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RESEARCH ARTICLE

Risk Assessment of Hydrogen Sulfide (H_2S) Gas and Its Impact on Human Health: Evidence from Tannery Industry of a Developing Country

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ABSTRACT

Hydrogen sulfide (H_2S) gas is quite risky and harmful for the tannery industry workers in Bangladesh. A proper measurement or assessment of this risk will help policymakers make crucial policy decisions, which will surely help the continued positive growth of this industry. This study has three specific objectives: identifying potential sources of hydrogen sulfide gas generation, assessing the root causes of hydrogen sulfide gas generation, and suggesting proper activities to reduce the impact of hydrogen sulfide gas generation. In order to carry out this study, a qualitative approach has been used, where qualitative data are used to find out the results. It started with reviewing the secondary documents but also included key informant interviews (KIIs), focus group discussions (FGDs), and a sample survey. This study has collected data from 20 different tanneries. Out of 20 tanneries, 80 respondents were selected via the purposive sampling method. Information has been taken from 80 respondents via Key Informant Interviews and Focused Group discussions, where each group consists of a different number of individuals and is selected on the basis of the location of the production process in tanneries. The study has found major sources and causes of H_2S generation. The major sources include the tanning chemical store, pre-tanning (Beam house area), Re-tanning area, Chrome effluent drain, Mix effluent drain, etc. The major causes of H_2S gas generation include intermixing of incompatible chemicals, lack of proper cleanliness, reaction of liming liquors, etc. The study also suggested various measures such as proper ventilation, separating chromium and re-tanning effluent from alkaline effluent, and reducing solid waste.

Keywords: Cleanliness, effluent, hydrogen sulfide, risk.

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1. Introduction

A colorless, extremely combustible, and toxic gas known as hydrogen sulfide (H_2S) is used in the production of natural gas, oil, and many industrial operations. H_2S gas is distinguished by a strong, pungent smell that is comparable to that of rotten eggs. Even at low concentrations, this gas has the potential to harm human health and the environment, as well as be fatal in high amounts. It is a typical industrial gas that is employed in the production of synthetic rubber, sulfuric acid, and other chemicals. Additionally, it is created naturally by the breakdown of organic material in places like wetlands, sewage systems, and manure pits. Workers in factories could be exposed to hydrogen sulfide gas. This is due to the fact that hydrogen sulfide is frequently employed in industrial operations and that, as a by-product of other industrial processes, it may be released into the air. Death is one of the worst health effects of hydrogen sulfide gas exposure.

A hazardous and flammable gas called hydrogen sulfide (H_2S) is commonly found in both industrial and natural settings. It tends to occur in oil and gas wells, wastewater treatment plants, and other industrial environments. It is created by the breakdown of organic matter. The concentration of the gas and the duration of exposure determine how harmful hydrogen sulfide exposure is to one's health. Eye, nose, and throat irritation can result from low exposure levels. Higher exposure levels may result in headaches, lightheadedness, nausea, vomiting, and trouble

breathing. Hydrogen sulfide can be lethal at extremely high doses. Hydrogen sulfide exposure can cause major health problems, such as brain damage, respiratory failure, and even death.

Human health can be seriously compromised by exposure to H_2S gas, which may result in a variety of symptoms depending on the concentration and length of exposure. H_2S gas can cause headaches, nausea, dizziness, and respiratory and ocular discomfort at low concentrations. H_2S gas is potentially fatal in greater amounts, causing respiratory collapse and death. Workers in factories that produce or consume H_2S gas are more vulnerable to its effects. The risks of H_2S exposure can be made worse by the tight areas sometimes found in industrial settings since the gas can build up to dangerous levels. For instance, because of the nature of their jobs, employees at paper mills, wastewater treatment facilities, and petrochemical refineries are at a higher risk.

The ecology can be significantly impacted by H_2S gas as well. H_2S gas can combine with other substances in the atmosphere to generate sulfur dioxide (SO_2), the main cause of acid rain. The creation of particulate matter, which can have a variety of harmful consequences for health, can also be aided by H_2S gas. Aquatic habitats can also be significantly impacted by H_2S gas. In water, H_2S gas can mix with oxygen to generate sulfuric acid, which can kill aquatic life and lower the pH of the water. In addition, H_2S gas can combine with metal ions in water to generate metal sulfides, which can be harmful to aquatic life like fish.

