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IMPACTS OF THE PARTIAL RELOCATION OF HAZARIBAGH TANNERIES ON THE ENVIRONMENT AND HUMAN HEALTH: FOCUS ON CHILDREN AND VULNERABLE POPULATION

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Abstract

Purpose of the study: The purpose of the study is to determine whether the partial relocation of Hazaribagh tanneries has any effect on the area's soil quality with respect to chromium and to determine a possible link between human exposure/diseases to chromium, with the focus being placed on children and vulnerable population.

Methodology: Geochemical sampling and public health research related to fieldwork (Focus Group Discussions, two In-Depth Interview, and Key Informant Interview).

Main Findings: The study indicates that there is a significant presence of chromium in the area's soil two years following the partial relocation of Hazaribagh tanneries. Flu-like symptoms, generalized skin rash, and fertility issues are common in the vulnerable population. The residents are ignorant, belong to the marginalized section of the society, and do not fully comprehend of the impact of environmental exposure to chromium.

Applications of this study: The geochemical data may be used to identify in situ treatment technologies for remediation of the area's soil. The public health data will allow health policymakers to generate ideas and implement solutions to one of the greatest health challenges faced by the impacted population.

Novelty/Originality of this study: The study is multidisciplinary by nature and employs science and technology to systematically develop an insight into the environmental contamination resulting from the release of untreated effluent and solid waste containing chromium.

Keywords: *Chromium, Environmental Pollution, Hazaribagh, Leather Processing, Public Health.*

INTRODUCTION

Since the 1970s, Bangladesh's leather industry has grown steadily and has been vitally important for the country's economy. According to the Export Promotion Bureau data, for the fiscal year of 2016-2017, total leather exports were USD 116.73 million (Al-Muti, 2017). Approximately 90% of the exported leather products from Bangladesh originate in the Hazaribagh leather processing industry in the southwestern part of Dhaka, the capital of Bangladesh (Alam et al., 2020). There are approximately 220 tanneries located in the Hazaribagh area (Paul et al., 2013), ranging in size from small operations with a few workers to larger ones that employ a few hundred workers.

Tanning is the chemical treatment of raw animal hide or skin to convert it to leather. For the past several decades, chrome tanning has been the primary method of processing leather that involves the use of chrome powder and liqueur. Basic Chromium(III) Sulfate ($[Cr(H_2O)_6]_2(SO_4)_3]$; BCS) is considered as the most efficient and effective tanning agent; however, the BCS employed in leather tanning processes is not completely taken up by the hides and skin (Fabiani et al. 1997; McCartor and Becker, 2010). It has been reported that BCS uptake is limited to ~60% and the remaining Chromium (Cr) containing untreated effluent is released into the environment without treatment (Fabiani et al. 1997). Rasul et al. (2006) estimated that during full operation, every day at least 60,000 tons of hides and skins are processed in Hazaribagh and approximately 95,000 L effluent is discharged directly into the neighbouring environment. The discharged tannery effluent runs through open canals and flows through a sluice gate that is part of the flood protection embankment. Subsequently, the effluent discharges onto low-lying areas and eventually ends up in the Buriganga River, which flows along the southwest portion of Dhaka (Paul et al 2013). The Buriganga River, once a lifeline of Dhaka City, is now a biologically dead river. It is noteworthy that the pollutant levels in the wastewaters frequently surpass Bangladesh's permitted limits for tannery effluent and in some instances by many thousands of times the permitted concentrations. Given the extent of pollution, it is likely that a significant portion of the residents of the Greater Dhaka City has been directly or indirectly impacted by the disposed waste. It is safe to say that 'Hazaribagh', or 'Thousand Gardens', could not be further from its name. Over the years, the tanneries' waste disposal issues have received attention from the local news outlets. The Government of Bangladesh gave the tanners until March 31, 2017, to cease operations and move to an industrial park at Savar located roughly 20 km west of the current location. In 2017, roughly 35% of the tanneries reportedly moved to Savar.

