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ORIGINAL ARTICLE

Gas Pipelines Importance, Accidents and Hazards: A Literature Review study

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ABSTRACT

Natural gas is an important infrastructure for companies, governments, and societies. Pipelines are a common, safe, and effective way of transferring natural gas. Gas pipelines, for some reason, have a high potential to create an accident. Accidents in this field could impose great costs on companies, governments, and the environment. Accidents in this field have many reasons. Fire, explosion, poisoning, and rupture are four common types of accidents result. Investigating accidents is important for preventing future accidents. So, the methods for doing this are important for finding the right reasons. This study tries to review pieces of literature from the viewpoint of used methods for investigating gas pipeline accidents and risk assessment of their hazards. Also, the study aimed to find out common hazard types, countries that published articles, publishing journals, and publishing years.

KEYWORDS: *gas pipeline, accident, explosion, fire, rupture*

INTRODUCTION

The International Labor Organization (ILO) estimates that 2.3 million people die every year from occupational accidents in the world. Moreover, there are about 360 million job incidents annually and 160 million victims of occupational diseases. Most of the industry tries to find new ways and approaches to decrease this trend and increase safety in workplaces [1]. The safety of the gas industry is very important for two following reasons.

a. In most countries of the world, natural gas is a major source of energy. Some economic and environmental advantages like a small initial investment, less pollution, and low cost are major causes for consuming more and more natural gas energy [2]. So, the demand for natural gas has been increased in the habitable, commercial, and industrial fields because natural gas is known as clean, effective, and high-quality energy. Natural gas constitutes 20% of the European nation and a quarter of United States energy consumption [3]. Also, the International Energy Agency predicted that the annual

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energy consumption will be 4960 billion m^3 in 2020 and 4790 billion m^3 in 2030 [4].

b. The gas industry is one of the high-risk environments and the death rate in this industry is higher than in other industries [5]. Several catastrophic accidents have been made through gas release all over the world. For example, on April 22, 1992, more than 500 deaths and 7000 injuries occurred due to gas leakage and explosion in Mexico. Also, a gas explosion that was caused by construction on December 11, 1999, led to more than 12 injured in Sian, China. On August 2, 2004, a gas explosion caused a fire and 250 people were dead in Asuncion, Paraguay [6]. Through an accident that occurred in 2004, fourteen people were dead and more than two hundred were injured in the Belgium gas factory. Also, In 2009 Moscow's greatest fire after the second world war ll happened due to a gas explosion [7]. In December 2010, hydrogen sulfide released from a natural gas well made more than 240 deaths in Kaixian, China [8]. Another accident that occurred on September 2010 resulted in 8 fatalities in Sanrano, California. Also in February 2011, a gas explosion occurred in Allentown, Pennsylvania, resulting in 5 fatalities [9](Table1).

Thus, the safety issue in this sector is important and requires more attention. In the following sections of the paper, a brief introduction of natural gas and gas pipelines will be introduced, and in the second section, the failure and the various types of hazards in gas pipelines will be explained. Finally, by introducing a method of review, the results of the review will be presented.

Gas pipelines

One of the safest, common, and most effective ways of transporting this kind of fuel is a long-distance pipeline. Since gas cannot be stored for a long time, if problems are encountered in gas pipelines, the whole process has to be shut down [10]. So, it is important to understand and, if possible, improve the safety of natural gas pipelines to decrease accidents and deaths [11]. Fig.1 shows natural gas manufacturing, purifying, treatment, storage, and transmission by pipelines and liquid natural gas terminals as critical infrastructures [12].

Typically, there are three kinds of gas pipelines; Gathering pipelines: used for collecting natural gas from wells and carrying it to processing facilities or transporting to transmission pipelines. The second type is the transmission pipelines, which are used for transporting natural gas to national markets and sites

Table 1. some gas industry's fatal accidents in world

country	year	fatality	injury
Mexico	1992	500	7000
china	199	12	12
Paraguay	2004	250	14
Belgium	2004	14	more than 2000
China	2010	240	-
USA	2010	8	-
USA	2011	5	-

