Journal of Advanced Research in Applied Sciences and Engineering Technology

Journal homepage:
https://semarakilmu.com.my/journals/index.php/applied_sciences_eng_tech/index
ISSN: 2462-1943

IoT-Driven Environmental Monitoring and Healthcare System: Shipbreaking Industry Perspective

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ARTICLE INFO

Keywords:
Internet of things; environment monitoring system; Sitakunda Shipbreaking Industry; cloud server; machine learning algorithm

ABSTRACT

Bangladesh's coastal region is ecologically significant and has a rich biodiversity. The country is well-known in the world for its shipbreaking industry. However, its commercial operations have severely impacted the coastal habitat. For example, the workers are exposed to a savage environment of effect that makes them vulnerable to a variety of health issues. Thus, the main objective of this research is to monitor the environmental pollution as well as the health condition of the workers of the shipbreaking industry in Sitakunda region of Chattogram in Bangladesh. We introduce an IoT-driven outdoor environmental monitoring system aimed that collects real-time data on five air parameters: PM2.5, dew point, temperature, surface pressure, and humidity, and six water parameters: pH, turbidity, conductivity, temperature, TDS (Total Dissolved Solids), and DO (Dissolved Oxygen) from the Sitakunda Shipbreaking Industry. The sensing devices are connected to a microcontroller board to gather sensor data and transmit the collected data to a cloud server for further processing and analysis. Moreover, we have collected past environmental data from various sources, such as NASA Power View, Dhaka US Console, Ministry of Environment, Forest and Climate Change, and WHO. We have also conducted a patient survey in six different hospitals of Chattogram to evaluate workers' health status, which is a distinctive and challenging aspect of our work. Subsequently, we have analysed environmental pollution using these datasets and health surveys, identifying three types of risk factors such as High, Medium, and Low, for the workers' health conditions in a shipbreaking industry. Finally, we have constructed a machine learning (ML) model using a variety of ML Algorithms, namely Ensemble Method, Extra Tree Classifier, Random Forest, Decision Tree, and KNN that achieved higher accuracy of 81.78% and 92.26% for air and water, respectively. It is observed that the Random Forest Classifier demonstrates the best precision compared to other models based on dataset accuracy. During the summer season, our system identifies a category of "Medium Risk Factor" based on the environmental condition. Our implementation provides a method to determine the affected rate of the environment and the margin for a healthy environment. Consequently, this approach will assist in estimating and informing the public about the hazardous situation of shipbreaking industries, particularly those in the Sitakunda region.

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https://doi.org/10.37934/araset.65.2.6994

1. Introduction

These days, there is a huge global market for the shipbreaking industry. Bangladesh is among the top shipbreaking nations of the world with its distinct modern neighborhoods and harbour, Chattogram is renowned as the center of the shipping industry. In particular, Chattogram's primary business is the shipbreaking industry located within this city. The term Shipbreaking, known as ship destruction, is a sort of ship disposal in which ships are dismantled for scrap and their hulls are dumped at ship yards [1]. Usually, it takes two to three months, and during that time, a lot of hazardous material is created that can possibly flow into the surrounding areas [2]. It covers the process of getting rid of recyclable items found in a used vehicle, such as steel scraps, furnishings, electronics, and so forth. This is a custom observed in Bangladesh's coastal regions that has risen in significance for the nation's macro and microeconomic systems due to the extreme poverty of the country. Despite the fact that this business is crucial to the nation, it gravely affects the coastal environment and poses a health risk to its workers. In shipbreaking yards, it is challenging to prevent environmental damages though the quantity of pollutants can be decreased by taking the necessary steps.

This preparation was restricted to a small number of industrialized nations before 1960, including UK, US, Germany, and Italy. The shipbreaking industry has distinguished itself over the course of time by supplying natural resources to the steel, shipyard, and other industries in Bangladesh as well as other South Asian countries including China, Turkey, Philippines, Vietnam, India, Bangladesh, and so forth [3,4]. The shipbreaking industry beat other industries, such as the aviation and automobiles sectors, in recycling 95-98% weight of the ship [5]. In Bangladesh, where there have been more than 50 shipbreaking yards since 1974, around 52% of decommissioned ships above 200 deadweight tons have been destroyed. Bangladesh has emerged as a key ship recycling country in the globe over the course of 1984 [6]. Bangladesh is home to some of the biggest shipbreakers in the world, yet the country did not publicly recognize the core activity as an industry until 2006 [7]. In terms of gross tonnage, she has destroyed the majority of ships over the past 3 years i.e., between 2016 and 2018 [8]. There are over 150 shipbreaking yards in Sitakunda and 100 of which are open all year round where about 25,000 people are directly employed, notably in the areas near Kumira, Bhatiary, and Fouzdarhat.

Based on research conducted by the Youthful Power in Social Action (YPSA) and World Bank, the number of individuals directly engaged at shipbreaking yards rises between 20,000 and 50,000, while the number of people indirectly employed climbs between 100,000 and 200,000 [9,10]. Numerous sources state that Bangladesh's tourism industry brings in an estimated 1.5 billion dollars annually. An "NGO Shipbreaking Stage (2020)" report claims that Bangladesh learned about ship reuse in 2019. Out of 234 units, 674 oceanic commercial ships and seaside units were proposed to scrap yards globally, including Bangladesh. Bangladesh continued to dominate the world in ship reuse, as documented in a document titled "Overview of Oceanic Vehicle 2019" by the "Exchange and Improvement 2019 for Joined Gathering Countries". Based on the report, the ship reuse industry in Bangladesh led the market in 2018, destroying more than 47.2% of all ships [11]. Therefore, there is no argument against the notion that Bangladesh's shipbreaking industry is essential. However, in recent years, it has generally ignored the environmental effects of shipbreaking yards in favour of focusing on their financial benefits.

Unfortunately, these businesses cause significant harm and natural contamination in Bangladesh's coastal areas, including radiation, blasting, and air, water, and soil pollution. Several variables, some of which are man-made and others due to natural causes, contribute to the contamination [12]. Every living thing on earth suffers from cancer, heart illness, pneumonia,

cardiovascular disorders, lung diseases, and asthma as a result of the poor quality of the air we breathe. Environmental contaminants include ozone (O_3), sulphur oxides (SOx), nitrogen oxides (NOx), temperature, dew point, humidity, surface pressure, and particles (PM2.5). According to research [13], more than 10% of the sulphur deposited in Cyprus (30%), Malta (56%), and more than 10% of the nitrogen removed in Greece (21%), Malta (51%), Cyprus (30%), Italy may be attributed to radiation from oceanic shipping. To create thorough air quality rules, the WHO and public norms, including the US Ambient AQI Standards, have thoroughly assessed the health consequences of air contamination [14]. Because of their detrimental effects, biogeochemical recycling, and environmental persistence, trace metals including Cd, Pb, Ni, Cr, As, and Hg are particularly concerning when they are present in the environment [15]. The measurements of the water indicate that the pH range is 8.22-6.79, TDS is 7740 mg/L-9370 mg/L, and TSS is 724 mg/L-512 mg/L. The acidity of the water was observed to range between 9.02 mg/L-5.40 mg/L, alkalinity 310.19 mg/L-229.47 mg/L, DO 6.89-3.01 mg/L, BOD 3.17-0.51 mg/L, COD 338-178 mg/L, and hardness 1100 mg/L-750 mg/L. The chloride of water was found to differ between 21535.87 mg/L-10138.70 mg/L, phosphate between 2.177 mg/L-1.062 mg/L, iron between 33.40 mg/L-19.025 mg/L, manganese between 2.648 mg/L-1.21 mg/L, and water nitrite between 0.030 mg/L-0.005 mg/L. All samples of Co, Ni, Zn, Cu, Pb, and Ag fell within the acceptable limits, according to the WHO [16].

In our study, we have selected the shipbreaking industry in Kumira of Sitakunda, which is in the northwest of Chattogram, Bangladesh. The geographical coordinates of this area range between latitudes 22.51721 and 91.72214. Our system employs IoT-based technology to monitor real-time environmental quality, encompassing both air and water, in the shipbreaking sector while also assessing worker's health conditions. Initially, we have deployed sensors to gather real-time data, storing it centrally on a cloud platform named "ThingSpeak", and we have also collected historical environmental data from various reliable locations. Moreover, we conducted a patient survey across six different hospitals within the Chittagong division to compile a health dataset. We have subsequently compared the affected rates of patients in Sitakunda with those in other areas, given our focus on the Sitakunda shipbreaking area. Based on our survey results, we have classified our risk factors into three categories: high, medium, and low. Then we have employed Machine Learning algorithms alongside Data Analytics techniques to enhance the accuracy of our model. Our findings suggest that the shipbreaking industrial zone exhibits more severe environmental pollution and poorer health conditions compared to non-industrial areas, impacting the health of shipbreaking industry personnel negatively. Finally, we have made an effort to offer some suggestions and proposals to address this issue.

Figure 1 displays the system's overview of our research, where we have shown how our system works. The major contributions of our work are stated below:

i. An IoT-driven real-time environmental monitoring system is developed for the largest shipbreaking industry of Sitakunda region.
ii. Primary health data is collected from six hospitals of different region to analyze the workers' health of the shipbreaking industry of Sitakunda.
iii. Finally, a Machine Learning Model has also been developed to monitor the environment of the shipbreaking industry that assesses the workers' health condition.

This section has already covered the introduction. The rest of the paper is organized as follows: Section 2 discusses the previous work that is closely related to our system, and we have demonstrated the necessity of this article by contrasting it with other surveys that are currently in existence. We cover our materials, methods, and strategies in Section 3. The experimental findings are presented in Section 4, and Section 5 discusses our work and offers a strategy for expanding it in

the future. Section 6 is where we finally put a stop to our work in the future direction. The structure of the paper is shown in Figure 2.

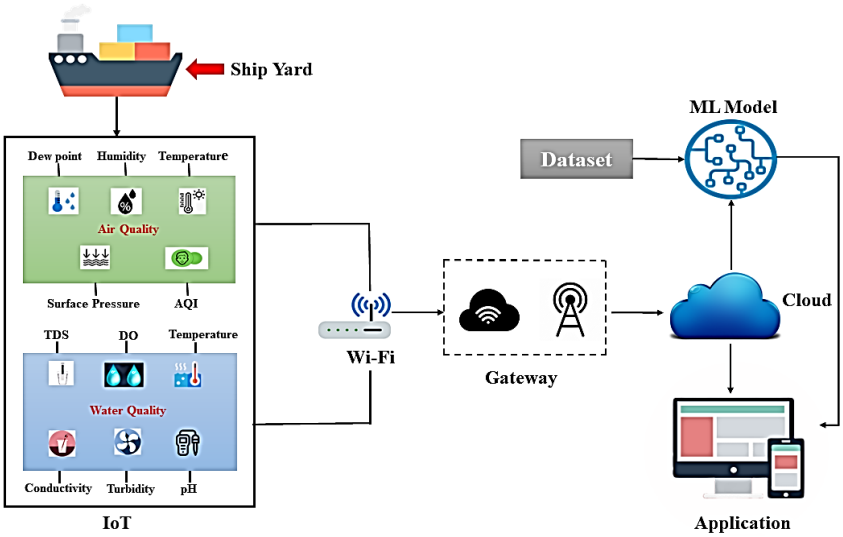


Fig. 1. Overview of the proposed system

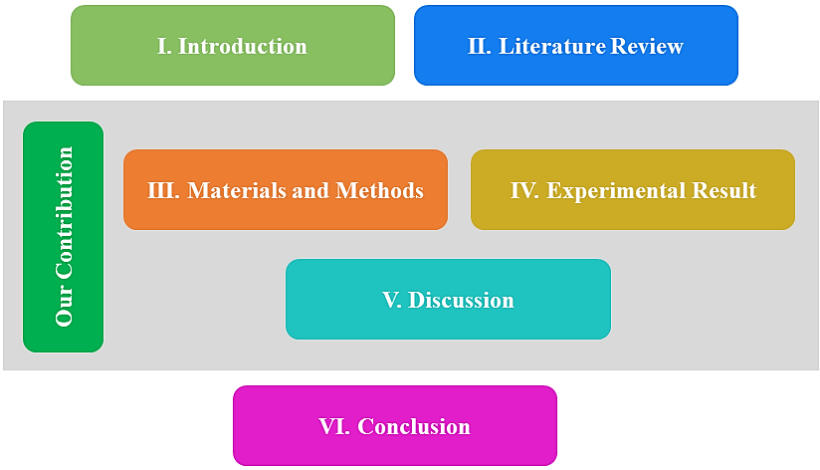


Fig. 2. Organization of paper

2. Literature Review

We have compared all the relevant research with our study to identify and illustrate the research gap, as shown in the Table 1. This section describes some related work in detail. In order to grasp environmental restrictions including humidity, temperature, atmospheric pressure, and dew point, Kalia and Mamtaz [17] created a structured equipment that investigates and estimates the Particulate Matter (PM) Concentration and Air Quality Index (AQI) for any specific area. Chen *et al.,* [18] present an overview of the key instruments that successfully reduces the nanostructured materials' operating temperature for gas recognition at low and room temperatures. Another study in Zhang and Simon [19] provided a hybrid model that combines both mobile and specified IoT sensors and installed on cars to observe the local air quality factors e.g., PM10 and PM2.5 of a particular area. The main advantages of these articles are their ability to measure several variables, e.g., air quality, climate, smart cities, well-being, clinical region, etc. 24 hours a day. The research flaw is that they focused only on PM matter with micrometer-sized centralization, low conductivity and selectivity, and few boundaries.

