European Journal of Chemistry 15 (2) (2024) 101-109

European Journal of Chemistry

ATLANTA PUBLISHING HOUSE

The pollution status of the ship breaking area and its impact on tree growth and human health in Sitakunda, Bangladesh

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RESEARCH ARTICLE

10.5155/eurjchem.15.2.101-109.2509

Received: 27 January 2024
Received in revised form: 7 March 2024
Accepted: 27 March 2024
Published online: 30 June 2024
Printed: 30 June 2024

KEYWORDS

Recycling
Plant growth
Soil pollution
Ship breaking
Water pollution
Organic pollutant
Hazardous materials

ABSTRACT

Chittagong Shipyard has been a source of pollution for the local ecosystem. From the shipyard, a substantial amount of pollutants is released into the environment during operations. Due to the release of heavy metals, chemicals, and oil into nearby water bodies, which subsequently contaminate the soil, pollution of both water and soil occurs. The pollution of air and water due to the burning of fuels and materials such as oil and paint has also slowed the growth of the plant. To evaluate the status of environmental pollution near the ship breaking industries in Sitakunda, several samples were collected and tested. The growth and yield performance of the *Swietenia mahagoni* Linn seedlings (Mahogani) was carried out in three different types of soil composition, such as nursery soil + shipyard soil, nursery soil + soil adjacent to the shipyard, and nursery soil + soil from a place away from the shipyard as a control in a ratio of 1:2. The seawater and soil samples collected from the three shipyards were found to be more polluted compared to those of the seawater and soil samples collected from an area away from the shipyards. The magnitude of pollution in different physical and chemical parameters of the seawater of the shipyard differs significantly (at $p < 0.01$) from the seawater away from the shipyard. The magnitude of pollution in different physical and chemical parameters of the shipyard soil differs significantly (at $p < 0.05$) from the soil adjacent to the shipyard and the soil away from the shipyard. The growth and yield of the *Swietenia mahagoni* Linn species were affected by growing on the shipyard soil with nursery soil. Total biomass production was minimum in seedlings grown in three different soils of shipyards, followed by seedlings grown in soil adjacent to the shipyards and seedlings grown in soil away from the shipyard.

Cite this: *Eur. J. Chem.* **2024**, *15(2)*, 101-109 **Journal website**: www.eurjchem.com

1. Introduction

The shipbreaking industry started in Bangladesh from 1964 with the stranded Greek vessel 'MD Alpine' by a local scrapyard 'Steel House' in Shitakundo, Chittagong [1,2]. Ship breakage is often referred to as ship recycling, ship demolition, ship dismantling, or ship cracking. It is a kind of ship disposal in which ships are broken down for parts that can be sold for reuse or for the extraction of raw materials, usually scrap [3]. As the shipbreaking yards in Bangladesh are located on the coast of the Sitakund-Bhatiyari area, Chittagong [4], during the ship breaking process, large amounts of heavy metals, crude oil and environmentally harmful substances such as polychlorinated biphenyls (PCB), polyvinyl chloride (PVC), polycyclic aromatic hydrocarbons (PAH), tributyltin (TBT) mercury, lead, isocyanates, sulfuric acid, etc. are released into the environment. Moreover, tides carry these hazardous materials away from the source [5,6]. This is due to the poor management of hazardous materials handling [7,8] and the lack of a specific regulatory framework to monitor this environmental damage [9]. Consequently, the biodiversity of both terrestrial and marine environments is threatened. Additionally, there is also a negative impact on the environment due to the removal of trees to provide space for additional recycling activities [10]. Chemicals released into the environment by this heavy industrial activity have a serious direct and indirect adverse effect on human, animal, and plant populations [11].

ISSN 2153-2249 (Print) / ISSN 2153-2257 (Online)
https://dx.doi.org/10.5155/eurjchem.15.2.101-109.2509

Table 1. Environmental sample collection point.

Soil sampling location	Latitude	Longitude
SQ-1 Bhatiari Shipyards	22°25'52.55"N	91°44'5.80"E
SQ-1 Bhatiari Shipyards Adjacent Area	22°25'52.87"N	91°44'13.72"E
SQ-2 Madam Bibir Hut Shipyard	22°27'9.52"N	91°43'37.64"E
SQ-2 Adjacent of Madam Bibir Hut Shipyard Area	22°27'1.55"N	91°43'45.92"E
SQ-3 Shipyard Near Kadam Rasul	22°26'48.39"N	91°43'47.77"E
SQ-3 Shipyard Near Kadam Rasul Adjacent Area	22°26'52.98"N	91°43'48.42"E
SQ-Control sample	22°29'44.51"N	91°42'24.92"E
Water sampling location		
SW-1 Ocean Near Bhatiari	22°25'45.37"N	91°42'34.69"E
SW-2 Ocean Near Madam Bibir Hut	22°27'6.72"N	91°42'3.58"E
SW-3, Ocean Near Kadam Rasul	22°26'44.84"N	91°42'14.05"E
SW-Control sample	22°29'19.32"N	91°40'52.97"E

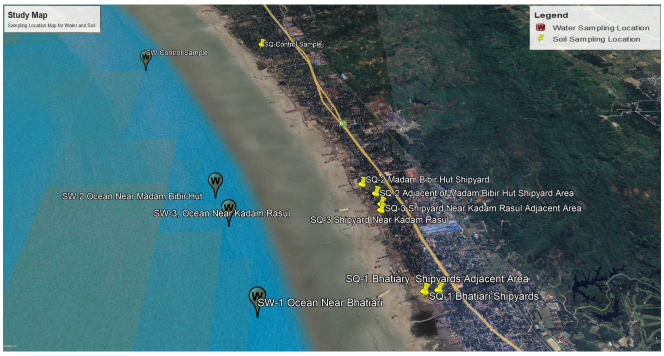

Figure 1. Map of the study area, water sampling location and soil sampling location, Source: Google Earth.

