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Effects of Fire Hazards Due to Leakage in Gas Circulation Lines in Bangladesh: A Comprehensive Review

Md Abdullah, Mohammad Zoynal Abedin and Saddam Hossen

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ABSTRACT
Fire hazards caused by leakages in gas circulation lines are dangerous and pose a threat that results in a significant loss of wealth, lives, and the environment. By adopting significant precautions, the risks of fire hazards can be reduced effectively through the use of new technologies and preventive measurements of the system. In addition, the effects of fire hazards due to leakage in gas circulation lines in the buildings as well as in the other systems can be assessed to create the context of preventive measures for a fire protection system in a way to overcome the fire hazards in gas circulation lines. The paper aims to review the effects of fire hazards due to leakage in gas circulation lines in Bangladesh. It is noted that in Bangladesh during 2018-2019, the total gas distribution line in the Titas gas system was measured as 13,138 km where the pressure-reducing system or gas riser was found as 1.2 million and the number of customers was found as 2.866 million. In the system, the number of fire accidents that occurred was 208 in the circulation system. Because of connecting the illegal gas lines and poor maintenance of the system, Bangladesh faces significant fire hazards every year. To avoid this kind of problem, proper maintenance along with the varieties of new technologies incorporating sensors and microcontrollers can be utilized.

Keywords: Fire hazard effect; Fire hazards; Leakage; Gas circulation line; Protection.

1. INTRODUCTION
Fire is an exothermic chemical reaction that occurs when fuel and oxygen are combined and releases energy, flame, and a number of other results [1]. The transformation of both the sluggish dual link in oxygen molecules to the bonds present in the smoke of both carbon dioxide and water causes the release of energy, resulting in the reason flame is found to be hot [2]. Additionally, it is observed that a flame is created, consisting of atmospheric CO_2, liquid water, air, and nitrogen, which, when heated sufficiently, may be seen to ionize in a way to form plasma [3]. Its capacity to support a variety of ecological systems and encourage growth are only two of its numerous advantageous impacts [4]. If a fire kills people, heavy rains may accelerate soil erosion caused by water. Additionally, when vegetation is burned, nitrogen is released into the atmosphere as opposed to nitrate and phosphate, which stay in the dust and are quickly regenerated into the soil. Even while ammonia vegetation like clover, peas, and beans and lightning may fix atmospheric nitrogen and turn it into ammonia, the nitrogen lost as a result of a fire gradually reduces soil fertility [5]. Humans have used fire in a variety of rituals, including cooking to produce heat and clearing land for agriculture. The capacity to manage fire marked a significant shift in the early civilization. People were able to cook food by using fire to provide heat and light, improving the diversity while also minimizing sickness through destroying its micro-organisms [6]. Nocturnal predators were also scared off by fire. Cooked food has been discovered dating back million years ago, while fire was seen to be used in various ways for the required purposes [7-10].

This efficient approach does have certain drawbacks, though. The earth's surface is becoming more and more susceptible to ever-larger uncontrolled flames as a result of the world's expanding population, fragmenting forests, and warming temperatures. On the other side, this practical strategy damages human infrastructure, ecosystems, and human health. Additionally, it generates rings with oxygen and smoke that might fuel new fires and further heating the atmosphere. Up to 5 million square kilometers of land can burn worldwide in a single year [11]. Modern applications for fire are numerous. Almost every human on the earth utilizes fire every day in a controlled setting, to put it broadly. Every time a person operates an internal combustion engine vehicle, they employ fire. The vast

Md Abdullah, Mohammad Zoynal Abedin ✉ and Saddam Hossen
Department of Mechanical Engineering
Dhaka University of Engineering & Technology
Gazipur 1707, Bangladesh
E-mail: abedin.mzoynal@duet.ac.bd

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majority of people on earth get their energy via boilers, which burn fuels before generating steam to turn turbines. The use of fire in combat has a long and illustrious history. Fire served as the foundation for all modern thermoelectric devices [12]. Usable energy is released when fuel is burned. Wood has been used as a power source in the past and the present. Fossil fuels including coal, fossil fuels, and petroleum are used to generate the great bulk of the world's energy today; International Energy Agency estimates that in 2002, these fuels generated nearly 80% of the world's electricity [13].