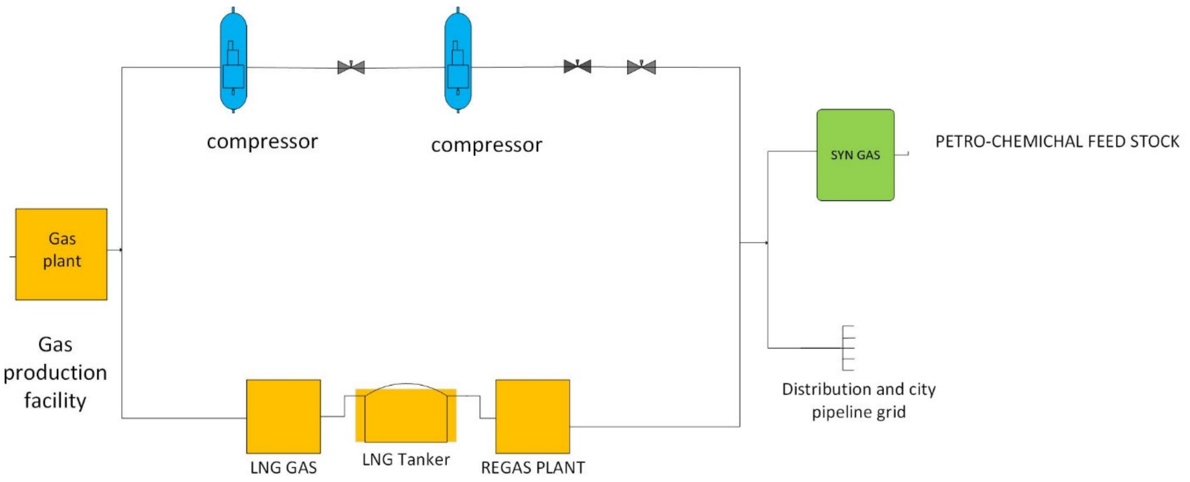

Figure 1. The flow sheet of gas manufacturing, purifying, treatment, storage, and transmission

Table 2. Three kinds of gas pipelines

Pipeline	Diameter(centimeter)	Pressure (pound per square meter)
Gathering pipelines	5.08 -30.48	800
Transmission pipelines	30.48-106.68	1440
Distribution pipelines	2.54-5.08	<100

of large energy users. The latest type is distributing pipelines that are used for distributing natural gas to habitable, commercial, and industrial field end-users (Table 2) [13]. It is worth remembering that there may be a different category in other sources. As mentioned, gas pipelines are one of the safest ways for transporting natural gas, but it has some problems. 1) Gas pipelines are aging and this increases the risk of accidents. 2) Social tolerance decreased for environmental pollution. 3) Sometimes gas lines overlap with people's residential sectors. 4) Gas pipeline accidents have a high fatality rate [14].

Failures and the various types of hazards in gas pipelines

Studying the release and displacement features of leaked gas is of great significance. Such features include distribution and speed within the soil, gas release, and movement to the ground surface, gas underground dispersion, and gas diffusion in the atmosphere. These features are key points for determining gas leakage risk [4]. Some factors (inner or outer) may result in rupture e.g., corrosion, aging, and quality of pipe material. A comprehensive study that has been conducted with the European Gas pipeline Incident data Group (EGIG) for a range of gas pipeline accidents distribution showed that external interference with 35% was the most common reason for accidents. After that, corrosion with 24% was in rank two and the third one was construction defect/material failure with 16%. Finally, ground movement and other reasons were 13% and 12% accidents in the next rank, respectively [15]. Pipeline ruptures and consequent leakage and desperation under soil may result in explosion, fire, and toxicity. Hence, this could impose significant hazards for human habitat and the surrounding environment, moreover, it may result in property losses. So, developing existing models and methods for predicting the consequent influence of leakage seems to be essential [4]. For doing this two models are of great significance: 1) near-field and 2) far-field. The first one is related to soil and ground and is input for the second one that is related to open space under or above ground.

