Sawyerr, 2022; Stephen et al., 2023). Water quality parameters elaborate comprehensive information on the ecological impacts of lagoon water contamination due to domestic, agricultural, and industrial effluents (Odipe et al., 2018). Water is categorized into four groups based on its attribute such as infected water, contaminated water, palatable water and potable water (Chatterjee, 1996). Contaminated water comprises undesired physical, chemical, biological, and radioactive elements, making it unsafe for consumption or household purposes. Infected water is categorised

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due to its contamination with pathogens. Potable water has sustainable benefits such as safe consumption and domestic efficacy. Palatable water comprises the chemicals those do not risk the humans. Lagoons contain all these types of waters due to natural and the anthropogenic activities. Table 1 illustrates all the physical, chemical, and biological parameters affecting the quality of lagoon water. Our research study have analysed every parameters in detail with respective to their threshold magnitudes of toxicology. Some experimental studies were also conducted using Sri Lankan lagoon water specimens using the available laboratory facilities to compare the lagoon water quality with the prerequisites mentioned for corresponding parameters in the literature sources.

2.1. Physical Parameters

2.1.1. Temperature

The biological activities in lagoon water are immensely influenced by temperature. It is an influential factor in terms of palatability, solubility, viscosity, odour and the biosorption of the Potentially Toxic Elements and metalloids (Abbas, Ismail, Mostafa, & Sulaymon, 2014; Olalekan et al., 2022a, b; Raimi 7 Sawyerr, 2022). It regulates metabolic activities, growth, reproduction, distribution, and migration of aquatic organisms in lagoon ecosystems (Suski, Killen, Kieffer, & Tufts, 2006; Odipe et al., 2018). Risks due to climate change impacts such as urban heat island (UHI) effect and wastewater discharge into lagoons due to anthropogenic activities all contribute to an increase in lagoon water temperature (Briciu et al., 2020). Since the majority of lagoon habitats are cold-blooded, the sudden changes in temperature due to environmental imbalances would stress the equilibrium and cause fatal results for fish species (Hall & Wazniak, 2005). Furthermore, aquatic species like fishes, phytoplanktons, zooplanktons, and insects have distinct body temperature ranges. The average temperature of five selected Sri Lankan lagoons recorded to test their nature is provided in Table 2.

Table 2. Physical characteristics of the selected Sri Lankan lagoons.

Physical Parameters	**Jaffna Lagoon**	**Negombo Lagoon**	**Batticaloa Lagoon**	**Koggala Lagoon**	**Puttalam Lagoon**
Temperature (°C)	34.27	27.51	32.28	25.17	29.88
Turbidity **(NTU)**	3.35-20.14	4.86-13.11	7.92-24.71	8.10-28.52	5.44-17.87

2.1.2. Turbidity

The turbidity of lagoon water is decided by the amount of suspended solids it contains. Both the light reflectivity of lagoon water and the extent of light penetration through water could be deduced by quantifying its turbidity. A turbidity test is conducted to estimate the ability of lagoon water to discharge waste corresponding to colloids (Meride & Ayenew, 2016). The content of suspensions such as clay, organic materials, planktons, silt, and other related particulates affects the amount of turbidity (Alley, 2007; Davis, 2010). These particulates due to various agricultural and industrial activities are emitted into lagoons. They serve as hotbeds for microorganisms; therefore, therefore prompted disinfection is required for the continuous supply of lagoon water for the existence of aquatic species.

Higher turbidity causes suspended matters to accumulate Potentially Toxic Elements, agricultural pesticides, and organic compounds such as polycyclic aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs) via adsorption. (Cole et al., 2000). Determining turbidity of water after a rainfall might will indicate the emergence of a new contaminant into a lagoon. Turbidity measurements must be conducted on lagoon water specimens every three to four hours under extreme care if the lagoon is proposed to be utilised for drinking water purposes (Davis & Cornwell, 2008). Table 2 of this manuscript illustrates the Turbidity test results conducted using turbidity tubes with water samples from five Sri Lankan lagoons.

2.1.3. Total Dissolved Solids (TDS)

The measure of total mineral content in a lagoon water sample is described by the measure of TDS. If the lagoon water was optimum in pH and higher in TDS, the root systems of aquatic plants would be nourished further (Abinaya, Saraswathi, Rajamohan, & Mohammed, 2018; Chen et al., 2018). However, due to the agrochemical, industrial, and fuel contamination, the Sri Lankan lagoons generally contain higher pH and higher TDS. Moreover, higher chemical contamination of inland water bodies has caused drastic ecological losses in recent times in Sri Lanka (Adikaram, Pitawala, Ishiga, Jayawardana, & Eichler, 2021). It shows that the higher TDS of lagoon water could not only help on its own for enhanced aquatic biodiversity. Water can be effectively classified based on TDS as mentioned in Table 3.

Table 3. Classification of water according to TDS (Al-Shujairi, 2013).

Type of Water	TDS Range (mg/L)
Fresh water	Less than 1500
Brackish water	1500-5000
Saline water	More than 5000

Minerals such as chlorides, bicarbonates, sulphates, potassium, magnesium, sodium and calcium are soluble after undergoing certain chemical transformations and produce detrimental changes in taste and colour of water. An extremely mineralized water sample contains excessive TDS and produces more deformations in water quality(S. A. Kader, Spalevic, & Dudic, 2022). Hard water is formed as a result of higher TDS. The most important factors in TDS are the constituents of chlorides, potassium, and sodium. These ions do not exist in higher amounts, but their presence would cause long-term effects. Most urban lagoons are contaminated due to urban runoff, pesticides, fertilizers, and construction debris, which lead to rise TDS in lagoons (Madarasinghe et al., 2020). Therefore, a comprehensive understanding of TDS using authentic past study results is compulsory to evaluate the undergoing sequences and to formulate effective solutions.