Methods like planned or controlled burns and the use of wildland fires may be used in international efforts to prevent wildfires [14-15]. Any natural fiber that is restricted yet permitted to burn is used in wildland fires. Fires started by public entities but under dangerous weather conditions are known as forest fires [16]. In the majority of developed locations, firefighting services are available to extinguish or control uncontrolled flames. An extensively trained firefighter is the first and foremost responder and rescuer in firefighting, primarily to extinguish hazardous fires that threaten lives, properties, and the environment as well as to rescue people and in some cases or jurisdictions also animals from the dangerous and deadly situations. Limiting sources of ignition is the aim of fire prevention. Another aspect of fire protection is fire prevention education [17]. In order to prepare people for a building fire, fire drills are routinely done in buildings, particularly in tall buildings and schools. Most jurisdictions consider arson, which is defined as purposefully starting destructive fires, to be a crime [18]. To lessen fire damage, model building regulations contain both passive and proactive fire protection features. Sprinkler systems are the most often used sort of active fire defense. Most developed nations assess the fire resistance, ignitability, and flash point of construction materials and equipment in order to improve passive fire safety of structures. In cars and ships, flooring, polymers, and upholstery are also put to the test. When damage cannot be avoided by fire prevention and fire protection, fire insurance may be helpful [19].

2. LEAKAGES AND FIRE HAZARDS IN GAS CIRCULATION

A sulfur stink is frequently employed to detect leaks early since natural gas is colorless, odorless, and explosive [20, 21]. Natural gas is produced as a result of layers of decaying plant and animal waste being subjected to extremely high heat and pressure under the Earth's surface over millions of years [22]. Chemical bonds in the gas store the energy that the plants received from the sun [23].

A fossil fuel is what natural gas is categorized as. Natural gas is a nonrenewable hydrocarbon that is employed in the production of energy, heat, and cooking. Additionally, it is used as a chemical feedstock for the production of plastics and other important substances for the economy. Natural is used for a multitude of purposes in homes around the nation. After electricity, natural gas is the energy source that is utilized in homes the second most frequently. Gas is indirectly used by houses in this way since it is also used to produce electricity. However, natural gas is mostly employed in equipment and systems that are made to run on this type of fuel. The most prevalent forms of this versatile energy source are compressed natural gas (CNG) and liquefied natural gas (LNG), although the latter is more frequently used for transportation than for heating homes.

Although natural gas has a better safety record than other main energy sources, it must still be used with caution. Explosions, massive fires, and the possibility of suffocation, either from smoke inhalation or carbon monoxide poisoning from badly burned gas, are all potential threats. Natural gas, fortunately, does not ignite or explode on its own. To spark combustion, particular conditions and a source are required. Here's some advice on how to minimize unnecessary damage, injuries, and even death. There are three main ways to detect a natural gas leak, and combining all three can assist evaluate whether or not a leak is likely. The most crucial is the sense of smell. If we smell something that smells like sulfur or rotten eggs but can't place the source, it could be a gas leak. After then, the simplest way to tell if a leak is occurring is to listen. The following sections deal with gas leakage, gas line leak and fire hazard in the gas circulation line in Bangladesh.

In Bangladesh during 2018-2019, the total gas distribution line in the Titas gas system was measured as 13,138 km where the pressure-reducing system or gas riser was found as 1.2 million and the number of customers was found as 2.866 million [24]. In the system, the number of fire accidents that occurred was 208 in the circulation system. Because of connecting the illegal gas lines and poor maintenance of the system, Bangladesh faces significant fire hazards every year [24].

