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Characterization of Coastal Water Deposits and its Subsequent Effect on Piping Materials

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ABSTRACT

The coastal water has common feature of high salinity and hardness. Besides these there are deposited materials in water. Bangladesh has a total area of 147,570 km2 where coastal region covers almost 29,000 km2 or about 20% of the country. About 53% of the coastal areas are affected by salinity. CaCO3, Cl- and pH has the greater effect on material. The chemical characteristics of the water flowing through a pipe will influence whether the water is stable and will also affect the extent of any corrosive reaction. Sample water collected from coastal region was undergone some test to evaluate some characteristics such as Alkalinity, Hardness, COD, BOD, EC, TDS, Sulfate, Ammonia etc. Primary factors include alkalinity, hardness, and pH, but oxidizing agents, carbon dioxide, and dissolved solids can also influence corrosion. These deposits plays vital role for corrosion and for destroying electric conductivity of the metal. Here pH of the coastal area water is found to be 6.94~7.85, which illustrates the hardness of water. Brienell Hardness Number (BHN), Rockwell Hardness, Impact load capacity & Shear test have been done on GI & copper pipes that carry coastal area water. An image of affected material has been captured on Scanning electron Microscope (SEM) to investigate the condition of scale forming and corrosion. Scaling tends to be the result of water with a high hardness. Hard water typically contains a lot of calcium compounds which can precipitate out as calcium carbonate. Some processes to solve these problems has been proposed.

Keywords: Piping Material (GI), Water Characterization, Brinell Hardness Number (BHN), Scale forming, Impact of Water

1. Introduction: Bangladesh, lies in the northeastern part of South Asia, has a total area of 147,570 km2 where coastal area covers about 32% of the country [1]. Due to influence of tide and presence of salinity in coastal rivers, the livelihoods of over 50 million inhabitants of coast area depend on groundwater for meeting domestic, municipal, industrial and other needs. Numerous water quality problems exist in ground water and surface water systems in Bangladesh, especially in its southwestern coastal belt, where salinity is a very alarming issue at present [2]. Khulna city is located on the banks of the Rupsha and Bhairab Rivers in the southwest region of Bangladesh. However, the southwest coastal belt of the country is facing enormous challenges in meeting the rising freshwater demand due to limited water supply from the available ground water and surface water sources as they are affected by the salinity and other water quality problems [2],[3]. The salinity was started to increase in Khulna after the commencement of Farrakka Barrage operation of India in 1975, which significantly reduced the Ganges flow, located at upstream of the Gorai River, a major source of freshwater to the rivers surrounding Khulna [4]. As salinity in the groundwater is a key factor, a clear idea of the extent of fresh –saline groundwater in various depths is required for optimal development and use of this precious potable water resource. The southwestern coastal region is characterized by the Ganges tidal flood plains with low relief, criss-crossed by rivers, tidal marshes and swamps. Although groundwater is abundant in the region, saline water intrudes into the aquifer system due to reduction of upstream freshwater flow, shrimp farming and over abstraction of groundwater makes the situation worse. As a consequence the coastal area may suffer from acute storage of potable water. It has also negative impacts on human activities, livelihood, agricultural production, aquatic ecosystem, infrastructure etc.

The availability of water determines the location and activities of humans in an area and our growing population is placing great demands upon natural fresh water resources. Technological growth has also put the ecosystem we depend on under stress and the availability of water is at a very high risk [5-6]. It is important to analyze water to determine its suitability for drinking, domestic use industrial use, agricultural use etc. It is also important in water quality studies to know the amount of organic matter present in the system and the quantity of oxygen required for stabilization of the water. The impact of organic pollutants on water quality in this work is expressed in terms of the Biochemical Oxygen Demand, BOD and Chemical Oxygen Demand, COD which all depend on the Dissolved Oxygen, DO. Total organic Carbon, TOC and Total Dissolved Solids; TDS on the other hand are

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used to define the organic content of the water and the total ions in solution respectively. It is estimated that over 80% of the wastewater generated across the world are not presently collected or treated [7]. Ground water pollution by various organic and inorganic substrates may alter the quality of that water, which may cause adverse health effects on humans. Several works on water quality have focused on the physicochemical characteristics of waters [8], [9]. The aim of this study therefore, physic-chemical analysis of the water and the mechanical test of GI pipe, water flowing through a pipe will influence the mechanical properties and extent of any corrosive action due to salinity. High alkalinities values in water are associated with high dissolved solids which can create scale build up on water pipeline systems, especially hot water pipeline systems. Scale build up in the pipeline system can increase power consumption and also increase the costs to heat the water.

