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## Invited Article

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# Chemical Management and Safety: Growing Concerns of Chemical Accidents in Bangladesh

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**Abstract:** A number of catastrophic events occurred in the chemical industries, chemical warehouses, transportation and distribution facilities in recent years, resulting in many deaths and substantial collateral losses. The government subsequently drafted and reconsidered safety regulations and intervene the management of chemicals to ensure protection of public safety and security. This study addresses key research points as (a) How to ensure safety and security of the critical chemical facilities? and (b) What are the key steps required to implement an effective chemical safety management system in Bangladesh? Four recent tragic chemical accidents are analyzed to understand the causes and consequences. The research article presents critical observations of each incident and the key lessons learned from those accidents. The research particularly focuses on the identification of priorities, formulation of national action plan, recommendations for improving national chemical management system and prevention of chemical accidents. The findings of this study and recommendations will be helpful for safety professionals, industry stakeholders, regulatory agencies, and policy makers for effective chemical management in chemical facilities and process industries in Bangladesh.

**Keyword:** Chemical Management, Chemical Accidents, Chemical Safety, Fire and Explosion, Lessons Learned and Bangladesh

## 1. Introduction

The ever-expanding manufacturing sector is the driving force behind the country's GDP expansion, which has resulted in a significant increase in chemical demand over the last decade. The risks associated with chemical facilities are often greater in a country like Bangladesh. The key players here seldom prioritize the safety concerns. The economy of Bangladesh is portrayed as a developing market economy in the world. Recently, Bangladesh was promoted to the community of middle-income countries. From the last decade she has inspired other countries which are underdeveloped by economic growth and sustainable development. Around 209 billion USD increased as Gross Domestic Product (GDP) in the last decade with the growth rate of around 5.5%. Before the COVID pandemic, the GDP growth rate was the highest in the value of 8.15%[1]. Such a higher growth rate was achieved due to the development of micro credit and the manufacturing sectors. The main players in the manufacturing sectors are the garment industries, fine chemicals industries, pharmaceuticals, plastics, tannery and consumer goods industries etc [2]. The demand of chemicals has substantially increased to continue their steady and sustainable growth. Bangladesh is now working and envisioned to achieve all SDG goals by 2030. It is important to note that ensuring workplace safety, chemical safety and security, industrial and process safety, pollution prevention have a significant relationship with several SDGs i.e. affordable and cleaner energy for safer environment [SDG 07], decent work and economic growth [SDG 08], sustainable cities and communities [SDG 11], and climate action [SDG 13]. Unfortunately, chemical safety and security issues are often ignored and are in the list of national priorities. Very few works have been reported on chemical safety and security issues in the context of Bangladesh. The current practices and prospects of chemical safety and security management in textile industries of Bangladesh had been reviewed by Haque et. al. [3]. Chemical Industries in Bangladesh are having serious safety deficiencies in various level [4]. Consequently, the rate of chemical accidents is increasing day by day as shown in Figure 1 (reported in national newspapers). The number of chemical accidents is increased significantly in year 2021 which caused many fatalities, significant loss of properties and impact on the business performance and economy of the country. The numbers often do not reflect the true scenario as many of the accidents are not reported properly.

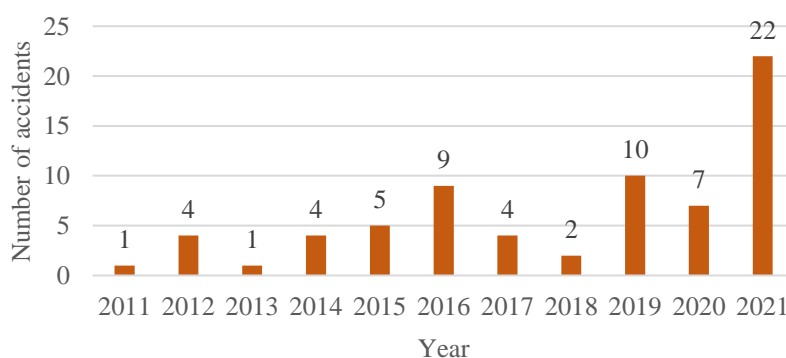


Figure 1. List of tragic chemical accidents reported in national newspapers in year 2011 - 2021

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Table. 01. Major catastrophic chemical accidents in Bangladesh [2016-present]

