ENVIRONMENTAL CONSEQUENCES OF DUMPING DEAD BATTERIES OF "INSTANT POWER SUPPLY UNIT (IPS)" ON SURFACE WATER: A CASE STUDY ON KHULNA CITY

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ABSTRACT

Lead acid batteries comprise electrolytes, lead, lead alloy grids, lead paste, organics and plastics. These components include a significant amount of toxic, dangerous, combustible, and explosive compounds, hence posing possible risks for both human and aquatic life. The primary objective of this research is to study the hazards posed by the recycling of lead acid batteries, specifically the metal, liquid, and plastic wastes generated in the process. Twenty-one surface water samples were collected from the Bhairab, Moyur, and Rupsha rivers, with three taken at the disposal point and the remaining eighteen taken at 165-foot intervals both upstream and downstream. Distinct variations in the quality parameters of surface water samples were evident upstream, whereas downstream showed negligible fluctuations compared to the disposal points. The pH and electric conductivity (EC) were found to be 2.1, 2, and 2.3; and 3564, 3422, and 3503 µS/cm for Bhairab, Moyur, and Rupsha rivers, respectively, at the disposal points. The TDS, COD, and BOD values were significantly higher than the standard limit for all three samples at the disposal points. The lead concentrations at the disposal points of the Bhairab, Moyur, and Rupsha rivers were determined to be 0.732, 0.617, and 0.795 ppm, respectively. Disposal points show about 8 to 10 times higher lead toxicity than the far-located samples from both up and downstream. It has been demonstrated that a significant proportion of both male and female workers are dealing with hypertension-related conditions. The workers in the open market experienced a range of health conditions, including headaches (37%), colic pain (25%), nausea (14%), tremors (15%), anemia (6%), brain damage (1%), cancer (1%), and kidney damage (2%). Hence, it is imperative to enhance the recycling process of lead-acid batteries while simultaneously minimizing and closely monitoring the discharge of industrial effluents.

Keywords: *Instant power supply unit (IPS), lead acid batteries, recycling, human health, aquatic ecosystem*

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1. INTRODUCTION

An Instant Power Supply unit (IPS) is an electrical device that supplies electricity at the time of primary supply failure. It is the best alternative for the power supply facilities to provide continuous electricity when the main supply is unavailable. Generally, it includes a charger circuit, a battery, an oscillator circuit, and an output circuit. The charger circuit charges the battery by using the electricity of the main supply when it is available, and at the time of primary supply failure, it provides the electricity. IPS is an automatic system that does not require any fuel like a generator (Kingsley & Stauffer, 2000; Mehbub, 2012; Roa, 2009). Lead-acid batteries are mainly used in the IPS unit. These batteries are made of lead, sulfuric acid, zinc–manganese dioxide, and lithium–copper oxide, which are very toxic substances (Jache et al., 2014; Osiak et al., 2014).

As the global energy demand continues to rise, the use of storage devices, or batteries, becomes increasingly crucial. Fortunately, our access to necessary components and raw materials puts us in a solid position to meet this demand while also promoting sustainability. However, the element lead, which is essential in lead-acid batteries and can be found in abundance in the Earth's crust, presents a significant challenge due to its harmful effects on the environment and human health. Lead usage worldwide is driven primarily by the production of lead-acid batteries, accounting for approximately 85% (Lewis, 1997; Liu et al., 2016; Organization, 2017).