Asbestos is a fibrous mineral that is widely used in different types of equipment as a thermal insulator in the ship such as joiners, bulkhead systems, hot water and steam piping, inside and outside boilers and tanks, machinery parts, *etc*. Approximately a ship contains more than 7 tons of asbestos particles [5,12]. Several researchers revealed that it has carcinogenic properties for humans [13].

Organic substances such as PCBs have excellent insulating properties [14], and are therefore widely used in electrical devices. A large amount of electrical and electronic waste (WEEE) is generated during the ship breaking, these trashes are dumped in landfills without any kind of waste management. Furthermore, openly incinerating WEEE garbage produces pollutants as byproducts, such as PAHs [15-17]. There is a negative impact of PCB pollution on the environment [18], and PCB pollution can also reduce or resist plant growth [19].

Heavy metals have an adverse health effect not only on humans or animals, but also on plants [20]. Heavy metals from the ship-breaking process contaminate the soil and water that are then taken up by plant roots and transported to different parts of the plant, reducing plant growth by phototoxicity or reducing the photosynthesis process [21,22].

Oil and lubricants released during ship breaking pollute soil and water, can cause respiratory, liver, kidney, adrenal gland, and heart diseases in humans, and can also have adverse effects on plants, as these pollutants can hinder the ability of plants to absorb water through their roots and subsequently transpire through their leaves, interrupting the evapotranspiration process [23], retarding the growth of plants [24].

This study aims to evaluate soil and water pollution in shipbreaking areas, investigate tree growth and yield performance in polluted soils, and assess the impact of pollution on human health, by examining the potential health risks and adverse effects associated with pollutants.

2. Experimental

2.1. Sample collection approach

Based on the reconnaissance survey, three shipyard areas from three separate locations (Bhatiari, Madam Bibir Hut, and Kadam Rasul) and one place apart from the shipyards in a location Jora Aamtol (as control) were deliberately selected (Table 1 and Figure 1). Soil samples were collected from the shipyard areas, areas adjacent to the shipyard area, and areas away from the shipbreaking industries. Water samples were collected from the sea adjacent to the different shipyards and from the control area along the coast. Based on the reconnaissance survey, a plant species, namely *Swietenia mahagoni* Linn, was selected for the study (as), it was found to be dominant in that area.

2.2. Soil sampling methodology

Five samples were randomly collected by hand auger sampler from two different depths 0-10 and 15-30 cm from multiple spots at each location and then mixed together separately to form a group of three composite samples of each depth denoted as three replications. Collected samples were taken in a labeled polyethylene bag and then brought to the laboratory for subsequent analyzes. In each location sampling was done in between 50×50 m plot size.

2.3. Water sampling methodology

The grab sampling method was applied to collect surface water samples. A stainless-steel scoop device was used as a grab sampler. All samples were preserved according to the standards of the Environment Protection Agency (EPA). This was done by pouring a small volume of sample over the strip.

2.4. Growth and yield performance Swietenia mahagoni Linn species

2.4.1. Selection and preparation of the experiment site

The study was carried out at the nursery of the Institute of Forestry and Environmental Sciences, Chittagong University, using sun-dried soil and meshed with a 7 mm sieve (to remove fragmented metals and gravels) soil from the shipyard area mixed with nursery soil. The seedlings were watered regularly until they were established, and when a new leaf flush was observed, various parameters were measured. The seedlings were placed in a complete randomized design (CRD) of four blocks before beginning the measurement. Four seedlings with new leaf flushes were placed in each block after the initial harvest on day 0 (D_0) of the experimental period.

2.4.2. Design of the experiment

Experiments were designed to find the differences in seedling growth performances, which were treated with normal Nursery Soil (NS) + Ship Yard Soil (SYS) in Bhatiari (T1), Nursery Soil (NS) + Ship Yard Soil (SYS) in Madam Bibir Hut (T2), Nursery Soil (NS) + Ship Yard Soil (SYS) in Kadam Rasul (T3); Nursery Soil (NS) + Soil Adjacent to Ship Yard (SASY) in Bhatiari (T4), Nursery Soil (NS) + Ship Yard Soil (SYS) in Madam Bibir Hut (T5), Nursery Soil (NS) + Ship Yard Soil (SYS) in Kadam Rasul (T6); and Nursery Soil + Soil form a place away from the Ship Yard as Control (T0), respectively. A complete randomized design (CRD) with 4 replications was used (total of 28 (4×7) samples). Each sample consisted of 4 seedlings. So, a total of (28×4) or 112 seedlings were raised in four different rows. Continuous harvests were carried out over a 20-day interval and in each harvest 28 (28) individuals the species from four rows were harvested randomly [25].

2.5. Analysis

2.5.1. Soil sample analysis

2.5.1.1. Soil moisture content

The moisture content of the subjected soil sample was carried out following the oven-dry method at a temperature 105±5°C over a period of 5 hours using the Grieve model LO-201C oven (Equation 1) [26].

$$\%\text{Moisture content} = \frac{W - W1}{W1} \times 100 \quad (1)$$

where W = Moist weight of the samples and W1 = Dry weight of the samples.

2.5.1.2. Soil pH

Field moist soil (20 g) was taken to carry out the soil pH test according to the 1:2 soil water ratio method by using a pH meter manufactured by TOA Corporation, Japan (Model: Portable pH/ORP/ion meter HM-40P) [27,28]. Soil extract was prepared by mixing 20 g of moist water and 40 mL of distilled water, and the mixture was left to settle. After settling, the relatively clear supernatant was separated out and the pH was measured.

2.5.1.3. Soil salinity or salt concentration

The 1:5 soil/water extract electrical conductivity method was followed to determine the soil salt concentration. EC/TDS meter (model HI 99301) was used to determine the electrical conductivity, and the total salt concentration was evaluated by using the equation $C \approx 10 \times EC_{w@25°C}$ where, EC is in dS/m or mS/cm and C is the salt concentration or salinity [29].

