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Water Quality Assessment of Keelung Port

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Abstract **–** This research aimed to conduct water quality assessment in the port area covered by the Keelung Port in Keelung City, Taiwan and to determine if spatial variability and tidal variability affect the water quality parameters. This research addresses the gap on the limited work published on the pollutants present and dissolved in the water. Relatively little attention has been given to the study area, where different shipping operations may have considerable impacts on the water quality in the port environment. Based on the standards set by the Taiwan International Ports Corporation (TIPC), pH and DO are within the permissible values. DO was markedly lower during high tide, which was consistent with the findings of other researchers. The concentration of mercury, arsenic, and chromium were all below the detection limits of the measuring equipment used in the research. Water quality is significantly affected by the location of sampling area, whereas the inner port area showed relatively higher level of contamination compared with the measurements taken at the outer port area. Based on the independent samples Mann-Whitney U test conducted, tidal condition does not significantly affect the distribution of measurements of the water quality parameters.

Keywords**:** Water quality assessment of port area

1. Introduction

Seaports continue to place water quality at the top of their environmental priority list. According to the study published by the European Sea Ports Organization in 2021, water quality is the sixth priority. Ports are inextricably tied and dependent on water, making water management and water quality essential to their operations, environmental responsibility, and operating license. This is evidenced by the fact that water quality has continued to climb the list of top priorities for ports, with 70 percent of European ports polled monitoring water quality in 2021. At the European level, there are ongoing discussions to update the present water legislation.

Comtois and Slack [1] conducted a study based on an analysis of the websites of 800 ports and 120 shipping lines from North America, Europe, and Asia. The researchers found that water quality was the most frequently mentioned environmental concern by port authorities (mentioned by 25 percent), which is also common among shipping lines.

The "Taiwan Greening the Ports Action Plan" considers water quality as one of the aspects of port environmental protection that must be addressed. The next paragraphs will elaborate on the strategy that has been devised.

The Taiwan International Ports Corporation (TIPC) has developed and implemented its "Taiwan Greening the Ports Action Plan" in order to keep up with the international trend of green ports and to transition to an eco-port. This has been done in order to preserve the environment and reduce the corporation's carbon footprint. Anping, Hualien, Kaohsiung, Keelung, Taichung, Taipei, and Suao are all international commercial ports, and they are all under the administration duties of the Taiwan International Ports Corporation (TIPC). As a result of this, it has developed green port plans for the short, the medium, and the long term with the objective of attaining the concept of a green port cluster [2].

The "Taiwan Greening the Ports Action Plan" aims to improve the quality of the port environment. It also hopes to improve the passenger cruise experience and the efficiency of cargo operation through the measures outlined in the action plan. The "Taiwan Greening the Ports Action Plan's" long-term goal is to boost and promote local city development through an optimal port environment and surrounding infrastructures.

The "Taiwan Greening the Ports Action Plan" [2] is divided into 4 distinct parts: port environment, cargo operations, cruise terminals, and community engagement. Two aspects that make up the environment of a port are its quality of the environment and its ability to operate sustainably. The goal of the TIPC is to enhance the environment of the port by improving the air quality and water as well as increasing the amount of green space.

TIPC reported in 2016 that three water quality indicators are within the set standard. However, the most recent report by TIPC [3] does not specify if the set water quality standards are still met. In a letter from TIPC given the researcher, they said that these data sets are not publicly available.

Thus, the main objective of this research is to generate the most updated baseline data of the water quality and trace metal concentrations in Keelung port. In addition, other water quality parameters were added to give more details to the state of the said port.

2. Methodology

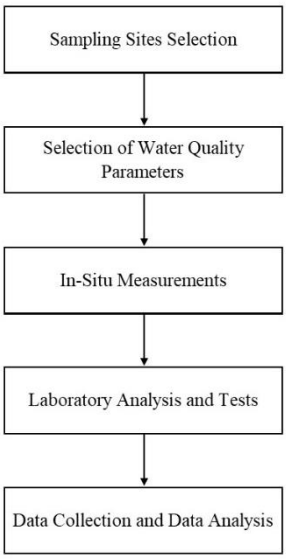

Fig. 1: Research flowchart.

2.1. Research Design

The figure above shows the general steps undertaken in this study. As part of the independent variables identified, sampling sites were established in the inner port and outer port. Using GPS, the sampling sites were geotagged for establishing consistency in getting the spatial variability.

Water quality parameters were initially listed out based on local and international standards. Factoring in the capacity of the instrument used as well as the capability of the laboratory to analyze the water samples, the parameters examined and reported here were narrowed down.

At planned intervals, in-situ measurements were done. Samples were then submitted to laboratory for water quality analysis.

2.2. Sampling Technique

2.2.1. Sampling materials

For this research, sample type is classified as area integrated. It is created by combining a series of samples collected at multiple sampling locations distributed around the water body (though generally all at the same depth or at predefined depth intervals) [4].