Heavy metals, notably lead, are known to be hazardous pollutants that have raised major environmental concerns worldwide. Dumping this kind of material in surface water is very detrimental to the environment. Several road materials, including Styrene Butadiene Styrene (SBS) (Modified & Binder, 2023), Ground Granulated Blast-furnace Slag (GGBS) (Adiba et al., 2020), Asphaltic materials (Zubaer & Riyad, 2023), fly ash (Riyad et al., 2021), and other compounds, can pollute surface water. The proper management and recycling of spent lead-acid batteries has garnered significant public attention and worry because of the potential harm it can cause to the environment. Given that lead is sourced and processed in different parts of the world, its detrimental effects have become a key topic of discussion (Saadat et al., 2023; Tong et al., 2000). Efficient management and recycling of solid waste are crucial for maintaining the environment's health (Ahmed et al., 2021; Ahmed & Moniruzzaman, 2018; Hamer, 2003; Hossain et al., 2011; Memon, 2010). The inappropriate disposal of hazardous substances, such as lead-acid batteries, presents a substantial risk. Specifically, facilities that break down lead acid batteries, which are frequently situated in close proximity to rivers, can potentially contribute to the contamination of surface water (Zhang et al., 2018). The emission of hazardous substances from these activities has a direct and detrimental effect on river ecosystems, threatening aquatic organisms and compromising the welfare of communities who depend on these water supplies (Roy et al., 2019, 2020). In order to reduce these hazards, it is crucial to implement strict rules on waste management (Ahmed & Chakrabarti, 2018; Ahmed et al., 2017; Alam, 2016), encourage recycling efforts (Roy et al., 2021; Tortajada, 2020), and strictly supervise the release of wastewater (Abdulhameed et al., 2021) from businesses such as lead acid battery dismantling to protect our waterways and ensure overall environmental sustainability.

While various battery types are available, lead-acid batteries have emerged as a reliable and economical solution for energy storage. In the realm of renewable battery systems, lead acid and nickel batteries (NiCd, NiMH) have historically been popular. However, nickel batteries are becoming obsolete due to their high cost and environmental considerations. Although lithium-ion batteries dominate the portable electronics sector, their large-scale application faces challenges in areas where volume, weight, temperature sensitivity, and low maintenance outweigh initial costs. Lead-acid batteries, with a history spanning 150 years, remain a well-established choice due to their low cost, recyclability, and conventional industrial base (Javed et al., 2020). Lead acid batteries are made of metallic lead, sulfuric acid, zinc–manganese dioxide, and lithium–copper oxide, which are very toxic substances (Jache et al., 2014; Osiak et al., 2014). The battery includes a box, cap, electrochemical cell, connector, electrical accumulator, electrolyte, anode, cathode, plate separator, vent cap, and sealant (Uddin et al., 2017). The usual lead-acid battery composition consists of 25–30 weight percent lead component, 35–45% electrode paste, 10–15% sulfuric acid, 5–8% polypropylene, 4–7% various polymers, and 1–3% ebonite.

Recycling practices in the lead-acid battery industry can have a significant environmental impact, with over 20 million tons of lead consumed worldwide in 2015. Lead exposure is a significant concern for children's health and occupational diseases, affecting the kidneys, gastrointestinal tract, central nervous system, and blood-forming system. The research aims to determine the impact of these practices on the environment. Lead-acid batteries are often disposed of in solid waste landfills or illegally, creating a potential for sulfuric acid and lead to mixing in soil, water, and land fields. Bangladesh's recycling infrastructure is underdeveloped, and many people are unaware of the harmful consequences. This research was designed for those backgrounds and aimed to make a profile of lead and sulfuric acid contamination in Khulna City. Ph, EC, TDS, COD, DOD, and Lead were measured in this investigation. Pollutant levels in lead-acid battery effluent can vary depending on the manufacturing process used. Solid wastes are recycled back into the industrial process, liquid wastes are neutralized by an appropriate ETP system (Islam, 2012), and air pollutants are eliminated using ATP.

2. MATERIALS AND METHODS

The inexpensive part for a better knowledge of numerous components and elements related to the research studies is the use of qualitative and quantitative approaches.