2.0 Materials and Methodology

2.1 Materials:

Generally Galvanized Iron is used as piping material. Galvanizing is a process of coating iron or steel with zinc in order to provide greater protection against corrosion for the iron or steel base. Chemical Composition of Soft Iron:-C = 0.03%Si = 0.05%Mn = 0.20%P = 0.01%S = 0.02%. Galvanized iron and steel's resistance to corrosion depends largely on the type and thickness of the protective zinc coating and the type of corrosive environment. The zinc coating on galvanized iron and steel may be corroded by: Acids, strong alkalis, and is particularly vulnerable to corrosion by sulfur acids produced by hydrogen sulfide and sulfur dioxide pollution in urban atmospheres. [10]

The zinc provides a barrier against corrosion so that the pipe may be exposed to the outdoor environmental elements. The protective barrier proves equally effective against damage from indoor humidity. The reason for this is the the zinc is oxidizes easier than the iron so even if the layer of zinc is broken the zinc will oxidize before the iron. [11]

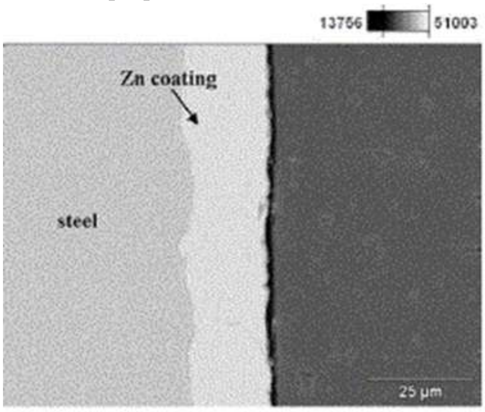


Fig.1: SEM image of cross section of galvanized Iron

The coating that develops during the galvanizing process is metallurgically bonded to the steel – virtually becoming a part of the steel itself. During the reaction in the kettle, the zinc interacts with the iron in the steel to form a series of zinc-iron alloy layers. The photomicrograph below is a cross section of the galvanized steel coating, showing a typical microstructure comprised of three alloy layers and a layer of pure metallic zinc.

Fig.2: The sample GI pipe used for carrying sample water

2.2 Methodology:

It is needless to emphasize the importance of water in our life. We need water for different purposes; we need water for drinking, for industries, for irrigation, for swimming, for fishing etc. Thus water for different purposes has its own requirements for the composition and purity and each body of water has to be analyzed on a regular basis to confirm to suitability. The types of analysis could vary from simple field testing for a single analysis to laboratory based multi component instrumental analysis. The representative sample of water that is taken should be the one that truly reflects the composition of the water sample to be analyzed. Due to varying period of time that may lapse between sample collection and analysis, storage conditions must be such as to avoid undesirable loses, contamination or other changes that could affect the results of the analysis. [12]

Khulna University of Engineering & Technology (KUET) is situated in southwestern part of Bangladesh, and the area of study is in the southwest coastal belt of the country, is facing enormous challenges in meeting the rising freshwater demand due to limited water supply from the available ground water and surface water sources as they are affected by the salinity and other water quality problems.

Water samples were collected in pre-cleaned plastic bottles from KUET in the form of ground water and surface water. The samples were analyzed for pH, DO, BOD, COD, TOC, TDS and alkalinities using standard analytical techniques. [13] Results obtained were expressed in bar diagram.

The pipe that carry the sample water has undergone some tests. Mainly the surface morphology of the GI material has been tested through Scanning Electron Microscope (SEM) images. Materials made with unique sizes and structures of grain are viewed by microscope. Generally, there are two types of electron microscopes, transmission electron microscope (TEM) and scanning electron microscope (SEM). TEM shoots electrons through the sample and measures how the electron beam changes as it is scattered in the sample; SEM images the sample surface by scanning it with electron beams in a raster scan pattern. SEM is used to investigate the crystal growth or structure evolution processes in our work. It is a very powerful tool to study the crystal growth morphology and assist the micro and nanofabrication.