To achieve the intended area-integrated samples, the following materials were used during the samples collection:

a. motorboat
b. multiparameter instrument (Hanna instrument model HI98194) - The HI98194 is a waterproof portable logging multiparameter water quality meter that monitors up to 12 different parameters. Its multi-sensor probe allows for the measurement of key parameters including pH, ORP, conductivity, dissolved oxygen, and temperature [5].
c. handheld GPS (Garmin model 78s)

d. Laboratory approved sampling bottles
e. Ice box

It is important to have an adequate number of containers to store the samples gathered during a sampling collection. Water samples should only be stored in sample containers, never chemicals or other liquids. Glass containers are popular and suitable for many tests, however plastic containers are recommended for samples intended for specific chemical analysis. Plastic has the obvious benefit of being less prone to break than glass. Sample containers must be meticulously clean so that the samples deposited in them are not contaminated.

2.2.2. Sampling site

The sampling locations are situated at Keelung Container terminals since the said terminals were the busiest in terms of port and ship activities.

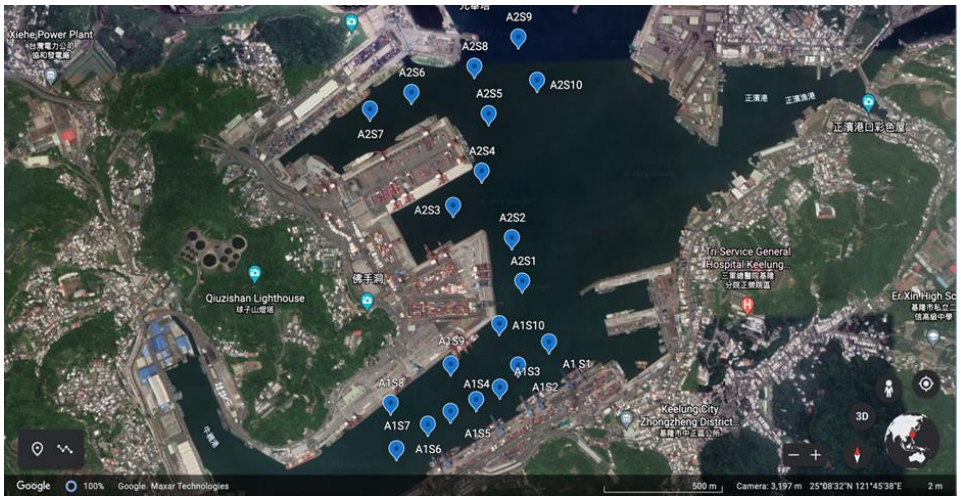

Fig. 1: Sampling sites.

2.2.3. Sample analysis protocol

The sampling locations are situated at Keelung Container terminals since the said terminals were the busiest in terms of port and ship activities.

Using a sterile sample bottle, the researcher using motorboat collected water samples on the pre-selected sampling sites. The researcher used handheld l GPS by Garmin model GPSMAP 78S with updated maritime maps of Taiwan to properly mark sampling site locations for succeeding sample collection.

Three samples per selected site were collected for error control. Collected samples were place on an ice chest or cooler for better handling and to avoid exposure to possible contaminants. Upon completion of sample collection, samples were immediately transferred to National Taiwan Ocean University for laboratory analysis.

Parameters like pH, dissolve oxygen, conductivity, salinity, total dissolve solids and oxidation reduction potential will be tested on site using portable multi parameter equipment by Hanna instrument model HI98194.

According to the ASEAN Marine Water Quality Management Guidelines and Monitoring Manual [4], the following are some general guidelines that can be applied to the process of collecting water samples from freshwater and marine areas in order to conduct an analysis for either physical or chemical variables:

- Before collecting any sample, record the location and position of the sampling site. This was done using the motorboat and handheld GPS.

- The temperature of the sample has to be measured and documented as soon as possible after the sample has been obtained.
- The pH and conductivity of the sample should each be tested on their own distinct parts of the sample. Because there is a chance that potassium chloride may diffuse from the pH probe, it is imperative that you do not use the same amount for both readings.
- The sample bottles' tops must be maintained clean at all times while they are open.
- In order to properly mix the sample, a little amount of air should be left in the sample bottle.
- Before leaving each sample site, all measurements acquired in the field must be documented in the field notebook.
- Before leaving each sample location, record all supporting information in the field notebook. Conditions such as ambient air temperature, weather, the occurrence of dead fish floating in the water or of oil slicks, algae development, or other strange sights or odors should be recorded, regardless of how insignificant they may seem at the time. These observations and comments will be very useful when evaluating analytical data.
- If samples are to be transported, they should be transferred to sample bottles as soon as possible after collection. If field analysis is to be carried out, it should begin as soon as possible.