Table 1
Comparison table of our article with existing 23 articles

Author	IoT or cloud computing or wireless sensor	ML or DM or DL or DA	Statistical survey or mathematical or review	Application
Kalia *et al.,* [17]	✓	X	X	X
Chen *et al.,* [18]	X	X	X	✓
Zhang *et al.,* [19]	✓	X	X	X
Saini *et al.,* [20]	✓	X	✓	X
Marques *et al.,* [21]	✓	X	✓	✓
Saini *et al.,* [22]	✓	X	✓	X
Jo *et al.,* [23]	✓	X	X	✓
Benammar *et al.,* [24]	✓	X	X	✓
Represa *et al.,* [25]	X	✓	✓	X
Liu *et al.,* [26]	X	✓	X	X
Zimmerman *et al.,* [27]	X	✓	X	X
Janarthanan *et al.,* [28]	X	✓	X	X
Basha *et al.,* [29]	X	X	✓	X
Yang *et al.,* [30]	✓	X	X	✓
Barthwal *et al.,* [31]	X	X	✓	X
Islam *et al.,* [32]	X	X	✓	X
Ali *et al.,* [33]	X	X	✓	X
Showva and Adib [34]	X	X	✓	X
Hossain *et al.,* [35]	X	X	✓	X
Mitra *et al.,* [36]	X	X	✓	X
Ahamad *et al.,* [37]	X	X	✓	X
Wu *et al.,* [38]	X	X	✓	X
Xu *et al.,* [39]	✓	X	✓	X
Our study	✓	✓	✓	✓

The article [20,21] presents a survey of IoT-based indoor air quality tracking devices over the preceding five years. Another survey [22] offers significant insights on the decision-making framework for indoor portable noticing in addition to a subjective and quantitative assessment of inexpensive sensors. The analysis and synthesis of significant data on existing frameworks is supported by these surveys. The important thing is to have a smart system that continuously checks the air quality, records data, helps professionals choose the best sensor units, and is valuable for later research. Their handling capacity, sensor accuracy, response time, cost analysis, and energy consumption are the limitations. Another IoT-driven indoor air structure is presented by Jo *et al.,* [23] article, which successfully monitors the air quality and dynamically transmits the real-time data to a web application server over LTE. One of the advantages of the framework is to develop a useful method for continuously monitoring air quality. The foundation is highly accurate, trustworthy, and accessible from anywhere. Nevertheless, more testing is anticipated to guarantee information accuracy over long periods.

In a framework for indoor air quality observing, Benammar *et al.,* [24] have used IoT servers, considerable level-introduced entryways, and remote AQ sensor center points. It continuously

broadcasts and saves information on the server. In order to ensure that no information is lost in the event that system correspondence is lost. The article contains the full hardware and software specifications for the recommended solution as well as the approach. However, the Qatar College grounds are the only location where this framework is tested. The objective of the system is to monitor air pollution, hazardous gas emissions, and pollution awareness in industrial areas. It is built on wireless network technology that allows the data of sensor to be sent in a timely manner with high resolution and cost effectively [40,41]. In order to help operating industries, Garcia *et al.,* [42] offer a comprehensive AQI monitoring architecture made up of instruments able to measure suspended particulate matter and harmful gases. However, the authors did not provide any web-based or app-based solution to display the network's status.

The literature on data mining's application to air pollution assessment published between 2014 and 2018 is compiled in this article. The goal of this research is to use new techniques for future projects and to provide an overview of the intelligent work that has been done in air quality and data mining. They discussed about different methods for handling data visualization pertaining to air quality. Nevertheless, they merely skim the surface of data mining's applications in air quality monitoring [25]. The authors in [26] constructed two expectation models based on ML algorithms utilizing the contamination focus forecast and the AQI expectation as specific examples. This methodology provided guidance for simulating and examining urban air quality as well as increasing the uniformity of air indicators. A specific alignment model of low-cost sensors produced and supported for a 16-19 Slope Multi-Poison sensor, which measures CO_2, CO, NO_2, and O_3, may be found in the work [27]. Using Random Forest, a special algorithm that tracks air pollution, the underlying strengths of both publications can produce excellent results. However, relying on RF-based ML algorithms for low-cost air quality modifications did not work well.

In [28], the authors proposed deep learning models such as Long Short-Term Memory and Support Vector Regression differentiated from the existing methods by offering a concise and explicit incentive for AQI in the city's designated territory. The effectiveness of the procedures depends on whether or not social occasion classifier expectations lead to more accurate class clamor finding and are appropriate for input data. Another advantage is using large data and numerous borders. However, they didn't use any deep learning algorithms to suggest air pollution in the systems of the executives. In this analysis, sporadic particle matter estimation finds from Gujarat, India's largest shipbreaking yard, are shown in graphical detail [29]. The statistical analysis and enrichment factor results suggested that shipbreaking operations must have had a substantial impact on a number of metals. The ability to measure the air quality at a reference terminal in Gopnath and the Alang-Sosiya Shipbreaking yard is the article's main strength. The loss of AQI data is being felt. According to research by Yang *et al.,* [30], who found a correlation between CO_2 preoccupation and people, large-scale microorganisms, and PM concentrations, it could be wise to use CO_2 fixations as a general indicator of the quality of the air. The data stage includes the data that follows and looks at the ability to justify IAQ enhancement initiatives. Massive amounts of data were too much for this system to handle.

Another study described many clinical concerns experienced by Delhi's foreign workers that might be inferred from their promise-related susceptibility to environmental hazards, including air pollution. In order to help associations with planning, exercising care, improvising in the field of general prosperity, and using safety measures, this document recommends that specialists and government authorities with relevant expertise assist. But they did not demonstrate how to gauge the quality of the air [31]. Islam *et al.,* [32] present a method to examine the Pasur River's water quality using toxicological and physicochemical criteria and to locate pollutants in the water using multivariate analytic techniques. The goal of the research was to determine the health hazards

connected with the water quality and pollution level in the shipbreaking area using a variety of indices, like Cd, Cr, Fe, Mn, Pb etc [43]. The main contribution of this study is that its findings can serve as the foundation for the creation of a system for monitoring surface water quality and for assisting decision-makers in setting priorities for waste water treatment. To determine the concentrations of Pb, As, Cd, and Cr of hazardous metals that build up and are toxic in water, are the main goals of this research [33]. The fact that this study examined the water quality in shipyards locations for the first time throughout Bangladesh's Bay of Bengal coast may be its strongest point.

The research paper by Showva and Adib [34] determines the physicochemical limits of groundwater and surface waters in the surrounding studies and evaluates the extent of water contamination and its effect on biodiversity in the shipbreaking yards of Bhatiary. They take into account factors that affect the quality of the water, such as pH, salinity, alkalinity, hardness, EC, turbidity, BOD, DO, and the presence of Pb, Cr, Cd, and Fe. This study aims to characterize the suitability of surface and groundwater for drinking and irrigation, as well as to quantify the non-carcinogenic and carcinogenic threat to human health resulting from the ingestion and cutaneous absorption of various heavy metals found in groundwater and surface water [44]. Singh *et al.,* [45] designed an IoT-based architecture that uses specialized hardware to track the amount and water quality in a home water container using 2.4 GHz radio-frequency links. They failed to use the temperature, conductivity, and DO sensors, which are essential for a more dependable system. According to the authors of [46], a wireless sensor network's architecture monitors the water quality by using data from sensors that are submerged in water. This method is special because it can obtain a low-powered, highly mobile, and frequent water monitoring system. They are limited in their attention to measuring river water characteristics due to budgetary constraints.

The strategy put forth by Hossain *et al.,* [35] offers a strong foundation for the dissemination of information on the usual impacts of Bangladesh's shipbreaking business and health issues that the workers in the industry. Their basic commitment is to limit shipbreaking practices and reuse designs for ships. They analyze a number of air pollution-related boundaries, although AQI information is not shown here. Mitra *et al.,* [36] created the energy-based CO_2 emissions from Bangladeshi shipbreaking operations to demonstrate how widely these emissions came from this region. The motivation of this research is to improve awareness among the workforce by questioning workers about their assessments of their susceptibility to risks. The main contribution is the application of the Geographic Weighted Relapse method to investigate the heterogeneity of the factors of CO_2 dispersion in the ship industry. Instead of quantifying the amount of pollution or its negative impacts, this study focused on the opinions of the respondents. Another paper examines the employment history and health risks of employees who engaged in shipbreaking activities at Bhatiari, Chattogram, Bangladesh. This study will contribute to the conclusion of the methodology choices and the enhancement of the nation's economy and working conditions for workers. Here, execution in such a dangerous environment was not shown [37].

In order to investigate the hypothesis that, over the course of a 24-year surveillance period, shipbreaking laborers exhibited an increased occurrence of neoplasms, particularly asbestos-related cancers, a cohort study linking male shipbreakers to the Taiwan Cancer Registry was conducted in this study [38]. A cloud-integrated design was developed by Xu *et al.,* [39] to monitor ecological factors, screen medical difficulties, examine the cycle of framework execution, and conduct assessment and analysis from the perspectives of safeguarding against and compensating for adverse working circumstances. They provide the necessary algorithms after analyzing the process of implementing the system. This system will enhance working conditions, carry out well-being verification and control, and safeguard the interests of assembly line workers. For real implementation, this innovation needs clear inspection and assessment procedures. The prior

researches have been summarized, with our findings, limitations, and key contributions, and are displayed in the Table 2.