2.1 Gas Leakages

A gas leak happens when natural gas or another gaseous product leaks into an unintended location from a pipeline or other containment system. Gas leaks pose a threat to the environment and to individuals. Over time, even a little gas leak into a structure or other enclosed space can accumulate to explosive or lethal proportions [25]. Leaks of natural gas and refrigerant gases into the atmosphere are particularly dangerous since they may result in ozone depletion and global warming [26]. Byproducts of gas leaks connected to industrial machinery and operations are fugitive emissions. Natural gas leaks brought on by the mining and use of fossil fuels are referred to as fugitive gas emissions.

Methane, the primary component of natural gas, is colorless and odorless. Uncomfortable smells, such as mercaptan residues, are frequently supplied to help find breaches [25]. This smell is like rotting eggs or a moderately repulsive

animal odor. To reduce the risk of fire and explosion, anyone who smells the odor should leave the area and avoid using open flames or power connections. The gas company is required to check for gas leaks in gas meters and internal gas lines from the entry point into the structure to the discharge end of the electric meter. As a result, biogas suppliers could need to check individual homes for potential hazards [25].

A Grade 1 leak needs immediate repair or continued effort until there is just no risk increase because it poses an immediate or imminent risk to people and assets. Here are a few instances of leaks from Grade 1 [26] such that—any leak that the operating staff on the site believes to be an immediate threat. Any signs that a structure, pipeline, or underground space has experienced gas migration. A measurement that is close to a structure's exterior wall or that is close to an area where gas is anticipated to flow. A result of 80% or higher lower explosive level (LEL) in a tight space. A result of 80 percent of overall lower explosive level or above in minor structures where gas is anticipated to move to a structure beyond the boundary. Any leakage that is audible, tactile, and visible could put people or property in danger.

A second-grade leak is one that is first determined to be quasi but necessitates scheduled repair owing to the possibility of further dangers [26]. There are a few illustrations of second-grade leakage. Defects that demand treatment before bottom chilling and other unfavorable shifts in ventilation circumstances fall under this category. During cold or other unfavorable weather conditions, any leak would probably make its way to the exterior wall of a building. Leaks that need to be fixed in 180 days. A result of a 40 percent lower explosive level or higher below a walkway inside a completely surfaced area does not indicate a Primary hole [26]. A result of 100 percent lower explosive level or higher below a road inside a masonry walking path to fossil energy movement of people although no primary leak. A result is less than 80 percent lower explosive level in tiny components where gas might possibly move, posing a threat. A result in a specific area that falls between 20 percent and 80 percent lower explosive level. On a pipeline with a required minimum elastic modulus of 30 percent or higher in a category 3 or 4 position that is not a primary leak [23]. A result of 80 percentage lower explosive level or higher in gas-related components. Any leak that is large enough, in the opinion of operational staff on the spot, to warrant planned maintenance.

A stage iii leak is quasi when discovered and is likely to remain so in the future. Some examples of grade 3 leaks can be found [26]. As a result, a result in minor gas-linked components that is less than 80 percent lower explosive level is considered. Measurement is taken beneath a roadway where there is no wall-to-wall paving, and the gas is unlikely to travel to buildings beyond the wall. A result that is less than 20 percent lower explosive level in a restricted area [26].

2.2 Gas Line Leak

Leaks in gas lines might be harmful. When breathed, natural gas can cause headaches, wooziness, nausea, and vomiting. Small leaks frequently go unnoticed, so people get ill without knowing why. However, because domestic natural gas has a sulfur-scented component, major leaks are much more noticeable. If we detect the scent of natural gas within our house, we should leave right once and call for help. The pipe that carries gasoline to our home is called a gas line (usually natural gas or propane). This fuel is necessary for running some appliances in the home, including the water heater, clothes dryer, oven/range, heaters, grill, and pool heaters. The supply pipe is often connected to the device by flexible steel tubing, and gas lines are typically built of black iron or copper pipe that goes through the wall or floor. Gas pipes in residences frequently leak. The gas line leaks most frequently at the threaded fitting. The most frequent reasons for leaks include pipe corrosion, poor quality lines and fittings, faulty connection assembly, damaged pipe threads, and outdated valves [28]. Here are five ways we may find gas leaks on our own [28].