It is crucial to control and manage the expulsion of H_2S gas in order to mitigate the detrimental effects it may have on both human health and the environment. Engineering controls, like ventilation systems and personal protective equipment, are the main strategy for reducing H_2S gas emissions. Other ways of controlling H_2S include using biological treatment systems to extract H_2S gas from wastewater and chemical scrubbers to remove H_2S gas from the air.

Standard operations in tanneries and effluent treatment plants require the involvement of hydrogen sulfide (H_2S) gas which is a safety risk acknowledged by both the industry owners and the government. To make the tannery industry in Bangladesh more sustainable and safer, the usage of hydrogen sulfide (H_2S) gas should be monitored and controlled by an unbiased entity [1].

Tannery industry is one of the most influential and contributing sector of Bangladesh's economy. Over the years, tannery industry has been enriching the economy of Bangladesh via direct contribution to export earnings and employment generation. It's high time the issue of hydrogen sulfide (H_2S) gas be dealt with otherwise the progress of the tannery industry will face roadblocks on the way ahead [2]. Thus, the main purpose of this paper is to find out the risk associated with hydrogen sulfide and its impact on human health.

2. Literature Review

Numerous studies have demonstrated that exposure to H_2S gas is linked to a number of health issues. In the Chinese population, exposure to H_2S gas was linked to a higher risk of cardiovascular disease and mortality. Han *et al*. revealed that exposure to H_2S gas was linked to a higher risk of developing asthma and chronic obstructive pulmonary disease [3].

Hydrogen sulfide (H_2S) gas has no color. Some notable attributes or properties of hydrogen sulfide (H_2S) gas are:

i) foul odor as rotten egg
ii) heavier than air
iii) invisibility
iv) poisonous
v) corrosive
vi) flammable

Due to the risky nature of hydrogen sulfide (H_2S) gas, accidents become more probable without proper safety measures [4].

Hydrogen sulfide exposure might have adverse environmental consequences as well. Hydrogen sulfide can be detrimental to aquatic life, including fish and other organisms, according to a study by Pandey *et al*. [5]. This is due to the fact that when hydrogen sulfide integrates with water, it creates sulfide ions, which can disrupt aquatic species' metabolic activities. Hydrogen sulfide can have major ecological ramifications in addition to its direct harmful effects by helping to create acid rain.

A very toxic gas, hydrogen sulfide, can have adverse effects on both human and animal health. Inhaling hydrogen sulfide can result in a number of respiratory symptoms, such as coughing, shortness of breath, and chest tightness, according to a study by Sener *et al*. [6]. Long-term exposure to hydrogen sulfide at high concentrations can result in respiratory failure, which can be fatal. Hydrogen sulfide exposure can also result in neurological symptoms such as headaches, dizziness, and disorientation, in addition to respiratory symptoms. Because these symptoms could show up at amounts lower than those needed to elicit respiratory symptoms, hydrogen sulfide is very worrisome.

Technology like gas sensors and control systems can be used to find and restrict the dispersion of hydrogen sulfide in industrial settings, according to a study by Zhang *et al*. [7]. To raise awareness of the possible adverse effects on health and encourage safe working habits, it is crucial to offer education and training for workers who may be at risk of exposure to hydrogen sulfide in addition to technological solutions.

Bangladesh, Brazil, China, India, Italy, Japan, Mexico, Pakistan, and South Korea—all these countries are the most influential leather-exporting industries in the world. Large meat-producing countries export hide to Italy, Japan, and Korea. However, Bangladesh produces its own hides. Hazaribagh, Savar, and Chattogramare the main hub for the tannery industry of Bangladesh [8]. From the birth of Bangladesh, tannery industries have played a quite influential role in the economy of Bangladesh. Being a labor-intensive and export-oriented industry, it created jobs for the poor and spaces for economic growth at the same time [9].

Sewage systems, animal containment, and slaughterhouses are crucial sources of hydrogen sulfide (H_2S) gas. Among industrial sources, hydrogen sulfide gas can be found in oil and gas sites, geothermal power plants, coke

TABLE I: Case Processing Summary

	Cases					
	Included		Excluded		Total	
	N	Percent	N	Percent	N	Percent
Headache	1	100.0%	0	0.0%	1	100.0%
Eye itch	1	100.0%	0	0.0%	1	100.0%
Throat irritation	1	100.0%	0	0.0%	1	100.0%
Generalized weakness	1	100.0%	0	0.0%	1	100.0%
Unconsciousness	1	100.0%	0	0.0%	1	100.0%
Odour threshold	1	100.0%	0	0.0%	1	100.0%
Allergy problem	1	100.0%	0	0.0%	1	100.0%
Leg pain	1	100.0%	0	0.0%	1	100.0%
Blurred vision	1	100.0%	0	0.0%	1	100.0%

ovens, food processing facilities, tanneries, and paper mills [10].