Table 2
Overview table of relevant studies

Author	Objectives	Limitations	Our contributions
Kalia and Mamtaz [17]	IoT-based platform for measuring the AQI and PM concentration.	Consider only PM concentration for air quality monitoring.	Air and water quality for measuring the environmental quality.
Chen *et al.,* [18]	A review paper of nano-structured substance for gas recognition at room temperature and below.	Detecting gas to monitor environmental conditions.	Considering 5 different parameters for air and 6 for water quality monitoring.
Zhang and Simon [19]	Suggested a hybrid system for air standard monitoring using ML algorithm in the smart city.	Considering fewer datasets.	Use huge amounts of dataset.
Marques *et al.,* [21] and Saini *et al.,* [20]	A systemic review of IoT-driven indoor air quality monitoring.	Absent outdoor air pollution monitor.	Outdoor air quality monitor with water quality monitor for the shipbreaking industry.
Saini *et al.,* [22], Jo *et al.*, [23] and Benammar *et al.,* [24]	IoT-based low-price sensor for monitoring indoor air quality.	Though sensors are low-cost, there were some issues in architecture, power, network, and data accuracy.	Use industrial sensors with high accuracy.
Represa *et al.,* [25]	Review on the basis of data analysis for measuring air pollution.	Real-time data missing.	Utilize real-time data with implementation.
Liu *et al.,* [26]	Air pollution prediction using SVR and RFR algorithms.	The SVR model was not working better for a large amount of data.	Apply 5 different algorithms like - Ensemble Method, RF, KNN, Decision Tree, and Extra Tree.
Zimmerman *et al.,* [27]	Improved the calibration techniques of the random-forest-based system for low-cost sensing using RAMP monitor.	Apply only the RF algorithm.	Use 5 different algorithms with high accuracy.
Janarthanan *et al.,* [28]	AQI monitors in metropolitan areas based on deep learning with fixed value compared to existing models.	AQI value was not so much good.	AQI monitoring for industrial areas with good accuracy.
Basha *et al.,* [29]	Seasonal measurements of particle matter obtained from the world's largest shipbreaking yard.	Analyzing theory-based observation.	Implementing the system by considering environmental parameters.
Yang *et al.,* [30]	An AI platform-based environmental monitoring system and wireless sensing is used to evaluate the air quality of a public hospital.	A small volume of dataset.	Unique dataset by doing hospital survey.

Table 2
Overview table of relevant studies

Author	Objectives	Limitations	Our contributions
Barthwal *et al.,* [31]	Several health problems that workers may have for being exposed to extreme weather and air pollution at work.	Only gave statistical results on the worker's health issues.	Surveying health issues of workers based on environmental data.
Islam *et al.,* [32]	Monitoring water quality in the seaport area of Bangladesh.	Only measuring water parameters.	Measuring environmental data in real-time.
Ali *et al.,* [33]	Determine the levels of accumulated hazardous metals and their poison in the water of the shipbreaking sector.	Consider only Pb, As, Cd and Cr metals.	Examine the parameters of water as well as real-time monitoring.
Showva and Adib [34]	Analyze the pollutants in the water and quantify the damage to biodiversity caused by the Shipbreaking business.	Deal with some water parameters.	Consider all environmental parameters (both air and water).
Hossain *et al.,* [35] and Ahamad *et al.,* [37]	Discussed the effects of shipbuilding activities, livelihood index, and health hazards associated with shipyard workers in Bangladesh.	Analysis-based system.	Implementation based system and monitoring the environmental pollution level in real-time.
Mitra *et al.,* [36]	Estimated the risks to workers' health posed by energy-based CO_2 emissions and shipbuilding businesses in Sitakunda, Bangladesh.	Did not analysis the pollution level.	Describe the level of air and water pollution.
Wu *et al.,* [38]	Over a 24-year follow-up period, men shipbreaking workers had an elevated risk of cancer.	Lack of personal dataset.	Collect personal dataset of patients from 6 different hospital in Chittagong division.
Xu *et al.,* [39]	An architecture that is cloud-integrated and has five layers for managing and tracking the health of manufacturing workers.	Lack of implementation with particular evaluation and verification techniques for practical uses.	IoT and data analysis-based implementation system.

The early research works covered a variety of topics, including the observing indoor air quality in workplaces and hospitals, water quality in industrial and coastal areas, and the result of the shipbreaking business on the health of workers and the environment. In our proposed approach, we have focused on monitoring the environment and also focused assessing the health of those area who work in the shipbreaking industry to fill the research gap left by earlier studies. Our system is built using a real-time monitoring technique, and the primary output of our study has the solitary dataset that we compiled based on the distinct topography of our country.

3. Methodology

The largest shipbreaking industry in the world is situated in Sitakunda, Chattogram, a primarily agricultural area. Lately, it has been accused of harming the environment and the health of workers, in particular by contaminating soil, air, and water that cause pollution. In this work, we have developed an environmental monitoring system for the shipbreaking sector that assesses the worker's health condition. We have divided our system into 4 stages, namely sensor data collection, cloud platform, past data collection, and data visualization, as shown in Figure 3.

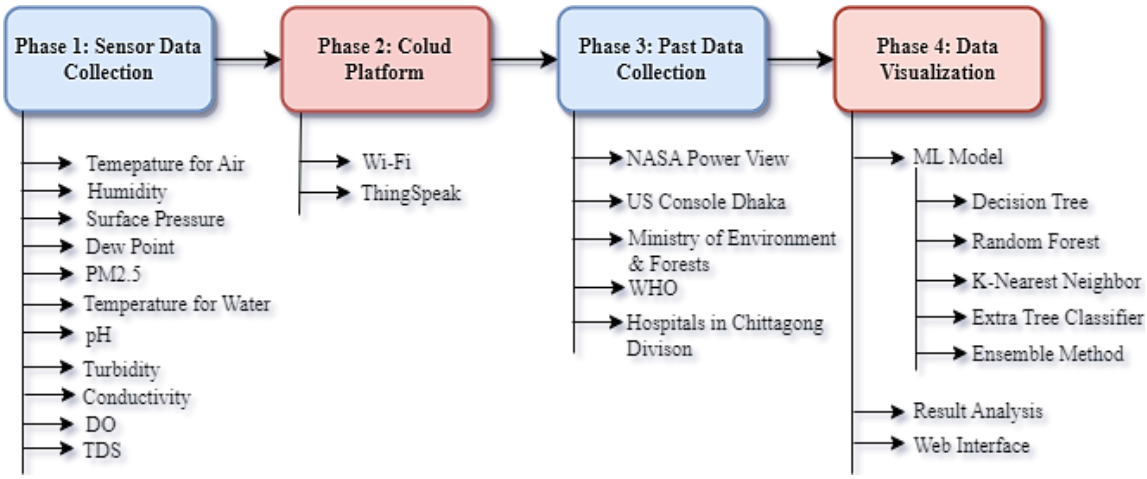


Fig. 3. Phases of the technique adopted in the research

3.1 Sensor Data Collection

To facilitate the real-time monitoring of environmental effects, we have considered IoT platform. IoT encompasses a wide range of applications made possible by the connection of devices like sensors, actuators, and monitors that are reachable via mobile and Internet. Because of their ease of use in gathering data from the real world and their capacity to transfer data between domains, the diverse range of IoT applications becoming popular [47]. In our study area, we have collected data on five parameters to assess air quality and six parameters to analyze water quality [48] by using IoT sensors. Our evaluation of air quality focuses on five primary factors e.g., PM2.5 concentration, dew point, temperature, surface pressure, and humidity.

i. PM2.5: To measure PM2.5, we have used a variety of gas sensors, such as, the MQ2 (identifies smoke, alcohol, hydrogen, LPG, and I-butane), the MQ7 (detects carbon monoxide at concentrations between 10 and 10,000 ppm), and the MQ135 (detects damaging gases such as sulphur, benzene, carbon dioxide, and other noxious gases).
ii. Dew point: The dew point estimates the actual airborne convergence of water vapours. A DHT22 sensor is also utilized to measure the dew point.
iii. Temperature: The air temperature is measured using the DHT22 sensor, a cost-effective physical temperature and humidity sensor that operates as a digital sensor.
iv. Surface pressure: We have used the BMP280 sensor to calculate surface pressure and wind speed of the surrounding area. This sensor measures barometric pressure and operates according to the I2C standard, making it ideal for versatile applications.
v. Humidity**:** We have determined the humidity by measuring the amount of water vapor, or dampness content, in the air using a DHT22 sensor.

In our assessment of water quality, we have considered six factors, e.g., temperature, pH level, turbidity, conductivity, DO, and TDS.

i. Temperature: The temperature of the water is measured using the DS18B20 sensor, a specific type of waterproof digital temperature sensor that monitors water temperature and produces values in the 9- and 12-bit range.
ii. pH: "Power of hydrogen" (pH) refers to a measurement of the body's concentration of hydrogen ions. The range of the entire pH scale is 1 to 14, with 7 being considered neutral. If the pH of a solution is below 7, it is referred to as acidic, and if the pH is above 7, it is referred to as primary or alkaline. The SEN0161 sensor has employed in our system to assess the level of pH in the water.
iii. Turbidity: We have deployed the turbidity sensor SEN0189, which measures the amount of infrared light that enters the phototransistor, and generates the voltage on the sensor while submerged in water.
iv. Conductivity: Conductivity measures the concentration of ions that dissolved in water by determining the amount of electricity that may theoretically move through the water (in Siemens). Here, we have measured the conductivity of water using the SEN0244 TDS sensor.
v. DO: The amount of free, non-compound oxygen that can be found in water or any other liquid is known as dissolved oxygen. Similar to how stirring dissolves salt or sugar, free oxygen molecules may dissolve in water. Here, we have measured the oxygen content of the water using SEN0237, which is a Gravity Analog Dissolved Oxygen sensor.
vi. TDS: The number of soluble particles dissolved in water and the TDS value are commonly employed as indicators of the quality of water. Here, the solid particles in the water are identified using the SEN0244 TDS sensor.
vii. Microcontroller board: The D1 Mini is used as our primary microcontroller board. The D1 mini is a Wi-Fi upgrade microcontroller board that can be used with breadboards in comparison to the ESP8266.
viii. ADS1115: The ADS1115 is a highly conservative, low-power, 16-bit precise, and internally referenced analog-to-digital converter. Most of the time we have used this device in high-precision equipment, battery voltage, smart electronics, and other high-precision scenarios. This system makes use of a few sensors.

To aid in further visualization, we have created a comprehensive taxonomy of our proposed system, which is depicted in Figure 4. Moreover, we have incorporated our sensors by using the jumper wires to connect the D1 mini to the breadboard along with the DHT22, BMP280, MQ2, MQ7, MQ135, DS18B20, SEN0161, SEN0237, SEN0189, and SEN0244 sensors. For the purpose of communicating with the D1 Mini, the ADS1115 sensor is accustomed to converting all analog pins into digital pins. Then, we have used a power cable, hub, or power bank to connect the D1 Mini to the laptop and formed a Wi-Fi connection in order to send data to the cloud server. The circuit diagram illustrated in Figure 5, has been developed utilizing the hardware components mentioned earlier.