2.1.4. Total Suspended Solids (TSS)

The total amount waterborne solids with larger than 2mm particle sizes those found as suspensions are categorized into TSS (Saranga, Premarathne, & Atapattu, 2021). In contrary, total dissolved solid (TDS) are larger than 2 microns. The major constituents of TSS are inorganic compounds. Algae and bacteria are common examples for TSS. These TSS form in lagoons often by the surrounding ecosystem. Due to the water contamination by decaying organics in lagoons, silty suspended solids accumulate the water bottom and the other TSS species float on both the middle and surface. Concentration of suspended solids are inversely proportional to the clarity of water.

TSS is the standard parameter to measure the lagoon operators. It is a conventional pollutant that mostly induces the grooming of algae cells, sulphur bacteria, and protozoa (Wiley, Brenneman, & Jacobson, 2009). TSS levels beyond a certain threshold raise water temperatures and would also reduce the concentration of dissolved oxygen in lagoons. The main cause is the absorption of intense heat from solar radiation by the suspended particles in lagoon water (S. Kader, Jaufer, L., 2022; Paaijmans, Takken, Githeko, & Jacobs, 2008). Algae use carbonates and bicarbonate from the suspended solids as carbon sources and leads to high rate of algal blooms in lagoon. Furthermore, these suspended solids are clogged into fish gills and lead to their immune systems fused while declining their larval maturation, which is a serious biological effect (Kiprono, 2017; Tarras-Wahlberg, Harper, & Tarras-Wahlberg, 2003). Table 4 shows the TSS types and the products in lagoon water effluents due to those corresponding TSS over existence.

Table 4. Reflection of excess TSS types (Richard & Bowman, 1991).

Excess TSS	Form of Existence
Algae	Overgrowth of Algae
Bacterial flocs	Accumulation of sludge

Filamentous bacteria	Low oxygen conditions in lagoon water (i.e., water septicity)
Old sludge particles	Necessity for sludge removal in lagoon water
Raw wastewater solids	Improper stabilization of wastes due to lack of aeration prevails in lagoon water
Sulphur bacteria	Over-exhibition of Anaerobic microorganisms

2.2. Chemical Parameters

2.2.1. pH

pH is one of the important indicator for lagoon water quality. It is one of the key factors that ensures the longevity of aquatic species. pH represents the intensity of active hydrogens in water. The optimum pH magnitude for lagoon water is 7.0, while the increase beyond the optimum amount is defined as acidic and the decrementing values from 7.0 are termed alkaline (Alley, 2007; S. Kader, Chadalavada, Jaufer, Spalevic, & Dudic, 2022; Raimi et al., 2022b, c; Olalekan et al., 2022a, b; Raimi & Sawyerr, 2012). There are several natural and man-made elements that might influence the pH of lagoon water. The majority of natural changes are caused by interactions with carbonate and bicarbonate compounds, as well as other elements. Acid rain, wastewater, residential garbage, and mining discharges can all alterate the lagoon water pH. The anthropogenic activities induce variations in lagoon water CO_2 concentrations and organic material decomposition intensities those passively influence the pH levels (Alam & Zohura, 2020; Raimi et al., 2022b, c; Olalekan et al., 2022a, b; Raimi & Sawyerr, 2012)). The recommended levels of pH for lagoon water is 6.5–8.5 according to the bibliographic references (Abowei, 2010; Davis & Cornwell, 2008; Organization, WHO., & Staff, 2004) for the existence of healthy ecosphere.

Since the majority of aquatic animals have adapted to a definite pH in aquatic ecosystems, the slight change in water pH could dearly cost its biodiversity (Cole et al., 2000). Because the fertility of fish eggs is drastically affected by the low pH of the water body due to the cell membrane being damaged by water acidity (Kiprono, 2017). Past studies have suggested that, pH below 4.0 or greater than 10.0 (i.e. $pH < 4.0$ or $pH > 10.0$) would disseminate the survival of most aquatic species including amphibians since they cannot endure the metabolic activities in such pH ranges (Abowei, 2010; Cole et al., 2000). Algal growths are heavily induced in water bodies beyond the 8.5 pH , which discrepancies the respiration of fishes (Ali, Salem, Younes, & Kaid, 2020). If the lagoon waters become more acidic, it induces the dissolving of Potentially Toxic Elements and lead to complicated level of toxicity for aquatic species. The water quality test results for pH conducted according to ASTM E70 guidelines in five different lagoons in Sri Lanka are provided in Table 5.

Table 5. Chemical and biological characteristics of the selected Sri Lankan lagoons.

Chemical Parameters	**Jaffna Lagoon**	**Negombo Lagoon**	**Batticaloa Lagoon**	**Koggala Lagoon**	**Puttalam Lagoon**
pH	7.1-8.9	7.1-8.3	6.4-9.1	7.3-8.3	7.2-9.4
Salinity (ppt)	34.7 – 36.1	30.8 – 33.1	37.0 – 38.2	43 – 45.7	32 – 34.5
DO (ppt)	3.8-6.6	3.9-5.6	2.3-6.8	4.1-6.9	5.5-7.3
BOD, at 30°C (mg/L)	25 - 170	30 - 120	10 - 210	15 - 130	10 - 140
COD (mg/L)	120-330	60-340	170-440	30-380	80-420
	170-390	150-370	200-490	110-380	130-460
Phosphate (mg/L)	0.01-0.28	0.03-0.24	0.06-0.56	0.02-0.44	0.02-0.27
Nitrate (mg/L)	0.36	0.92	0.71	1.28	0.96
Ammonia (ppb)	226	333	262	195	352
Faecal coliform (MPN per 100 ml)	2500	2510	1500	2100	2310

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2.2.2. Salinity

Salinity is the measure of mineral salt concentration in water. It is calculated using the freshwater discharge, evaporation, surface runoff, and precipitation classifications. Low salinity in lagoon water could result in ammonia toxicity in lagoon water, which could lead to eutrophication (Valencia-Castañeda, Frías-Espericueta, Vanegas-Pérez, Chávez-Sánchez, & Páez-Osuna, 2019). Along with temperature, salinity is a key determinant of the productivity of organisms in lagoons, and variations in salinity have affected the breeding rates of aquatic fishes (Lawson, 2011; Perera & Priyadarshana, 2015). The salinity of lagoon water mainly depends on two factors, namely rainfall and proximity to the sea. It increases the salinity of lagoon water because of the incoming saline water from the sea. Due to the higher rate of evaporation, salinity in lagoon water will be comparatively higher in dry season. The global salinity of lagoon water exists within 33-37 ppt at 30°C (Huber et al., 2000). In the context of the overall sustainability of aquatic ecosystems, a proper level of salinity maintenance is highly preferable. However, high salinity is a favoured habitat for prawns (Sugirtharan, Pathmarajah, & Mowjood, 2015), and the ample salinity for the dwelling for prawn species was 4-25 ppt (Banerjee, 2008). Salinity test results for the Sri Lankan lagoon water samples are provided in Table 5.