a) Smell: When processed for home use, mercaptan is added to naturally odorless natural gas to give it a strong odor that is frequently compared to sulfur or the smell of rotten eggs. (Propane also has a strong smell.) We may occasionally smell natural gas when using our appliances; however, if the smell becomes overpowering, leave the house and call a professional for evaluation and repair.
b) Bubble Test: If we think a gas line is leaking, we should mix water and liquid dish soap and use a sponge or cloth to apply the mixture to the pipe where the leak may be. If suds start to look like soap, we have a little leak.
c) Inaccurate Pilot Light: If the pilot light on our appliance keeps going out, there could be a leak in the gas line, which would disrupt the fuel supply.
d) Dead Plants: There might be an underground gas leak if we observe an area of grass or plants in our yard that are dying for no apparent cause.
e) In-Home Testing: Online and at home improvement stores, there are many different electrical gas leak testers to choose from.

Depending on the cause, fixing a gas line leak may include tightening and resealing the fittings' threads or completely replacing the damaged line. We should get in touch with a qualified plumber if we notice a leak since gas and other fuels are combustible. Gas line leaks can be prevented, despite the fact that they could seem terrifying [29].

- Hire a professional to install our gas appliances.
- Gas appliances should not be moved or jostled regularly.
- Double-check that all fittings are secure and sealed with sealant paste.

- Have a licensed plumber inspect our pipes once a year.

Due to the potential risk posed by the gases used in houses, it is crucial to seek the advice of experts who can maintain and repair our gas lines in a secure manner.

2.3 Fire Hazards

Fire hazards are workplace dangers that entail the presence of a flame, enhance the likelihood of an uncontrolled fire, or increase the severity of a fire if it occurs [28]. Fire hazards include [29] flames, sparks, hot objects, flammable chemicals and acceleration of chemicals. The term fire hazards encompass a wide range of potential dangers. It encompasses anything that prevents fire protection materials or equipment from working properly, as well as anything that prevents people from acting in a fire-safe manner. A barrier that prevents safe escape and a malfunctioning sprinkler system, for example, are both considered fire dangers. This is because a facility's level of risk influences both the likelihood of a fire and the severity of the potential harm caused by a fire if one does occur. Our concept of what constitutes a fire danger has evolved through time; in general, cultures around the world have been less tolerant of fire hazards, and as a result, a greater number of situations are now considered hazardous. Some common fire hazards include [31]:

a) Candles and other open flames, chimneys that concentrate creosote, combustible storage areas with insufficient protection, and combustibles near equipment that generates heat, flame, or sparks.
b) Cooking appliances – stoves, ovens, electrical wiring in poor condition, electrical systems that are overloaded, poorly maintained, or defective.
c) Electronic and electrical equipment and Exterior cooking equipment – barbecue.
d) Heat-generating devices that use combustible materials.
e) Wood stove fireplaces, along with flammable liquids and particulates, are not cleaned properly or regularly.
f) Flammable solvents are placed in enclosed trash cans as well as thermal devices including open fires, bamboo cookers, heaters, water heaters, electric baseboard heaters, and liquid fuel.
g) Kitchenware, along with household appliances, hair straighteners, clothes dryers, fridges, chillers, heaters, and kitchen fires caused by unattended cooking, grease fires, and chip pan fires.
h) Leaking/faulty batteries, personal ignition sources such as matches and lighters, as well as cigarettes.

Statistics from the Bangladesh Fire Service and Civil Defense (BFSCD) Directorate, which oversees fire stations, show that in the years 2010, 2011, 2012, and 2013, respectively, 18.17 percent, 15.36 percent, 15.96 percent, and 16.14 percent of all reported fire incidences in Bangladesh occurred in the greater Dhaka district [31]. Table 1 shows economic loss due to fire incidents in the greater Dhaka districts [31].