2.3. Data analysis

Data from the waterproof portable logging multiparameter water quality meter were extracted and imported as Excel file. The Laboratory test results were transcribed and encoded using Excel as well.

All statistical analyses were done using SPSS software. In order to determine whether parametric or nonparametric technique should be used, data were subjected to tests of normality. The obtained results led to the use of nonparametric tests, particularly the independent-samples Mann-Whitney U test.

3. Results and Discussion

Table 1 shows the overall descriptive statistics of the water quality index parameters, along with their observed standard deviations. The mean pH of the Keelung port was 8.22 ± 0.05, with a range of 7.95 to 8.26. The values recorded are well within the standard values of 7.0 to 8.5 pH.

Table 1: Descriptive statistics of water quality index parameters.

	N	Minimum	Maximum	Mean	Std. Deviation
Temperature (°C)	60	18.88	20.02	19.26	0.23
pH	60	7.95	8.26	8.22	0.05
DO (%)	60	73.10	89.70	84.22	3.13
Conductivity (mS/cm)	60	42.66	51.80	48.04	1.63
Salinity (PSU)	60	27.51	34.15	31.42	1.17
TDS (mg/L)	60	21.33	25.90	24.02	0.89
ORP (m/V)	60	290.30	368.70	315.73	14.84
Valid N (listwise)	60				

Normal pH levels at Keelung Port imply excellent water quality and a healthy marine ecology. The pH number also shows that the water is not experiencing acidification, which has negative impacts for marine creatures, particularly the mollusk family, since acidic water prevents the formation of carbonates, which is essential for shell development. Continuous decline of carbonates in the water may result in the elimination and extinction of mollusks.

Furthermore, the disappearance of seashells in marine ecosystems will result in a continual decline in water quality as the natural water filters on the seafloor decline. Without them, the water will become polluted and the oxygen level will fall, making the water uninhabitable for other marine species and causing an imbalance in the ecosystem.

The Dissolved Oxygen (DO %) ranged from 73.10 to 89.70, with a mean of 84.22 ± 3.13. Keelung Port's dissolve oxygen level is within an acceptable limit. An acceptable oxygen content in water indicates excellent water quality,

that allows aquatic organisms to exist and grow. Fish and other species, on the other hand, may suffocate and die if oxygen levels get too low. Decreases in oxygen in water are typical throughout the summer because heat dissipates oxygen in the water. This can lead to fish kills and the continuous growth of harmful algae, which can pollute the water and soon lead to oxygen deficiency. The ORP, or oxidation reduction potential, of water evaluates its capacity to break down pollutants in the water. If the DO in the water is normal, it implies that the ORP is normal as well, but for check and balance reasons, both DO and ORP may be checked.

Salinity having a minimum value of. 27.51 and maximum value of 34.15 standard deviation ± 1.17 with a mean value of 31.42. The salinity of the ocean water is typically between 33 and 37 grams per liter, however the tropics, which are situated near the equator can get the most rainfall on a consistent basis, have a lower salinity. Because of this, the fresh water that runs down into the ocean helps to bring the salt of the surface water in that region down. Keelung port is considered to be estuaries, the average salinity of the water is much lower than that of the surrounding ocean. Another aspect that contributes to lower salinity is the climate, which, in comparison to that of other parts of Taiwan, often produces a greater amount of precipitation.

Table 2: Group statistics of inner port and outer port in-situ measurements.

Sampling Area		N	Mean	Std. Deviation	Std. Error Mean
Temperature	Inner	30	19.28	0.23	0.04
	Outer	30	19.24	0.23	0.04
pH	Inner	30	8.19	0.06	0.01
	Outer	30	8.25	0.01	0.00
DO	Inner	30	82.98	2.78	0.51
	Outer	30	85.46	3.00	0.55
Conductivity	Inner	30	47.27	1.35	0.25
	Outer	30	48.81	1.55	0.28
Salinity	Inner	30	30.89	0.99	0.18
	Outer	30	31.95	1.11	0.20
TDS	Inner	30	23.64	0.84	0.15
	Outer	30	24.41	0.77	0.14
ORP	Inner	30	321.94	17.08	3.12
	Outer	30	309.52	8.75	1.60

A comparison of the parameter readings taken at the inner and outer ports is shown on Table 2. Inner ports tend to have lower values for water quality parameters such as pH, DO, conductivity, salinity, and total dissolved solids (TDS) because of factors such as waterways and drainage that lead to the port area. If it is not adequately treated, the grey water that is generated by residences, commercial enterprises, and adjacent industries in Keelung will have a significant impact on the quality of the water in the port area, especially the inner port where it flows continually.

Based on the hypothesis test summary presented on Table 15, we can see that sampling area significantly affects the distribution of in-situ measurements for pH, DO, conductivity, salinity, TDS, and ORP.