Time	Location	Events	Consequence	Short Description
June 2016	Tongi, Gazipur	Hydrocarb on fire	7 fatalities and several injuries	A fire erupted after a boiler exploded at the factory of Smart Metal and Chemical Industries in Gazipur. The factory produced furnace oil from old tyres which did not have any license and legal documents.
2016	Chittagong	Ammonia	250 injured from toxic exposure	An explosion occurred at the factory of a 500-ton liquid ammonia tank located in Anwara upazila of Chittagong. The tank contained more than 325 tons of liquid ammonia at the time of the explosion. A huge gas cloud is formed and dispersed into the air. The toxic ammonia gas spread over several kilometers and wind carried away the gas to the other bank of the Karnaphuli River leaving nearly 250 people fell sick inhaling the toxic ammonia gas
2016	Gazipur	Fire	43 fatalities and more 70 injuries	A fire and explosion occurred in a plastic packaging factory named Tampaco Foils in Tongi BSCIC industrial town of Gazipur. After the explosion, the ceiling and walls of the factory collapsed which killed 43 people, including two pedestrians. Fire service professor took more than 48 hour to control the fire as huge amount plastic resin and flammable raw materials were inside the factory premises.
2019	Old Dhaka	Fire and Explosion	71 fatalities and hundreds injured	Known as churihatta tragedy. An explosion occurred in 1 <sup>st</sup> floor of wahid mansion. A chemical warehouse where huge amount of flammable and combustible chemicals was stored. After the explosion, these chemicals spread all over after the explosion and fire massive fire engulfed the nearby roads. People were stacked there due a heavy traffic and died in the fire.
2019	Keranigonj	Fire	22 fatalities and 16 injuries	The devastating fire sparked by a LPG release from cylinders had gutted the Prime Pet and Plastic Industry factory. Peoples working inside the factory were unable to evacuate and burnt to death.
2019	Gazipur	Fire	10 dead and 15 injured	The fire broke out on the top floor of the three-storied building at a luxury fan factory in Gazipur. Flammable solvent was stored and used for painting work. Four units of firefighters doused the fire after one-and-half hours of frantic efforts. Most of the bodies were charred beyond recognition.
2020	Narayanganj	Fire and Explosion	34 death and several other injured	The explosion, triggered by a gas leak, ripped through Baitus Salat Jame mosque at once bewildering the pilgrims. The glasses of the door and windows were shattered in the blast. The leaking pipeline might have caused gas to accumulate inside the Mosque, and a spark then probably led to the explosion. It produced intense heat and critically burned the over 40 peoples.
2021	Dhaka	Fire	4 dead and 24 injured	A fire broke out at a chemical warehouse in Armanitola of Old Dhaka. The fire started at the ground floor of a six-storey building named Haji Musa Mansion at 3:18am. The fire later spread quickly due to the presence of combustible material stored in the eight to ten warehouses on the ground floor of this building and the whole building was engulfed in smoke. People trapped inside who were residing the building in the upper floor.
2021	Gazipur	Fire	3 dead and 22 injured	Fire damaged most parts of the hydrogen peroxide of SM Chemical. The factory produced and stored hazardous chemicals including hydrogen peroxide, chlorine, bleaching powder, caustic soda, etc. The fire service officials suspected that the fire broke out following an explosion in the storage facility for hydrogen peroxide. There was a huge explosion at the factory, causing spread of toxic gases in the area and shattering windows of around 50 adjacent buildings.
2021	Dhaka	Explosion	11 fatalities and 100 injuries	The blast took place on the evening of 27 June at the ground floor of a three-storey building in the Moghbazar area of Dhaka. The Fire Service and Civil Defences suspected that the explosion

Time	Location	Events	Consequence	Short Description
				occurred due to the accumulated methane gas from leaked pipelines. The blast wave destroyed the ground floor and 3 buses that were crossing the front side of the building
2021	Narayanganj	Fire	52 killed and 100 injured	The devastating accident took place on 08 July 2021 due to improper storage of highly flammable chemicals, plastic resin, packaging and other combustible materials. A 35,000 square-foot warehouse was being used for production, with no minimum fire safety. Workers trapped inside the factory and died due to fire and toxic smoke inhalation.
2021	Bagura	Fire	5 dead and several injured	The fire broke out around 11:30 am in the BIRS Disposable Plastic Factory in the Santahar, Bagura. Ten units from the Bogura and Naogaon Fire started from a factory machine explosion. Fire Service were managed to get the blaze under control after nearly three hours effort. The damage from the fire was claimed about Tk 250-280 million.
2021	Jhalakati	Fire	40 fatalities and 100 injured	A fire broke out on the Barguna-bound MV Avijan-10 launch carrying approximately 800 passengers from Dhaka, off the coast of Jhalakathi on 24 December 2021. After two hours of frantic efforts, the fire was brought under control. According to the Barishal Divisional Fire Service, the fire might be started in the engine room where fuel was stored and quickly spread as the ferry travelled along the river Sugandha.
2022	Chittagong	Fire and explosion	51 dead including 13 fire service professionals and over hundred injured	The first smoke was detected on Saturday 4 June at 9:00 pm from a container of the BM Container Depot. Twenty personnel from two fire service stations initially tried to control the fire by water spraying. At approximately 10:30 pm, a container exploded with a loud noise razing everything within 100 meters of the front from the center of the explosion to the ground instantly. About 12000 m <sup>2</sup> container freight station destroyed completely. The explosion shook the neighborhood and shattered glasses of windows of nearby houses. Firefighters brought the fire under control after three days of the explosions.