Table 1: Economic loss due to fire incidents in the greater Dhaka districts [31].

Year	No. of Incidents	Loss (BDT in Millions)
2010	2669	1470
2011	2422	960
2012	2794	2400
2013	2891	4070

Figure 1 shows the average loss of fire incidents in Millions BDT according to location (2011-2013) [31]. It is evident from Figure 1 [31] that industrial land use experiences higher economic loss as a result of fire occurrences than any other land use category, with an average loss of BDT 0.6 million, for mixed uses, the loss is 0.5 Million BDT, and for commercial, the loss is 0.3 Million BDT. According to the graph, the average loss of property for all residential purposes (including both non-slum and slum areas) is BDT 0.15 million. However, the observed average loss is BDT 1.279 million only in slum regions, which is higher than the loss incurred in industrial land usage. Slum areas in Bangladesh refer to densely populated metropolitan regions marked by subpar housing and squalor. Additionally, the study discovered that across all types of land uses, slum areas suffer the most economic losses as a result of fire events.

Figure 2 shows the distribution of sources of fire incidents according to structure type (2014) [31]. It is seen from the Figure that in frequency of fire incidents one, two and three, there are 3%, 3.67% and 9.82% of gas line fire accidents, respectively. In a Pacca structure, the two major sources of fire are an electric line and a gas line, however, in a kacha structure, 30 percent of the fire also comes from a cigarette and a stove in addition to an electric short circuit. Kutcha constructions, the fire spreads quickly and results in a significant loss of property quickly [31].

3. PREVENTION OF GAS LEAKAGES IN BANGLADESH

The following section deals with the various techniques such as manual technique, algorithmic technique and modelling and simulation technique used for the prevention of gas leakages in Bangladesh.

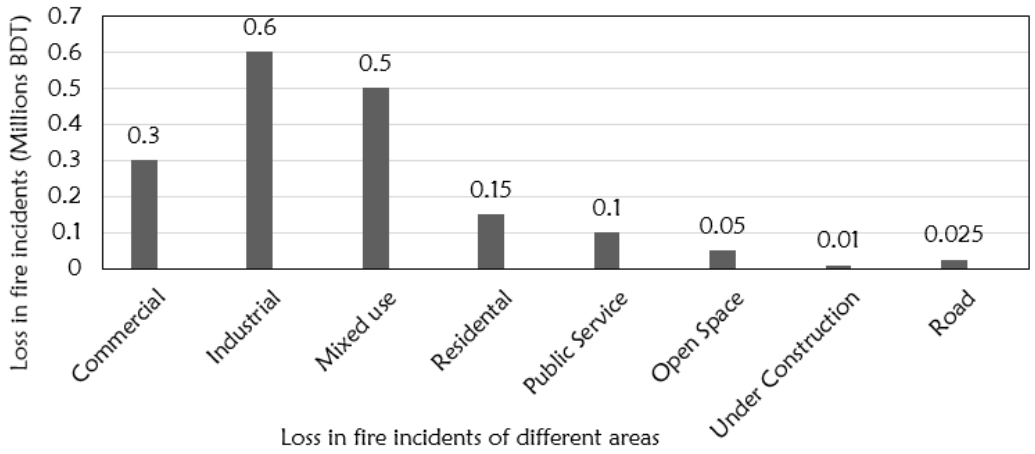

Figure 1: Average loss of fire incidents in Millions according to location (2011-2013) [31].