2.2.3. Dissolved Oxygen

Due to the necessity of oxygen for survival, DO has a distinguished value among the other water quality parameters since it has a direct influence on the longevity of aquatic biodiversity. Dynamic models are designed in field experiments for estimating the waste assimilating capacity (WAC) for organic wastes need to be deposited into a body of water in order to maintain ideal DO conditions in lagoons respective to natural and anthropogenic activities in the ecosystem (Hendriarianti et al., 2019). In lagoons, the atmosphere and aquatic plants are the main suppliers of oxygen. Plant decays, faecal excretes, domestic wastes, oil leakage from boats, industrial and agricultural aspects are all inhibitors of DO levels in lagoons. The increase of DO in water would raise the pH. Furthermore, atmospheric pressure of oxygen gas, temperature, and salinity are the main influencers in determining the DO levels in lagoon waterbodies (Lawson, 2011). In Table 5, the mean magnitude ranges of dissolved oxygen in the selected Sri Lankan lagoon water specimens are provided.

2.2.4. Biochemical Oxygen Demand

Biochemical Oxygen Demand (BOD) is the quantity of oxygen consumption by bacteria and fellow microorganisms when decomposing organic material under aerobic environment at a certain temperature. It is a statistic for determining water quality. BOD measurements are being utilised to remediate polluted lagoons. BOD has an effect on the quantity of dissolved oxygen in streams and rivers. The pH, microbe intensity, temperature, organic materials, and trace materials in lagoon water all influence the levels of oxygen by aquatic species (Tawalbeh et al., 2020; Afolabi & Raimi, 2021). It is also critical to understand that high BOD levels have similar impacts as low dissolved oxygen (DO) levels.

Bacteria and other microorganisms consume organic substances during fermentation. The broken organics were converted into simple compounds consisting of CO_2 and H_2O. The released energy is used up by microbes for their reproduction and growth. Water is considered to be contaminated at BOD levels exceeding 4mg/L. Tolerance range of BOD is between 5 and 6 mg/L in relation to Sri Lankan Central Environment Standards which is the governing body of water quality and maintenance in the inland water body of country (Piyasiri, 2009; Afolabi & Raimi, 2021). Table 5 illustrates the BOD measured in five Sri Lankan lagoons using the manometric method.

2.2.5. Chemical Oxygen Demand

In terms of lagoon water ecosystem, Chemical Oxygen Demand (COD) is the amount of oxygen consumed in the lagoon water for chemical oxidation in organic substances. Elevated COD levels result the depletion of oxygen content due to high microbial decomposition. It leads to detrimental aquatic life. COD serves in the lagoon as an indicating parameter for biodegradable and non-biodegradable organic content from its channels. The study related to municipal wastewater hydrodynamics using lagoon systems shows that redox potential (ORP) and COD show proportionality between the two parameters (García-Martínez et al., 2017; Raimi et al., 2022b, c; Olalekan et al., 2022a, b; Raimi & Sawyerr, 2012). High ORP due to more oxygen requirements for organic oxidations caused high concretions of COD in the field study. Furthermore, COD parameters seem to always be higher than the BOD of a particular sample (Metcalf, Eddy, & Tchobanoglous, 1991).

COD test determines the quantity of oxygen required for the chemical oxidation of organic compounds and mineral salts in water such as the ammonia and nitrates (S. Kader, Novicevic, & Jaufer, 2022). Unlike BOD, COD determines the extent of oxygen need to be removed from an organic substance after absorbing water due to bacterial activities. COD test is built upon the concept that a strong oxidising agent has heavy potential under an acidic medium to completely oxidise any organic substance into carbon dioxide (Meng et al., 2020; Raimi et al., 2022b, c; Olalekan et al., 2022a, b; Raimi & Sawyerr, 2012). After this oxidation, the intensity of organic substances at specimen is estimated by determining the oxidants. Titration with an indicator solution is typically used. COD is measured in milligrammes per litre of solution and represents the mass of oxygen used per litre of solutions. Unlike the BOD test, which takes 5 days, the COD test takes only 2-3 hours. Table 5 shows the COD results obtained from the selected Sri Lankan lagoon waters.

2.2.6. Alkalinity

Alkalinity is the ability of aqueous solutions to neutralise strong acids. The presence of calcium, sodium, and potassium carbonates, bicarbonates, and hydroxides causes lagoons to be alkaline (Patil & Patil, 2010). The sources of these compounds are salt sediments, industrial wastes, and dissolved rocks. An experimental study based on Malala lagoon in Hambanota, Sri Lanka, has identified its alkalinity as 2.14 mmol/L with a tolerance of 0.59 mmol/L (Titus, Deepananda, & Cumaranatunga, 2017). The ambient alkaline levels for shrimp, fish, and planktons breeding in lagoon water were extracted from literature source (Boyd, 2019) and illustrated by Table 6. The excessive alkalinity may disrupt the dynamic nature of the lagoon ecosystem and lead to the destruction of its biodiversity.