2.5.1.4. Soil organic carbon and organic matter

The percentage of organic matter and organic carbon was determined by loss of ignition value. Where loss of ignition was determined at 850 °C for 30 minutes by thermogravimetric analysis of the soil (Equations 2-4) [30,31]. The oven dry method was applied at 105 °C for 8 hours to remove moisture from the soil [32].

$$\%\text{ of Loss on ignition }(\%\text{ LOI}) = \frac{W_2 - W_3}{W_2 - W_1} \times 100 \quad (2)$$

where W_1 = Weight of empty crucible, W_2 = Weight of crucible + soil sample after drying in the oven at 105 °C for 8 hours, W_3 = Weight of crucible + residue after ignition at 850 °C for 30 minutes.

$$\%\text{ of Organic carbon }(\%C) = 0.476 \times (\%\text{ LOI} - 1.87) \quad (3)$$

$$\%\text{ of Organic matter }(\%OM) = \%C \times 1.72 \quad (4)$$

2.5.2. Water sample analysis

2.5.2.1. Total suspended solid (TSS) analysis

Glass fiber TSS filter paper (Whatman 934-AH (catalog number: 1827 047) with a pore size of 1.5 µm was used to determine the TSS of the water sample. 100 mL of sample was filtered through pre-weighed oven-dried filter paper. The filter paper was then dried in a 105±2 °C oven for 1.30 hours and the final value was weighted [33,34]. The total suspended solid was calculated using Equation 5,

$$\text{TSS of water sample} = \frac{(F2 - F1) \times 1000\text{ mg}}{0.1\text{L}} \quad (5)$$

where initial weight of filter paper: F1 (g), final weight of filter paper: F2 (g), volume of the water sample: 100 mL or 0.1 L.

2.5.2.2. pH determination

The standard EPA Method 150.2 Continuous Monitoring (Electrometric) using the pH meter method was followed to determine the pH of the collected surface water sample. A portable pH/Temperature Tester with 0.01 pH resolution and 3-point calibration (Model: HI98128, Romania) was used for this pH analysis [35-37].

2.6. Dissolved oxygen and biochemical oxygen demand analysis

The direct method was selected to determine the immediate dissolved oxygen and biochemical oxygen demand after five days of incubation. Titration was carried out for a definite amount of sample against the sodium thiosulfate solution after fixation of dissolved oxygen by adding manganese sulfate. Alkali-iodide azide was added for precipitation (brown) formation. The oxygen in the water reacts with the manganous hydroxide to form a brown-colored manganic hydroxide. After a few minutes of concentration, sulfuric acid was added to it so that the precipitation dissolved. This acidification converts manganic hydroxide to manganic sulfate. Here the dissolved oxygen is fixed and can be evaluated by titration against 0.02 N sodium thiosulfate, as at the same time, iodine from potassium iodide in the alkaline potassium iodide azide solution is oxidized by manganic sulfate, releasing free iodine into the water. The amount of iodine released is directly proportional to the amount of oxygen present in the original sample [38-41]. The dissolved oxygen was calculated using Equation 6,

$$\text{Dissolved oxygen}\left(\frac{mg}{L}\right) = \frac{\text{mL of titrant} \times \text{normality of sodium thiosulfate} \times 8 \times 1000}{\frac{V_2(V_1 - V)}{V_1}} \quad (6)$$

where, V_1 = volume capacity of the BOD sample bottle (300 mL), V_2 = sample volume taken from the BOD sample bottle for titration (100 mL), V = Sum of the volume of manganese sulfate and alkali azide (1 mL + 1 mL = 2 mL),

Table 2. Physiochemical properties of seawater from four different sampling stations (three different shipyards and one away from the shipyard as control) under different weather conditions. Values are the average of three observations with (±) standard error of mean.

Physicochemical properties of seawater	Unit	Sampling stations							
		Bhatiari		Madam Bibir Hut		Kadam Rasul		Jora Aamtol (Control)	
		Dry and sunny	Wet and rainy	Dry and sunny	Wet and rainy	Dry and sunny	Wet and rainy	Dry and sunny	Wet and rainy
Total suspended solids	mg/L	4095±12.76	4211±13.31	4258±8.18	4277±10.69	3942±16.42	4119±15.03	2177±11.28	2284±9.30
Total dissolve solids	mg/L	850±9.08	830±11.25	810±10.00	770±14.17	870±13.02	810±11.83	1610±10.13	1544±9.33
pH	-	7.70±0.11	7.61±0.13	7.65±0.08	7.69±0.06	7.82±0.15	7.73±0.11	7.22±0.06	7.16±0.10
Electric conductivity	µS/cm	1700±13.82	1650±15.25	1610±11.59	1525±16.11	1725±12.84	1620±10.61	3210±9.87	3088±13.94
Dissolve oxygen	mg/L	4.13±0.13	4.30±0.09	3.98±0.11	4.11±0.15	4.23±0.10	4.30±0.17	6.42±0.08	6.54±0.13
Biochemical oxygen demand	mg/L	6.98±0.23	7.21±0.17	7.38±0.14	7.69±0.22	7.63±0.18	7.68±0.26	4.17±0.17	4.26±0.23
Chloride	mg/L	483±17.28	513±21.03	521±15.00	558±17.13	507±11.89	528±18.67	776±13.92	789±16.07
Total iron	mg/L	39.43±0.29	44.37±0.81	37.62±0.42	39.94±0.78	35.58±0.26	38.06±0.31	2.57±0.18	2.63±0.23
Oil and grease	mg/L	7232±24.81	3967±19.13	8078±27.22	4079±20.87	6623±25.27	3755±17.68	229±29.33	161±26.12

Similarly, the dissolved oxygen was measured after five days of oxygen to determine the biochemical oxygen demand using Equation 7,

$$BOD_5\ (mg/L) = DO\ before\ incubation\ (DO_0) - DO\ after\ five\ days\ of\ incubation\ (DO_5) \quad (7)$$

2.7. Oil and grease analysis

Oil and grease were extracted from the samples according to the protocol of US EPA Method 1664, Revision B. *n*-Hexane extractable material (HEM; Oil and grease) method was used to determine the total suspended oil and grease from the water sample [42].