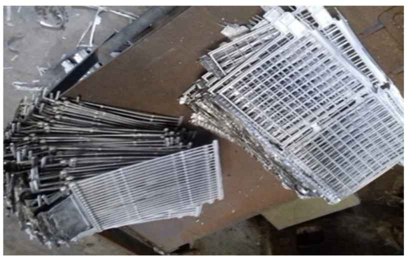
1.1. Study Area

Khulna is the third largest and one of Bangladesh's most crucial river port cities. It is in the southwestern part of the country and surrounded by the rivers Rupsha and Bhairab. On the north side of the city, the Bay of Bengal is connected to the lower extreme of the Ganges delta, the world's largest river. The largest mangrove forest, Sundarbans, is in the southern part of the city. The city covers a total area of approximately 150.57 square kilometers. The study area was at Bhairab River, Moyur River, and Rupsha River Khulna, Bangladesh.

Figure 1: Study area Bhairab River, Moyur River, and Rupsha River Khulna, Bangladesh Khulna.

1.2. Field survey and Industry visit

To manufacture lead acid batteries, the lead plate, and machine that produces lead balls and lead balls are required, which is shown in the following pictures 2, 3, &4.

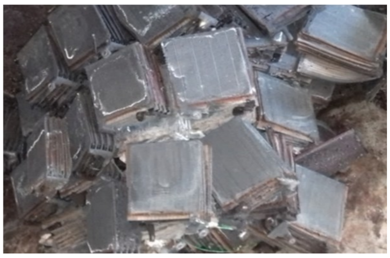


Picture 2: Lead plate

Picture 3: Machine for producing lead ball

Picture 4: Lead ball

and Pictures 5, 6, &7 show the dead batteries recycling process from used lead acid batteries, workers breaking batteries, and preliminary recycling.



Picture 5: Used Lead acid batteries

Picture 6: Workers breaking batteries.

Picture 7: Preliminary recycling.

1.3. Sample Collection

Twenty-one surface water samples were collected from the rivers Bhairab, Moyur, and Rupsha, with three taken at the disposal point and the remaining eighteen taken at 165-foot intervals both upstream and downstream. Whereas Samples 1, 2, and 3 were collected 495 feet, 330 feet, and 165 feet upstream away from the disposal point, Sample 4 was collected at the disposal point, and Samples 5, 6, and 7 were collected from 165 feet, 330 feet, and 495 feet downstream away from the disposal point of the three rivers Bhairab, Moyur, and Rupsha.

1.4. Experimental Methodology

Atomic absorption spectroscopy (AAS) technology is used to determine the lead. In this process, hollow cathode lamps were used, where lamp current was used five mA and wavelength 283.3 nm. Hot nitric acid and then distilled water were used to wash the containers before using in the experiments. Water samples collected from the rivers were then filtered through the Millipore Filtration technique by using a 0.45 mm membrane filter, and some sediment was found. The sediment was then stored in the dark at four degrees centigrade, and a 50 ml sample was taken for analysis. The sample was acidic (pH 2 to 3) already, so there was no need to acidify the sample. At 120-130 degrees centigrade on a hot plate, the sample was boiled until it achieved a volume of about 25-30 ml and a light color. After that, the sample was again filtered through the filter paper. 2 gm of dried sediment was taken in a 100 ml beaker and 15 ml of concentrated HNO3 was added and then heated at 130-degree centigrade temperature for 5 hours until 2-3 ml remained in the beaker. After finishing the digestion process, the residual content was filtered through filter paper and made up to 100 ml volume with deionized water.

BP (blood pressure) of workers in the open market was measured by stethoscopes. A questionnaire survey was done about male and female workers who were facing various disease occurring symptoms because of working in the lead-acid recycling industry.

2. RESULT AND DISCUSSIONS

Numerous quality parameters of the water sample were examined, and the results are shown in numerical form in Tables 1, 2, and 3 compared with the standard surface water. This study primarily examined the pH level and heavy metal (lead) concentration in surface water, as well as the environmental risk assessment in Bangladesh's coastal rivers (Bhairab, Moyur, and Rupsha). In the case of downstream rivers, lead contamination decreases with increasing sample water collection distance from the disposal point; in the case of upstream rivers, the pattern varies.