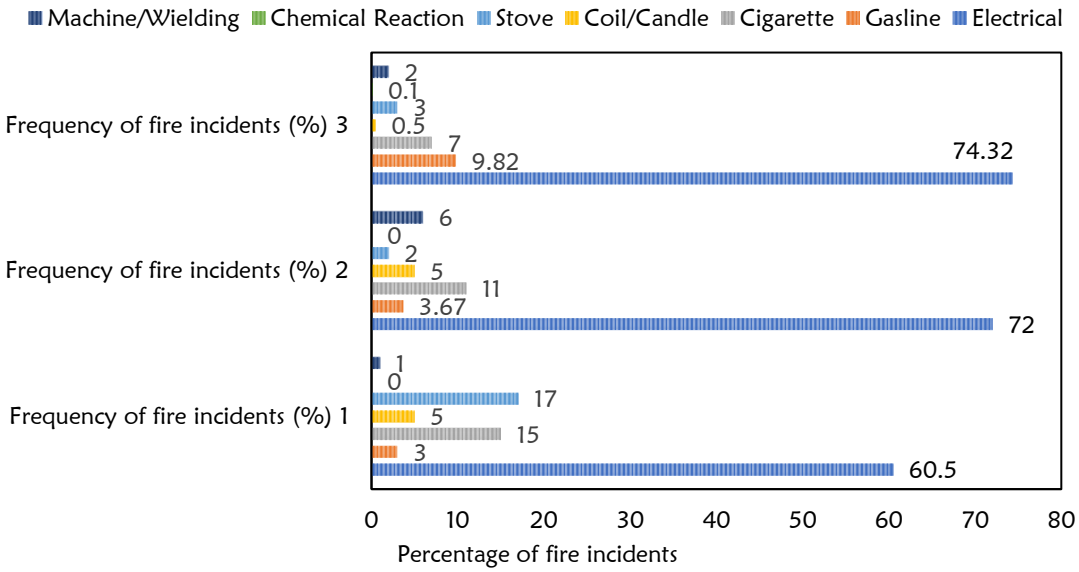

Figure 2: Distribution of sources of fire incidents according to structure type (2014) [31].

3.1 Manual Technique

As a result, basements, particularly those in lower flats, are at risk in the event of a leak. Small amounts of smells are added to household gases to help people comprehend how gas leaks. The smells make it simple to detect the gas. Because odorants are filtered and the characteristic odor is lost when a gas leak occurs in underground gas piping and the gas rises through the ground to the surface, only a gas analyzer can detect the gas level in the air. The gas explosion is distinguished by the fact that the fire that created the explosion is also dampened at the time of the explosion. This means that after a gas explosion, there is usually no fire [11]. This is due to two factors: first, the explosion occurs quickly, preventing other objects in the room from catching fire, and the burning gas itself quickly dissipates. Second, the room's explosion creates such a high pressure that the flames are suppressed. The ensuing pressure is great enough to cause the weakest buildings to collapse, allowing the gases to escape. Doors, windows, and shutters are installed in gas facilities in such a way that they open outwards and expel explosive gases, reducing the impact of explosions. In addition, lightweight panels are used for intermediate ceilings, and the number of glass surfaces is increased. If the same conditions exist in other locations or buildings where gas is used, the explosion's consequences will be less severe. If there is a gas leak in the room but no contact with the source of ignition, a saturated combination (too much gas and too little oxygen) will form at some point, rendering the room non-flammable. Alternatively, if the liquid level falls below the area being heated as a result of repeated venting, the tank construction can be overheated and weakened in that area [11].

If either of these events occurs, the container may explode violently, launching portions of the vessel at high speeds, while the discharged products may burn, posing a threat to anything close, including neighboring containers. LPG is

a highly flammable gas made up of a mixture of propane and butane. It is an odorless gas to which Ethanol has been added as a potent odorant to enable leak detection. LPG is now one of the most often utilized alternative fuels. LPG, LP gas, and Autogas are some of the other names for liquefied petroleum gas [12]. This gas is often used to heat appliances, provide hot water, cook, and for a variety of other uses. Due to the rising cost of gasoline and diesel, LPG is also employed as an alternative fuel in vehicles. Some people with a poor sense of smell may or may not react to low levels of gas leakage. In this circumstance, gas leakage security systems have become vital for preventing gas leakage mishaps. A lot of research articles on gas leakage security systems have been published. In the literature, an embedded system for hazardous gas detection and alerting has been proposed.