Besides the Brinell Hardness Number (BHN or HB) of the internal surface of the pipe has been determined by a Tensometer using conventional method. The value of BHN was compared with the conventional value to evaluate the changes of the pipe surface due to the impact of water.

Fig.3: Tensometer used for BHN test

3.0 Impact of Water:

Many water quality factors affect corrosion of pipes used in water distribution, including the chemistry and characteristics of the water (e.g., pH, alkalinity, biology), salts and chemicals that are dissolved in the water, and the physical properties of the water (e.g., temperature, gases, solid particles). The tendency of water to be corrosive is controlled principally by monitoring or adjusting the pH, buffer intensity, alkalinity, and concentrations of calcium, magnesium, phosphates, and silicates in the water. The following Table 1 illustrates the significance of major constituents of water and their subsequent significance.

Table 1: Major constituents of water and their effect

Constituent or physical property	Significance
Calcium (Ca) & Magnesium (Mg)	Cause hardness and most of the scale- forming properties of water;
Iron(Fe)	On exposure to air, iron in ground water oxidizes to reddish brown sediment. More than about 0.3 mg/L stains laundry and utensils reddish brown. Iron and manganese together should not exceed 0.3 mg/L.
Carbonate (CO_3^{2-})	Bicarbonateandcarbonateproducealkalinity.
Sulfate(SO_4^{2-})	Sulfate in water containing calcium forms hard scale in pipe. In high concentrations, sulfate in combination with other ions gives a bitter taste to water. Concentrations above 250 mg/L may have a laxative effect.
Nitrate(NO_3^-)	Concentrations much greater than the local average may suggest pollution. Nitrate encourages growth of algae and other organisms which produce undesirable tastes and odors.
Totaldissolved solids(TDS)	Total dissolved solids concentrations are useful for comparison to established water-quality standards. Water with more than 1000 mg/L of dissolved solids may contain minerals which impart a distinctive taste.
pH (Hydrogen-ion activity)	The pH is a measure of acidity. A pH of 7.0 indicates neutrality of a solution. Values higher than 7.0 denote increasing alkalinity; values lower than 7.0 indicate increasing acidity. Corrosiveness of water generally increases with decreasing pH, but excessively alkaline waters may also attack metals.
Hardnessas $CaCO_3$	Hard water consumes soap before a lather will form, deposits soap on bath tubs, and forms scale in boilers, water heaters, and pipes. Waters of hardness 0 to 60 mg/L are termed soft; 61 to 120 mg/L moderately hard; 121 to 180 mg/L hard; and more than 180 mg/L very hard.

4.0 Result Analysis:

4.1 Water Deposits

In present investigation the pH values of the ground water and surface water sample are found in 7.6 and 6.9, respectively. Acid-base reactions are very essential in ground water, because of their effect on pH and their ion chemistry in water influences materials. BOD of ground water and surface water sample were zero. In general, the BOD of groundwater must be zero because organic matters are mostly filtered through subsurface strata and thus leaving no space for the development of microorganisms which are responsible for water borne diseases. But some time there is BOD in water which is due to industrial effluent might have contributed some organic pollutants sometime percolate through the sub soil and reaches the ground water table forming contaminated pool, which is potential threat of water contamination in future. In present investigation COD of ground water and surface water sample were found 9 and 5mg/L. The COD is used to measure pollution load in terms of quantity of oxygen required for oxidation of organic matter to produce carbon dioxide and water. Water with high COD indicates that there is presence of organic waste and oxygen is required for the oxidation of these wastes so all oxygen is used for the oxidation of organic waste and that are why there is inadequate oxygen available in water sample.