After each fatal chemical accidents, questions were raised on the poor performance of regulatory authorities. The demand for effective regulations and management of chemicals and chemical facilities has increased. However, very little progress has been made so far. Table 01 shows the recent accidents and its consequences. The accidents took many lives, destroyed properties and facilities, interrupted the business and country's economic growth. Many of those accidents occurred for just not following safety procedures and guidelines [5]. Several committees were always formed to investigate the accident by different agencies, ministries and regulatory authorities. The findings and learnings from those accidents had not been made public. In most cases, investigation committee focused particularly on the immediate causes of the accidents. The root or underlying causes of the incidents had often been ignored. Unfortunately, the similar events or accidents are recurring. There has been some improvement of safety standards and practice especially in textile sectors due to the client/buyer pressure, but these are not seen in other chemical intensive industrial sectors. The uncultivated culture and lacking safety procedures in chemical sectors caused accidents including fire, explosion, toxic release etc.

In recent years, fire accidents have happened frequently bearing high mortality, huge economic loss and environmental damage [6]. The examples of recent accidents are like BM container depot fire and explosion, Hashem food industries fire, Moghbazar blast, Churihatta fire and explosion, Tampaco fire and explosion and Narayanganj mosque explosion as described in Table-01. Such accidents shook the heart of people all over the country and made people rethink the establishment of proper and effective chemical safety management. Such accident will repeat unless the intervention or necessary steps are taken by the key stockholders involved in managing hazardous chemicals. The regulatory standards, guidelines, role of regulatory authorities were reviewed and a framework of sound management chemicals in Bangladesh was proposed by Prof. Syeda[7]. In this article, the four tragic chemical accidents are analyzed critically to understand the causes and deficiencies. The analysis aims to find out the needs for improvement in the area of hazardous chemical storage, use and transportation and to prevent chemical accidents. The study also focuses to identify the key stakeholders and prepare national action plan recommendation for effective management of chemicals. The national standards and guidelines had been reviewed to identify the gaps and needs related to chemical safety of chemical and process industries.

## 2. Case Studies: Chemical Catastrophe in Bangladesh

The major chemical accidents in past five years are described in Table 01. Some of these accidents were disastrous and exposed the vulnerability to manage chemical safety, lack of awareness and safety cultures in Bangladesh. Here, four recent tragic chemicals accidents occurred are discussed and analyzed in this section to understand the causes, consequences and lessons learned.

### 2.1 BM Container Depot Fire and Explosion: June 04, 2022 (Chittagong)

A devastating explosion occurred on the night June 04, 2022 at BM Container depot situated in 20 km away from Chittagong port which took away 51 lives including 13 fire service professionals and damaged the BM container facilities. The origin of fire was presumed from a container loaded with hydrogen peroxide that was kept in the yard for export. There were 533 containers in total and 37 of them contained 50%-60% of hydrogen peroxide. The estimated amount of hydrogen peroxide is 20,400 kg in each container. Out of 37 containers, 25 containers were damaged in the fire incident. A container was exploded with a huge bang about 1.5 hours after the fire was initially detected by depot security personals [8].

Primary investigation suggested that the origin of fire and explosion caused by the hydrogen peroxide containers. The exploded container was placed horizontally along the east-west direction. The explosion was so powerful that it had created a 15-20 feet crater at the center. The container freight station located 30 meters from the front was extensively damaged. Figure 2 shows the intensity of the damage due to explosion.



Figure 2: Damaged containers and freight station due to explosion

The powerful explosion produced a strong blast wave that shattered the structures and window glasses up to around 4 km distances. The container was fragmented into small pieces due to the explosion and flying debris travelled over hundreds of meters with high velocities. Such a powerful explosion had not been possible without the presence of chemicals. The detonation might have occurred due to the confined space explosion or boiling liquid expanding vapor explosion. People died mainly from direct blast impact or because of the impact from the flying debris. Some of them were critically injured and unable to evacuate the site and later charred as fire intensified after the explosion. People living nearby were also exposed to hydrogen peroxide vapor, mist or liquid and got severe skin and eye injuries. Some were experiencing hearing problems due to the blast effect. Hundreds of people got hospitalized because of their injuries.

Bangladesh had never experienced such catastrophic accidents where 13 fire service professionals have lost their lives in a single incident. On August 4, 2020, at precisely at 6:07 pm, a cache of 2750 tons of ammonium nitrate exploded at the Beirut Port minutes after a firework, the warehouse had caught fire which is the largest non-nuclear explosion of modern times [9]. The explosion destroyed the port facilities and half of the Beirut city. However, explosion of BM depot was quite unlikely to happen. BM container depot usually handle all export items and licensed for low risk imported products. However, BM depot stored hydrogen peroxide container loaded with 20.4 ton of 50% hydrogen peroxide solution in the container yard for export. Hydrogen peroxide (50% solution) is strong oxidizing chemicals and considered as Dangerous Goods (DG) (UN 2014) as per IMDG Code. Hydrogen peroxide may cause fire in contact with metal or flammable materials. Moreover, it may decompose slowly and generate extensive heat to create fire even without presence of an ignition source.