2.8. Growth analysis of seedlings

2.8.1. Keeping records of different growth attributes

The effects of treatment were periodically evaluated by measuring various growth parameters, including root length, shoot height, collar diameter, and leaf count. Seedlings were observed for a total of 80 days. One seedling from each replicate sample was randomly selected and uprooted very carefully to estimate seedling biomass. The seedlings were then separated into its shoot and root components. The shoots, roots, and leaves were oven dried at 65 ° C for 48 hours until the constant weight was obtained. To assess the seedling vigor of the experiment, the total height was measured using a ruler to the nearest 0.1 cm and for collar diameter measurement, a screw gauge (in mm) was used [43-46].

2.8.2. Measurement of the matured trees

The measurement of mature tree species of *Swietenia mahagoni* Linn species was carried out in three different areas, classified as shipyard area and area adjacent to shipyard and area away from the shipyard as control. Six individuals were measured in the case of trees along the boundary of the shipyard areas and 12 individuals in the case of trees adjacent to the shipyards and away from the shipyards from different spots of each location as replications. In each spot, trees of similar ages were measured. The height (h) of the trees was measured using a Haga altimeter, and the DBH (d) or diameter at breast height was measured using a dia-tape [47,48]. The volume of the tree was then calculated using the simple formula volume $= \pi \times r^2 \times h$ [49,50].

3. Result and discussion

3.1. Physical characteristics of the seawater

The amount of total suspended solids (TSS) determined in the collected water samples was significantly high in the three areas of the studied shipyards (4095, 4258, and 3942 mg/L, respectively) compared to the TSS of the area away from the shipyard (2177 mg/L). The TSS of the shipyard areas varies significantly from the control site ($p \leq 0.01$). The F value across both sites and seasons is less than the F-critical value. Therefore, there is no significant difference in the TSS. The amount of total dissolved solids (TDS) determined in the collected water sample was also significantly high in the three shipyard areas (1944, 1893, and 1855 mg/L, respectively) with respect to the TSS of the control area (1233 mg/L). The TDS of the shipyard area varies significantly from the control site ($p \leq 0.01$). The value of F in both site and seasons is more than the F-critical value. Therefore, TDS is significantly affected by both seasonal and treatment variations. Representative data are shown in Table 2.

3.2. Chemical characteristics of the seawater

The pH of the seawater samples collected from three (Bhatiari, Madam Bibir Hut, and Kadam Rasul) shipyard areas was higher (7.70, 7.65, 7.82, respectively) compared to the sample collected away from the shipyard area (7.22), so that the seawater near the ship breaking industries is more alkaline than the control area. The pH of the water in the shipyard areas varies significantly from the control site ($p \leq 0.01$). The F value across treatments being greater than the corresponding F-critical value indicates that the soil pH is significantly affected by the treatments, as well as the sampling depth. The value previously studied for the average value of surface water pH was 8.03 which was closest to the current values found according to the pH perspective [51].

Electric conductivity (EC) determined in the collected water samples was significantly lower at the three sampling stations in the shipyard area (1700, 1650, and 1610 µS/cm, respecttively) relative to the EC of the area away from the shipyard (3210 µS/cm). The value found in the current study is lower than the average value studied previously (6391.20 µS/cm) at the Kumira Ghat shipbreaking site in Sitakunda [51]. There may be an effect of low and high tides. The EC of the control area varies significantly from the shipyard areas ($p \leq 0.01$). The F value across both sites and seasons is more than the F-critical value. Thus, EC is significantly affected by both seasonal and treatment variation.

The level of dissolved oxygen (DO) present in the water samples collected from the three shipyard areas was determined to be lower (4.13, 3.98, and 4.23 mg/L, respecttively) compared to the samples collected away from the shipyard area (6.42 mg/L). The DO of the control site varies significantly from the shipyard areas ($p \leq 0.01$). In 2021, a study revealed that the average concentration of dissolved oxygen in surface water at the Kumira Ghat shipbreaking in Sitakunda, Chittagong was 7.28 mg / L, which is higher than the result of the current study established in all locations near the shipbreaking in Sitakunda [51].

The biochemical oxygen demand (BOD) of seawater samples collected from three shipyard areas (Bhatiari, Madam Bibir Hut and Kadam Rasul) was determined to be high (6.98, 7.38 and 7.63 mg/L, respectively) compared to the sample collected away from the shipyard area (4.17 mg/L). The F value across both sites and seasons is more than the F-critical value. Therefore, DO is significantly affected by seasonal variation and variation in treatment. The current study values are higher than the study values found during the 2021 period at the Kumira Ghat shipyard (1.90 mg/L) [51]. This indicates that the level of pollution is high at the current study point. The BOD of the shipyard areas varies significantly from the control site ($p \leq 0.01$), which could be attributed to the high abundance of oil and grease, as will be discussed later. The F value is less than the F-critical value across treatments, indicating that the treatments have no significant effect on BOD. Therefore, the change in BOD is only affected by the seasonal factor. In 2014, a study was conducted in coastal waters near the Alang-Sosiya ship breaking yard, Bhavnagar, India. The samples collected near the shipyard were found to be highly polluted compared to the control sample. The highest biochemical oxygen demand was found at 3160 mg/L and the highest iron concentration was found at 164.99 mg/L in winter [52].