If the gas concentration exceeds the normal threshold, the alarm is immediately activated. In India, the Bhopal gas catastrophe was an example of a gas leaking event. This was the world's worst industrial gas leakage accident. Not only is it critical to detect gas leaks, but it is also critical to halt them. This study presents a low-cost, high-precision system that not only detects gas leaks but also alerts (beeps), shuts down major power and gas supply, and sends an SMS. A GSM module is used to deliver an SMS to the user as an alert [31]. The MQ-6 gas sensor was utilized to offer great accuracy. In industry, heating systems, home appliances, and cars, toxic and flammable gases are commonly used. Combustible gases such as propane, ethane, butane, methane, and ethylene fall under this category. Liquefied Petroleum Gas (LPG), commonly known as propane or butane, is often stored in liquid form in pressurized cylinders and vaporizes at room temperature [14]. A leak can produce an explosion if it ignites. As a result, gas leak detection has gotten a lot of attention in recent years, notably in the domains of safety, industry, the environment, and emission control. A traditional gas leak detection system uses on-site alarms to signal the presence of a leak. The typical leakage system has the disadvantage of being ineffective in the absence of a first-responder team on-site. As a result, a system to identify the leak and convey the information to the first response team via wireless media is required. In the absence of employees on-site, a leakage detection system that sends out a warning call or SMS is more effective [31].

3.2 Algorithmic Technique

Natural gas sensor, GSM module a microcontroller is connected to the fire sensors and will operate the entire system. Two sensors are employed in this system, and four conditions are specified while programming these sensors. A gas sensor and a fire sensor are calibrated in the first and second steps using the reference value provided. If the sensor reading exceeds the setup reference value, the microcontroller will sound an alarm until the gas or fire is detected. The third condition report will be displayed on the LCD screen. In the fourth scenario, the GSM module will send a text message to the fire station advising them of a gas or fire detection on any specific floor. Figure 3 shows an algorithm for detecting gas leakage [31]. Firstly, GAM module is to be started for detecting gas leakage. The system is queried for LPG or Fire. If the system is answered as yes then it sends data to microcontroller and shows to display the result [32].

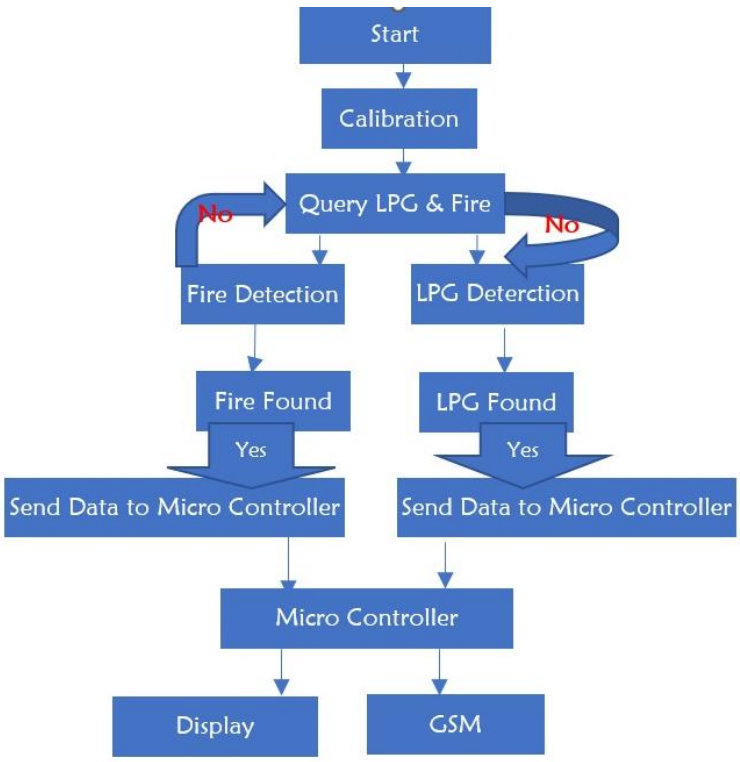

Figure 3: Algorithm for detecting gas leakage [32].