Table 1: Comprising water parameters value of Bhairab (B*) river with standard surface water

Location from disposal point	Sample No.	pH	EC (uS/cm)	TDS (mg/L)	COD (mg/L)	BOD (mg/L)	Lead (mg/L)
495 ft away (upstream)	B1	7.65	4634	2280	185	45	0.062
330 ft away (upstream)	B2	7.24	4250	2370	273	75	0.055
165 ft away (upstream)	B3	6.89	4170	2592	392	92	0.078
At disposal point	B4	2.1	3564	2921	436	121	0.732
165 ft away (downstream)	B5	5.10	3720	2862	355	86	0.433
330 ft away (downstream)	B6	6.23	4070	2640	258	57	0.235
495 ft away (downstream)	B7	7.58	4320	2422	183	43	0.127
Standard surface water for industry effluent	_	6 to 9	1200	2100	200	50	0.100

*B = Samples from Bhairab River

Table 2: Comprising water parameters value of Moyur (M*) river with standard surface water

Location from disposal point	Sample No.	pH	EC (uS/cm)	TDS (mg/L)	COD (mg/L)	BOD (mg/L)	Lead (mg/L)
495 ft away (upstream)	M1	7.87	4245	2201	193	49	0.071
330 ft away (upstream)	M2	7.31	4002	2444	281	82	0.064
165 ft away (upstream)	M3	6.77	3781	2632	401	101	0.083
At disposal point	M4	2	3422	3010	452	135	0.617
165 ft away (downstream)	M5	4.29	3593	2759	363	91	0.397
330 ft away (downstream)	M6	5.53	3924	2590	282	63	0.241
495 ft away (downstream)	M7	7.33	4021	2345	205	47	0.112
Standard surface water for industry effluent	_	6 to 9	1200	2100	200	50	0.100

*M = Samples from Moyur River

Table 3: Comprising water parameters value of Rupsha (R*) river with standard surface water

Location from disposal point	Sample No.	pH	EC (uS/cm)	TDS (mg/L)	COD (mg/L)	BOD (mg/L)	Lead (mg/L)
495 ft away (upstream)	R1	6.77	4921	2504	298	68	0.079
330 ft away	R2	6.13	4753	2654	377	97	0.084

(upstream)							
165 ft away (upstream)	R3	5.56	4302	2794	466	117	0.098
At disposal point	R4	2.3	3503	3102	532	167	0.795
165 ft away (downstream)	R5	4.11	3812	2997	421	99	0.582
330 ft away (downstream)	R6	5.31	4224	2820	376	83	0.363
495 ft away (downstream)	R7	6.93	4746	2701	287	61	0.207
Standard surface water for industry effluent	_	6 to 9	1200	2100	200	50	0.100

*R = Samples from Rupsha River

1.1. Graphical representations of water parameters

Figure 1 indicated the pH values of 3 rivers were 5.10, 4.29, and 4.11 up to 165 ft (downstream) from the disposal point, and 6.89, 6.77, and 5.56 up to 165 ft (upstream) away from the disposal point, both of which were below 7, indicating that the three rivers water had become acidic. The EC of all water samples negatively impacts the riverine environment, as shown in Figure 2, which is significantly greater than the standard value of surface water for industrial effluent.

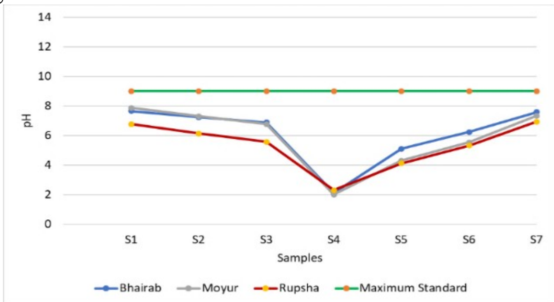


Figure 1: Comparison of three river samples pH with standard value of surface water.