H_2S gas exposure was linked to respiratory symptoms and lowered lung function in oil and gas workers [11].

H_2S gas can have long-term negative consequences for health in addition to its immediate harmful effects. Chronic H_2S exposure can have negative consequences for the respiratory system, the nervous system, the gastrointestinal system, and the cardiovascular system. H_2S exposure was linked to a higher risk of neurological symptoms and decreased cognitive function in wastewater treatment plant workers [12].

The potential adverse effects of H_2S gas on the environment are another key effect. In addition to contributing to acid rain, H_2S gas emissions have the possibility of mixing with other airborne pollutants and producing secondary pollutants, including sulfuric acid and sulfate aerosols. These pollutants may have detrimental effects on ecosystems, human health, and the environment as a whole. The effects of H_2S emissions on the environment have been investigated in a number of studies. For instance, a study that appeared in the journal Atmospheric Environment discovered that H_2S emissions from the extraction of oil and gas can contribute to the acidification of neighboring lakes and streams [13].

Environmental pollution and health hazards are two great risk factors for the tannery industry in Bangladesh. Whereas environmental pollution creates a high risk for the sustainable development of the country, health hazards create fear among the long-time workers of the industry and later may turn into a reason for labor-scarcity. Moreover, the issue of reputation and holding up international standards are also great concerns in this regard. Measuring the risk associated with using hydrogen sulfide gas is quite a challenging and over-encompassing task—which is yet to be taken up by any Bangladeshi social scientist with the proper equipment and required skills [14].

3. Research Objectives

The objective of this study is to:

- identify potential sources of H_2S gas generation;
- assess the probable root causes of H_2S gas generation;
- suggest activities to mitigate H_2S gas generation and its harmful effects.

4. Research Methodology

In order to carry out this study, qualitative data have been used. It started with creating eight different groups based on the location of the production process. The first and second groups are based on the tannery chemical store and beam house area, respectively. For the first two groups, 22 people are interviewed and eleven individuals are considered for each group. The third group is based on re-tanning area where 8 individuals are considered for interview. The fourth group is based on employees from Chrome effluent drain. The fifth group comprised individuals from Sedimentation tank (Chrome effluent and Mix effluent). People from Sewerage tank area are considered for group number six. Effluent discharge line (Chrome effluent + Mix effluent) is reckoned as group seven and finally, employees from the Empty pit or tank are considered for group eight. On the other hand, every group consists of 10 individuals. Each of the individuals was asked a set of questions to find the desired result. The study collected data on the basis of key informant interviews (KIIs), focus group discussions (FGDs), and a sample survey. This research has collected data from 20 different tanneries. Out of 20 tanneries, 80 respondents were selected via purposive sampling method.

5. Findings and Analysis

Table I, Table II, Table IV, and Table V show the case processing summary for all the respondents.

The pie chart represents the total different observations (Fig. 1).

This study identified a total of 11 and 13 potential sources of attannery operations and other designated places i.e., CETP, CCRU, EPS, DY, etc., respectively. Beam-house area and tanyard area are very close for maximum tanneries. From the survey, the same data is found for both beam-house and tanyard areas in maximum tanneries. It is to be mentioned here that these sources represent the most common and significant areas where H_2S gas is generated from tanneries and other spots.

Table III is the summary of those identified sources.

5.1. *Major Causes of H_2S Generation*

There are various reasons for H_2S gas generation in the tannery and in associated areas. This study primarily on those reasons that are most common in daily operations, comparatively easy to detect and rectify without much investment, and still can create good impact. The following causes/reasons for H_2S gas generation are proven to be important.