3.3 Modelling and Simulation Techniques

Considering the acrylic rectangular vessel in Figure 4 that is 100 mm x 30 mm and 2 mm in dimension. A 40 kHz ultrasonic sensor with a transmitter and receiver is mounted with a 10 mm gap on the chamber's left side. Both the transmitter and receiver are presumed to be 5 mm in size. The acoustic wave is transmitted by the transmitter, and it travels through the gas-filled chamber [33]. The wave reflects off the wall opposite and is picked up by the receiver. The acoustic wave's time of flight varies with changes in gas density. Utilizing software for finite elements, simulation was performed [33]. The signal needs to fly for 1270 microseconds in normal air to cover a distance of 200 mm across the gas medium. After that, the simulation was carried out by injecting SF_6 gas into the vessel. SF_6 gas density gradually increased. The signal's time of flight was calculated for each density value. Figure 5 narrates the change in flight time with rising gas density. The time the wave takes to travel rises with density, according to simulation data. The R_2 value of 0.9 indicates that the reaction is linear [33].

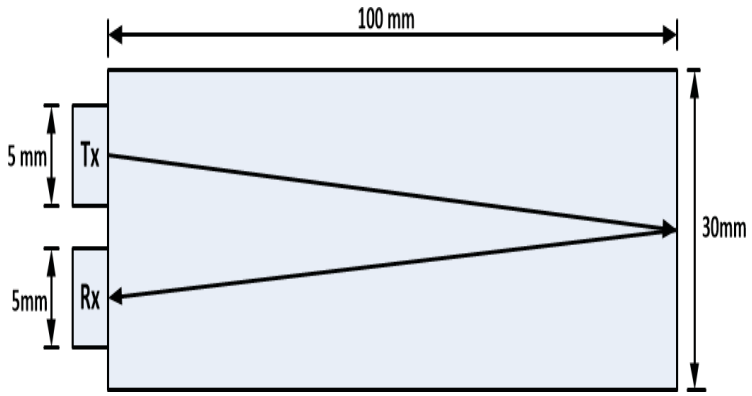

Figure 4: Schematic of the proposed method for detection of gas leakage [33].

4. CONCLUSIONS

The fire hazards caused by leakages in gas circulation lines are of great importance that results in a significant loss of wealth, lives and the environment. The risks of fire hazards can be reduced effectively through the use of new technologies and preventive measurements of the system. The aims of the paper is to review the effects of these fire hazards due to leakage in gas circulation lines in Bangladesh. The following findings can be depicted in present research.

a) In Bangladesh during 2018-2019, the total gas distribution line in the Titas gas system was measured as 13,138 km where the pressure-reducing system or gas riser was found as 1.2 million and the number of customers was found as 2.866 million. In the system, the number of fire accidents that occurred was 208 in the circulation system. Because of connecting the illegal gas lines and poor maintenance of the system, Bangladesh faces significant fire hazards every year.
b) A result of 80 percent lower explosive limits (LEL) or higher in a confined space is regarded as a grade 1 leak; result of 20 percent to 80 percent lower explosive limits (LEL) in a confined space are regarded as grade 2 leaks, and result of less than 20 percent lower explosive limits (LEL) in a confined space are regarded as grade 3 leaks.
c) The leak can be noticed if an unexpected hissing sound can be heard emerging from just about any pipes or regions that may house gas pipelines. The course of most recent but still not distant, our sense of sight can assist us in identifying if there is a natural gas leak outside our building or around. If we detect bubbling in puddles or dead plants in otherwise favorable positions, there may be an outside leak. If any fuel appliances have quite a yellow flame instead of a blue flame, there may be an inside leak. Since any of these leaks could result in an explosion or carbon monoxide poisoning, they have to be corrected quickly and immediately.
d) A key undertaking to lessen the risk of fire is the detection of leaks, repairs needed on the gas risers, and measurement of fugitive gas.

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