As containers were exposed to fire, hydrogen peroxide decomposed rapidly and produced extreme heat and pressure inside the containers and subsequently caused explosion. Using TNT equivalency [10] method and consequence analysis, the intensity of the explosion was estimated equivalent to detonation of 150 kg - 200 kg of TNT. The explosion released huge amount of energy which created a powerful shock wave and flying fragments. The sources of energy were basically from a) the external fire, b) the internal fire due to presence wooden support materials inside the containers and c) the exothermic decomposition reaction of hydrogen peroxide. After the explosion, fire intensified and propagated as hydrogen peroxide spread all over the container yard and container freight station. The damaged



hydrogen peroxide jars were found all over container yard, evident from Figure 2. Fire service professionals relentlessly worked for four days to extinguish the fire completely.

The BM depot accident gave a wakeup call regarding the chemical safety issues, possible consequence, lack of knowledges, awareness and management system. Some critical observations on BM container depot fire and explosion are given below.

- The BM depot explosion was a preventable accident and quite unlikely to occur. The event could be prevented if the storage guideline for storage of oxidizing chemicals was followed. The IMDG code and CPA traffic guideline clearly mention the potential fire and explosion hazard of oxidizing chemicals, such as 50% hydrogen peroxide solution.
- BM depot is a private inland container depot (ICD) approved by ministry of shipping and Chittagong port authority to facilitate export and import of low-risk items. Private ICDs are mainly involved to handle all export goods, low-risk imported products and not authorized for Dangerous goods.
- Bangladesh did not export any DG goods in the past. However, it started exporting hydrogen peroxide thorough private ICD as they are eligible for all exporting items. The container depot is under regular inspection by regulatory authorities like CPA and Ministry of Shipping. However, responsible authorities failed to identify the potential hazard of handling dangerous goods (hydrogen peroxide) in Private ICD. Private ICDs are not equipped and structured for handling DG items.
- BM depot were not aware about potential fire and explosion hazards of hydrogen peroxide. Hydrogen peroxide containers were stored together with other combustible items, locked, and kept in container yard at hot sunny weather.
- BM depot did not have personnel to oversee the safety and security issues of its activities in chemical storage and handling. BM depot did not have its own firefighting capability and standard operating procedure (SOP) for emergency response. The depot had to wait for arrival of fire service professional from FSCD to extinguish the fire. Due to the lack of ERP, instead of immediate evacuation, people were engaged taking photos, live streaming of the fire scene which were main reason for so many casualties.
- Fire service professionals were unable to extinguish fire as fire was inside the container. They were trying cool the container with water spray. Fire service professional were not trained enough to evaluate risk of potential explosion. There were series of small explosion with loud sound inside the container. These loud sounds were due to explosion of 30 kg of plastic jar containing hydrogen peroxide. This was a clear indication of large-scale explosion from confined container. Fire fighters were closer when the container exploded and 13 of them lost their life due the blast effect.

## 2.2 Fire Tragedy at Hashem Food Industries: 8 July, 2021 (Narayanganj)

On July 8, 2021, a deadly fire razed Hashem Foods Limited in Rupganj of Narayanganj and killed at least 52 workers and staffs of the factory. Fire originated at ground floor of the five storied building and people at the upper floor were trapped and were unable to evacuate. 49 bodies were found at third floor as the escape route was locked with a latticed gate at the back [11]. The poor workers took shelter in an air condition room and were asking for help. Deaths were mainly caused by inhalation of toxic smoke and lack of oxygen. The bodies were later charred due to fire spreading at the floor. Figure 3 shows the black smoke scaping off the building due to fire. Unfortunately, people were trapped and burnt alive for at least three hours inside the fire-blazed building.



Figure 3. Black, thick and toxic smoke produced from Hashem food industry fire

A vast amount of flammable and combustible chemicals and plastic raw materials were stored at the ground floor. Fire spread quickly and smoke blocked the evacuation routes. According to several local and international media, the factory employed approximately 7000 workers in its 35000-square-foot building with only two staircases, which were not adequate enough for emergency evacuation. There was no emergency staircase in the building. Moreover, the escape route at third floor was locked. There were no smoke detectors, fire alarms or emergency exits anywhere in the six-story building. The occurrence of fire at hashem food industry fire demonstrate the reflection of our industrial

- Hashem food industry fire tragedy was a preventable accident. The industry does not have safety personnel and minimum safety procedures at their factory.
- The same building housed different categories of production process. A pipeline system that carried edible oil; the large quantity of paper and plastic raw materials stockpiled on the premises.
- Both gates on the third floor were locked making it impossible for workers to flee which was very unfortunate. This clearly indicates the poor performance of monitoring agency especially Department of Inspection for Factories and Establishments (DIFE), and the Fire Service and Civil Defence (FSCD).
- No emergency response plan (ERP) existed in the factory. Workers were trapped inside the factory for hours and fire service professionals were unable to rescue them alive. The strength and capability of fire service personnel were also questionable.

The strong blast took place on the evening of 27 June 2022 at the ground floor of a three-story building in the Moghbazar area at the capitalcity, Dhaka. Twelve people died in the incident and over hundreds got injured. The explosion destroyed the ground floor and the windows of seven buildings nearby were shattered. Figure 4 shows the intensity of damage caused by the blast.