Table 3: Hypothesis test summary with sampling area as independent variable.

No.	Null Hypothesis	Mann-Whitney U Test Statistic	Sig.	Decision
1	The distribution of Temperature is the same across categories of Sampling Area.	870	.000	Reject the null hypothesis.
2	The distribution of pH is the same across categories of Sampling Area.	722	.000	Reject the null hypothesis.
3	The distribution of DO is the same across categories of Sampling Area.	739	.000	Reject the null hypothesis.
4	The distribution of Conductivity is the same across categories of Sampling Area.	717	.000	Reject the null hypothesis.
5	The distribution of Salinity is the same across categories of Sampling Area.	705	.000	Reject the null hypothesis.
6	The distribution of TDS is the same across categories of Sampling Area.	234.5	.001	Reject the null hypothesis.

Tides may have a significant influence on the flow of sediments and the degree of mixing within an estuary. As a result, advective forces may affect a number of water quality indicators such as salinity, total dissolve solids, dissolved oxygen, and pH. In contrast, the tidal conditions at Keelung port had no substantial effect on the observed parameters.

The summary of hypothesis test above shows that using independent samples Mann-Whitney U tests, in-situ water quality parameters measurements were not significantly affected by tidal conditions.

Table 4: Group statistics of high tide and low tide in-situ measurements.

Tide		N	Mean	Std. Deviation	Std. Error Mean
Temperature	High	40	19.23	0.26	0.04
	Low	20	19.31	0.15	0.03
pH	High	40	8.22	0.04	0.01
	Low	20	8.21	0.07	0.02
DO	High	40	83.78	3.35	0.53
	Low	20	85.10	2.48	0.55
Conductivity	High	40	48.13	1.90	0.30
	Low	20	47.86	0.89	0.20
Salinity	High	40	31.48	1.35	0.21
	Low	20	31.31	0.69	0.15
TDS	High	40	24.01	1.00	0.16
	Low	20	24.05	0.61	0.14
ORP	High	40	314.61	13.80	2.18
	Low	20	317.98	16.89	3.78

Table 5: Group statistics of high tide and low tide in-situ measurements.

Study Area / Condition	Inner Port		Outer Port		Low Tide		High Tide	
Analytes (mg/L)	Min	Max	Min	Max	Min	Max	Min	Max
Hg	Bd	Bd	Bd	Bd	Bd	Bd	Bd	Bd
As	Bd	Bd	Bd	Bd	Bd	Bd	Bd	Bd
Cr	Bd	Bd	Bd	Bd	Bd	Bd	Bd	Bd
Nitrite	0.01	0.04	Bd	0.01	Bd	0.02	Bd	0.04
Ammonia	0.02	0.89	Bd	0.29	Bd	0.07	Bd	0.89

Bd - below detection

In all the sampling areas and regardless of spatial or tidal condition, there were no presence of Hg, As and Cr detected. There were presence of Nitrite and Ammonia at the inner port and outer port. Both parameters were also detected during low tide and high tide. The standard that is utilized by TIPC for bodies of water that fall into the Type C category does not set a minimum standard for the concentration of nitrite and ammonia (industrial water area). On the other hand, according to international standards, the ideal Nitrite concentration is between 0.01 to 0.04 parts per million, which means that Keelung port is still meet the minimum international standard. While the ammonia concentration in the port water is at 0.089 mg/l which exceeds the allowable limit which is set at maximum allowable value of 0.07mg/l.

4. Conclusions and Future Work

Water quality is significantly affected by the location of sampling area, whereas the inner port area showed relatively higher level of contamination compared with the measurements taken at the outer port area. According to the findings of a study that was carried out at Keelung Container terminals, the level of contamination in the water is within the permissible limit established by the National Government of Taiwan and other international standards except for the level of concentration of ammonia that has a maximum value of 0.89mg/l. The satisfying result indicates that TIPC, the company that manages the ship and port operations, is carrying out the appropriate level of monitoring and surveillance to maintain good water quality in the area. The presence of heavy metals like mercury, arsenic and chromium in water were not detected.

Based on the independent samples Mann-Whitney U test conducted, tidal condition does not significantly affect the distribution of measurements of the water quality parameters.

Here are some suggested future works:

1. To thoroughly analyze the water quality of Keelung port, more factors must be considered.
2. To provide an accurate picture of the current state of the water quality, it is necessary for the study area to include the whole port region, including all ship terminals.
3. Separate research has to be conducted in the area where drainage discharges or effluents are situated as this will have an effect on the water quality in the estuaries.
4. Research that takes place throughout the summers is required in order to determine whether or not the weather and temperature might considerably influence the water quality.
5. In order to guarantee that Taiwan's other local and international seaports are environmentally compliant with national and international requirements, a similar research has to be conducted at each of them.

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