Background data exists on the area's geology and concentrations of some chemical elements of concentrations in soil and Buriganga River from different governmental and non-governmental agencies. Previously detailed investigation on Cr concentrations of Hazaribagh sediments conducted about 19 years ago indicated Cr accumulation in these sediments and suggested possible mobilization of solid-phase Cr into underlying aquifers (Saha, 2001). Kabir et al. (2017) characterized the tannery effluent focusing on the growth of Cr (VI)-resistant bacteria and reported that the order of trace metallic constituents in the samples to be Cr > iron > lead > manganese > zinc > cadmium > copper. Additionally, these researchers found that the Cr level in the tannery effluent was 3887 times higher than the standard permissible limits, prescribed by ISW-BDS-ECR (1997). Note that Kabir et al. (2017) conducted their study prior to the partial relocation of the tanneries to Savar. It is important to note that following relocation, the soils in these areas were neither chemically evaluated nor treated for any non-hazardous or hazardous wastes. Any kind of settlement in such areas should proceed with much caution as windblown toxins along with possible contamination of water bodies may cause health hazards to the inhabitants. Common exposure routes of Cr to humans are ingestion, inhalation, and dermal contact. Although Cr, in trace amounts, is important for humans, exposures to certain Cr compounds are a real threat to living organisms (Losi et al., 1994; Zayed and Terry, 2003; Tumolo et al., 2020). The adverse health effects associated with Cr exposure include damage to gastrointestinal, respiratory, and immunological systems, along with reproductive and developmental problems.

Many researchers have studied different components of the Hazaribagh environmental pollution problem but to the best of our knowledge, there has been no systematic study to address the release and subsequent impact of Cr into the various environmental compartments specifically following the partial relocation of the tanneries. Also, there are no studies on Hazaribagh that have looked at the effects of Cr exposure on children including other vulnerable populations following the relocation. The proposed study is multidisciplinary by nature and employs science and technology to systematically develop an insight into environmental contamination resulting from the release of untreated effluent and solid waste containing Cr. In the first phase of the project, two sets of soil samples (during wet and dry months of the year) were collected from appropriate locations within the Hazaribagh leather processing area. Subsequently, the soil samples were analysed for Cr_{total} levels. Comparative analyses of the project data with past data are expected to indicate whether the partial relocation of tanneries to Savar has impacted the soil quality of the study area. In the second phase of the project, the goal is to determine whether a link exists between Cr exposure and human diseases of the study area, with particular focus on the children under 18 years of age and vulnerable population (i.e., pregnant women, and elderly). The second phase of the study employed standardized social surveys, group discussions, and participatory community meetings to develop a qualitative understanding of the extent of exposure to Cr.

The 2011 census lists the total population of the Hazaribagh sub-district as just over 185,000. Generally, low-income communities in Bangladesh are viewed as the path of least resistance as such these communities have fewer resources and political influence to oppose the establishment of unwanted facilities. The findings of the current study may be used as a basis to develop an awareness program(s) for these residents in order to mitigate health issues related to exposure to Cr.

STUDY AREA

The leather processing industry occupies an area of 4 km^2 in Hazaribagh Thana in the western part of Dhaka (Figure 1). Hazaribagh is located between 23˚43'30" - 23˚44'30"N latitude and 90˚20'30" - 90˚22'00"E (Zahid et al., 2006). Hazaribagh is connected to other parts of Dhaka through major arterial roads. To the west, the area is bounded by a flood protection embankment built in the late 1980s (Khan, 2017). The area beyond the embankment is a flood plain of the Buriganga River. The elevation of Dhaka ranges from 1 m to 14 m above mean sea level (Karim et al., 2019). The area's average temperature is 26˚C and a maximum of 33˚C in the month of March (Zahid et al., 2006). The area has a typical monsoon climate with average annual precipitation between 1,800 and 2,400 mm. The rainfall is unevenly distributed throughout the year, maximum occurring during July and August. Mean monthly rainfall is less than 50 mm in winter and 400–450 mm during summer. The evaporation over the area is fairly high (Bangladesh Water Development Board 2003).