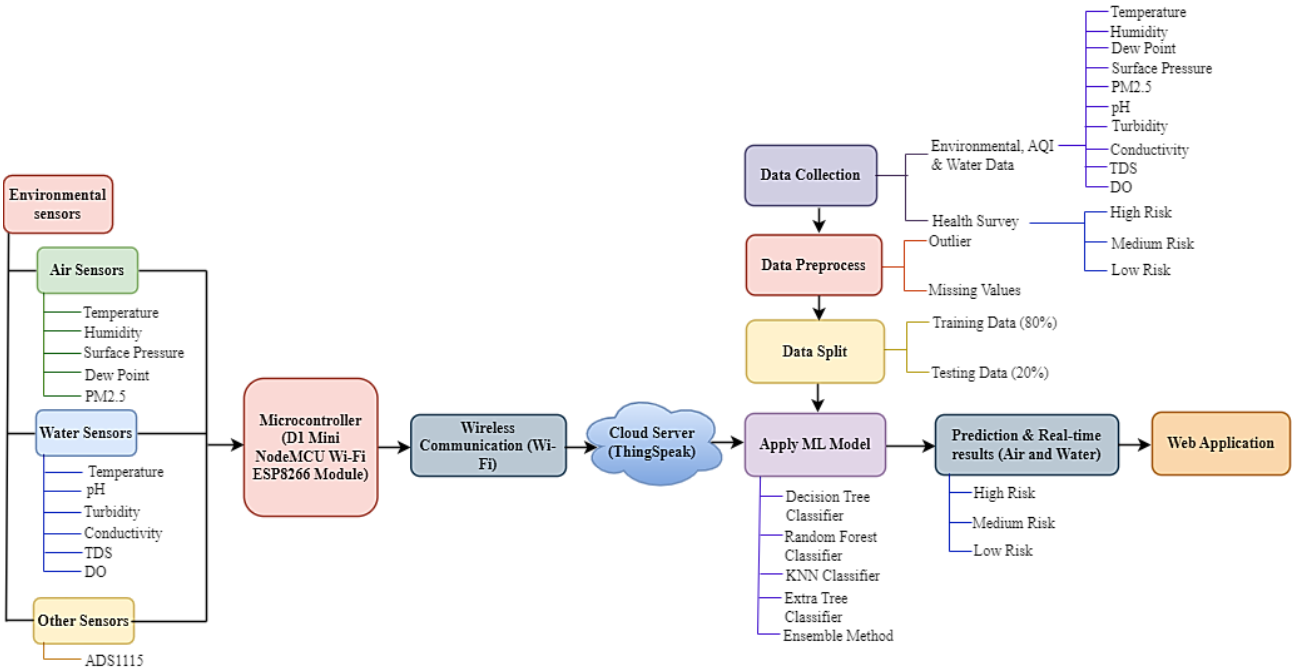


Fig. 4. Taxonomy

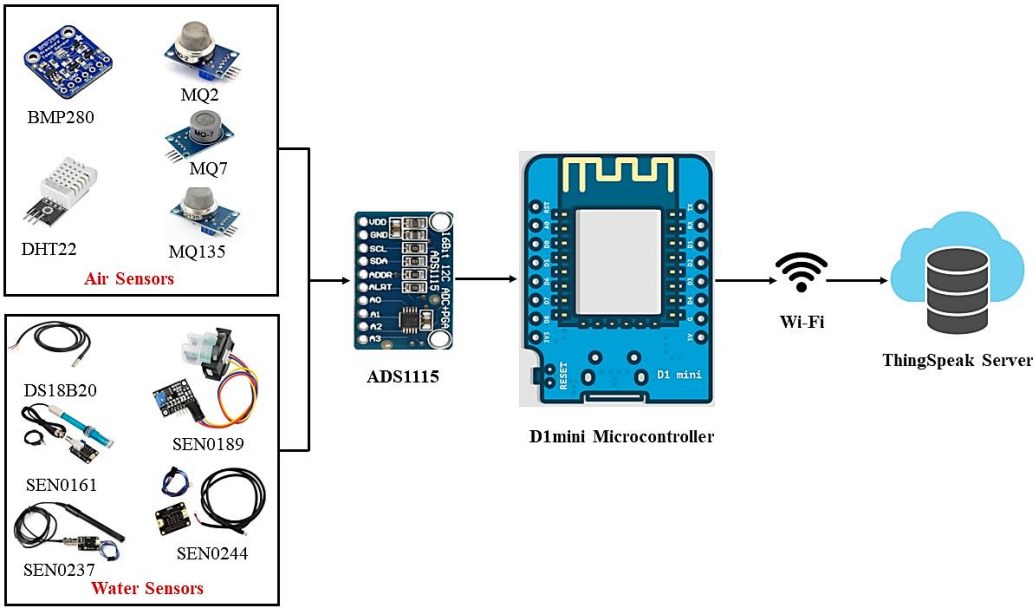


Fig. 5. Circuit diagram

3.2 Cloud Platform

In this stage, we implemented an IoT-driven system using the D1 Mini microcontroller board, which features a built-in ESP8266 Wi-Fi controller, to monitor environmental parameters in the shipbreaking industry at Sitakunda, Chattogram. Data from the sensors were transmitted to the cloud via ThingSpeak, enabling real-time storage and monitoring. For this purpose, we set up new channels with defined fields, allowing data retrieval through the channel's API key. We acknowledge that air and water quality may be independently impacted by other factors, such as emissions from adjacent industry or natural weather patterns. However, our main focus in this stage was to design and implement the IoT gateway system for efficient data collection.

3.3 Past Data Collection

We have assembled two distinct datasets for the environmental monitoring system: one for air and another for water. Initially, we have gathered 2373 historical air data points over a span of seven years, between January 2016 and June 2022. We have taken into account five aspects of air, temperature, humidity, dew point, and surface pressure from "NASA Power View" and AQI from "Dhaka US Console" and "Ministry of Environment, Forest and Climate Change". Additionally, we have obtained 2588 historical water dataset from the WHO (World Health Organization, encompassing water quality metrics such as temperature, pH, turbidity, conductivity, DO, and TDS.

i. Health survey: The most challenging aspect of our system lies in collecting health surveys. Many healthcare professionals were hesitant to engage with us due to confidentiality concerns surrounding patient data.

Moreover, access to hospital register books was strictly regulated and it requires government authorization, thus makes it challenging to gather relevant information. It was extremely difficult to speak with anyone as the staff are forbidden from disclosing information about these locations and steadfastly refusing to engage due to fear of losing their jobs.

In the Chattogram division, we have conducted visits to six distinct hospitals to compile our health survey dataset. We have discovered that the majority of patients at the Sitakunda Upazila Health Complex are adult males and suffer from lung cancer, breathing issue, and fever. In the winter, this rate is too high (almost 80%), in the summer, it is medium (almost 60%), and in the rainy season, it is low (almost 40%). Fever, respiratory issues, and cancer patients made up 30-40% of the population at the Anwara Upazila Health Complex, with children making up the majority of the patient population. Throughout the year, the rate fluctuated; it was highest in the winter, middle in the summer, and lowest during the rainy season. After that, we have found situations that were almost identical (20-30%) to other upazilas in Chattogram, such as Boalkhali Health Complex, Anwara Health Complex, Ramgarh Health Complex, and Patiya Health Complex. Additionally, our findings revealed that the affected rate at the Chattogram Maa-O-Shishu Hospital (CMOSH) ranges from 30-40% within the city limits, with a predominant number of patients being children.

Moreover, we have observed that the Sitakunda region exhibits the highest incidence of lung cancer cases. These observations have significantly influenced our survey planning process. Given that exposure to air pollution in densely populated urban areas can lead to various health complications such as chronic bronchitis, lung cancer, heart disease, asthma attacks, high fevers, and breathing difficulties, we have adjusted our survey methodology to account for these conditions. After gathering experimental data, some Machine Learning algorithms, like as Decision Tree, RF, KNN, Extra Tree Classifier, and Ensemble Method has been used to preprocess data, classify the model, and identify the optimal model. ML is a category of computer algorithm that describes a system's capacity to learn from training data relevant to a given problem in order to automate the process of creating analytical models and gradually enhance its performance [49].

3.4 Data Visualization

In the final stage of data visualization, we have focused on generating reports and visual representations that emphasize the outcomes of the preceding stages. The results of both real-time data and historical environmental data have displayed in our web interface throughout this phase, when we have applied different ML models to find the ones that provided the best accuracy for our system.

4. Results

For the Sitakunda shipbreaking industry, we have made an effort to monitor the environment in order to ensure that regulations are being obeyed, to control pollution, to protect worker's health, to uphold the industry's good name, and to support ongoing environmental practice improvement. The results of our experiment are divided into two categories: IoT and Data Analysis. Descriptions for both of these outcomes are provided below.

4.1 IoT Result

This section encompassed tasks related to hardware device configuration, setup, data storage, and retrieval. In our model, an ESP8266 microcontroller with a D1 Mini is used in our model which has IEEE 802.11 Wi-Fi integrated system. Due to the D1 Mini's single analog sensor, we are only able to incorporate one sensor on the device itself; the other sensors are included via ADS1115. Two distinct device connections are put into place: one for measuring air quality and the other one for evaluating water quality.

i. Hardware connection for measuring air quality: Temperature, humidity, and dew point are measured using DHT22, which is coupled to a breadboard, D1 Mini, and other devices. With the help of ADS1115, the BMP280 registered with 0X76 as its address, is the source of the surface pressure. Three separate gas sensors, namely MQ2, MQ7, and MQ135, are linked to D1 Mini and ADS1115 to measure PM2.5.

To get a real-time estimation of the air quality, we have used physical sensors to analyse the data and evaluate air characteristics. We can see from the global standard that the AQI (Air Quality Index) is calculated on a scale from 0-500. As AQI values increase, corresponding levels of air pollution and associated health risks have been determined. To enhance comprehension regarding the implications of local air quality on human health, the Air Quality Index (AQI) was developed. There are 3 distinct molecular indices in the AQI: PM10, PM2.5, and PM1.0. The PM2.5 is the air poison that causes the most damage. In order to make things clearer, the AQI is divided into 6 categories of health issues, such as 0-50 showing good, 51-100 indicating moderate, 101-150 indicating caution, 151-200 denoting unhealthy, 201-300 indicating very unhealthy, and more than 301 indicating hazardous [50].

ii. Hardware connection for measuring water quality: We have utilized DS18B20 sensor for temperature measurements, connected digitally to the D1 mini's digital pin. The SEN0189 sensor for turbidity and the SEN0161 sensor for pH are employed as analog sensors and interfaced with the D1 mini via ADS1115. Additionally, for TDS and conductivity readings, we have utilized the SEN0244 sensor, directly connected to the D1 mini. To measure the water oxygen levels, a dissolved oxygen meter is employed, with its sensor interfaced to the D1 mini through ADS1115.

After connecting all the sensors, we have developed the system. The experimental setup (both air and water quality monitoring) is depicted in Figure 6. After collecting sample water from various locations within the shipbreaking areas of Sitakunda, Chattogram, we have conducted real-time analysis of sensor data to assess water quality. Our observations indicate that the water quality falls within the standard limit. Table 3 show the comparison between water data and standard water limit of WHO.

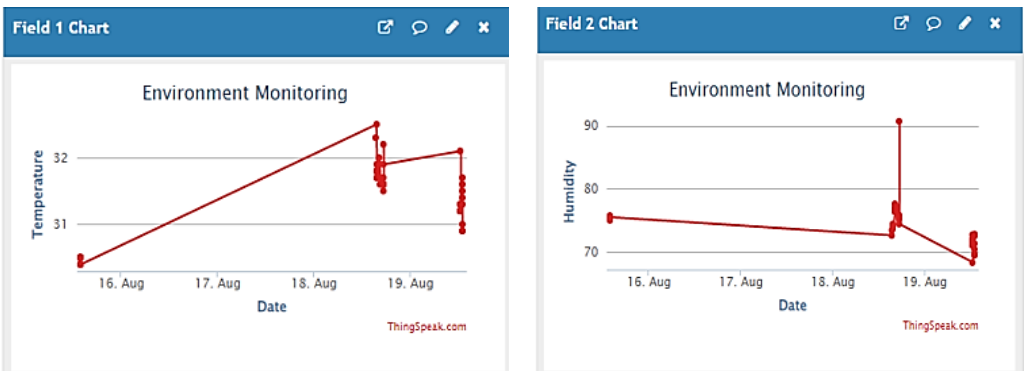
(a) (b)

Fig. 6. Experimental setup for environmental monitoring (a) Hardware setup for air (b) Hardware setup for water

Table 3
Comparison table of collected sample water data and standard water limit of WHO [51]

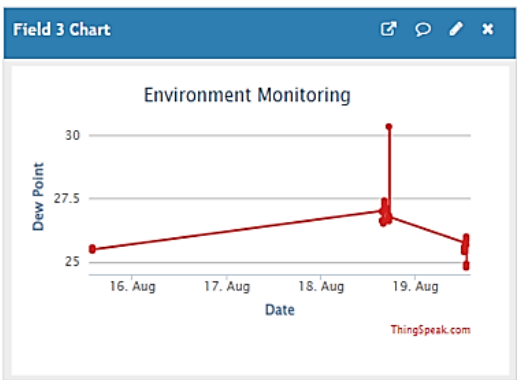
Parameters	Sample data	Standard limits from WHO
Temperature	30.33°C	30°C
pH	7.88	6.50-8.50
Turbidity	5.92 NTU	1-5 NTU
Conductivity	1278 µc/cm	1200 µc/cm
DO	7.50 mg/l	5-8 mg/l
TDS	3520 mg/l	2100 mg/l

Furthermore, the pH value of the water provides insights into its alkalinity. However, concerning water turbidity, which ideally ranges between 1 and 5 NTU, our sample water recorded a turbidity of 5.92 NTU, rendering it unsuitable for any use. Our research has exposed alarmingly high levels of pollution in the area, as evidenced by elevated levels of EC and TDS exceeding safe limits. Despite this, the absence of industrial wastewater discharge into the sea has resulted in Dissolved Oxygen values remaining within permissible limits. We have used IoT sensors to gather real-time data from specified areas, and we have taken our sensors into different environments to see how much data we could get. After connecting, we transferred the collected data to the "ThingSpeak" cloud server. With the API key, users can view and download the data streaming over the ThingSpeak server. Here, anyone can access all of the prior data as well as the recent data. From the ThingSpeak server, we have found all the values of air parameters such as PM2.5, dew point, temperature, surface pressure, and humidity. Figures 7 and 8, illustrates the graphical view to represent the values of all air parameters for our study area.