Alkalinity contributes to aquatic species through buffering the pH alterations that indirectly reduce the vulnerability of acid rain (Apau, Appiah, & Marmon-Halm, 2012). This buffering against acidity protects the aquatic species from undergoing a sudden pH change in their surroundings (Omer, 2020). Alkalinity does not change at the top, middle, or bottom of water columns in lagoons (Titus et al., 2017) but the decrease in alkalinity leads to eutrophication effects in water bodies (Verspagen et al., 2014). Therefore, the increment in the alkaline or acidic nature of lagoon water is also an indicator of chemical pollution.

Table 6. Recommended level of alkalinity for breeding of aquatic species.

Species	**Allowable Alkaline Level (mg/L)**
Shrimp	30 – 500
Fish	30 – 500
Plankton	20 – 50

2.2.7. Hardness

The extent of mineralization in lagoon water is often described by its hardness. Lagoon water gets hardened mainly due to the increased concentration of calcium ions (Ca^{2+}), magnesium ions (Mg^{2+}), or due to the increment of both ions (Patil & Patil, 2010; Spellman, 2008; Raimi et al., 2022b, c; Olalekan et al., 2022a, b; Raimi & Sawyerr, 2012). The existence of these metal ions during rock formation is a substantial cause of water hardness in lagoon water. Most common example is the deposition of limestone near the water bodies (Nadiri et al., 2022). Common forms of these ions are bicarbonates, chlorides, nitrates, and sulphates (Davis & Cornwell, 2008). Ions like barium (Ba^{2+}), strontium (Sr^{2+}) and iron (Fe^{2+}) have negligible contributions to water hardness.

Water hardness is categorised into temporary and permanent hardness. Temporary hardness is the result of carbonates and bicarbonates, while permanent hardness is due to chlorides and sulphates (Metcalf et al., 1991). Generally, water hardness is given as total calcium and magnesium contents in water, given in milligrammes per litre of $CaCO_3$. (Omer, 2020). The occupation of toxic elements like As, Cd, Pb, and nitrate compounds cause hardness in lagoon water. However, most countries including Sri Lanka do not have predetermined policies regulations regarding the thresholds for hardness. Therefore, they are not comparable incomparable since some literary sources offer a suggested range while others mandate minimum or maximum limit levels. Our conclusion upon the water hardness is well supported by data analytical study focused on water hardness in European Union member countries (Kozisek, 2020).

2.2.8. Oil and Grease

The lagoon environment endures significant pollution due to oil and grease by the effluents from petroleum-related disciplines such as transportation, industrial and municipal solid wastes, urban runoff, offshore effluents, and sediment erosion (Nadiri et al., 2022). The probable reasons for oil and grease contamination are unplanned infrastructure development thus causing hindrance to human benefits. Oil sediments in lagoon water surround the gills of fishes under low and high oil concentrations, causing suffocation for respiration. Oil pollution is responsible for the destruction of coral reefs and lead to the increased erosion of the lagoon coast. It also provides a passive contribution to the destruction of mangroves (Tong, Goh, Abdulah, Tahir, & Wang, 1999; Raimi & Sabinus, 2017; Olalekan et al., 2018; Raimi et al., 2021; Raimi et al., 2022b, c; Olalekan et al., 2022a, b; Raimi & Sawyerr, 2012).

In the Sri Lankan context, the main mode of oil contamination in lagoon waters are the transportation of engine boats in lagoons. Tolerance limits for oil and grease within the discharged effluents according to Sri Lankan standards is up to 20 mg/L (Najim & Kithsiri, 2021). However, a recent study have indicated that the oil and grease levels in Sri Lankan lagoons is getting exceeded beyond the allowable limits due to the existence of sea ports in the territories (Kanchana, Chandrasekara, Weerasinghe, Pathirana, & Piyadasa, 2021).

2.2.9. Sulphates

Sulphates are common pollutants in lagoons. The concentration of sulphates and their complex accumulation are directly influenced by the leaching of natural deposits, atmospheric deposition, and human discharges. In general, industrial activities like tanneries, textile mills, paper mills, mines, agricultural runoffs and smeltings release sulphates into lagoons (Meays, Nordin, Protection, & Branch, 2013). However, high sulphate concentrations are of particular concern to the mining industry. The most common forms of sulphates are gypsum ($CaSO_4.2H_2O$), barites ($BaSO_4$) and epsomites ($MgSO_4.7H_2O$) and water contact in these kind of forms will pollute lagoons with sulphates (Greenwood & Earnshaw, 2012). Compounds such as Na_2SO_4, K_2SO_4 and $MgSO_4$ have high solubility in water during the sulphur compound contaminations, while $CaSO_4$, $BaSO_4$ and the other cationic sulphates exhibit low solubility (Delisle & Schmidt, 1977).

Elevated sulphate concentrations in lagoon water cause long-term consequences for aquatic life. Maximum sulphate content in lagoon water should not exceed 2,700 mg/L (S. Kader, Jaufer, Shiromi, & Asmath, 2021; Meays et al., 2013). Turbidimetric experiments quantify the sulphate content in lagoon water. This test consider the reaction of sulphate ions with aqueous barium chloride is induced in an acidic medium to study the resulting turbidity (Hatiboruah, Talukdar, Ahamad, & Nath, 2021). The passive outcome of turbidimetric test is that the turbidity would be proportional to the sulphate concentration in the water specimen.

2.2.10. Phosphates

Agricultural runoff, detergents, home and industrial untreated sewage are all causes of phosphate pollution in the lagoon. For healthy aquatic life, the maximum permitted phosphate content is 0.4 mg/L (Bama, Thushyanthy, Alvappillai, & Pirabhaharan, 2013). Higher phosphate content would cause eutrophication, which gives both short-term and long-term BOD in lagoons. The maximum phosphate limit that a lagoon could buffer without eutrophication is 0.1 mg/L (Muthucumaran, Pathmarajah, & Mowjood, 2015). Phosphates are one of the most important constituents required in lagoon water since they significantly contribute for the formation and propagation of aquatic plant root systems. But they should not exceed their threshold limits.