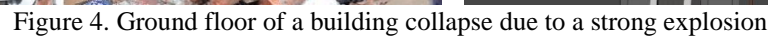


Table 02: Blast pressure and its effects at different distance from the explosion center.

The natural gas accumulation inside the Bengal meat chiller room might be a reason to form a flammable mixture which later detonated. There was a natural gas pipeline riser which passed thorough the building and placed next to the stairs. The Fire Service and Civil Defence claimed that the explosion took place due to the accumulated gas. However,

they failed to pinpoint the sources of the leaked gas. An official of the explosives department, on condition of anonymity, said that there is evidence that the gas which caused the explosion came from a leaked Titas pipeline [12]. The inquiry report submitted by Titas mentioned that Titas had no liability in the accident as there were no gas connections in the building. The abandoned riser was mentioned, but no details were given. The accidents reflect the potential danger of fire and explosion from urban gas pipelines leakage. The critical observations of the accident are discussed below.

- Several investigation committees were formed after the accident and their findings were contradictory to each other. Some findings are not scientific and baseless i.e sewerage gas, LPG cylinders which were found in shwarma house, a restaurant nearby the explosion area.
- No organization admitted that they might have deficiencies or issues considered to be corrected for prevention of such accidents
- Gas pipeline leakages are in common scenarios in urban areas in Bangladesh. The probability of natural gas riser leakage found about 10% from a study conduction Karnaphuli Gas Distribution Company Limited (KGDCL) has been a great concern for public safety.

#### 2.4 Churihatta Fire and Explosion: 20 February 2020 (Old Dhaka)

On the night of 20 February 2019, a devastating fire and explosion occurred at Churihatta area in Chawkbazar, Old Dhaka causing over 71 deaths and numerous injuries. Total 37 fire-fighting units worked incessantly for 15 hours to extinguish the fire [7]. There was a huge traffic at the adjacent road due to the closure of some roads at that night. A deadly fire erupted from a sudden explosion at the 1<sup>st</sup> floor of wahid mansion. A huge amount of highly flammable, body spray, perfume and different types of oil were stockpiled inside the building. The 5-inch thick external wall of the storage building collapsed during the explosion and highly pack flammable material spread all over the adjacent roads as shown in Figure 5. A massive inferno caused by the blast engulfed the traffic, trapped people and burnt to ashes. Many took shelter in a narrow space on the ground floor where they died due to oxygen deficiency and toxic vapor inhalation.

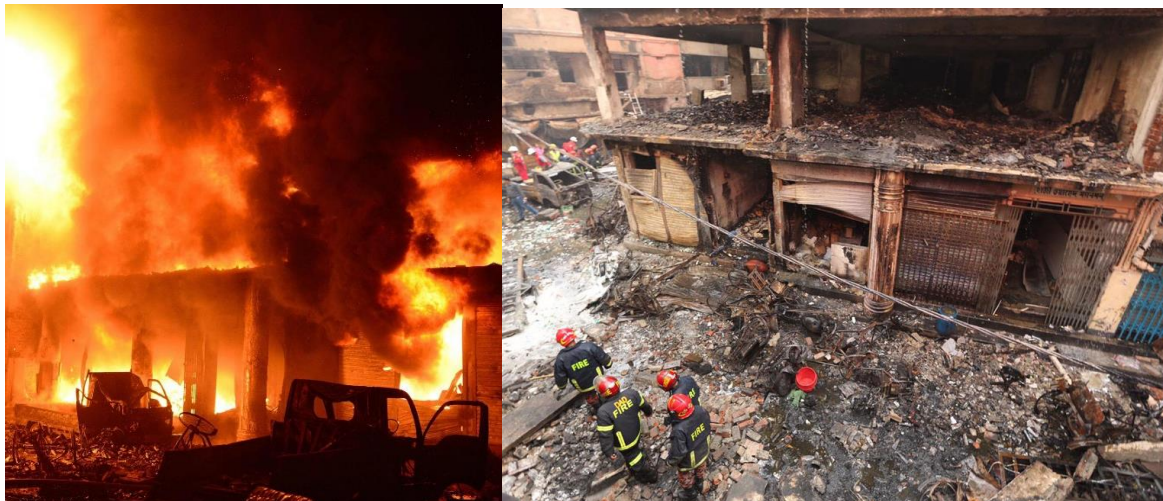


Figure 5. Fire and explosion scene of Churihatta tragedy

After the incident, different agencies including the Ministry of Industries, Ministry of Home Affairs, Ministry of Labour and Employment (MoLE), FSCD, and Dhaka South City Corporation (DSCC) formed investigation committees to find out the causes of the accident. However, the opinion from the different committee contradicted with each other. The probe committee of Ministry of Industries submitted a report claiming the fire was sparked by a gas cylinder blast on the road and that the explosion of a roadside transformer contributed to it. Contrarily, the probe committee of Ministry of Home Affairs reported that the fire originated from a chemical explosion on the first floor of Wahed Mansion, the worst affected building, where hundreds of damaged cans of body spray and canisters to refill gas lighters were found. The latter view was supported by most other probe committees.