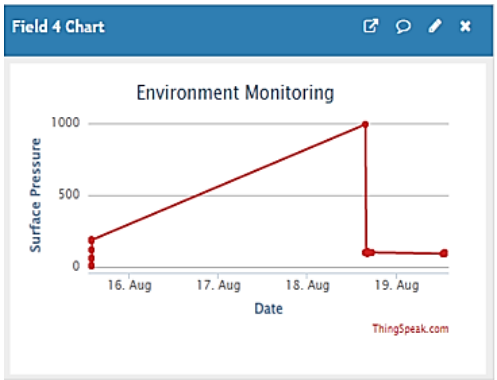


(a) (b)

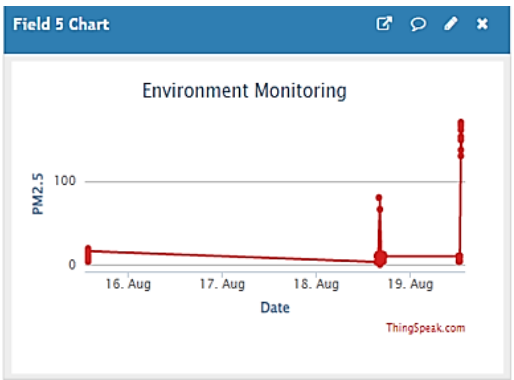
Fig. 7. Real-time data representation of air in ThingSpeak (a) Temperature (b) Humidity



(a)



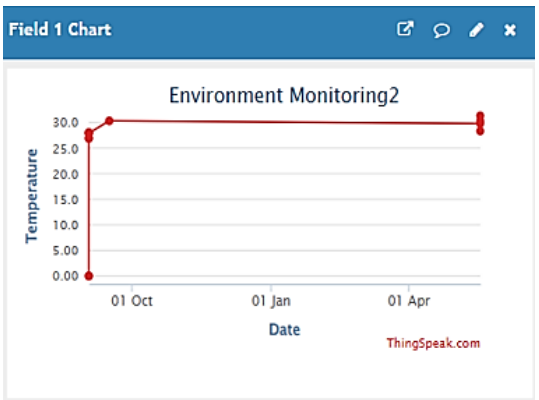
(b)



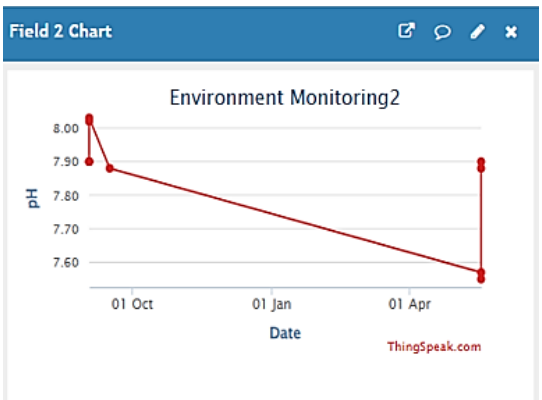
(c)

Fig. 8. Real-time data representation of air in ThingSpeak (a) Dew point (b) Surface pressure (c) PM2.5

From Figures 9 and 10, we have extracted all values of water parameters, including pH, turbidity, conductivity, temperature, TDS, and DO. These values are presented graphically to depict the water parameter data for our study area. We intend to utilize this data for application to the ML model and visualize the results on our web interface.



(a)



(b)

Fig. 9. Real-time data representation of water in ThingSpeak (a) Temperature (b) pH

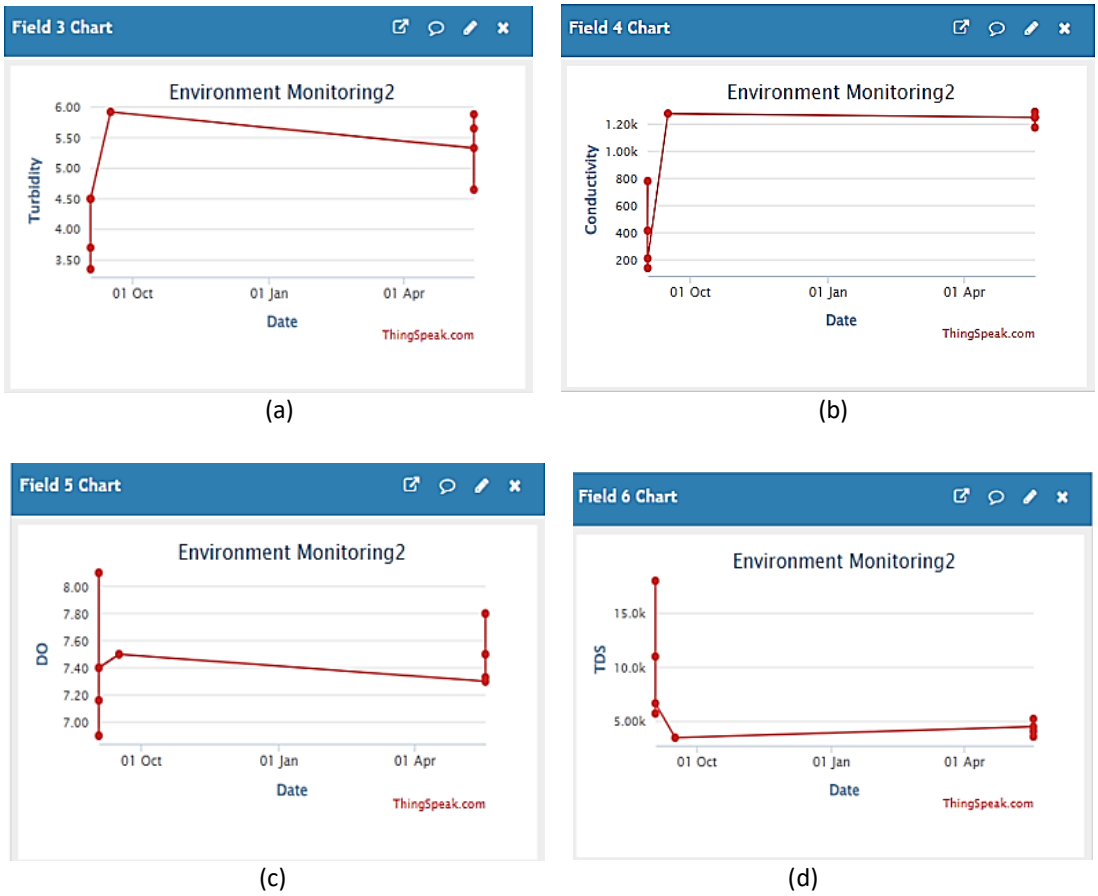


Fig. 10. Real-time Data Representation of Water in ThingSpeak (a) Turbidity (b) Conductivity (c) DO (d) TDS

4.2 Past Data Analysis

As part of our research, we gathered primary and secondary data, with the primary dataset representing a significant challenge and contribution to this system. Six different hospitals were visited in order to gather primary data. During these visits, patient registration books were reviewed to analysis the infection rates, and discussion with doctors were conducted to learn more about patient trends. In order to find trends and classify infection levels, the patient-affected rates from the six hospitals were compared. To guarantee consistency, it is essential to provide information about the analysis of these records and whether a methodical approach was taken. Doctor consultations and information from other sources, such as the US Consulate Air Quality Levels [52], were used to classify infection rates into high, medium, and low categories. The World Health Organization (WHO), the US Consulate in Dhaka, NASA Power View, and the Ministry of Environment Forests in Bangladesh were among the reliable national and international sources of secondary data. These databases gave more background information on environmental factors, specifically, air pollution levels that affect patient health.

A summary of the hospital survey results is included in Table 4 however further information about the study's methodology would increase the validity of the results. To reduce bias and preserve consistency, hospitals must establish explicit policies for data collection, validation, and aggregation. During the survey, we have discovered that the patient rate is excessive in the shipbreaking industry region; the majority of those afflicted are adult males, as opposed to the non-industrial area, where the majority of patients are children, and this is caused by environmental pollution. Since our

research field is in the Sitakunda region, we have used hospital data from the Sitakunda Health Complex for the experiment and categorized our dataset into season based.

Table 4
Hospital survey

Serial no.	Name of hospital	Patient infected rate	Maximal Patient category	Industrial region	Status
1	Sitakunda Upazila Health Complex	60-70%	Adult male	Yes	High risk
2	Anwara Upazila Health Complex	30-40%	Child	Yes	Medium risk
3	Boalkhali Upazila Health Complex	20-30%	Average	No	Low risk
4	Patiya Upazila Health Complex	20-30%	Average	No	Low risk
5	Ramgarh Upazila Health Complex	20-30%	Average	No	Low risk
6	Chattogram Maa-O-Shishu Hospital	30-40%	Child	No	Medium risk

Additionally, we have gathered historical data for both the air and water from different authentic sites. We have surveyed the risk factor along with all input features to analyze environmental pollution and output features to observe the health status of workers. The overall sample input dataset, both air and water, for our study is depicted in Figure 11.

	Date	Temperature	Humidity	Dew Point	Surface Presure	PM2.5	Risk Factor
0	1/1/2016	19.52	74.12	14.58	101.50	176.0	High
1	1/2/2016	19.80	71.12	14.19	101.40	179.0	High
2	1/3/2016	19.48	70.81	13.73	101.29	181.0	High
3	1/4/2016	19.04	72.50	13.77	101.33	174.0	High
4	1/5/2016	18.82	73.75	13.77	101.29	178.0	High
...	...	...	...	...	...	...	...
2368	6/26/2022	28.23	84.94	25.37	100.08	92.0	Medium
2369	6/27/2022	27.94	87.75	25.68	100.17	73.0	Medium
2370	6/28/2022	27.94	84.44	25.01	100.09	74.0	Medium
2371	6/29/2022	28.38	84.69	25.48	99.93	98.0	Medium
2372	6/30/2022	28.00	88.19	25.83	99.89	117.0	Medium

2373 rows × 7 columns

(a)