2.2.11. Nitrate

Nitrates are soluble compounds those washed into ground water and gradually into lagoons. It is the primary source of algal blooms. The maximum contaminant level for nitrates is 10 mg/L (Boyer, 2014). Nitrogen polluted water appears grey colour and results health impacts including dizziness, fatigue and cardiac problems to aquatic organism (Davis, 2002; Raimi & Sabinus, 2017; Olalekan et al., 2018; Raimi et al., 2021; Raimi et al., 2022b, c, d; Olalekan et al., 2022a, b; Raimi & Sawyerr, 2012). Nitrates reach lagoons through faecal matters, solid waste deposits, septic tanks, agro fertilizers and wastewater sewages (Odipe et al., 2018). The main sources of nitrates are the municipal wastes, domestic wastes and the agricultural effluents.

Thermal treatment for nitrates is irrelevant since nitrates cannot evaporate like water. Nitrate pollution would cause higher carbon emissions due to greenhouse gas production (Kader, Chadalavada, et al., 2022) The total dissolved inorganic nitrogen is the sum of nitrates (NO_3), nitrites (NO_2) and ammonium (NH_4). Nitrification of lagoon waters can be explained as follows:

$NH_3 + O_2$ + *Nitrosomonas sp* bacteria $\longrightarrow$ NO_2

$NO_2 + O_2$ + *Nitrobactor sp* bacteria $\longrightarrow$ NO_3

2.2.12. Ammonia

Ammonia exists in lagoon water due to the microbial activities involving nitrogen-containing compounds and sewage effluents. Ammonia pollution in lagoons occur primarily due to wastewater effluents from anthropogenic activities like industries, public services like hospitals and due to the improper solid waste disposals by dumping besides lagoons (Vesilind & Morgan, 2004). The reduction of these nitrogen compounds results in ammonia in small amounts in water bodies. The existence of ammonia levels beyond 0.1mg/L Nitrogen indicates the water contamination. The maximum allowable ammonia limit in lagoon water surface is 0.8 mg/L (800 ppb). (Buijs & Toader, 2007). Excessive sewage pollution causes pathogenic offspring in lagoons. In terms of health issues, the presence of ammonia should be seriously considered to prevent the possibility of sewage pollution due to microorganisms in lagoons (Vesilind & Morgan, 2004). Water temperature, DO and algal concentrations in lagoons have an undisputed influence on the effluent rates of ammonia and nitrogen. Therefore, it can be inferred that the maintenance of DO and algal blooms under the tolerance limit is essential to prevent any contamination due to ammonia breeding in the lagoon. Table 5 shows the ammonia levels measured using chemical titration on selected lagoons.

2.2.13. Potentially Toxic Elements

Human activities are the main contributors to the Potentially Toxic Element contamination in lagoons. Both agricultural and industrial effluents due to the toxic chemicals used in all those scenarios could accelerate Potentially Toxic Element contamination in lagoon water (Renu, Agarwal, & Singh, 2017). Lagoons accumulate highly concentrated Potentially Toxic Elements due to their biochemical nature. Environmental toxicity of Potentially Toxic Elements due to anthropogenic pressure in ecosystems has dwindle the lagoon water quality, decline the existence of lagoon species, and lead to destruction of resources. The presence of Potentially Toxic Elements beyond allowable range could challenge the health since they are carcinogenic and non-biodegradable (Qasem, Mohammed, & Lawal, 2021), thus causing the aquatic fishes to be inconsumable due to their intake of Potentially Toxic Element contaminated water. Commonly found Potentially Toxic Elements in lagoons are Lead (Pb), Arsenic (As), Zinc (Zn), Cadmium (Cd), Mercury (Hg), Nickel (Ni), Chromium

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(Cr) and Copper (Cu). Potentially Toxic Elements induce hatching delays, deformities, and mortality in fish (Sfakianakis, Renieri, Kentouri, & Tsatsakis, 2015; Raimi & Sabinus, 2017; Olalekan et al., 2018; Raimi et al., 2021; Raimi et al., 2022b, c; Olalekan et al., 2022a, b; Raimi & Sawyerr, 2012). The toxicity of Potentially Toxic Elements could vary according to their type, compound formation, and the quantity of deposition (Lawson, 2011). The maximum contaminated level standards for those Potentially Toxic Elements established by the USEPA are summarised in Table 7.

Table 7. The maximum contaminated level standards for the most hazardous Potentially Toxic Elements (Gunatilake, 2015).

Potentially Toxic Elements	Maximum Contaminated Level (ppm)
Arsenic	0.05
Cadmium	0.01
Chromium	0.05
Copper	0.25
Nickel	0.20
Zinc	0.80
Lead	0.006
Mercury	0.00003

2.3. Biological Parameters

2.3.1. Faecal Contamination

Intestinal guts of warm-blooded species produce faecal coliforms (Seo, Lee, & Kim, 2019). The existence of faecal coliforms is an indicator of the quality of water to be used for drinking purpose. These coliforms survive longer in water than most pathogenic bacteria. Total coliforms contain both faecal bacteria and non-faecal bacteria. When effluents from laundry sinks, domestic and industrial wastewater enter the lagoon, coliform bacteria enter via pastures, a faulty septic system, and animal waste. The existence of faecal coliforms in lagoon water could change its odour and cause some health-related effects on the living organisms.

Despite their pathogenic properties, their main advantage is that they can be used as a reliable and easy indicator of faecal pollution. The main sources of faecal bacteria are sewage. Surface water class II standard values for faecal coliform and total coliform are 14 and 70 MPN/100 mL, while class III standards for surface water are 200 and 1000 MPN per 100 mL (Consultants, 1994). The total coliforms and faecal coliforms were measured via membrane filtration (Munasinghe-Arachchige, Delanka-Pedige, Abeysiriwardana-Arachchige, Zhang, & Nirmalakhandan, 2019) and the results of the experiment are presented in Table 9.