The amount of chloride (Cl) determined in the collected water samples was significantly lower at the three shipyard sampling stations (483, 521, and 507 mg/L, respectively) compared to the Cl of the area away from the shipyard (776 mg/L). This high contamination of chloride near the surface water of the ship breaking yard also supports previously studied data (470-789 mg/L) given by Hossain *et al.* 2006 [3]. The Cl concentration at the control site varies significantly from the shipyard areas ($p \leq 0.01$).

The amount of total iron determined in the seawater samples collected from three (Bhatiari, Madam Bibir Hut, and Kadam Rasul) shipyard areas was determined higher (39.43, 37.62, 35.58 mg/L, respectively) compared to the sample collected away from the shipyard area (2.57 mg/L). Previous studies also support the data from the current study on iron. The surface water near the area of the shipbreaking yard contains a large amount of iron [3,52]. The amount of total iron observed in the water samples from the shipyards varies significantly from the control site ($p \leq 0.01$).

The amount of oil and grease suspended in the seawater samples collected from three (Bhatiari, Madam Bibir Hut, and Kadam Rasul) shipyard areas were determined significantly high (7232, 8078 and 6623 mg/L, respectively) compared to the sample collected away from the shipyard area (229 mg/L). This high contamination of oil and grease pollutants near the surface water of the shipbreaking yard also supports the previously studied data (9280-10600 mg/L) given by Hossain *et al.* 2006 [3]. The amount of oil and grease found in the water samples from the shipyards varies significantly from the control site ($p \leq 0.01$). None of these parameters was found to vary significantly with seasonal variation. Like other pollutants, oil, grease, or lubricants are also responsible for environmental pollution in large amounts by shipbreaking industries in Bangladesh, similarly in India, Pakistan, and China [53]. Representative data are shown in Table 2.

3.3. Physical characteristics of the soil

The moisture content of the soil collected from the area away from the shipyard was significantly higher ($p \leq 0.01$) at depth than the area adjacent to the shipyard. In the shipyard areas the moisture content at all three sampling stations near the surface was lower (26.58, 31.20 and 27.62%, respectively) whereas their corresponding values in the areas adjacent to the shipyard were 36.61, 40.29 and 39.29%, respectively. Similar differences were between the control, adjacent and shipyard areas at 15-30 cm depth. The F value across treatments is greater than the corresponding F-critical value, indicating that the moisture content of the soil is significantly affected by the treatments, but not the sampling depth since the F value across columns is less than the corresponding F-critical value.

The particle density of the soil collected from the shipyard area was higher ($p \leq 0.05$) at depth compared to the control site, followed by the areas adjacent to the shipyard. In the shipyard area, the particle density at all three sampling stations near the surface was higher (2.43, 2.37, and 2.46 g/mL, respectively), while their corresponding values in the areas adjacent to the shipyard were 2.18, 2.31 and 2.07 g/mL, respectively, while the particle density of the control site was 2.23 g/mL. The F value across treatments being greater than the corresponding F-critical value, indicates that the soil particle density is signify-cantly affected by the treatments and is independent of the sampling depth.

3.4. Chemical characteristics of the soil

The pH of the soil collected from the three shipyard areas was significantly higher ($p \leq 0.05$) at both depth and that of the area adjacent to the shipyard and the control area. The pH values of the soils collected at three different shipyards (Bhatiari, Madam Bibir Hut and Kadam Rasul) in the surface soil were 7.87, 8.13 and 7.46 respectively, while their corres-ponding values of the adjacent areas to the shipyards were 7.17, 7.10 and 7.18; at the same time, the pH of the corresponding control site was 7.23. In the present study, soil pH increased significantly in all sampling stations with respect to soil depth. Both the soil and the water sample were more alkaline at the dismantling site. In 2013, a study near the Madam Bibirhut Shipbreaking Industrial Area in Sitakunda found the closest soil pH value as 8.5±0.4 [25].

In the present study, soil salinity in three different shipyards in surface soil was 0.13, 0.22 and 0.16 dS/cm, respectively, while their corresponding values of areas adjacent to the shipyards were 0.09, 0.12 and 0.10 dS/cm, respectively; at the same time, the pH of the corresponding control site was 0.12 dS/cm. Salinity increased significantly ($p \leq 0.05$) in all sampling stations with respect to soil depth. It was also revealed that the salinity of the soil increased from areas adjacent to shipyards to shipyards.

Soil organic carbon content of the soil collected from the site of the shipyard was determined less ($p \leq 0.01$) at both depth and compared to the control site and was followed by the areas adjacent to the site of the shipyard. Soil organic carbon content of the soil of surface soil collected from three different shipyards (Bhatiari, Madam Bibir Hut and Kadam Rasul) was 0.81, 1.13 and 0.69%, respectively, while their corresponding values of the areas adjacent to the shipyards were 2.09, 2.24 and 2.20%, respectively; at the same time the organic carbon content of the corresponding control site was 2.44%. Previous studies also found the closest value for organic carbon content near the Madam Bibirhut Shipbreaking Industrial Area at Sitakunda (1.99±0.07%) and for organic matter it was 3.43±0.09 which was slightly higher than the present conditions [25]. The F value across treatments being greater than the corresponding F-critical value, indicates that soil OC is significantly affected by the treatments, but not sampling depth since F value across columns is less than the corresponding F-critical value. The organic matter content of the soil increased significantly ($p \leq 0.01$) in the three areas adjacent to the shipyard and in the area away from the shipyard compared to the three areas of the shipyard studied.

The organic matter content of surface soil collected from three different shipyards was 2.09, 2.24, and 2.20%, respect-tively, while the corresponding values of the areas adjacent to the shipyards were 3.60, 3.85, and 3.78%, respectively; at the same time, the organic carbon content of the corresponding control site was 4.20%.

Table 3. Physicochemical properties of soil of four different sampling stations (three different shipyards and one away from the shipyard as a control) in two different soil depths (0-10 and 15-30 cm). Values are the average of three observations with (±) standard error of mean.