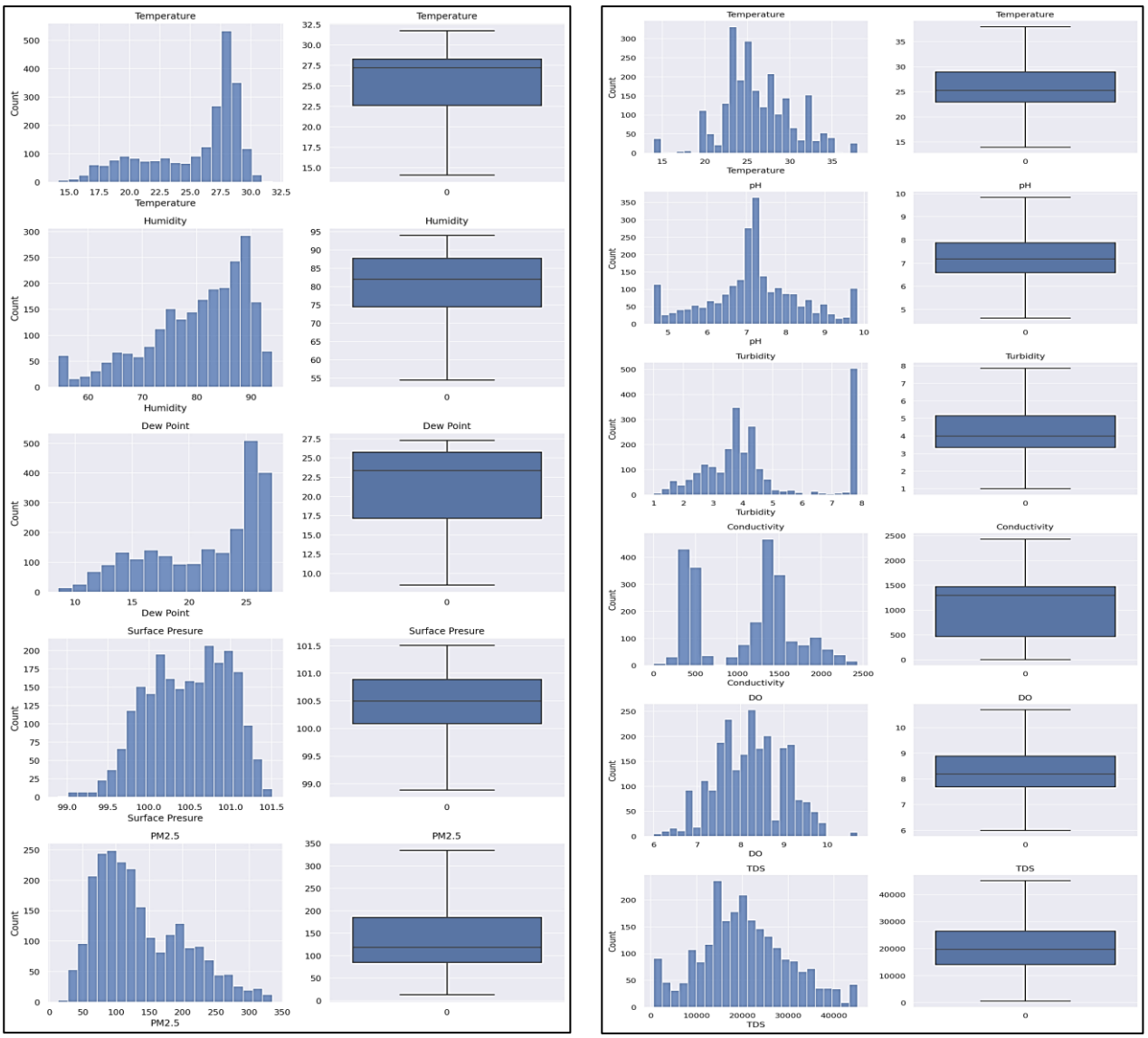
	Temperature	pH	Turbidity	Conductivity	DO	TDS	Risk Factor
0	23.1	7.25	2.50	1182.60	7.8	1940.75	Medium
1	22.3	7.11	2.10	1016.90	6.2	9909.54	Medium
2	30.5	7.03	4.90	988.22	8.3	2018.42	Medium
3	22.9	7.38	3.20	1195.70	6.8	7978.99	Medium
4	25.3	7.45	2.61	1236.28	7.1	8748.69	Medium
...	...	...	...	...	...	...	...
2583	23.0	5.80	4.63	366.80	6.9	27193.32	Low
2584	24.0	8.90	13.90	1485.42	7.6	356975.34	High
2585	33.0	7.21	3.78	1471.05	7.7	28338.66	Medium
2586	24.0	7.31	13.60	1419.51	9.8	33279.37	High
2587	29.3	7.15	4.03	1355.18	7.4	19356.92	Medium

2588 rows × 7 columns

(b)

Fig. 11. Past data (a) Air (b) Water

After gathering these datasets, we conducted preprocessing to refine the data and estimate statistical values for all variables. To facilitate feature selection, we have utilized the conversion method for our target values, transforming categorical values into numerical ones. The histogram and boxplot for both air and water quality monitoring are portrayed in Figure 12. A histogram represents a visual depiction of a dataset's distribution. Boxplots are useful for visualizing numerical data distributions, especially when comparing values across different groups.

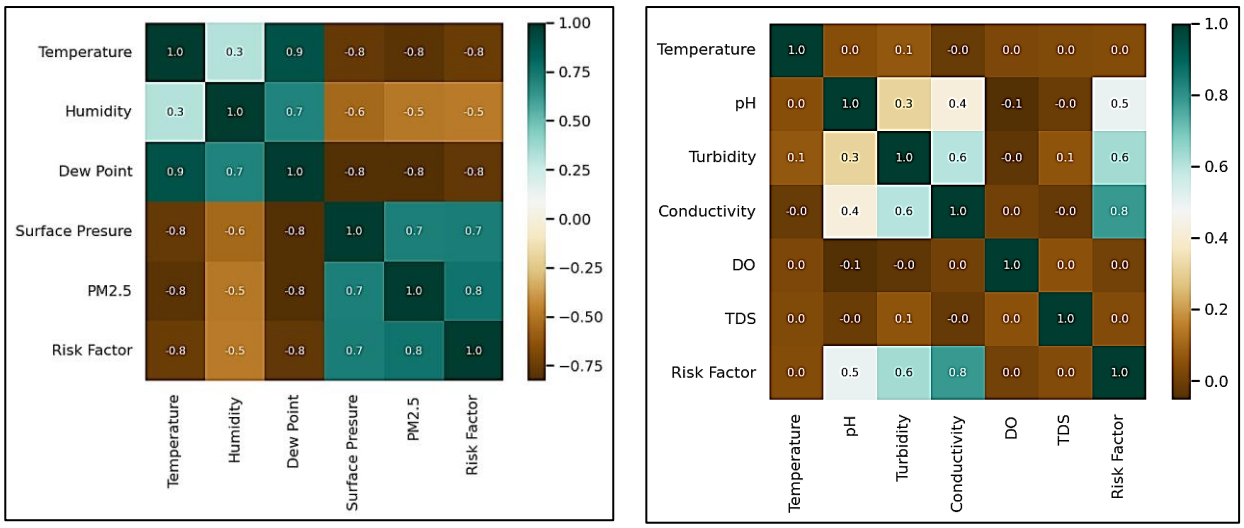


(a) (b)

Fig. 12. Histogram and boxplot (a) Air parameters (b) Water parameters

Our research analysed the correlation between environmental parameters for air and water quality and their impact on workers' health using heatmaps and advanced statistical tools. Among air parameters, PM2.5 showed the strongest correlation with health risk factor, while conductivity emerged as the most significant water parameter linked to risk factor, as illustrated in Figure 13. The analysis highlights the pollution levels and associated health issues, particularly in industrial areas where the impacts are most pronounced.

We have partitioned our dataset into two subsets: one for model development (i.e., training) and the another one for model validation (i.e., testing). This division involves allocating 20% of the data for testing purposes, while the remaining 80% is utilized for training the model. This approach allows us to construct the prediction models using the training dataset and subsequently evaluate their performance using the testing dataset. Then, in order to identify the greatest accuracy, we have employed various ML algorithms, including the Ensemble Method, Extra Tree Classifier, Decision Tree Classifier, KNN (K-Nearest Neighbour), and Random Forest Classifier. The accuracy of all algorithms is shown in Figure 14.



(a) (b)

Fig. 13. Correlation between all features (a) Air (b) Water

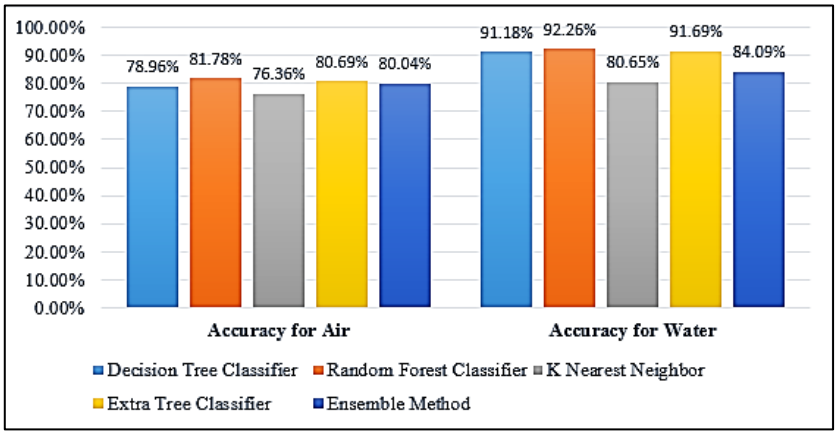


Fig. 14. Results of our ML model

Our dataset has demonstrated the good accuracy rate after implementation, enabling us to forecast the desired outcomes. The Random Forest classifier model has the highest accuracy of all of these, e.g., scoring 81.78% for air and 92.26% for water. For processing and analysis, we have previously stored real-time data on the ThingSpeak server. It is then transmitted to the Google Colab using an API key, and finally fitted into the Random Forest model as it has the highest accuracy. After running the code, the results for both air and water fell into category "1", which means "Medium Risk Factor", because our system was tested during the summer, as can be seen in Figure 15. Our health survey has acknowledged that the health risk factor is moderate during the sunny season. As a result, the results of our sample data collection and historical environmental data are the same.

```
[1]
---------------------------------------------------------------------------
KeyboardInterrupt                         Traceback (most recent call last)
```

Fig. 15. Final result of IoT

As a result, we have shown how to develop a cost-effective IoT method for monitoring environmental quality while having access to worker health data. Remote technology not only costs less money and uses less energy than traditional connection methods, but it also takes up less room, can be placed virtually anywhere, and provides greater functional flexibility.

4.3 Interface

On the website dashboard, we have integrated a patient survey alongside a graph illustrating the air quality index. Additionally, in the IoT history data section, we have presented all our historical information that was previously uploaded to the cloud server "ThingSpeak". For the most recent IoT data, we have retrieved both air and water data from the ThingSpeak server, presenting it in a tabular format on the IoT last data section, along with expected outcomes. Figure 16, demonstrates our system's entire web interface. After conducting a thorough comparison between the two findings, we can confidently assert the effectiveness of our system. The results obtained from our dataset derived from field surveys closely align with the real-time data, validating the robustness and reliability of our system.

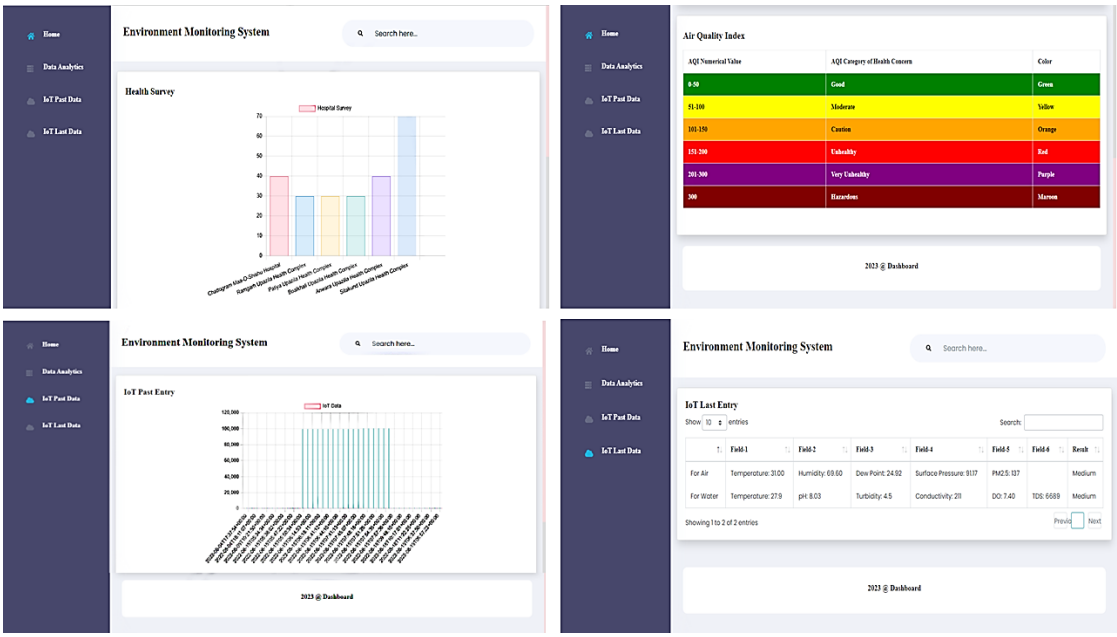


Fig. 16. Web interface

5. Discussion

In order to evaluate the effects of environmental pollution on public health, we have created a health observation environment monitoring system utilizing IoT and machine learning techniques. Obtaining trustworthy industrial sensors to track the quality of the air and water and gather health data from various sources was the main obstacle. Despite these challenges, we were able to collect health (such as patient infection rates) and environmental (such as air and water pollution levels) data to assess the system's performance. We used statistical studies and machine learning approaches to create a strong link between environmental parameters and health outcomes. For instance, in order to account for confounding variables such as seasonal fluctuations, we employed multiple regression models to measure the effect of air quality indicators on respiratory illness rates. Although causality needs to be confirmed, the data show a substantial correlation between environmental contamination and negative health effects.