In 1997, Montiel et al reported that, from 185 incidents in natural gas, 127 were associated with the pipeline and mechanical failure was of great significance. In fact, the failure rate varies due to pipe diameter. For example, the failure rate for small diameter pipe and large diameter pipe from European failure rates are 2×10-8 and 7.1 ×10-4 per km per year, respectively. While the standard failure rate probability is 10-6 per km per year [16]. Rupture in the pipeline is a very common cause of pipeline accidents. Typically, there are three kinds of rupture. The first one is called a small diameter rupture that has a crack size (diameter) of <20 mm that in most cases may lead to leaks. The second one is named hole (of size, d0) that has a size of 20mm<d0< pipe diameter. The last one is a complete rupture with a crack size equal to the pipe diameter [16]. Most of the time rupture has resulted in gas leakage. It is defined as the action of unmeasured gas that releases from a natural gas pipeline and this could happen due to inner or outer factors such as aging, corrosion, inappropriate welding, and long service time and so on. Leakage could lead to fire, explosion and sophistication of downwind, so leakage survey is important. Therefore, it is important that the gas leakage point is detected as soon as possible. In general, this could be done in two ways by hardware-based and software-based methods and this is the first step for calculating the leakage rate [17,18]. Statistics of 259 accidents showed that there are 7 kinds of common leakage types. 1) Bleeding valve (kind of valve) leakage with the amount of 78 accidents 2) valve leakage with the number of 76 accidents 3) flanges and pipes leakage with 61 accidents 4) buried pipeline leakage due to construction quality and corrosion with 17 accidents 5) the original transfer pipeline leakage with 12 accidents 6) Buried steel converter leakage with an amount of 8 accidents and 7) external damage with 7 accidents [19]. So these statistics could help us to determine crucial points and design a comprehensive plan for their risk management.

Risk assessment methods of gas pipeline

Risk assessment of gas pipelines and other natural gas infrastructure is very important because any accidents in this field have the potential to create a disaster and

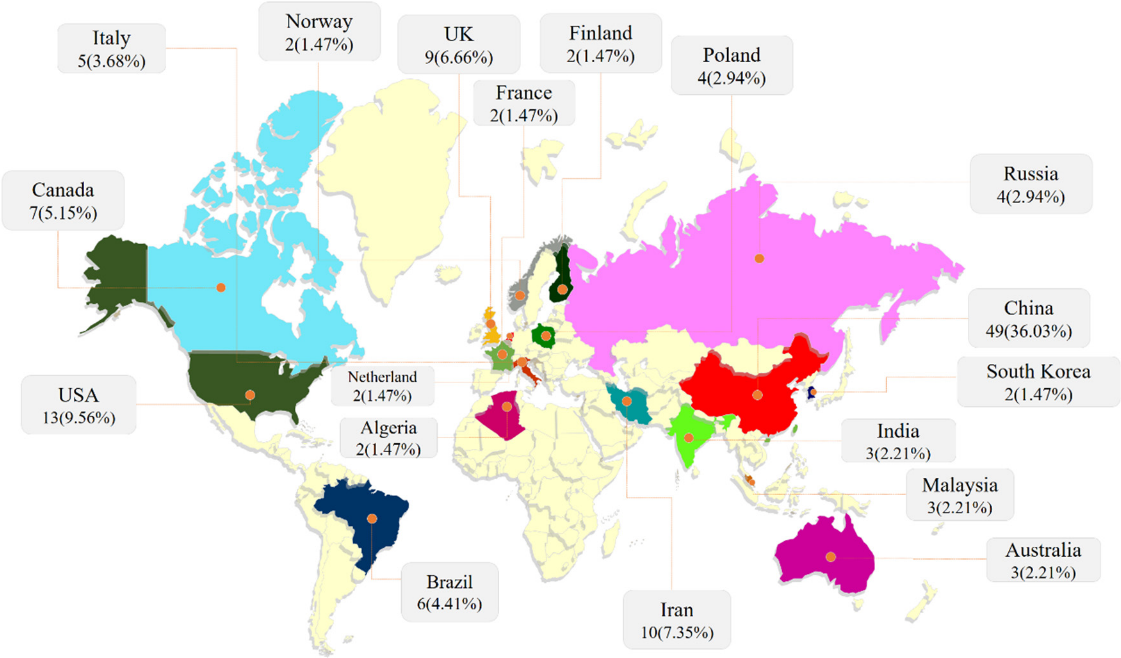

Figure 2 The number of published articles by country
* All of the unmarked countries (yellow color) have published 8(6.66%) off articles