2.3.2. Virus

Lagoons are becoming the predominant breeding places for viruses in recent times. The adverse effect of viral contamination of lagoons is the spread of diseases that affect the environmental balance. Impacts of viruses on the lagoon's water quality lead to harmful drawbacks in biological and economic aspects. Lagoons have been identified as a primitive source of mosquito-borne diseases in several case studies. Viruses of the genus *Culex annulirostris* and *Orbivirus* have been found in stretch lagoons in Australia, causing blue tongue disease in sheep, cattle, donkeys, and horses (Cowled et al., 2009). Studies conducted in the urban lagoons of Rio de Janeiro determined the breeding of rotavirus, norovirus, and human adenovirus within the surface water of the lagoon (Vieira et al., 2012). Shrimp farming in Sri Lanka in 1990 was heavily destroyed by the spread of the *Monodan baculo* virus and white spot syndrome virus in Puttalam lagoon (Arthur, 1998).

In the statistical sources of Sri Lankan context, it is evident that the country had suffered an enormous loss of 1 billion Sri Lankan rupees due to white spot disease in fishery exports (Senarath & Visvanathan, 2001). Moreover, the brood stocks in Sri Lanka's Puttalam lagoon region were affected

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by yellow head disease back in 1998, which coincided with white spot disease and resulted in a whopping 70% drop in shrimp exports (Munasinghe, Stephen, Abeynayake, & Abeygunawardena, 2010). The reasons for the viral contamination of lagoons are the destruction of mangrove habitats and paddy cultivation at surrounding locations.

2.3.3. Algae

Algal blooms in lagoon water bodies are a common occurrence due to nutrient enrichment by wastewater, agricultural waste, and storm water drainage. Overgrowth of algae causes high TSS and BOD in lagoon ecosystems, which causes problems for aquatic organisms (Lapointe, Herren, Debortoli, & Vogel, 2015). Furthermore, overgrowth of algae species releases toxic substances into lagoon waters, depletes deep water oxygen, decreases water column transparency, reduces health and size of corals, mitigates the overall aesthetic value in lagoons, conceals economic repercussions, and declines the existence, biomass, and diversity of aquatic plants (Smith, 2003). When the effluent discharges to the lagoon are in high intensity, algal blooms happen more in the offshores compared to the lagoon water (Hsieh et al., 2021) due to high turbidity of interior lagoon water and because of the short residence time of algae.

3. Results and Discussion

3.1. Physical Parameters

3.1.1. Temperature

Experimental observations of Table 1 show that the temperature of the selected Sri Lankan lagoons exist between 25°C - 35°C. Temperatures over 30°C would result in a decay in the growth rate of aquatic plants (Kara, Kara, & Basaran, 2004). Furthermore, the phenol toxicity among all species was greater at higher temperatures since phenol became more noxious with increased temperature (Patra, Chapman, Lim, Gehrke, & Sunderam, 2015). A rise in temperature could induce an algal bloom, thus reducing the oxygen concentration of the water and causing the demise of aquatic animals. Since the warm water consists of less dissolved oxygen levels compared to cool water there would be a toxic nature created in lagoons with excessive surface temperature and it would challenge the comfort of aquatic species (Patra et al., 2015) when subjected to temperature increases.

3.1.2. Turbidity

The maximum turbidity was recorded Table 2 as 28.52 NTU in Koggala lagoon at the upstream location. The lowest turbidity magnitude was found downstream of Jaffna lagoon. The standard turbidity limit recommended by WRC for sustainable aquatic life and domestic use is 5 NTU (Miyittah, Tulashie, Tsyawo, Sarfo, & Darko, 2020). The variation in turbidity values in the lagoons is due to the different patterns of seasonal flows in the corresponding locations, which result in dissimilar sediment deposits. Suspended sediments settle on the bottom when the lagoon water reduces its velocity while travelling from upstream towards downstream (P. Jain, Sharma, Sohu, & Sharma, 2006). In general, the tolerant limit for turbidity in class II and class III water is less than 29 NTU (Consultants, 1994). Water turbidities of less than 5 NTU are easily detectable in a glass of lagoon water and they are not tolerable due to aesthetic objections (Davis, 2010). High turbidity nature diminishes the available disinfectants and induces pathogen activities (Ireland, 2001) and protect the existence of microorganisms in lagoon water. Therefore, turbidity requires to be controlled within the allowable limits by treating the lagoon water with chemical flocculants to prevent the exceeding beyond the allowable tolerance.

3.2. Chemical Parameters

3.2.1. pH

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It was observed that the surface pH was high at the lagoon inlet compared with the inner lagoon. Excessive pH ranges (i.e. pH > 8.5) were observed in coastal plumes of Jaffna, Batticaloa, and Puttalam lagoons since heavy rainfall was experienced due to the Southwest monsoon in the first two weeks of July 2022. However, the pH magnitudes during the wet season in Sri Lanka from August to December would be even higher than the measured pH magnitudes in the dry season (Hsieh et al., 2021). There are two possible explanations for such unusual pH change after a heavy rainfall at dry season as observed at experimental recordings. One could be the industrial effluents discharge and septic wastewater excretions through runoffs and the photosynthesis of marine phytoplanktons, which increases the pH due to the carbon dioxide fixing (Chrachri, Hopkinson, Flynn, Brownlee, & Wheeler, 2018; Hsieh et al., 2021).

pH of lagoon water is highly influenced by photosynthetic activities. It is also reported that the sea grass is abundant in lagoons such as Negombo lagoon (Udagedara, Fernando, Perera, Tanna, & Bown, 2017), Jaffna lagoon (Digamadulla, Sivashanthini, & Thavaranjit, 2017) and Puttalam lagoon (Ranahewa, Gunasekara, Premarathna, Karunarathna, & Jayamanne, 2018) and this abundancy is a significant cause for large pH variations observed in table 5 due to the intense photosynthetic activities of seagrass angiosperms.

3.2.2. Salinity

The salinity values recorded in dry season are generally higher than the salinity of lagoon water in the wet season. Because the seasonal precipitation of the wet season makes the surface water temperature lower and more uniform compared to the dry season (Hsieh et al., 2021). Salinity increases due to high evaporation in a dry climate, which leads to hypersalinity. Variations in salinity could also occur due to freshwater influx and tidal variations (Kankara & Panda, 2020; Mahanty et al., 2016). They alter the lagoon water nutrient levels, inflow from inland streams and the constituents of nutrients. Migratory birds are often attracted towards lagoons with a low salinity for food resources since more freshwater fishes in lagoons breed in shallow depths (Null & Wurtsbaugh, 2020).