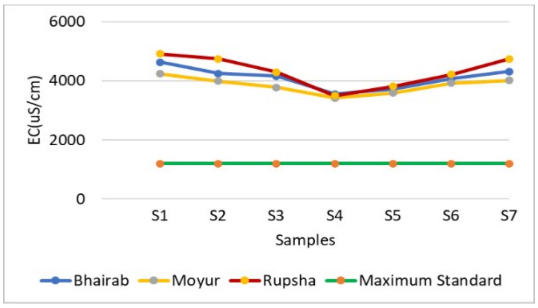
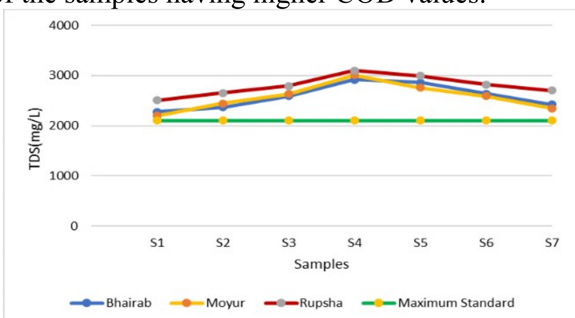


Figure 2: Comparison of three river samples EC with standard value of surface water.

Figure 3 clearly shows that all the sample water from three rivers have higher TDS values when compared to the standard value. This could have a negative impact on the Bhairab, Moyur and Rupsha River residents who use the water for domestic purposes. Figure 4 illustrates that the Bhairab River with the exception of samples B1 and B7, has COD values above the standard value, and sample B4 has the highest COD value. In Mayur River, only sample M1 has the lowest COD value below the expected value but all other samples from Mayur and Rupsha River have COD values higher than the standard value. The water is highly contaminated and unfit for drinking, as evidenced by the majority of the samples having higher COD values.



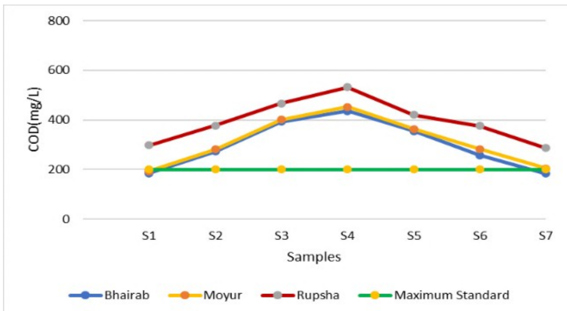


Figure 3: Comparison of three river samples TDS

Figure 4: Comparison of three river samples

with standard value of surface water. COD with standard value of surface water.

Similarly, figure 5 displays the variation in BOD values for all samples. In Bhairab River, Sample B4 has the highest BOD value, Moyur River's sample M1 has the lowest BOD value, and all the other samples of Moyur and Rupsha River's BOD values are relatively higher than the standard value. It also demonstrates the similar characteristics of COD. Figure 6 shows the concentration of Lead. The majority of the samples, particularly those from downstream, show that the three rivers are contaminated with lead metals because their values are higher than the standard value. Higher lead values severely harm human health. It can damage the kidneys, and the brain, causing anemia and weakness. It can also damage the developing nervous system of a baby. Extremely high concentrations can occasionally be fatal.

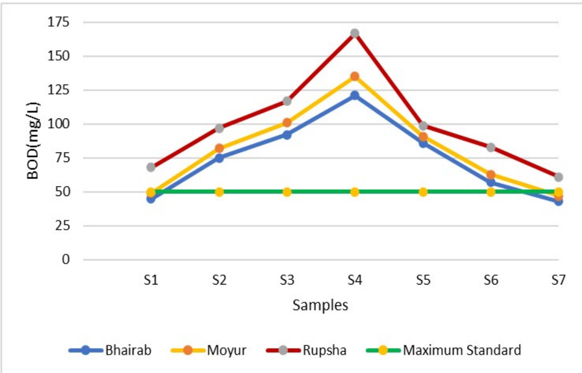


Figure 5: Comparison of three river samples BOD with standard value of surface water.