Despite some negative impacts, the shipbreaking industry cannot be stopped for the sake of nation's financial interest. Rather, a long-term strategy for reducing the impact of shipbreaking operations in coastal areas ought to be put into place. To prevent issues, the shipbreaking business in Bangladesh needs to pay greater attention. We attempt to give direction to figuring out how to

decrease the environmental effect, contribute to building a green city, and improve health and security conventions, which are stated below:

i. Manage the task and get it back in a different season, as the winter season is at that point high-risk.
ii. Prior to breaking the ship, an effective format should be established.
iii. With new materials, a shipbreaking area should be integrated.
iv. For the most significant reduction in contamination, a persuasive management plan for environmental effects should be given.
v. There is a need to develop efficient training programs for workers.
vi. It is possible to provide goggles, hoods, gloves, safety shoes, and medical care for laborers while they are working to address security and health concerns.
vii. The review's findings can be used by managers of shipbreaking operations, government agencies, and non-governmental organizations to promote a healthy work environment and ensure the health of workers.

6. Conclusions

Chattogram is often known as Bangladesh's commercial capital, with its different modern districts and seaport. These days, the shipbreaking industry is among the most productive and quickly expanding businesses, not only in Bangladesh but also worldwide. With a focus on the shipbreaking industry, several industries in Bangladesh completed a material stream assessment of steel and have already obtained one of the best economic circumstances in the country [53]. Unfortunately, from a socioeconomic perspective, this company has certain challenges. When reviewing many assessments, the previous experts from Bangladesh paid relatively little attention to ship reuse methods and their effects on the shoreline zone [54]. There were significant amounts of both organic and inorganic contaminants in shipbreaking yards. Important synthetic collections of naturally occurring contaminants, primarily polycyclic sweet-smelling hydrocarbons, polychlorinated biphenyls, and organochlorine insecticides, are released by shipbreaking businesses [55]. Bangladesh's coastal ecosystem has suffered as a result of the growth of the shipbreaking business in recent years [56]. Therefore, we have developed an IoT-based technique to analyze environmental quality by taking into account some environmental parameters. The real-time data received by the ThingSpeak server is a cloud-based, centralized database system that is free to use.

Again, we have gathered various historical data types, including data on the air and water, to analyze environmental pollution in the shipbreaking industrial region. The primary contribution of our research is the collection of environmental and health data from field surveys conducted at several hospitals in Chittagong. We have performed some statistics on our historical data to examine the distribution of previous data in order to analyze these data and extract features from them. In order to evaluate the actual health situation of the shipbreaking industrial area, a health survey is done to determine the risk factors for workers' health based on seasonal outcomes. Consequently, we have implemented a variety of ML techniques to analyze the data and build the model. Every technique works as intended, although the accuracy of the Random Forest Classifier is more, coming in at almost 82% for air and 92% for water. Moreover, we have compared historical data with the most recent real-time data. The findings of the overall comparison are displayed on our web interface. According to our research, people who live in the shipbreaking industrial area are more likely to be affected than people who live in non-industrial areas, and during the winter season, the rate becomes too high.

In the future, we plan to collect more patient data to improve the accuracy of the model. Moreover, we plan to look for toxic metal subcategories e.g., As, Cd, Cr, Pb, etc., in the shipbreaking sector. Although our system is primarily designed for the shipbreaking industry, we eventually aim to expand its application to other industrial sectors as well.

Acknowledgement
This research is partially funded by the Institute for Advanced Research Publication Grant of United International University Publication Grant No. IAR-2024-Pub-078.

References

[1] Hasan, Asma Binta, Sohail Kabir, AHM Selim Reza, Mohammad Nazim Zaman, Mohammad Aminul Ahsan, Mohammad Ahedul Akbor, and Mohammad Mamunur Rashid. "Trace metals pollution in seawater and groundwater in the ship breaking area of Sitakund Upazilla, Chittagong, Bangladesh." *Marine Pollution Bulletin* 71, no. 1-2 (2013): 317-324. https://doi.org/10.1016/j.marpolbul.2013.01.028

[2] Lin, Lin, Kuishuang Feng, Peng Wang, Zheng Wan, Xianghui Kong, and Jiashuo Li. "Hazardous waste from the global shipbreaking industry: Historical inventory and future pathways." *Global Environmental Change* 76 (2022): 102581. https://doi.org/10.1016/j.gloenvcha.2022.102581

[3] Rizvi, Md Jahir, Mohammad Rafiqul Islam, Olalekan Adekola, and Oguguah Ngozi Margaret. "A sustainable shipbreaking approach for cleaner environment and better wellbeing." *Journal of Cleaner Production* 270 (2020): 122522. https://doi.org/10.1016/j.jclepro.2020.122522

[4] Yan, Hongsheng, Liyang Wu, and Jianxing Yu. "The environmental impact analysis of hazardous materials and the development of green technology in the shipbreaking process." *Ocean Engineering* 161 (2018): 187-194. https://doi.org/10.1016/j.oceaneng.2018.03.024

[5] Sujauddin, Mohammad, Ryu Koide, Takahiro Komatsu, Mohammad Mosharraf Hossain, Chiharu Tokoro, and Shinsuke Murakami. "Characterization of ship breaking industry in Bangladesh." *Journal of Material Cycles and Waste Management* 17 (2015): 72-83. https://doi.org/10.1007/s10163-013-0224-8

[6] Hossain, Khandakar Akhter. "Overview of ship recycling industry of Bangladesh." *Journal of Environmental & Analytical Toxicology* 5, no. 5 (2015): 1-7. https://doi.org/10.4172/2161-0525.1000312

[7] Alam, Shawkat, and Abdullah Faruque. "Legal regulation of the shipbreaking industry in Bangladesh: The international regulatory framework and domestic implementation challenges." *Marine Policy* 47 (2014): 46-56. https://doi.org/10.1016/j.marpol.2014.01.022

[8] Alam, Iftakharul, Suman Barua, Kento Ishii, Satoshi Mizutani, Mohammad Mosharraf Hossain, Ismail MM Rahman, and Hiroshi Hasegawa. "Assessment of health risks associated with potentially toxic element contamination of soil by end-of-life ship dismantling in Bangladesh." *Environmental Science and Pollution Research* 26 (2019): 24162-24175. https://doi.org/10.1007/s11356-019-05608-x

[9] Afrin, Rezuana, Sydur Rahman Gazi, Abu Abdulla Al-Mamun, Md Hossain Khan, Muliadi Muliadi, and Shamim Al Mamun. "Assessment of water quality in surface water of shipbreaking sites at Kumira Ghat, Sitakunda, Bangladesh." *Techno: Jurnal Penelitian* 10, no. 1 (2021): 85-93. https://doi.org/10.33387/tjp.v10i1.2915

[10] Rabbi, Hasan Ruhan, and Aevelina Rahman. "Ship breaking and recycling industry of Bangladesh; issues and challenges." *Procedia Engineering* 194 (2017): 254-259. https://doi.org/10.1016/j.proeng.2017.08.143

[11] Chowdhury, Mohammad Mahfuzul Islam, Khatijah Binti Othman, Mohammad Aktaruzzaman Khan, and Ibrahim Fahad Sulaiman. "Occupational training and health-safety of bangladesh ship-breaking industry workers: An evaluative study." In *GARA E-Conference* 42. (2021): 42-54.

[12] Ullo, Silvia Liberata, and Ganesh Ram Sinha. "Advances in smart environment monitoring systems using IoT and sensors." *Sensors* 20, no. 11 (2020): 3113. https://doi.org/10.3390/s20113113

[13] Chatzinikolaou, Stefanos D., and Nikolaos P. Ventikos. "Critical analysis of air emissions from ships: Lifecycle thinking and results." In *Green Transportation Logistics: The Quest for Win-Win Solutions*, p. 387-412. Cham: Springer International Publishing, 2016. https://doi.org/10.1007/978-3-319-17175-3_11

[14] Anenberg, Susan C., Anna Belova, Jørgen Brandt, Neal Fann, Sue Greco, Sarath Guttikunda, Marie-Eve Heroux, Fintan Hurley, Michal Krzyzanowski, Sylvia Medina, Brian Miller, Kiran Pandey, Joachim Roos, and Rita Van Dingenen. "Survey of ambient air pollution health risk assessment tools." *Risk Analysis* 36, no. 9 (2016): 1718-1736. https://doi.org/10.1111/risa.12540

[15] Odabasi, Mustafa, Doganay Tolunay, Melik Kara, Ezgi Ozgunerge Falay, Gizem Tuna, Hasan Altiok, Yetkin Dumanoglu, Abdurrahman Bayram, and Tolga Elbir. "Investigation of spatial and historical variations of air pollution

around an industrial region using trace and macro elements in tree components." *Science of the Total Environment* 550 (2016): 1010-1021. https://doi.org/10.1016/j.scitotenv.2016.01.197

[16] Islam, M. Nazrul, M. Jamaluddin Ahmed, M. Akram Hossain, and S. Siraj. "Physicochemical assessment of water pollutants due to the ship breaking activities and its impact on the coastal environment of Chittagong, Bangladesh." *European Chemical Bulletin* 2, no. 12 (2013): 1053-1059.