According to Brammer (1996), the study area belongs to the Madhupur Soil Tract and is covered by lower Turag and Buriganga floodplain deposits, which is underlain by Madhupur clay. The Madhupur clay of the Pleistocene age is the oldest sediment exposed in and around the Dhaka city area having characteristic topography and drainage (Islam et al., 2013). The soils of the tract have a clayey texture and consist of a significant amount of iron and aluminium that are highly aggregated (Brammer, 1996). Karim et al. (2013) report that the area's top subsoil is chiefly comprised of silty sand mixed with organic matter up to a depth of ~0.61 m and a subsequent silty clay layer up to a depth of ~4.9 m. In addition, these investigators reported that the permeability of topsoil and deep soil range from 2.0 x 10^{-6} to 2.29 x 10^{-2} m/day and 5.46 x 10^{-2} to 1.84 x 10^{-1} m/day, respectively. Furthermore, in the study area, the Madhupur clay formation is underlain by Plio-Pleistocene Dupi Tila formation, which consists of medium to coarse yellowish brown sand and occasional gravel (Islam et al., 2013). The Dipu Tila formation is the primary source of groundwater in Dhaka (Zahid

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et al., 2006; Haque, 2018). The Upper Dupi Tila aquifer is overexploited with a significant portion already dewatered; withdrawal from the lower Dupi Tila started fairly recently.

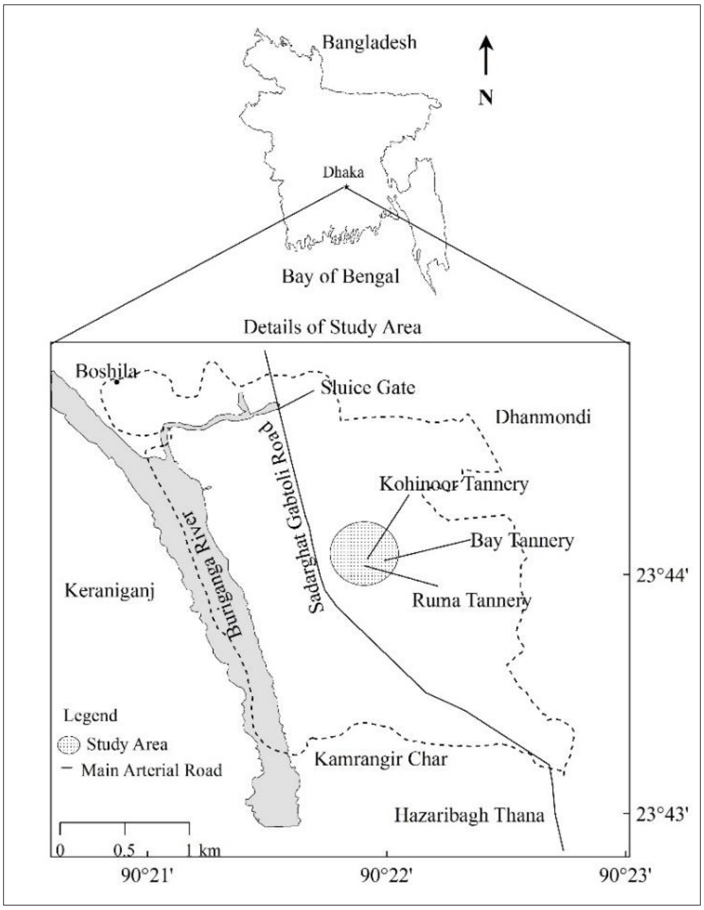

Figure 1: Map of the study area in Hazaribagh, Dhaka

METHODOLOGY

GEOCHEMICAL SAMPLING

In 2019, soil samples were collected during both wet (i.e., June) and dry (i.e., November) months of the year. In June 2019, five top layer soil samples that represented the wet season samples were collected from appropriate locations within the study area by employing proper sampling procedures (Haque and Johannesson, 2008). In November of 2019, five soil samples that represented dry season samples were collected from roughly the same sampling locations. All samples were collected from in and around the vacated or closed tanneries. Collected samples were placed in clean Ziplock bags to minimize possible contamination. All samples were placed in coolers at 4◦C till transfer to the Bureau of Research, Testing and Consultation Laboratory at Bangladesh University of Engineering and Technology (BUET), Dhaka, for analyses. The testing method followed for Cr_{Total} was APHA 22TH Edition 2012 by Inductively Coupled Plasma – Mass Spectrometry. To maintain quality control and quality assurance in sampling a variety of blanks, laboratory control standards along with the calibration check standards were included.