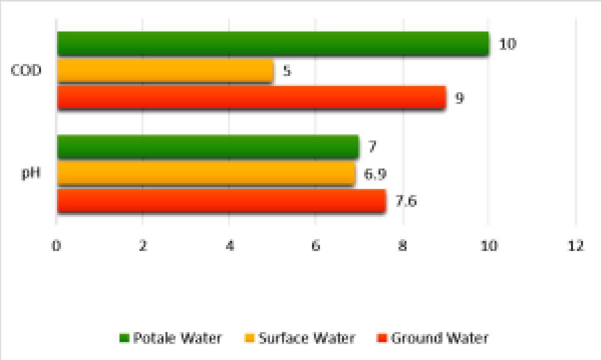


Fig.4: Comparison of COD and pH of three sample water

Alkalinity of ground water and surface water sample in present study came 412 and 399 mg/L. This indicates that water from sampling location is hard, this high alkalinity values indicates the presence carbonate and bicarbonate ions. Effect of alkalinity is that much low and much high values of alkalinity can cause nuisance problems. Alkalinity values less than 75 mg/L can change pH levels in water system and make the water corrosive. Corrosive water can then lead to potentially harmful metals dissolving from the plumbing into the drinking water which may cause several health effects by increasing metal concentration in water. High alkalinities values, over 500 mg/L are in water are associated with high dissolved solids which can create scale build up on water pipeline systems, especially hot water pipeline systems. Scale build up in the pipeline system can increase power consumption and also increase the costs to heat the water. The total hardness of ground water and surface water were found 750 and 446 mg/L. In present investigation TDS of the ground water and surface water sample were found 350 and 602 mg/L.

The salinity behavior of any water samples is generally characterized by its total dissolved solids content17. In the present study the range of total solids of ground water and surface water sample were found 390 and 650 mg/L. The term solid refers to the matter that are either filterable or in filterable and remain as residue upon filter paper by drying at a defined temperature after drying. Different forms of solids (TDS, TSS and TS) are defined on the basis of method applied for their determination. High concentration of total solids during summer was probably due to low level of water, the direct relationship between rainfall and total solids was attributed to an increased load of soluble salts as results of surface runoff. In water total solids, total dissolved solids and total suspended solids are composed mainly of carbonates, bicarbonates, chlorides, sulphates, nitrates, Ca, Mg, Na, K, Mn and other organic matter silts which are present either in dissolve or in suspended form.

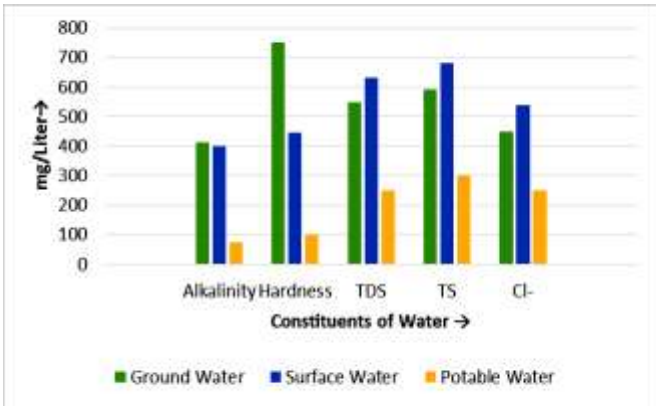


Fig.5: Graphical comparison of values of major constituents of three sample water

4.2 Material Properties

The Brinell Hardness has been measured using the following equitation. The values of load and Impression diameters are measured by Tensometer. Hardness is a vital mechanical property of material. Brinell hardness measurement principle is the test force F(N) with a certain size, the diameter D (mm) of hardened steel balls or carbide ball pressed into the surface of the metal under test, to maintain a predetermined time after the drop test force, the the indentation average diameter d (mm) measured with a reading microscope, and then the equation Brinell hardness HB value, or the value d from the prepared Brinell hardness table to detect HB Brinell hardness measurement method is suitable for cast iron, non-alloy, annealing and quenching and tempering steel, the determination should not be too hard, too small, too thin and the surface does not allow the larger indentation specimen or work piece. [14]

$$\text{BHN:} \quad \frac{P}{\frac{\pi D}{2}\{D-\sqrt{(D^2-d^2)}\}}$$

Where
BHN = Brinell hardness number
P = load on the indenting tool (kg)
D = diameter of steel ball (mm)
d = measure diameter at the rim of the impression (mm)
It is desirable that the test load are limited to an impression diameter in the range of 2.5 to 4.75 mm.
Here, for interior surface of pipe
P= 9 KN= 917.745 Kg
D= 5 mm
D= 2.6 mm,

BHN (Internal surface)= 161 and
BHN (External surface) = 198

So BHN or HB of the affected (Used 14 Months) GI pipe is 161.
A GI pipe before using has a BHN of 260-350.
If used in normal conditions where potable water is transferring, after 14 months BHN is around 220~240.
There is a drastic change in BHN if used to transfer saline water.