3.2.3. Dissolved Oxygen (DO)

The required threshold level for lagoon water DO is 5.0 mg/L in terms of aquatic life existence (Tran, Schwabe, & Jassby, 2016). In all five lagoons, the value fell outside the recommended limit in many scenarios for raw lagoon water samples. Furthermore, the experimental results recorded in Sri Lankan lagoon waters are significantly lower than a similar type of DO experiment conducted at Aby lagoons, Ivory Coast (Netto Mireille Seu-Anoï, 2018). Because of the large amount of domestic and industrial effluents, the organic content and waste disintegration of Sri Lankan lagoons are comparatively higher than Ivory Coast. A study was conducted in Sri Lankan lagoons regarding the DO levels and the survival of aquatic species found that the lives of fishes and other aquatic species become perilous when DO drops below 3.9 mg/L (Sugirtharan et al., 2015) since most of the spots were recorded to be below 5.0mg/L. It is even reported that the fish species eventually die if the aquatic DO level further dwindles beneath 2.0 mg/L (Sugirtharan et al., 2015) and cause imbalance within the aquatic ecosystems.

This study output was even verified during the questionnaire survey conducted among the communities surrounding the Batticaloa lagoon by understanding the lagoon spots where the majority of community members reported the floating of dead fish over the past 6 months, and the pH recorded in those corresponding locations was in the 2.1–4.6 mg/L range. A comprehensive unidimensional model was setup for a case study in Chilka Lagoon (Basavaiah et al., 2014) incorporated with biological (mineralization, photosynthesis, and respiration), chemical (i.e. nitrification), and physical (aeration) activities to study the influence of DO in lagoon water. It was found that the photosynthetic activities of aquatic plants were largely controlled by super-saturation. Furthermore, under-saturation of oxygen (Basavaiah et al., 2014) is largely required for nitrification.

3.2.4. Biochemical Oxygen Demand

The measured BOD range of Sri Lankan lagoon water ranges from 15–210 mg/L. It shows that all the selected lagoons are under critical conditions in terms of BOD since they exceed the allowable range. The highest BOD concentration was observed in the Batticaloa lagoon and the least existed in the Negombo lagoon. The main reason for BOD reductions across lagoons is the variation of rainfall. Negombo lagoon experiences more rainfall than the other four lagoons due to the South West monsoon from May to September (Bandurathna, Wang, Zhou, Cheng, & Chen, 2021) and the high-intensity rainfall increases the dilution in lagoon water and leads to the drop of BOD (Longe & Ogundipe, 2010).

The higher levels of BOD indicate that the lagoon is polluted by various organic substances, which could be as a result of oil spills from fishing boats, dumping of solid waste besides the lagoon, excretion of sewage waste, and overuse of shrimp feeds (Bozorg-Haddad, Delpasand, & Loáiciga, 2021). The excess BOD posses a serious threat to a wide array of aquatic species by reducing the dissolved oxygen levels (Garg, 2006). If the oxygen amount consumed in water bodies was not promptly replaced, it would cause a stipulation of oxygen in the aquatic system. Excess BOD in lagoon water can be effectively treated using aeration and by the addition of hydrogen peroxide (H_2O_2) (Aslam et al., 2004; Ksibi, 2006).

3.2.5. Chemical Oxygen Demand

Table 5 shows the COD loading levels of the selected Sri Lankan lagoons. Experiments were conducted using unfiltered lagoon water samples in the acidic media using DR-5000 spectrophotometer. Because spectroscopic method became successful in previous studies such conducted on wastewater effluents (Daud, Awang, Nasir, Ridzuan, & Ahmad, 2015; Rice, Baird, Eaton, & Clesceri, 2012). We have used Potassium dichromate ($K_2Cr_2O_7$) as the oxidant at COD test. The experimental results have outlined that the mean COD during the wet season was more compared with the dry season at all five lagoons, and it has verified the conclusion of (Jayasiri et al., 2022) stating that highest COD in Sri Lankan water bodies are observed during the rainy season. The rainfall significantly alters the lagoon water quality by accelerating the BOD_5, COD, TDS, and phosphates (Momou, Akoua-Koffi, Traoré, Akré, & Dosso, 2017).

Allowable COD range for less polluted water is 20 – 200mg/L (S. K. Jain & Singh, 2003) and the experimental results on Sri Lankan lagoon waters do not comply with this range at all the times. The increase in COD in lagoon waters can be controlled using sedimentation tanks while utilising the coagulants and flocculants to bind the sludge together (Arceivala & Asolekar, 2006; Davis, 2010) in large masses and filtering them out of the tank. It is also possible to use hydrogen peroxide (H_2O_2) to reduce the COD and BOD levels in polluted lagoon water through oxidation. However, the selection of the best possible method entirely depends on a comprehensive feasibility study on the environmental, economic and technical aspects of the considered lagoons.

3.2.6. Phosphates

Table 5 represents the spectroscopic outcomes of Phosphate magnitudes in the Jaffna, Negombo, Batticaloa, Koggala and Puttalam lagoons. The experimental outcomes have shown that the phosphate levels observed at Sri Lankan lagoons are relatively lower between 0.01 milligrams per litre in the upstream and 0.56 milligrams per litre in the downstream. Allowable phosphate limit for the suitability of aquatic life is 0.4 mg/L as per the Sri Lankan standard guidelines (Jayasiri et al., 2022), and it was derived that the phosphate levels in Jaffna, Negombo, and Puttalam lagoon waters according to Table 5 are sufficient for aquatic survival. Appropriate phosphate treatment method such as chemical precipitation method using metal salts in tertiary filtration (Ilyas & Masih, 2018) is required for Batticaloa and Koggala lagoon waters to enhance their viability for aquatic species.