PUBLIC HEALTH-RELATED FIELDWORK AND SAMPLING

All public health surveys and interviews primarily focused on the age, gender, and health concerns of participants to seek out information to identify potential problematic areas. To achieve the research goal, in 2019, four Focus Group Discussions (FGD), two In-Depth Interviews (IDI), and one Key Informant Interview (KII) were conducted with the low-income residents of the study area with a particular focus on children under 18 years of age and other vulnerable population (i.e. elderly, pregnant women). A Focus Group Discussion is a qualitative data collection method, which aims to gain an in-depth understanding of social issues (Green and Thorogood 2018). In this method, data is collected from a deliberately selected group of individuals in lieu of a statistically representative sample of a broader population (Nyumba et al., 2018). Local contacts were established and FGDs of both male and female populations were conducted with a purposely selected group of local residents from within the study area. The participants were asked questions about their perceptions, attitudes, beliefs, view, or ideas on the topic. In-depth interviews are a qualitative research method that involves direct, intense interviews with individual participants (Brinkmann and Kvale 2015; Green and Thorogood 2018). Intensive individual interviews were conducted with a small number of respondents to explore their perspectives on tannery related health issues. In addition, KIIs, which are qualitative in-depth interviews conducted with the local residents who have first-hand knowledge about the community and were capable of articulating that knowledge. The participants of the FGDs and IDIs were drawn from a broad range of residents. Most of the male participants were involved in the leather processing industry or other businesses as day labourers whereas the vast majority of the female participants were housewives.

The FDG, IDI and KII were carefully planned to create a non-intimidating environment to ensure that participants feel free to talk openly and give their honest opinions. Participants were selected following appropriate sampling techniques and maintaining strict ethical considerations that are an integral part of the qualitative research method. Prior to conducting any interview, all participants were well informed about the study's objectives in their mother language Bangla and their consents were obtained after making it clear that their participation is entirely voluntary. A project information sheet (PIS) in Bangla was given to each participant. Furthermore, inappropriate details, anonymity, confidentiality, and informed consent were discussed with the participants. Note that to collect information regarding health issues of children under the age of 18 years, only parents/legal guardians were interviewed.

RESULTS AND DISCUSSION

GEOCHEMICAL DATA ANALYSIS AND INTERPRETATION

Table 1 presents soil data for soil samples collected during both dry and wet seasons from the study area. The pH values of the soil samples collected during the wet season range from 6.0 to 7.5, with a mean value of 6.8. The pH values of the soil samples collected during the dry season range from 6 to 8, with a mean value of 7.1. Past investigators found that the average pH value of the Hazaribagh area's soil samples to be 7.72 (Karim et al., 2013). These researchers indicate that the pH value is reflective of the presence of a large amount of $Ca(OH)_2$ indisposed of effluents (Anawar et al. 2000). Others have also reported similar soil pH values in the area's topsoil (Zahid et al. 2006; Shams et al. 2009).