Initially, after the news of the inferno spread, people mistakenly assumed that a cylinder blast in Rajmahal Hotel and Restaurant had caused the fire. Footage from Rajmahal's closed-circuit camera later helped to reveal that the fire broke out from the 1<sup>st</sup> floor of the adjacent five-storey Hazi Wahed Mansion resulted from a confined space explosion. Somehow, a vapor-air explosive mixture was formed inside the room either from hydrocarbon gas or volatile organic chemicals used in perfume or body spray. The explosive mixture later ignited and exploded with massive fireball. In addition, another video showed air-freshener canisters falling onto the street during the blast. The fire later spread quickly due to presence of plastic goods and other flammable items, preserved in the adjacent warehouses. The Fire Service and Civil Defence's probe body found the warehouses on the first, second and third floors contained huge quantities of body spray, high pressure deodorant canisters, raw plastic granules, air freshener, aerosol, gas lighter, fuel, etc. The Criminal Investigation Department of police found ethanol,



butane, isobutene, propene, butoxyethanol, glycol ether, diethyl phthalate, propylene and polyethylene – among the seized products, all flammable products were found on the spot. The critical observations are listed below.

- Storage of highly flammable chemicals in residential building was the key contributing factor of this accident. Release of small amount of these chemicals may have formed explosive mixture with air in a confined area and could have caused explosion.
- Chemical factories and warehouses in residential building is serious concern for public safety, especially unplanned urban area like old Dhaka. According to an estimate by Bangladesh Poribesh Andolan (Bangladesh Environmental Movement), more than 25 000 chemical warehouses are in Old Dhaka, of which some 15 000 are in residential buildings [7]
- Relocation of these chemical business from old Dhaka is very necessary. A project of BSCIC chemical industrial park had been initiated after Nimtoli tragedy (124 fatalities, 2010). However, the project is still ongoing and there location process has yet to start after a decade. It clearly indicates the lack of prioritization as government has completed many megaprojects within this timeframe i.e padma bridge.
- Many of these chemical businesses and establishments do not have valid license. This is much more concerning as they are not compliant as per national regulations. In many cases, the business has been identified illegal after the accident occurs. Thus, it is quite important to identify the illegal business and stop them functioning to avoid any future incident.
- Public safety should be prioritized rather than the business. However, it is evident that key stakeholders remained silent and have been continuing their unsafe business in residential area even risking their own lives

### **3. Lessons learned**

Every accident provides some opportunities to learn. Recurrence of similar accident shows a clear sign of failure to learn lessons from the accidents. The perfect example of such failure is Beirut port explosion in 2020. A huge quantity of ammonium nitrate was stored for 7 years at Beirut port. During this time, a similar explosion was happened in Chinese Tianjin port in 2015. Beirut explosion could have been prevented if Beirut port authority had learnt lessons from Tianjin explosion [13]. If the safety incidents were properly investigated and lessons learned were shared with the relevant organization, recurrence of accidents could have been prevented with necessary control measures. The root causes are almost the same in most chemical accidents in global context. The key lessons learned from the accidents discussed in previous section are presented below.

#### **3.1 Management of Change**

The key principle of management of change is to conduct risk analysis and make risk-based decision making before making any changes. In the case of Sitakunda BM Depot accident, the high-risk DG items export through private ICD has not been approved through proper procedures considering safety and security issues. Private ICDs are licensed for handling and storing of empty container, temporary storage of selected low risk import items and all export goods. This indicates that private ICDs are not approved or designed to handle high-risk items or dangerous goods (DG). Bangladesh do not export any high-risk goods and so ICDs allowed for all export goods. However, customs provide permission to private ICDs for storing and handling of DG goods like hydrogen peroxide as an export item (not considering its inherent risk). Therefore, management of change must be effectively implemented before making any changes related to DG storage, handling and use.

#### **3.2 Cost of Negligence and Noncompliance**

Organization often ignores safety due to its additional cost of implementation. Sometimes these are from negligence. Father of safety in chemical engineering, Trevor Kletz famously reported as “there’s an old saying that if you think safety is expensive, try an accident” [14]. Accidents cost a lot of money. A perfect example for cost of negligence is Hashem food industry fire accident which took 52 lives. Accidents are not acts of God; every accident is preventable if people do the right things.

#### **3.3 Emergency Management Plan**

Organization must have its own emergency management plan. In cases of BM depot explosion and Hashem food industry fire, it was apparent that both organizations did not have emergency management plan. Tragic loss of lives could have been avoided or reduced significantly if the management had evacuated their staffs and workers in time. In BM depot fire and explosion, many died or critically injured who were just watching, taking picture, or making live streaming of the fire scene.

#### **3.4 Risk-based Decision in Emergency Response**

In BM depot explosion, 13 fire service professionals lost their lives while performing their duties. They were conducting aggressive firefighting from a very close distance and unaware of potential explosion hazard from closed containers. Fire service professional must have necessary expertise to assess the potential risk while doing their job.