5.2. *Overall Reasons for H_2S Gas Generation at Various Sources in Tanneries*

- In chemical stores due to intermixing of incompatible chemicals, mainly acids with sodium sulphide

TABLE II: Case Summaries

		Headache	Eye itch	Throat irritation	Generalized weakness	Unconsciousness	Odour threshold	Allergy problem	Leg pain	Blurred vision
1		65	47	56	52	33	31	36	9	25
Total	N	1	1	1	1	1	1	1	1	1
	Mean	65	47	56	52	33	31	36	9	25

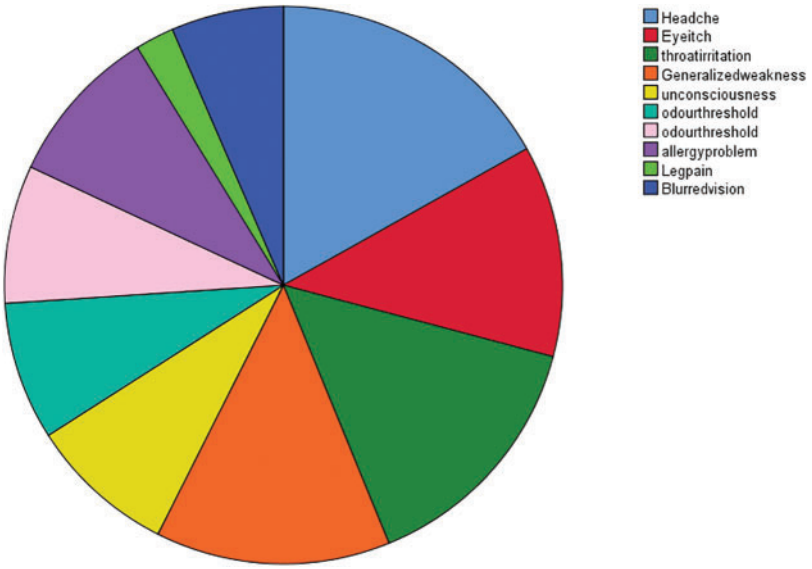

Fig. 1. Potential sources of H_2S generation identified.

TABLE III: Identified Potential Sources of H_2S Generation

Locations/sources at the tanneries	Sl	Locations/sources at CETP, CCRU, EPS, Dumping Yard etc.
Tannery chemical store	1	Inlet area (Fine screen & Vortex type Grit chamber)
Pre tanning (Beam house area) and Tanyardarea	2	Equalization tank area
Re-tanning area	3	Settling tank area
Chrome effluent drain	4	Oxidation area
Mix effluent drain	5	Chemical dosing area
Sedimentation tank (Chrome effluent)	6	Sludge thickening area
Sedimentation tank (Mix effluent)	7	Dewatering area
Sewerage tank area	8	Final output area
Effluent discharge line (Chrome effluent)	9	Screening area in CCRU
Effluent discharge line (Mix effluent)	10	Inner house area in CCRU
Empty pit or tank	11	Outer house area in CCRU
	12	Effluent pumping station (EPS)
	13	Dumping yard

flakes (due to poor handling and storage practices, chemical accidents e.g., acid spills, etc.).

- At waste storage/deposit area, due to long time exposure, lack of proper cleanliness & mixing of various hazardous & non-hazardous.
- In drums, paddles, or pits, which are used for liming, de-liming as well as pickling.
- When acid is added in drums, paddles, or pits during pickling to inadequately de-limed skins and hides that still contain sulphide from the liming stage.
- In drums, re-tanning used of sulfur or sulphate containing chemicals at higher pH.
- Reaction of liming liquors or other liquors containing sulphide, with acidic liquors (e.g., acids, pickle, etc.) can cause a hazardous release of hydrogen sulphide.
- Empty/unused tank or pits, where may deposit H_2S gas.

A concentration of 15 ppm is internationally acknowledged as short-term exposure limit (STEL) also indicating the maximum permissible exposure level in the work environment. However, recently, the American Conference of Governmental Industrial Hygienists (ACGIH) changed their recommended threshold limit values (TLVs) for airborne hydrogen sulphide (H_2S) exposure. From 1976 till 2009, the ACGIH 8-hour time-weighted average TLV (TLV-TWA) was 10 parts per million (ppm).

TABLE IV: Effect of H_2S on Human Health at Various Concentrations – Exposure via ppm = Part per Million in Air Inhalation

Exposure in ppm	Time	Potential effect on unprotected person
0.03	No limit	No effect
0.03–2	15 minutes	Odour threshold
10	Up to 8 hours	No effect
10–20	15 minutes	Threshold for eye irritation
20–200	15 minutes	Headache, nausea, general weakness, pain in legs
200–500	1 minute	Irritation of nose & throat, vertigo, blurring of vision, loss of consciousness lasting a few minutes
500–900	1 minute	Profound coma, muscular spasm-twitching convulsions, disorientation after recovery
> 900	1 minute	Instant coma and death

5.3. *Recommendations*

Recommendations for tannery areas were shown in Table V.