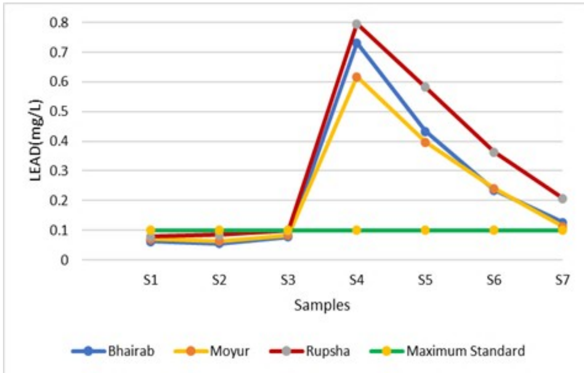


Figure 6: Comparison of three river samples LEAD with standard value of surface water.

The concentrations of parameters such as EC, TDS, COD, BOD, and Lead in the river water samples exceeded the standard limits at disposal points for all three samples. This occurrence was primarily attributed to the discharge of lead-acid battery braking water at these specific points. Other factors, such as the mixing of wastewater and landfill leachate, could also contribute to the elevated parameter values. To substantiate this, measurements were taken at various locations upstream, at battery water disposal points, and downstream along the rivers. As the sampling distance increased from the disposal points, the parameter values decreased, with some values falling below the standard limits at 495 ft upstream and downstream. If the elevated values were not solely due to the dumping of battery braking water, the values would be expected to be similar or close at all sampling points. Therefore, it can be concluded that the discharge of lead-acid battery braking water significantly impacts the surface water quality parameters.

2.1. Health effects on battery breaking associates

A survey regarding health concerns, age distribution, and the proportion of male to female employees in the battery-breaking industry was conducted among workers in Khulna City. The survey, which was conducted among industrial workers in Khulna City, focused on two manufacturers of lead-acid batteries and the recycling sector. Additionally, workers in the open market lead-acid battery recycling were surveyed.

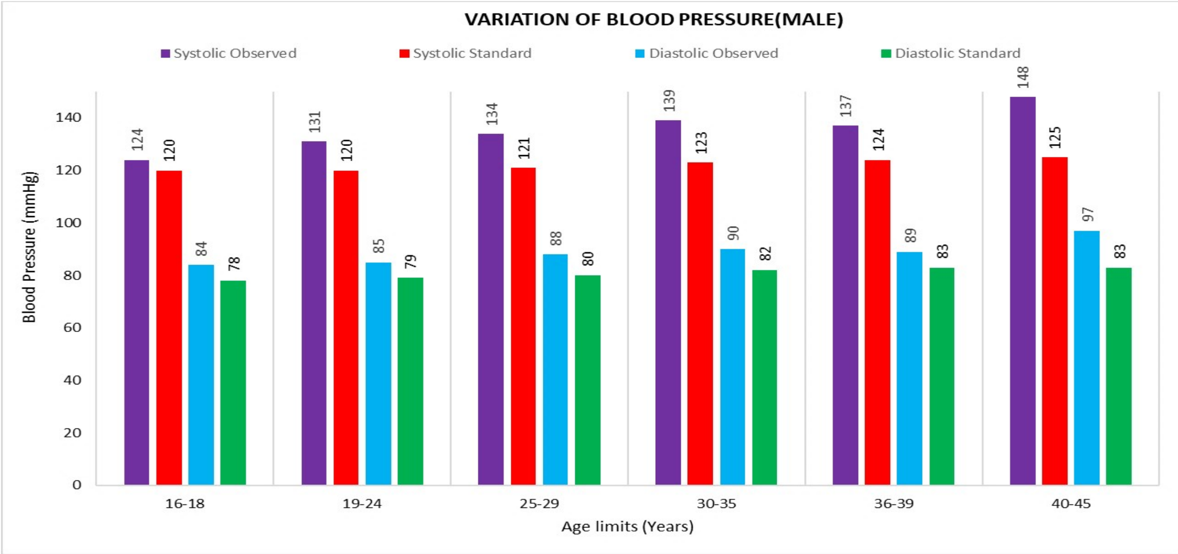


Figure 7: Comparison of average male Blood Pressure (BP) in different age limits with respect to standard.