There were clear indications of explosion hazard during the BM depot fire i.e. a) closed container is always prone to explosion, b) presence of Hydrogen peroxide, a strong oxidizing chemicals has explosion hazard in confined space, c) Series of small explosion with a loud bang observed from the container during the firefighting. This unfortunate loss of life could have been avoided if they had assessed the explosion risk beforehand and taken defensive firefighting approach. Therefore, expertise of fire service professionals needs to be enhanced in the area of technical knowledge on fire and explosion, risk assessment and risk-based decision making during the emergencies.

### **3.5 Lack of coordination in Accident Investigations**

As discussed in previous section, immediately after the catastrophic accident, different regulatory agencies, ministries and organizations forms probe committees. These committees usually make a visit to the site and produce a report within very short period. Many of this committees do not publish their report. They often provide their opinions on print and electronic media. In many cases, their findings and opinions contradict with each other [7]. It creates confusion to the public. The objective of these committees mostly focuses on the immediate causes of the accident not the underline/root causes. Human, organizational, regulatory and 'cultural' shortcomings are identified as underlying causes of major accidents in safety critical industries [14]. Dr. Kletz says that accident prevention should be about looking for root causes, and not individual blame: "For a long time, people were saying that most accidents were due to human error and this is true in a sense but it's not very helpful. It's a bit like saying that falls are due to gravity." [15] The objective of accident investigation should be focused on the underlying causes, shared the learning and recommendations with others so that organizations can take mitigative measures to prevent similar accident to occur in future. This objective has not yet been achieved in Bangladesh due to the lack of coordination and technical merit of existing accident investigation procedures. We strongly proposed formation of a 'National Accident Investigation Board' to conduct the accident investigation. The board will form a team comprises of expertise from relevant fields who will be responsible for accident investigation, find out root causes of the accident and prepare recommendations for respective stakeholders, industries, and regulatory bodies.

## **4. National Guideline related to Chemical Safety**

This section covers mainly rules, act, policy and guidelines related to the perspective of chemical management and safety.

### **4.1 Bangladesh labor law 2006**

The Bangladesh Labour Act (2006) is the key labour legislation that sets Occupational Safety and Health standards, and compensation for injury and accidents in the workplace. In 2013, significant amendments were made to the BLA (2006), regarding occupational safety and health, primarily in response to the Rana Plaza collapse. The Bangladesh Labour Rules (2015) set implementation procedures to corresponding sections of BLA (2006).

### **4.2 OSH policy 2013**

In the context of global, ethical and legal obligations to ensure a safe and healthy working environment for all, the National Policy on Occupational Health and Safety was formulated and adopted on 5th November 2013, with the understanding that the implementation of such a National Policy would firstly ensure the safety of workers and secondly, help increase industrial productivity. The Policy applies to all workplaces in Bangladesh, including formal and informal sectors of industries, factories, enterprises, business and commercial entities and farms.

### **4.3 The Environment Conservation Rules, 1997**

The Environment Conservation Rules (1997) classifies industrial projects into four categories according to chemical process for purpose of license, prescribe the license requirements with procedures, issues declaration of ecologically critical areas and sets the standard values for different pollution parameters. The rules were developed under The Environment Conservation Act (1995) to protect the environment and ecological system from pollution of physical or chemical processes.

### **4.4 Explosive Rule 2004**

Explosive Rules (2004) as well as The Explosive Act (1884), Explosive Substance Act (1908) deal with regulation of production, stock piling, transport, sale, use and importation of explosive chemicals. The explosive materials include gunpowder, nitroglycerine, dynamite, blasting powders and fulminate of mercury or of other metals.

### **4.5 The Dangerous Cargoes Act, 1953**

The Dangerous Cargoes Act (1953) issued provision for the safety of port regarding working, transit and storage of hazardous cargoes including sulfur, tetrafluoroethane, calcium carbide, isobutene, liquefied gas etc. The act is legalized for ensuring the safety of ports, shipping companies and container depots which is enacted for preventing or dealing with explosions and fires on vessels carrying dangerous cargoes within the limit of any port.

### **4.6 The LPG Rules 2004**

In order to ensuring safety of gas reservoir or cylinder, safety of liquefied petroleum gas, strong management and handling process, transportation procedure and storing process of the LPG gas in a cylinder, The LPG Rules (2004) is legalized.

#### **4.7 The Petroleum Rules 2018**

The Petroleum Rules (2018) as well as The Petroleum Act (2016) was enacted by Department of Explosives, Ministry of Power, Energy and Mineral Resource to control storage, transportation, distribution, refining, blending, testing, licensing and importation of petroleum products.

#### **4.8 The Ammonium Nitrate Rules 2018**

Ammonium Nitrate Rules (2018) is used to control the manufacture, stocking, packaging, sale, use, transport and importation of ammonium nitrate. Ammonium Nitrate is a fertilizer product which is also an explosive material under heating condition. The last incident happened on Beirut shook the Lebanon caused by this chemical agent in 2020.

#### **4.9 The CNG Rules 2005**

Under the Explosive Act (1884), the CNG Rules (2005) were implemented by Ministry of Power, Energy and Mineral Resource to ensure the safety of gas reservoir or cylinder, safety of liquefied petroleum gas, strong management and handling process, transportation procedure and storing process of the Compressed Natural Gas (CNG).