5.4. *Implications and Suggestions for Management*

A highly poisonous gas, hydrogen sulfide, can have adverse effects on both human and animal health as well as the environment. The effective use of technology, as well as worker education and training, can lessen the detrimental effects of hydrogen sulfide. In order to prevent the release of hydrogen sulfide from having a detrimental impact on both human health and the environment, it is crucial to monitor and manage this leak in industrial settings. To reduce exposure, it is crucial for those who operate in sectors that generate H_2S gas to take the proper precautions and adhere to existing rules and regulations. Additionally, more investigation is required to better comprehend the possible health and environmental effects of H_2S gas and to create efficient mitigation and exposure control techniques.

TABLE V: Recommendations for Tannery Areas to Ensure Sustainability

Sources/Location	Specific recommendations
Tannery chemical store (Area)	Ensure proper ventilation and strictly follow chemical compatibility matrix.
Pre-tanning (Beam house area) and tanyard area	Keep the raw hide/skins trimming in airy and in dry condition. Reduce sulfide based liming agents. Shifting of lime flesh as soon we can. Use de-liming agents. Acid and salt free pickle.
Re-tanning area	Tannery has to separate chromium and re-tanning effluent from alkaline effluent carefully.
Chrome effluent drain	Care must be taken during discharging waste chrome liquor into the chrome effluent drain and confirm sufficient flow rate.
Mix effluent drain	Confirm sufficient flow rate and reduce/control solid waste.
Sedimentation tank (Chrome effluent)	Don't mix the liquor, reduce solid waste, and clean regularly.
Sedimentation tank (Mix effluent)	Don't mix the liquor and reduce solid waste.
Sewerage tank area	Clean regularly and ensure ventilation to release gas.
Effluent discharge line (Chrome effluent)	Reduce solid waste and clean regularly.
Effluent discharge line (Mix effluent)	Reduce solid waste and clean regularly.
Empty pit or tank	Clean regularly and arrange sufficient air flow with proper ventilation.

Tannery Industry in Bangladesh is a highly potential industry that can become the next "RMG" industry for Bangladesh. However, to reach that stage, a three-pronged approach is necessary. First, the government needs to set up a regulatory authority for monitoring the health risks of the workers involved not only in tannery industry but also for all the industries in Bangladesh. It can be a publicly funded government entity. Second, incentives should be created for those industries that are following sustainable waste management practices and proper health safety protocols. At the same time, the industries that do not follow these standard practices should be punished and fined properly. Third, compensation and health insurance should be arranged for those who have been affected by any kind of chemical component or hazardous waste material while working. This approach surely create an environment friendly face for the tannery industries of Bangladesh and will generate trust among the laborers involved in this industry.

6. Conclusion and Future Research Direction

The study attempted to explore the different health hazards and side effects in the environment of tannery industry which can serve as a foundation or reference to any future full-scale empirical studies. This study has not attempted to show any detailed picture arising from any full-length survey which future researchers may concentrate. Based on the factors and issues identified from the study, future studies may attempt to conduct a detailed causal study that will show the impact and influence of the harmful chemical substances and environment on the employees' health. A further detailed exploratory study may be conducted that will derive the appropriate measures or treatments that will reduce and minimize the harmful impacts of hydrogen sulfide in tannery industrial practices.

List of Abbreviations

APTA	Asia Pacific Trade Agreement
BFLLFEA	Bangladesh Finished Leather, Leather goods and Footwear Exporters' Association
BPC	Business Promotion Council
BSCIC	Bangladesh Small and Cottage Industries Corporation
BTA	Bangladesh Tanner's Association
BRTC	Bureau of Research, Testing and Consultation
BUET	Bangladesh University of Engineering and Technology

BDS	Business Development Services
CETP	Central Effluent Treatment Plant
CCRU	Common Chrome Recovery Unit
DTT	Double Taxation Treaty
DE	Data Enumerator
EPB	Export Promotion Bureau
EPZ	Export Processing Zones
FGD	Focus Group Discussion
GDP	Gross Domestic Product
GSP	Generalized System of Preferences
IIFC	Infrastructure Investment Facilitation Company
ILO	International Labour Organization
LDC	Least developed country
LFMEAB	Leather goods and Footwear Manufacturers & Exporters Association of Bangladesh
LETS'B	Leather Engineers and Technologists Society, Bangladesh
OHS	Occupational Health and Safety
ppm	Parts per million
ppb	Parts per billion
RAT	Risk Assessment Team
TIED	Tannery Industrial Estate, Dhaka
TWU	Tannery workers Union

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