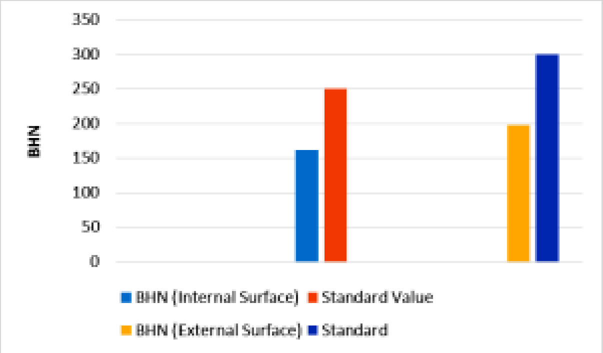
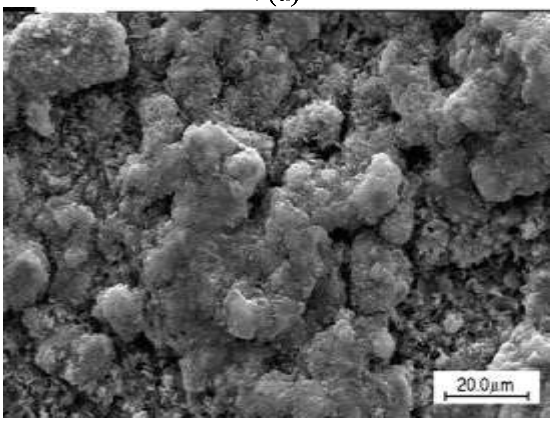


Fig.6: Comparison of Brinell Hardness for External and internal surface of GI pipe

Surface Morphology:
Electrochemical or Mechano-chemical behavior of a surface, such as corrosion or corrosive wear, is extremely complicated and involves various chemical, physical and mechanical factors. Fig. 2 shows the micrograph appearance of the GI pipe interior surface.

7(a)



7(b)

Fig.7: Corroded pipe surface (a) 1000X and (b) 50000X (SEM)

Fig. 7 shows the appearance of the metal through electron microscope. Fig 7(a) is the view of 1000X by microscope and 7(b) is the view of 50,000X by SEM. Amounts of Pitting holes are observed on the surface of the metal in the SEM image. It shows that the susceptibility of the metal to breakage for corrosion was more in the internal surface of pipe. The pitting corrosion readily occurred on the surface of the pipe in the presence of Sulfate Reducing Bacteria (SRB).The surface of the pipe was still contained the polishing grooves in the internal surface. However, the grooves were not apparent in the 1000X view because Light cannot be used to see the Nano world, as its resolution is limited by its own wavelength, so optical microscopes are useless for nanotechnology. The large scale is formed in the internal surface of pipe which indicates that the severe corrosion has occurred.

5.0 Discussion & Conclusion

The characterization of sample water collected from ground and surface were illustrated in bar diagram figure 4 and figure 5. In figure 4 the values of organic compound for sample waters has been compared. The Chemical Oxygen Demand (COD) for surface and ground water are 5 and 9 respectively. The requisite amount for potable water suggested by World Health Organization (WHO) is 10. The hydrogen ion activity (pH) was around the standard value for both cases. Figure 5 focuses on the characteristics which are critical for corrosion and scale formation in the pipe. Alkalinity of surface and ground water are much more than the amount of potable water which indicates the presence of Bicarbonate (HCO3) and Carbonate (CO3). These compounds are reasonably responsible for scale forming. The hardness is also much higher in case of ground and surface water. Hardness can also be expressed as the equivalent amount of CaCo3. If the amount exceeds 180 mg/L for any water it is said as very hard. So the sample water is undoubtedly very hard as its hardness is more than 400 for both case. The amount of Total Dissolved Solid (TDS) and Total solid constituents are very high compared to the WHO standard. For these unexpected higher values of chemical compounds the properties of piping material has changed a lot. The pipe sample used for testing had carried sample water for not more than 14 months. The Brinell Hardness test shows there is a drastic change in the BHN or HB value for both the internal and external surface of the pipe. The microscopic image shows the corroded and scale formed internal surface of the pipe.

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