A survey has been conducted among 200 male employees, ranging in age, who are involved in recycling lead-acid batteries. 30 of the 200 participants were between the ages of 16-18 years. 40 between the ages of 19-24 years, 37 between the ages of 25-29 years, 55 between the ages of 30-34 years, 24 between the ages of 35-39 years and 14 between the ages of 40-45 years. To calculate the average blood pressure for each group, the blood pressure of 200 workers was measured and the results were gathered. The comparison between each age limit's moderate blood pressure and standard blood pressure is displayed in Figures 7 (for men) and 8 (for women). It has been observed that workers who have been employed in this industry for longer than six months have blood pressures that are higher than the average blood pressure for their age, given the age limit.

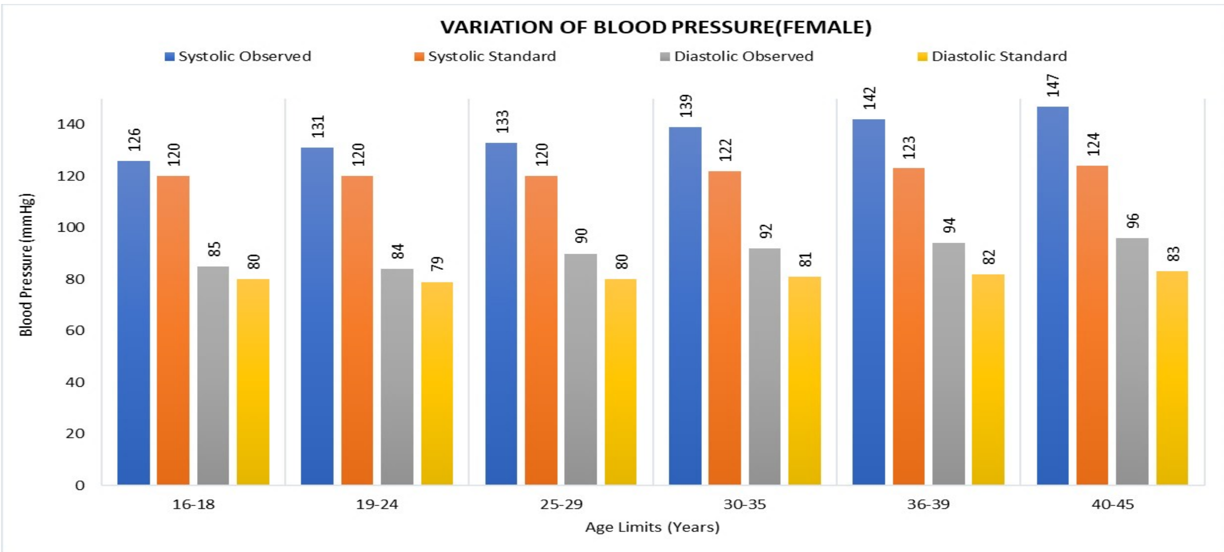


Figure 8 : Comparison of average female Blood Pressure (BP) in different age limit with respect to standard.

A survey has been conducted among 260 female employees, ranging in age, who are involved in recycling lead-acid batteries. 32 of the 260 participants were between the ages of 16-18 years. 38 between the ages of 19-24 years, 47 between the ages of 25-29 years, 72 between the ages of 30-34 years, 42 between the ages of 35-39 years and 29 between the ages of 40-45 years. To calculate the average blood pressure for each group, the blood pressure of 260 workers was measured and the results were gathered. The comparison between each age limit's moderate blood pressure and standard blood pressure is displayed in Figure 6. It has been observed that workers who have been employed in this industry for longer than six months have blood pressures that are higher than the average blood pressure for their age, given the age limit.