Physicochemical properties	Unit	Sampling stations													
		Bhatiari				Madam Bibir Hut				Kadam Rasul				Jora Aamtol (control)	
		Shipyard		Adjacent		Shipyard		Adjacent		Shipyard		Adjacent			
		0-10 cm	15-30 cm	0-10 cm	15-30 cm	0-10 cm	15-30 cm	0-10 cm	15-30 cm	0-10 cm	15-30 cm	0-10 cm	15-30 cm	0-10 cm	15-30 cm
Moisture content	%	26.58± 2.21	29.11± 1.95	36.61± 1.14	37.90± 2.42	31.20± 1.53	28.86± 1.19	40.29± 1.17	36.52± 2.38	27.62± 1.14	25.93± 0.96	39.29± 1.55	39.04± 1.94	43.03± 2.49	41.29± 1.06
Particle density	g/mL	2.43± 0.04	2.48± 0.12	2.18± 0.02	2.21± 0.04	2.37± 0.01	2.33± 0.07	2.31± 0.11	2.24± 0.16	2.46± 0.06	2.51± 0.12	2.07± 0.04	2.13± 0.07	2.23± 0.02	2.35± 0.16
pH	-	7.87± 0.15	8.10± 0.16	7.17± 0.21	7.40± 0.10	8.13± 0.06	8.38± 0.01	7.10± 0.03	7.23± 0.10	7.46± 0.36	7.70± 0.06	7.18± 0.23	7.33± 0.16	7.23± 0.06	7.30± 0.11
Salinity	dS/cm	0.13± 0.01	0.17± 0.01	0.09± 0.01	0.11± 0.01	0.19± 0.01	0.22± 0.00	0.12± 0.01	0.13± 0.01	0.16± 0.01	0.18± 0.00	0.10± 0.01	0.11± 0.00	0.11± 0.01	0.12± 0.01
Organic carbon	%	0.81± 0.13	0.66± 0.07	2.09± 0.05	2.12± 0.03	1.13± 0.04	0.85± 0.01	2.24± 0.09	2.19± 0.14	0.69± 0.05	0.74± 0.03	2.20± 0.05	1.87± 0.13	2.44± 0.03	2.38± 0.01
Organic matter	%	1.39± 0.21	1.14± 0.12	3.60± 0.09	3.65± 0.05	1.94± 0.07	1.46± 0.02	3.85± 0.16	3.77± 0.23	1.19± 0.09	1.27± 0.05	3.78± 0.09	3.22± 0.21	4.20± 0.05	4.09± 0.02

Table 4. Maximum yield performance of Swietenia mahagoni Linn seedlings grown in a polyethylene bag containing three different types of soil in a 1:2 ratio over a period of 80 days of final harvesting *.

Variable	Parameter	Unit	After 80 days		
			CS	NS+SASY	NS+SYS
Bhatiari	Leaf length	cm	5.39	5.18	4.74
	Stem elongation	cm	49.05	48.62	48.19
	Collar diameter	mm	6.58	6.52	6.47
Madam Bibir Hut	Leaf length	cm	5.36	5.18	4.78
	Stem elongation	cm	48.77	48.5	48.31
	Collar diameter	mm	6.56	6.53	6.46
Kadam Rasul	Leaf length	cm	5.17	4.96	4.7
	Stem elongation	cm	48.49	48.54	48.2
	Collar diameter	mm	6.55	6.51	6.44

* Nursery soil (NS) + Shipyard soil (SYS), Nursery soil (NS) + Soil adjacent to the shipyard (SASY), Nursery soil + Soil from a place away from the shipyard as control (CS).

The F value across treatments being greater than the corresponding F-critical value indicates that the soil OM content is significantly affected by the treatments, but not the sampling depth, since the F value across columns is less than the corresponding F-critical value. Representative data are shown in Table 3.

3.5. Seedlings morphological growth

Leaf elongation and increase in collar diameter of *Swietenia mahagoni* Linn seedlings were affected in shipyard soil. On day 80, the leaf length of Mahogani seedlings grown in the soil of the control site was found to be maximum (5.39, 5.36, and 5.17 cm, respectively) followed by seedlings grown under the soil adjacent to the shipyard areas (5.18, 5.18 and 4.96 cm) and the shipyard soil (4.74, 4.78 and 4.70 cm). The maximum elongation of the stem was found in *Swietenia mahagoni* Linn, which were grown under the soil collected from an area away from the shipyard as 49.05, 48.77 and 48.49 cm, respectively, the seedlings grown under the soil collected from the areas adjacent to the shipyards as 48.62, 48.50 and 48.54 cm, respectively, and the seedlings grown under the soil collected from the area of the shipyard as 48.19, 48.31and 48.20 cm, respectively (Table 4). The collar diameter of the *Swietenia mahagoni* Linn seedlings grown in the soil of the control site was measured as 6.58, 6.56 and 6.55 mm, respectively, the seedlings grown in the soil adjacent to the shipyard areas as 6.52, 6.53 and 6.51 mm and the soil of the shipyard as 6.47, 6.46 and 6.44 mm. The growth and elongation of the stems of both species differ significantly from each other under three different soil conditions. Total biomass was found to be the least in seedlings grown in soil collected from three shipyard areas (8.51, 8.83, and 8.37 g, respectively) and the highest in the case of seedlings grown in soil collected from areas away from shipyards (11.51 g) over a growing period of 60 days. The total dry biomass (11.51 g) was found to be the highest grown in the control soil, followed by the seedlings grown in the soil collected from areas adjacent to the three shipyards (9.74, 10.51, and 10.24 g, respectively) and the seedlings grown in the soils of the three shipyards (8.51, 8.83 and 8.37 g, respectively) at the end of the harvest on day 60 shown in Table 5. Regression analysis showed that the correlation coefficient between total biomass and collar diameter was very strong (R^2 = 0.9943) in the case of seedlings grown in soil collected from an area outside the shipyard, followed by adjacent and shipyard areas. The correlation coefficient between leaf length and leaf biomass is also very strong (R^2 = 0.9633) in the case of seedlings grown in soil collected from the control area rather than from the shipyard areas.