Large differences in Cr concentration were observed in the soil samples collected from the study area. Total Cr content in the wet season soil samples ranges from 483 to 1758 mg/kg, with a mean of 1070 mg/kg dry mass, whereas total Cr in the dry season soil samples ranges from 15.5 to 5198 mg/kg dry mass, with a mean of 1441 mg/kg. The relatively lower concentrations of Cr during the monsoon season are possibly due to the dilution of soils. It is well established that total Cr concentrations in soil differ according to location and the degree of contamination from anthropogenic sources of Cr. Richard and Bourg (1991) reported that tests performed on natural soils have shown average Cr concentration ranging from 1 to 3016 mg/kg with a typical concentration of 53 mg/kg. It is noteworthy that previous studies conducted on soil samples prior to the partial relocation of tannery industries to Savar have reported remarkably high levels of Cr in the area's topsoil samples ranging from 15,000 to 33,500 mg/kg (e.g., Saha, 2001; Zahid et al., 2006; Shams et al., 2009; Karim et al., 2013; Mondol et al., 2017). The soil Cr concentrations found in this study are lower compared to that of the pre-relocation studies, however, the concentrations still well exceed the typical level of Cr in soil. As such, the persistence of Cr in soil along with its mobility into other environmental compartments is of great concern. Stępniewska et al. (2007) suggest that the mobility of Cr in soil, surface, and groundwater environments from its source largely depends on its speciation along with pH and redox conditions of the environment. In the soil environment, Cr persists as a combination of both trivalent Cr(III) and/or hexavalent Cr(VI) species. The Cr species undergo various transformations (e.g., oxidation, reduction sorption, precipitation, and dissolution; Kimbrough et al., 1999) and display varying chemical properties, toxicological and epidemiological characteristics (Fendorf 1995). Under anaerobic conditions, Cr(VI) can be reduced to Cr(III) by soil organic matter, sulphide, and ferrous ions and has been detected in deeper groundwater (Wuana and Okieimen, 2011). Despite the thermodynamic stability of Cr(III), the presence of colloidal manganese oxide can increase the oxidation rate of Cr(III) to Cr(VI) in soil (Jong-Bae and Tong-Min, 2001; Avudainayagam et al., 2002; Apte et al., 2006). This particular geochemical behaviour of Cr has become an increasing concern as Cr(VI), a well-established human carcinogen (Wang et al., 2017), is known to be soluble and mobile. Elevated levels of Cr have also been found in the shallow groundwater (i.e., 10-20 m) of the study area (Zahid et al., 2006). Due to its highly mobile nature, Cr(VI) poses a threat to the contamination of groundwater resources. It is important to note that Saha (2001) previously reported high levels of Cr (> the drinking water standard of 0.05 mg/l) in groundwater samples collected from the Hazaribagh area. Saha (2001) further indicated that in the absence of any natural source of Cr in the environment, it is likely that the waste disposed by the Hazaribagh leather processing industry was contaminating groundwater in and around the Hazaribagh area.

Table 1: Soil data from Hazaribagh Leather Processing Area

Wet Season Soil Data				
Soil Sample	**Latitude**	**Longitude**	**pH**	**Cr (mg/kg)**
1	23°44'6.36"N	90°22'1.56"E	6.5	767
2	23°44'6.72"N	90°22'0.48"E	7.5	483
3	23°44'7.08"N	90°22'0.48"E	7.0	1537
4	23°44'0.24"N	90°21'49.68"E	7.0	1758
5	23°44'11.04"N	90°21'55.8"E	6.0	805

Dry Season Soil Data				
1	23°44'6.15"N	90°22'1.87"E	7	1212
2	23°44'6.44"N	90°22'0.47"E	8	650
3	23°44'7.31"N	90°21'57.81"E	6	5198
4	23°43'59.93"N	90°21'50.02"E	7	1245
5	23°44'7.03"N	90°21'56.90"E	7	323

PUBLIC HEALTH DATA ANALYSIS AND INTERPRETATION

All qualitative interviews were conducted to explore health issues of the elderly, children below 18 years of age and vulnerable populations (i.e. pregnant women) living near Hazaribagh tanneries. Overall, residents of the Hazaribagh area have both positive and negative perceptions regarding impacts related to the presence of tanneries in the area. In general, the qualitative data resulting from the FDG, IDI, and KII indicate that frequently occurring diseases within the community include flu-like symptoms, skin rash, and fertility issues. The participants indicated that first-time employees (regardless of their age) of the tanneries are more likely to experience various health problems including skin diseases. The participants associated the onset of diseases with repeated exposure to chemicals from leather processing. Furthermore, they observed that the symptoms appear to subside after long-term exposure to the chemicals. The participants of the male FGD agreed that using gloves can protect workers against the chemicals used in tannery settings. The participants also mentioned that tannery workers who are in direct contact with tannery chemicals are not usually provided any personal protective equipment by their employers.