due to the intrinsic nature of this kind of accident, human habitat, environment, and property are at great risk. A typically quantitative and qualitative approach has been used in literature and there is a vast range of approaches for analyzing and identifying risk. For example, Parvini et al. in their study carried out leakage modeling for buried lines under the ground, and finally presented a complete model for the propagation of gas from these lines. They used an event tree for analyzing gas leakage [20]. In another study, Bariha et al used a mathematical approach for hazard analysis of failure of natural gas and petroleum gas pipeline [16]. Wang et al. used fault tree analysis and Bayesian network for failure probability analysis of urban buried gas pipelines [21]. In another study that was conducted with Witek et al. in 2016, they used the Monte Carlo method for gas transmission pipeline failure probability estimation [22]. Li et al. used the bowtie approach and Bayesian network for risk analysis on leakage failure of submarine oil and gas pipelines [23]. Zhu used Computational Fluid Dynamics (CFD) model to find out a hazardous distance from the source of hazard and finally presented four important factors for gas leakage. Based on two types of parameters: 1) environmental parameters and 2) parameters of the source of emission they computed four distances for gas leakage: 1) Suffocation distance 2) Flammable vapor cloud distance 3) Overpressure distance 4) Thermal radiation distance [4]. In recent years, due to the fastest-growing rate of computer science, using computer-based approaches has been raised and researchers tried to simulate consequences of accidents with this technology. Tong et al. used MATLAB software for determining the hazardous area [24]. In another study conducted with Zhian et al., they used FLUENT software for simulation of flame propagation [25]. Mishra et al. used CFD software for investigating the explosion [26]. In recent years, using new technology has grown trend. Using this technology could help researchers to survey gas field infrastructure and incidents for more detailed information and increasing safety in this field.

CONCLUSION

Yes, in recent years, China has had a very high range of publishing about gas pipelines. This may be related to the high demand for natural gas for consumption and this trend is also high for countries that have high consumption and production of this type of fuel, such as the USA, UK, and Iran. Figure 2 demonstrates the countries that have publications of papers in this area.

Nowadays, the study of gas pipeline risks has been of great importance in recent years. Typically, the hazard analysis of gas lines is done in two ways: conventional methods and new methods. A review of studies for the methods that have been used has found that there is a varied range of methods used in the gas industry. These methods are used for various purposes, such as

Table 3. Methods that authors used for inspection of gas pipeline

Used method	Source
Bayesian Approach	[15,21,23,27-31]
Acoustic Emission	[17,32-39]
Computational Fluid Dynamic (CFD)	[8,26,36,40-48]
Fuzzy Approach	[9,12,21,39,49-52,]
Mathematical and Numerical Approach	[16,25,42,45,48,53-83]
Monte Carlo Simulation	[22,84-88]

Table 4. Articles that examine four different types of gas pipelines incidents

Study characteristic (Number)	Document
Number of study about explosion(25)	[4,12,13,15,16,20,24-26,28,33,46,48,49,66,89-96]
Number of study with fire(26)	[13,15,16,19-21,23-42,47,48,58,65,66,82,89-92,93,95-98]
Number of study about poison(26)	[8,13,16,24,26,31,42,44,46,49,52,72,82,86-88,90,92,93,65,99-104]
Number of study about rupture(18)	[13,27,33,49,51,60,66,70,72,88,89,91,93,94,96,97,105,106]

leak detection and simulation of consequences. Table 3 shows the methods that were commonly used in studies. It is worth mentioning that there are some other kinds of methods that were less common in studies and are not included in Table 3.

Gas pipeline accidents commonly occur in four ways: fire, explosion, poison, and rupture. Studies have been reviewed for these types of accidents. From 136 studies, 95 (69.85%) mostly discussed these features, and from these, 25 (26.31%) studies discussed explosions, 26 (27.36%) discussed fires, 18 (18.94%) discussed ruptures, and finally, 26 (27.36%) studies discussed poisoning in gas pipeline accidents (Table 4).

Regarding the day by day growing of the gas industry and consequently its related accidents, and development of computer-based Evaluator software and technologies, it can help researchers to use new methods and ways for searching in this field. Especially, as mentioned, software like MATLAB and CFD could be more helpful.

Herein, it was tried to review literature about the gas pipelines. The aim was to discuss and review literature from the viewpoint of gas pipeline accidents and their potential hazards and also, how researchers deal with these problems. Obviously, without gas, human life will interface with some serious problems; especially, in the fields of industry and residential sectors. Thus, imaging humans live without natural gas is very hard and besides natural gas, there are very significant hazards and there is no choice other than accepting them. Thus, the only choice is safety and one must try to improve safety of gas pipeline and its other sectors.

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