3.6. Growth and yield performance of trees grown in the study area

In the present study, the growth and yield performance of the *Swietenia mahagoni* Linn tree species grown in the area away from the shipbreaking yards were found to be the highest followed by the trees grown in areas adjacent to the shipyards and the trees grown in the shipyard areas. The total biomass production was minimum in Mahogani, grown along the boundary lines of the shipbreaking yards at three different sampling stations were 0.043, 0.049, and 0.047 m^3, respectively, while the corresponding volumes of trees grown in areas adjacent to the shipyards were 0.076, 0.081, and 0.070 m^3, respectively. The average volume of the tree grown at the control site yields the maximum volume (0.089 m^3) Table 6.

The F value of the dry weight of the stem in both the treatment and the period was higher than the corresponding F-critical values, indicating that the dry weight of the stem is significantly affected by both factors. In the case of the dry weight of the root, the F value across treatments is higher than the F-critical value. This indicates that the treatments do significantly affect the dry weight of the root, which is also dependent on the measurement interval, as the F value over time is greater than the F-critical value.

Table 5. Yield performance of Swietenia mahagoni Linn seedlings grown in a polyethylene bag containing three different types of soil in a ratio of 1:2 over a period of 60 days at Bhatiari (A), Madam Bibir Hut (B) and Kadam Rasul (C). Values are an average of four observations with ± standard error of the mean *.

Variable	Parameter	Unit	Day 0	Day 20			Day 40			Day 60		
			CS	CS	NS+SASY	NS+SYS	CS	NS+SASY	NS+SYS	CS	NS+SASY	NS+SYS
Bhatiari (A)	Dry weight of the roots	g	1.82±0.24	2.13±0.17	2.09±0.36	1.91±0.31	2.26±0.13	2.21±0.18	1.99±0.23	2.56±0.11	2.52±0.47	2.17±0.38
	Dry weight of stem	g	2.68±0.43	3.30±0.21	3.13±0.19	2.89±0.29	3.80±0.17	3.37±0.15	3.02±0.17	4.82±0.21	3.78±0.24	3.46±0.23
	Dry weight of the leaves	g	2.35±0.21	3.26±0.12	3.21±0.24	2.46±0.09	3.96±0.20	3.48±0.18	2.97±0.19	4.13±0.13	3.57±0.29	2.94±0.26
	Total dry weight	g	6.85±0.29	8.69±0.16	8.43±0.29	7.26±0.23	10.02±0.16	9.06±0.17	7.98±0.19	11.51±0.15	9.87±0.33	8.51±0.37
Madam Bibir Hut (B)	Dry weight of the roots	g	1.82±0.24	2.13±0.17	2.06±0.41	1.96±0.21	2.26±0.13	2.30±0.21	2.10±0.17	2.56±0.11	2.38±0.36	2.17±0.33
	Dry weight of stem	g	2.68±0.43	3.30±0.21	3.08±0.23	2.81±0.13	3.80±0.17	3.50±0.14	3.22±0.23	4.82±0.21	4.26±0.21	3.63±0.24
	Dry weight of the leaves	g	2.35±0.21	3.26±0.12	3.30±0.17	2.54±0.18	3.96±0.20	3.53±0.23	2.88±0.16	4.13±0.13	3.87±0.23	3.03±0.19
	Total dry weight	g	6.85±0.29	8.69±0.16	8.44±0.27	7.31±0.17	10.02±0.16	9.33±0.18	8.20±0.19	11.51±0.15	10.51±0.26	8.83±0.25
Kadam Rasul (C)	Dry weight of the roots	g	1.82±0.24	2.13±0.17	2.10±0.37	1.93±0.27	2.26±.13	2.23±0.18	2.01±0.28	2.56±0.11	2.40±0.33	2.17±0.42
	Dry weight of stem	g	2.68±0.43	3.30±0.21	3.00±0.16	2.76±0.23	3.80±0.17	3.47±0.15	2.97±0.22	4.82±0.21	4.17±0.21	3.33±0.19
	Dry weight of the leaves	g	2.35±0.21	3.26±0.12	3.10±0.19	2.47±0.14	3.96±0.20	3.43±0.18	2.71±0.13	4.13±0.13	3.67±0.24	2.87±0.36
	Total dry weight	g	6.85±0.29	8.69±0.16	8.20±0.24	7.16±0.21	10.02±0.16	9.13±0.17	7.69±0.21	11.51±0.15	10.24±0.2.6	8.37±0.32

* Nursery soil (NS) + Shipyard soil (SYS), Nursery soil (NS) + Soil adjacent to shipyard (SASY), and Nursery soil + soil from a place away from the shipyard as control (CS).

Table 6. Growth and yield performance of 13-year-old Swietenia mahagoni Linn trees grown under three different conditions, viz: Along the Boundary of Shipyard (ABSY), Area Adjacent to Shipyard (AASY), and Area away from the Shipyard, i.e., Control (CS), in four sampling stations. Values are the mean of six observations in the case of the shipyard site and twelve observations in the case of the adjacent and control site.