#### **4.10 Bangladesh National Building Codes (BNBC 2020)**

Bangladesh National Building Code (2020) was implemented to provide building design guidelines for residential, commercial, industrial and hazardous indoor facilities. Physical hazards as well as chemical hazards are considered in the codes. BNBC (2020) is implemented by Ministry of Housing and Public Works.

#### **4.11 The Chemical Weapon (Prohibition) Act 2006**

The Chemical Weapons (Prohibition) Act (2006) prohibits the development, acquisition, stock piling, production, transfer or use of discrete organic chemicals and schedule chemicals. Government of Bangladesh (GoB) decided to sign the Chemical Weapons Convention (CWC) on 14 January 1993. Bangladesh National Authority for Chemical Weapons Convention (BNACWC) was formed after enacting the Chemical Weapons (Prohibition) Act.

#### **4.12 LPG Storage, Bottling, Transportation and Dispensing Codes and Standards, 2016**

The Bangladesh Energy Regulatory Commission's LPG Storage, Bottling, Transportation and Dispensing Codes and Standards, 2016, deals with certifying quality and safety as well as environmental protection for LPG bottling, transportation, dispensing and storage.

#### **4.13 Solid Waste Management Rules 2021**

Solid Waste Management Rules (2021) was formed under the Environment Conservation Act (1995) to impose collection, recycling, disposal responsibilities on manufacturers of non-biodegradable products as well as the responsibilities of businesses included in solid waste management.

#### **4.14 Air Pollution (Control) Rules 2022**

The Ministry of Environment, Forest and Climate Change formed Air Pollution (Control) Rules (2022) to manage air pollution for environmental conservation and sustainable development. Air quality standards as well as emission standards from vehicles were set in the rules. The Department of Environment (DoE) is bound to prepare a National Air Quality Management Plan that involves an efficient management system and organizational working framework of indoor air quality.

### **5. Recommendations for Effective Chemical Management and Safety**

The policy, rules and guidelines discussed in the previous sections are associated to some extent with chemical management and safety. However, standardized rules and regulation are yet to develop for chemical safety management in process industries. For effective safety management of hazardous chemicals, countries need to investigate the problem deeper and take a holistic approach for improving systems, existing practices and culture. The case studies discussed in the previous sections have revealed that current practices in chemical management have many levels of deficiencies. The weakness and challenges of effective chemical management are observed as,

- Absence of standardized rules, regulations, or procedures regarding chemical management
- Lack of widescale national or governmental coordination or integration of chemical safety and security
- Lack of financial resources or allocation in research for safer chemical management
- No centralized database for the identification, storage, and management of chemicals
- Unskilled, untrained, and unauthorized personnel handling hazardous chemicals
- Improper waste management
- Lack of chemical incident reporting means no immediate emergency response

- Lack of coordination in investigating chemical accidents
- Absence of a chemical safety culture
- Lack of awareness on risk of handling and transportation of hazardous chemicals

Chemical management and safety must be improved, and a safety culture should be built to prevent recurrence of chemical accidents. The objectives and methods of implementation for national action plan recommendations are given Table 3.

Table 3. Objectives and methods of implementation for national action plan recommendations

Objectives	Methods of Implementation
Standardization of rules and regulations on chemical safety management systems	Collaboration with local and international bodies and the creation of a central regulatory body for chemical security
Creation of a national authority for chemical management and safety	Formed after interactions with all stakeholders. Through stakeholder engagement program
Standardization of chemical storage and management practices	Through trainings and workshops from local and international experts
Standardization of and improvements to personnel training	Through regular trainings and monitoring from relevant experts and the development of SOPs for personnel
Increased government involvement towards chemical safety concerns	Increased engagement with relevant local and national government bodies
Stakeholder engagement program	Coordination with different regulatory agencies, industry stakeholder and academia
Regulatory Enforcement	Through regular inspection and monitoring
Establishment of National Accident Investigation Board.	Collaboration with local and international bodies, Coordination with different regulatory agencies
Awareness and Training	Through trainings and workshops from local and international experts
Chemical Safety Education	Establishment of a center of excellence in chemical safety research. Developing chemical safety courses in engineering curriculum
Emergency management	Develop SOP in collaboration with local and international bodies, Coordination with different regulatory agencies

## 6. Conclusion

The analysis of tragic chemical accidents reveals that Bangladesh is clearly lacking in different areas concerning chemical management and safety, i.e. standards and guidelines, risk analysis, risk communication, risk-based decision making, accident investigation, management of changes, research and development, safety education, training, safety awareness and emergency management. It is evident that chemical management system cannot be implemented only by standardization of rules and regulations. There must have to be clear national interest, strong regulatory enforcement, resource allocation, capacity building, awareness building and skilled manpower. The article presents the weakness and challenges concerning chemical management and provides national action plan recommendations with clear objectives and method of implementation to improve chemical management and prevent recurrence chemical accidents. The recommendations of this study can play a steering role to formulate a comprehensive national chemical management framework in Bangladesh.

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