[17] Kalia, Puneet, and Mamtaz Alam Ansari. "IOT based air quality and particulate matter concentration monitoring system." *Materials Today: Proceedings* 32 (2020): 468-475. https://doi.org/10.1016/j.matpr.2020.02.179

[18] Chen, Xiaohu, Michelle Leishman, Darren Bagnall, and Noushin Nasiri. "Nanostructured gas sensors: From air quality and environmental monitoring to healthcare and medical applications." *Nanomaterials* 11, no. 8 (2021): 1927. https://doi.org/10.3390/nano11081927

[19] Zhang, Dan, and Simon S. Woo. "Real time localized air quality monitoring and prediction through mobile and fixed IoT sensing network." *IEEE* 8 (2020): 89584-89594. https://doi.org/10.1109/ACCESS.2020.2993547

[20] Saini, Jagriti, Maitreyee Dutta, and Gonçalo Marques. "Indoor air quality monitoring systems based on internet of things: A systematic review." *International Journal of Environmental Research and Public Health* 17, no. 14 (2020): 4942. https://doi.org/10.3390/ijerph17144942

[21] Marques, Goncalo, Jagriti Saini, Maitreyee Dutta, Pradeep Kumar Singh, and Wei-Chiang Hong. "Indoor air quality monitoring systems for enhanced living environments: A review toward sustainable smart cities." Sustainability 12, no. 10 (2020): 4024. https://doi.org/10.3390/su12104024

[22] Saini, Jagriti, Maitreyee Dutta, and Goncalo Marques. "Sensors for indoor air quality monitoring and assessment through Internet of Things: a systematic review." Environmental Monitoring and Assessment 193, no. 2 (2021): 66. https://doi.org/10.1007/s10661-020-08781-6

[23] Jo, JunHo, ByungWan Jo, JungHoon Kim, SungJun Kim, and WoonYong Han. "Development of an IoT-based indoor air quality monitoring platform." *Journal of Sensors* 2020, no. 1 (2020): 8749764. https://doi.org/10.1155/2020/8749764

[24] Benammar, Mohieddine, Abderrazak Abdaoui, Sabbir HM Ahmad, Farid Touati, and Abdullah Kadri. "A modular IoT platform for real-time indoor air quality monitoring." *Sensors* 18, no. 2 (2018): 581. https://doi.org/10.3390/s18020581

[25] Represa, Natacha Soledad, Alfonso Fernández-Sarría, Andrés Porta, and Jesús Palomar-Vázquez. "Data mining paradigm in the study of air quality." *Environmental Processes* 7, no. 1 (2020): 1-21. https://doi.org/10.1007/s40710-019-00407-5

[26] Liu, Huixiang, Qing Li, Dongbing Yu, and Yu Gu. "Air quality index and air pollutant concentration prediction based on machine learning algorithms." Applied sciences 9, no. 19 (2019): 4069. https://doi.org/10.3390/app9194069

[27] Zimmerman, Naomi, Albert A. Presto, Sriniwasa PN Kumar, Jason Gu, Aliaksei Hauryliuk, Ellis S. Robinson, Allen L. Robinson, and Ramachandran Subramanian. "A machine learning calibration model using random forests to improve sensor performance for lower-cost air quality monitoring." *Atmospheric Measurement Techniques* 11, no. 1 (2018): 291-313. https://doi.org/10.5194/amt-11-291-2018

[28] Janarthanan, R., P. Partheeban, K. Somasundaram, and P. Navin Elamparithi. "A deep learning approach for prediction of air quality index in a metropolitan city." *Sustainable Cities and Society* 67 (2021): 102720. https://doi.org/10.1016/j.scs.2021.102720

[29] Basha, Shaik, Premsingh Mansingh Gaur, Ravikumar Bhagwan Thorat, Rohitkumar Harikrishna Trivedi, Sandip Kumar Mukhopadhyay, Nisha Anand, Shalin Hemantbhai Desai, Kalpana Haresh Mody, and Bhavnath Jha. "Heavy metal content of suspended particulate matter at world's largest ship-breaking yard, Alang-Sosiya, India." *Water, Air, and Soil Pollution* 178 (2007): 373-384. https://doi.org/10.1007/s11270-006-9205-z

[30] Yang, Chao-Tung, Chi-Jui Liao, Jung-Chun Liu, Walter Den, Ying-Chyi Chou, and Jaw-Ji Tsai. "Construction and application of an intelligent air quality monitoring system for healthcare environment." *Journal of Medical Systems* 38 (2014): 1-10. https://doi.org/10.1007/s10916-014-0015-3

[31] Barthwal, Vaishnavi, Suresh Jain, Ayushi Babuta, Chubamenla Jamir, Arun Kumar Sharma, and Anant Mohan. "Health impact assessment of Delhi's outdoor workers exposed to air pollution and extreme weather events: an integrated epidemiology approach." *Environmental Science and Pollution Research* 29, no. 29 (2022): 44746-44758. https://doi.org/10.1007/s11356-022-18886-9

[32] Islam, M. Shahidul, Kei Nakagawa, M. Abdullah-Al-Mamun, Abu Shamim Khan, Md Abdul Goni, and Ronny Berndtsson. "Spatial distribution and source identification of water quality parameters of an industrial seaport riverbank area in Bangladesh." *Water* 14, no. 9 (2022): 1356. https://doi.org/10.3390/w14091356

[33] Ali, Mir Mohammad, Md Saiful Islam, Abu Reza Md Towfiqul Islam, Md Simul Bhuyan, AS Shafiuddin Ahmed, Md Zillur Rahman, and Md Mostafizur Rahman. "Toxic metal pollution and ecological risk assessment in water and sediment at ship breaking sites in the Bay of Bengal Coast, Bangladesh." *Marine Pollution Bulletin* 175 (2022): 113274. https://doi.org/10.1016/j.marpolbul.2021.113274

[34] Showva, Nazmir-Nur, and Adib Bin Rashid. "Water pollution and its adverse effect on biodiversity in ship breaking area of Bhatiary, Chattogram." *Applied Ecology and Environmental Sciences* 7, no. 3 (2019): 96-100.

[35] Hossain, Md Shakhaoat, Abu Naieum Muhammad Fakhruddin, Muhammed Alamgir Zaman Chowdhury, and Siew Hua Gan. "Impact of ship-breaking activities on the coastal environment of Bangladesh and a management system for its sustainability." *Environmental Science & Policy* 60 (2016): 84-94. https://doi.org/10.1016/j.envsci.2016.03.005

[36] Mitra, Nandita, Shihab Ahmad Shahriar, Nurunnaher Lovely, Md Shohel Khan, Aweng Eh Rak, S. P. Kar, Md Abdul Khaleque, Mohamad Faiz Mohd Amin, Imrul Kayes, and Mohammed Abdus Salam. "Assessing energy-based CO_2 emission and workers' health risks at the shipbreaking industries in Bangladesh." *Environments* 7, no. 5 (2020): 35. https://doi.org/10.3390/environments7050035

[37] Ahamad, Abu Faisal, Petra Schneider, Romaza Khanum, Mohammad Mojibul Hoque Mozumder, Sabrina Jannat Mitu, and Md Mostafa Shamsuzzaman. "Livelihood assessment and occupational health hazard of the ship-breaking industry workers at Chattogram, Bangladesh." *Journal of Marine Science and Engineering* 9, no. 7 (2021): 718. https://doi.org/10.3390/jmse9070718

[38] Wu, Wei-Te, Yu-Jen Lin, Huei-Sheng Shiue, Chung-Yi Li, Perng-Jy Tsai, Chun-Yuh Yang, Saou-Hsing Liou, and Trong-Neng Wu. "Cancer incidence of Taiwanese shipbreaking workers who have been potentially exposed to asbestos." *Environmental Research* 132 (2014): 370-378. https://doi.org/10.1016/j.envres.2014.04.026

[39] Xu, Xiaoya, Miao Zhong, Jiafu Wan, Minglun Yi, and Tiancheng Gao. "Health monitoring and management for manufacturing workers in adverse working conditions." *Journal of Medical Systems* 40 (2016): 1-7. https://doi.org/10.1007/s10916-016-0584-4

[40] Yi, Wei Ying, Kin Ming Lo, Terrence Mak, Kwong Sak Leung, Yee Leung, and Mei Ling Meng. "A survey of wireless sensor network based air pollution monitoring systems." *Sensors* 15, no. 12 (2015): 31392-31427. https://doi.org/10.3390/s151229859

[41] Simbeye, Daudi S. "Industrial air pollution monitoring system based on wireless sensor networks." *Kournal of Information Science and Computing Technologies* 6, no. 2 (2017): 612-624.

[42] García, Laura, Antonio-Javier Garcia-Sanchez, Rafael Asorey-Cacheda, Joan Garcia-Haro, and Claudia-Liliana Zúñiga-Cañón. "Smart air quality monitoring IoT-based infrastructure for industrial environments." *Sensors* 22, no. 23 (2022): 9221. https://doi.org/10.3390/s22239221

[43] Hasan, Asma Binta, AHM Selim Reza, Md Abu Bakar Siddique, Md Ahedul Akbor, Aynun Nahar, Mehedi Hasan, Mohammad Nazim Zaman, Md Irfanul Hasan, and Md Moniruzzaman. "Spatial distribution, water quality, human health risk assessment, and origin of heavy metals in groundwater and seawater around the ship-breaking area of Bangladesh." *Environmental Science and Pollution Research* 30, no. 6 (2023): 16210-16235. https://doi.org/10.1007/s11356-022-23282-4

[44] Zakir, H. M., Shaila Sharmin, Arifa Akter, and Md Shahinur Rahman. "Assessment of health risk of heavy metals and water quality indices for irrigation and drinking suitability of waters: a case study of Jamalpur Sadar area, Bangladesh." *Environmental Advances* 2 (2020): 100005. https://doi.org/10.1016/j.envadv.2020.100005

[45] Singh, Rajesh, Mohammed Baz, Anita Gehlot, Mamoon Rashid, Manpreet Khurana, Shaik Vaseem Akram, Sultan S. Alshamrani, and Ahmed Saeed AlGhamdi. "Water quality monitoring and management of building water tank using industrial internet of things." *Sustainability* 13, no. 15 (2021): 8452. https://doi.org/10.3390/su13158452

[46] Chowdury, Mohammad Salah Uddin, Talha Bin Emran, Subhasish Ghosh, Abhijit Pathak, Mohd Manjur Alam, Nurul Absar, Karl Andersson, and Mohammad Shahadat Hossain. "IoT based real-time river water quality monitoring system." *Procedia Computer Science* 155 (2019): 161-168. https://doi.org/10.1016/j.procs.2019.08.025

[47] Ali, Tasnuva, Azni Haslizan Ab Halim, and Nur Hafiza Zakaria. "3D Lightweight Cryptosystem Design for IoT Applications Based on Composite S-Box." *International Journal of Computational Thinking and Data Science* 3, no. 1 (2024): 40-54. https://doi.org/10.37934/ctds.3.1.4054

[48] Shiddike, Jasrin, Afsana Ahmed, Mohammad Farshid, and A. K. M. Muzahidul Islam. "IoT and Satellite Image Driven Water Quality Monitoring and Assessment Method in Coastal Region." In *International Conference on Engineering, Applied Sciences and System Modeling*, p. 29-42. Singapore: Springer Nature Singapore, 2017. https://doi.org/10.1007/978-981-99-8438-1_3

[49] Aburashed, Laila, Marah AL Amoush, and Wardeh Alrefai. "SQL Injection Attack Detection using Machine Learning Algorithms." *Semarak International Journal of Machine Learning* 2, no. 1 (2024): 1-12. https://doi.org/10.37934/sijml.2.1.112

[50] Moursi, Ahmed Samy, Nawal El-Fishawy, Soufiene Djahel, and Marwa Ahmed Shouman. "An IoT enabled system for enhanced air quality monitoring and prediction on the edge." *Complex & Intelligent Systems* 7, no. 6 (2021): 2923-2947. https://doi.org/10.1007/s40747-021-00476-w

[51] World Health Organization. "A global overview of national regulations and standards for drinking-water quality." *Geneva; World Health Organization* (2021).
[52] The World Air Quality Index Project. Dhaka US consulate air pollution: Real-time Air Quality Index (AQI). 2008-2025.
[53] Sujauddin, Mohammad, Ryu Koide, Takahiro Komatsu, Mohammad Mosharraf Hossain, Chiharu Tokoro, and Shinsuke Murakami. "Ship breaking and the steel industry in Bangladesh: A material flow perspective." *Journal of Industrial Ecology* 21, no. 1 (2017): 191-203. https://doi.org/10.1111/jiec.12423
[54] Hossain, Mohammad Belal, Md Abu Noman, Jahanara Akhter Lipi, Abu Hena Mustafa Kamal, and Mohd Hanafi Idris. "Effects of ship-breaking activities on the abundance and diversity of macrobenthos in Sitakundu Coast, Bangladesh." *Biodiversitas Journal of Biological Diversity* 21, no. 11 (2020). https://doi.org/10.13057/biodiv/d211113
[55] Yılmaz, Atilla, Burak Karacık, Sevil D. Yakan, Bernhard Henkelmann, Karl-Werner Schramm, and Oya S. Okay. "Organic and heavy metal pollution in shipbreaking yards." *Ocean Engineering* 123 (2016): 452-457. https://doi.org/10.1016/j.oceaneng.2016.06.036
[56] Abdullah, Hasan Muhammad, M. Golam Mahboob, Mehmuna R. Banu, and Dursun Zafer Seker. "Monitoring the drastic growth of ship breaking yards in Sitakunda: A threat to the coastal environment of Bangladesh." Environmental Monitoring and *Assessment* 185 (2013): 3839-3851. https://doi.org/10.1007/s10661-012-2833-4