Growth and yield parameters	Sampling stations						
	Bhatiari Shipyard area		Madam Bibir Hut Shipyard area		Kadam Rasul Shipyard area		Control site (CS)
	ABSY	AASY	ABSY	AASY	ABSY	AASY	
Height (m)	6.3±0.19	6.6±0.22	6.2±0.21	6.5±0.19	6.6±0.21	6.5±0.17	6.6±0.18
DBH (cm)	9.3±0.30	12.1±0.34	10.0±0.29	12.6±0.37	9.5±0.27	11.7±0.31	13.1±0.36
Volume (m^3)	0.043±0.013	0.076±0.014	0.049±0.013	0.081±0.014	0.047±0.012	0.070±0.012	0.089±0.013

In the case of between treatments, we can see that the F value (34.949) is greater than F-critical value (2.591), which indicates that the treatments have a significant effect on the leaf dry weight of the seedlings during the treatments, it can be seen that the F value (34.949) is greater than F-critical value (2.591), which indicates that the treatments have significant effect on the dry leaf weight of the seedlings. The F value of the total dry weight between treatments (2.691) is higher than the F-critical value (2.591). This indicates that the treatments do significantly affect the total dry weight, which is also dependent on the interval of measurement, as the F value across time (74.851) is greater than F-critical value (3.634). Since both the F value is greater than the F-critical value (in ANOVA) and the t-Stat is significantly different from 0 (negative), and it is well beyond the t-critical two-tail (in t-test), we have strong evidence to reject the null hypothesis, *i.e.*, we can say that the treatment has significant effects on the tree growth parameters.

3.7. Survey result of human health effect

As shipbuilding industries around the world are on the beach along the coastal area, as a result the coastal environment is most vulnerable to polluted air, water, soil, animals, plants and humans [54]. Madam Bibir Hut shipbreaking was found to cause the highest percentage of asthma and wounds, that is, 23 and 19%, respectively, as reported by respondents in our survey. Among the other problems, sneezing, skin diseases, eye irritation, and chest pain showed a level of occurrence of 10, 15, 13, 12% and other diseases (3%) among workers in this field. In Bhatiari 22% of workers suffered from respiratory problems, followed by wounds (19%), skin diseases (17%), chest pain (16%) and eye irritation (13%). In Kadam Rasul, a significant abundance of respiratory problems (17%) & skin diseases (17%) was observed. At the same time, 15% of the workers had eye irritation, followed by wounds (14%), scratching (10%), chest pain (13%), and 10% sneezing. The highest occurrence of the diseases detected among the Bhatiari workers and local people residing in the shipyard areas were respiratory problems of 22% and 37% of the respondents, respectively. Other health problems are skin diseases (19 and 13%, respectively), wound (16% in case of workers), irritation (13 and 23%, respectively), sneezing (10 and 20%), chest pain (12% in case of workers), scratching (9%) and other diseases (3%), *etc*. In Madam Bibir Hut workers and locals are affected by asthma (23 and 32%, respectively), skin diseases (17 and 12%, respectively), eye irritation (14 and 17%, respectively), chest pain (16% workers), scratching (4% workers) were observed. At Kadam Rasul the severe health problem occurred among the workers working in the shipyards and people living along the shipyard areas are of asthma (17 and 27%, respectively), eye irritation (15 and 29%, respectively), skin diseases (17 and 25%, respectively), chest pain (13% workers), wound (14% workers), scratching (10% workers) and others (4%) were reported. The high rate of injuries of workers in this industry is due to the nature of the operations involved in the ship breaking process and the lack of sufficient safety gear [3]. Dermatological problems are also significantly common in forms of skin diseases, scabies, fungal infections, etc., which have also been suggested in a 2016 study [55]. The high rate of respiratory disease has also been reported by a 2021 study [9].

4. Conclusions

The current research values for water and soil are very similar to the values obtained in previous studies carried out in Bangladesh. The reason for this can be said to be that the quality of water or soil in the places where the ship breaking industries are located is polluted in the same way due to the type of ship breaking process. Compared to India, Pakistan, China, Turkey, and other countries in the world having shipbreaking industries, Bangladesh contributed the highest amount of pollutant into the environment in all prospects like PCB, oil/lubricant, paint material, ozone depleting substance or heavy metals, *etc.* during the dismasting process of the ship, which is alarming for Bangladesh. Man's mastery of his surroundings has caused significant harm to humans and the environment, impacting well-being and economic development. Environmental management is crucial to sustainable use. Ship-breaking activities pose threats to both terrestrial and marine environments, public health, and living organisms. Despite its economic benefits, better regulation can bring social and environmental benefits to Bangladesh's economy.

Acknowledgements

We express our sincere gratitude to the Institute of Forestry and Environmental Sciences of the University of Chittagong for their valuable support and guidance throughout our research work. Their expertise and resources have played a crucial role in the successful execution of this study. We also extend our gratitude to the Department of Environment, Ministry of Environment, Forest, and Climate change, Dhaka and Chittagong Office, Bangladesh, for their cooperation and assistance. Their input and collaboration have significantly contributed to the quality and relevance of our research findings. Finally, we thank all individuals and organizations who have contributed directly or indirectly to this research project.

Disclosure statement DS

Conflict of interest: The authors declare that they have no conflict of interest.
Ethical approval: All ethical guidelines have been adhered to.
Sample availability: Samples of the compounds are available from the author.

CRediT authorship contribution statement CR

Conceptualization: Mohammed Anisuzzaman Talukder, Mohammed Khorshed Ali; Methodology: Ahmed Jubaer, Mohammed Anisuzzaman Talukder; Software: Muhammad Tasneem Zafar, Mohammad Zahirul Islam Talukder; Formal Analysis: Mohammed Anisuzzaman Talukder, Sajia Islam; Investigation: Ahmed Jubaer, Mohammed Anisuzzaman Talukder; Resources: Mohammed Khorshed Ali, Mohammad Zahirul Islam Talukder; Data Curation: Rubayat Tahrim Sourav, Ayesha Meherun Nahar; Writing - Original Draft: Ahmed Jubaer, Muhammad Tasneem Zafar; Writing - Review and Editing: Mohammed Khorshed Ali, Rubayat Tahrim Sourav; Visualization: Rubayat Tahrim Sourav, Mohammad Zahirul Islam Talukder; Supervision: Mohammed Khorshed Ali, Mohammad Zahirul Islam Talukder; Project Administration: Mohammed Anisuzzaman Talukder, Mohammed Khorshed Ali.

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