With respect to maternal health, the female participants mentioned that local pregnant women suffered from seizures during pregnancies and had various fertility issues. The female participants further reported that local children suffer from various health problems, such as fevers, respiratory distress, pneumonia, skin problems along with various eye diseases. However, the participants did not directly relate the health issues faced by the pregnant women and children with the presence of tanneries in the Hazaribagh area. The participants observed that the area's senior residents are more severely affected by various diseases and are comparatively slow to recover in comparison to the affected population. Most male FGD participants' opined that health issues related to maternal and child health are not directly connected to exposure to chemicals from the tanneries. The male participants were dismissive of the idea that the vulnerable population could be susceptible to the effects of environmental exposure to Cr. It is evident from the male participants' narratives that employment at the leather processing industry plays a central role in their lives and loss of income along with subsequent financial instability arising from the relocation of tanneries was more of a concern to them than their physical wellbeing.

Both male and female FGD participants indicated that tannery workers along with the residents of Hazaribagh are affected by environmental pollution resulting from the improper disposal of a huge amount of solid and liquid tannery wastes. In addition, they mentioned that the residents are commonly subjected to gases and odours emitting from tannery wastes. In particular, the female participants mentioned that such gases and odours commonly trigger temporary headaches and nausea along with eye problems in the vulnerable population. The participants further expressed concern about noticeable tap water quality problems associated with unusual colours, offensive smells, and tastes. The participants also mentioned that it is a common sight to see a huge amount of solid tannery waste blocking sections of local streets. The disposed of waste often ends up blocking the area's drainage system, which subsequently leads to flash flooding following heavy rainfall**.** The participants observed that the residents suffer from skin conditions when they are forced to wade through floodwaters.

In the past, numerous studies have been conducted on occupational exposure Cr compounds and the prevalence of diseases among Hazaribagh tannery workers (for e.g., HRW, 2012; Muralidhar et al., 2017; Hasan et al., 2019), however, to the best of our knowledge, there are no previous studies available focusing only on the children and vulnerable population. Hasan et al. (2019) assessed the hazards arising from metal exposure due to industrial contamination among the industrial workers and neighboring residents in the Hazaribagh area where Cr was used as an indicator of exposure. The study analyzed tissue samples from industry workers and nearby residents and found that the subject population was exposed to elevated levels of Cr compared to people living in a distant village that had no industrial establishment. Furthermore, Cr levels in tissue samples of tannery workers and the neighboring area's residents ranged from 21.85 to 87.45 mg/kg and 6.01 to 21.89 mg/kg, respectively. In 2012, Human Rights Watch conducted research in the Hazaribagh area to understand the health repercussions of Bangladesh's leather processing industry. These researchers interviewed past and current tannery workers, slum residents, healthcare professionals, workers with nongovernmental organizations, trade unions and government officials, leather technologists, and chemical suppliers. The HRW (2012) report indicates that local residents reported an array of health problems, which included fevers, diarrhoea, respiratory problems, and skin, stomach, along with eye conditions. The findings of our research are aligned with that of the previously reported health problems, which suggests that in spite of the relocation of the industry, the waste disposal problems continue to pose a threat to public health.

CONCLUSION

The geochemical data indicate a significant presence of Cr in the area's soil following the partial relocation of Hazaribagh tanneries. The majority of the local residents are illiterate and poor, and are not fully aware of the effect of environmental exposure to Cr. In general, male FGD participants were dismissive of the notion that health issues faced by the vulnerable population may be linked to Cr exposure. The majority of the participants are more concerned about the partial relocation of tanneries to Savar impacting their current and future financial state than their physical well-being. The improper use, management, and disposal of tannery chemicals are impacting the area's environment and leading to increased human exposure and associated health risks. As such, awareness building program at the community level will likely help the residents to understand the consequence of exposure to Cr and other contaminants.

LIMITATION AND STUDY FORWARD

The study provides a preliminary assessment of the study area's Cr concentration in soil samples following the partial relocation of tanneries to Savar. Further research is necessary to fully address the complex nature of the contamination problem. Continuous monitoring of Cr concentration in the area's soil is also essential to determine the natural attenuation of Cr in the area's soil environment. The findings may be used to help identify in situ treatment technologies for remediation of the area's soil. Such an evidence-based approach is of vital importance as policymakers and industry owners both aim to mitigate the environmental pollution that affects the lives of thousands of people.

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AUTHORS CONTRIBUTION

The contribution of the first, second, third, fourth, fifth, sixth, seventh and eighth authors are 25%, 20%, 20%, 10%, 10%, 5%, 5% and 5%, respectively.

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