3.2.7. Nitrate

Nitrification consumes substantial level of dissolved oxygen in lagoons. DO level of 2.0mg/L is adequate for uninhibited nitrification (Luo et al., 2017). Table 5 illustrates the spectroscopic outcomes in terms of nitrates from five different Sri Lankan lagoon waters during the dry season at July 2022. The minimum level of NO_3^- concentration was observed in the Jaffna lagoon with 0.36mg/L. According to Table 1, Jaffna lagoon possessed the highest water temperature with 34.27 °C. It is noteworthy to account here that the temperature rise could hinder the nitrate runoff levels from effluents (Tjandraatmadja & Diaper, 2006). This phenomena have resulted Jaffna lagoon to possess the lowest NO_3^- concentration and Koggala lagoon to accumulate high NO_3^- level due to its lowest temperature 25.17 °C according to table 1.

In Sri Lanka, most of the domestic and industrial discharges are not treated before delivering to the environment (Quyen, Masahiro, Otaki, & Chaminda, 2021). Excess nitrates accelerate eutrophication in lagoon water. However the reduction of nitrates into nitrites cause blue baby syndrome (i.e. *Methaemoglobinaemia*) for newborn babies and several health affects for human such as thyroid, cancers and acute ailments (Ward et al., 2018). The recent newspaper articles, community statements and the research findings on Sri Lankan lagoon waters shows ambient evidence for considering the recent nitrate water pollution issues in lagoons as severe threat. Several ways can be implemented in Sri Lankan lagoon waters to mitigate the nitrate pollution such as utilizing bioreactors, drainage water recycling and controlled drainage (Liu et al., 2020) and it is a crucial measure to undertake to select and proceed with the most suitable technique to mitigate current nitrate pollution trends in Sri Lankan lagoons.

3.2.8. Ammonia

The tested specimens from the lagoon waters show that the ammonia levels are within the threshold limit in all five locations. Unlike the nitrate concentration trends, the concentration of ammonia in the dry season is often greater than in the rainy season (Jayasiri et al., 2022). The main modes of ammonia accumulation by lagoon waters are the runoff water containing fertilizers (Mateo-Sagasta, Zadeh, & Turral, 2018) and the industrial effluents. The concentration of ammonia is diluted during the wet season due to frequent and intense rainfall. The study on ammonia-based research on lagoons should always incorporate readings from both the dry season and the wet season to arrive at a rational conclusion regarding the ammoniacal concentrations and their ecological impacts.

3.3. Long-Term Monitoring PLan to Assess the Quality of Lagoon Water

3.3.1. Necessity of Conducting a Monitoring Plan for Lagoon Waters

Based on the physicochemical and the biological parametric experimental studies on the water quality of Sri Lankan lagoons, it was decided to propose a sustainable monitoring plan to ensure the long-term serviceability of water quality assessments. The objective of this monitoring plan should incorporate the identification of natural and cultural values of lagoons, and the plan should propose measures to mitigate threats to natural and cultural values. The Central Environmental Authority (CEA) is the primary responsible authority for Sri Lankan lagoons for verifying the water quality for the viability of sustainable ecosystems. The Road Development Authority (RDA) of Sri Lanka is responsible for providing unhindered transportation via sophisticated roads and drainage systems. The solid waste contamination of lagoons should be prevented by appropriate actions from the Municipal Councils. Table 9 provides the authorities and policies (Lanka, 2018) associated with the conservation of Sri Lankan lagoons.

3.3.2. Methodology for Implementing the Monitoring Plan

The initial step of methodology should incorporate a background study on bibliographical references, such as the journal articles, book chapters, conference proceedings, technical reports, experimental findings, questionnaires, and annual reports based on the selected lagoon water parameters. A comprehensive data analysis is essential to be implemented in relation to the sanitary sewage system and the local drainage networks connected with lagoon inlets. The investigations should be carried out with the cooperation of the municipal council to get the support of the local community. Historical data should be acquired with water quality monitoring using suitable technologies such as TECMA (Gandhi, Marcelo, & Leite, 2019). The sample collections should be taking place by rearing the lagoon water samples twice a week for the entire year. The selected parameters in this study, like DO, turbidity, temperature, pH, and the salinity of lagoon waters, could be studied with portable electronic equipment consisting of electrodes (Gandhi et al., 2019). Samples could be collected with packaged polyethene flasks and could be sent to laboratory for analysis prior to the deadline for preservations. Experimental results should be analysed for every season with appropriate statistical representations. The graphs should explicitly show the minimum, average, and maximum magnitudes for each stage. The spatial variations need to be compared with temporal variations and assessed by comparisons with allowable thresholds, meteorological rainfall data, and the air temperature to determine their influence on altering the biological and physiochemical lagoon water parameters.

4. Conclusion

This study has effectively described the corresponding effects caused by the change in lagoon water parameters on the water quality of lagoons. The objective was achieved through identification of the influential parameters, their classifications, their significance, their allowable limits, and by proposing a sustainable long term monitoring plan for lagoons. Appropriate experiments were conducted in standard procedures to analyse some of the viable parameters in five selected lagoons from Sri Lanka based on the availability of technical facilities in the country, and their values were compared with threshold limits of corresponding tested parameters. The experimental results have shown that the values of selected parameters exhibit significant deviations within different Sri Lankan lagoons. The sources of bibliographic references show that there are substantial variations in those values that could have been experienced between dry and wet seasons. Hence, the respective changes were described from a rational point of view from the takeaways of relevant research studies.

For the long-term success of preserving and maintaining high water quality within lagoons, regular and systematic monitoring of the illegal accumulation of waste materials in lagoon waterbodies is critical. Therefore, a comprehensive monitoring plan was proposed in this study, which targets the long-term ecological and economic sustainability of Sri Lankan lagoons. This research article shows a way on how the literary sources regarding the lagoon waters can be gathered, classified and studied regarding their influence on lagoon water quality, and to propose a sustainable monitoring plan to ensure the long-term conservation of lagoon water systems in Sri Lanka and other parts of the world.

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