2.2. Health effects on industry and open market workers

This research, which investigates the health implications of discarding dead batteries from Instant Power Supply Units (IPS) into surface water in Khulna City, revealed a notable incidence of health issues among workers in both industrial settings and open markets. Figures 9 and 10 depict the ailments prevalent among individuals directly involved in lead acid battery breaking. In the industry personnel, the most commonly reported symptom was headaches, documented by 43% of individuals, highlighting a broad impact on neurological health. Colic pain, reported by 28% of individuals, and nausea, experienced by 17% of individuals, indicate potential gastrointestinal disturbances within this demographic. Furthermore, 12% of the workers reported experiencing tremors, a symptom commonly associated with neurological or muscular issues.

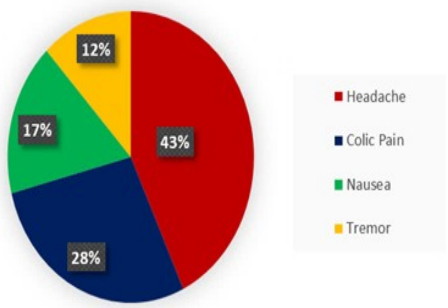


Figure 9: Diseases of industry worker

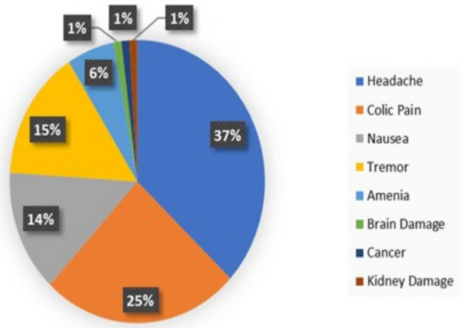


Figure 10: Diseases of open market workers

Among open market workers, the prevalent health concerns were headaches, affecting 37%, followed by colic pain at 25%. Moderate health effects were observed in 14% and 15% of individuals experiencing nausea and tremors. Additionally, 6% of individuals were affected by unspecified health issues. A concerning 1% reported being affected by more severe conditions such as brain damage, cancer, and kidney damage. These findings underscore the substantial health risks linked to exposure to hazardous substances from discarded batteries. They emphasize the urgent need for enhanced waste management practices and the implementation of protective measures to safeguard the well-being of these workers.

3. CONCLUSION.

This study has provided insistent evidence of significant lead pollution in the Bhairab, Rupsha, and Mayur Rivers, with lead concentrations surpassing safe thresholds. The downstream locations near the disposal points showed distinct variations in quality parameters, including pH and electric conductivity (EC), with readings of 2.1 to 2.3 for pH, and 3564 to 3503 µS/cm for EC across the three rivers. The total dissolved solids (TDS), chemical oxygen demand (COD), and biological oxygen demand (BOD) values were alarmingly higher than standard limits. Notably, the lead concentrations at these points were 0.732, 0.617, and 0.795 ppm for Bhairab, Moyur, and Rupsha rivers, respectively, indicating an utter increase in lead toxicity, about 8 to 10 times higher than locations farther from the disposal points.

The environmental impact of this lead pollution extends to substantial health ramifications for the local workforce. A considerable number of both male and female workers in the vicinity are suffering from hypertension-related health issues. The workers in the open market, in particular, reported a range of health conditions with varying prevalence: headaches (37%), colic pain (25%), nausea (14%), tremors (15%), anemia (6%), brain damage (1%), cancer (1%), and kidney damage (2%).
These findings underscore the urgent need for enhanced recycling processes for lead acid batteries and rigorous monitoring of industrial effluents' discharge. It is important to adopt comprehensive and effective strategies to mitigate the environmental and health impacts of lead contamination in these riverine systems not only for preserving environmental integrity but also for safeguarding public health, particularly that of workers who are directly exposed to these hazardous conditions.

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