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Research on Safety Precautions of Pipeline Supply Chain Aiming at Zero Accidents

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Abstract

Oil and gas accidents typically involve leaks from pipelines that disrupt normal operations, particularly in pipeline sections. However, China's existing trunk pipeline capacity is insufficient, and the degree of pipeline networking is still low. Additionally, the construction of natural gas peak-shaving facilities supporting pipelines lags behind, some pipelines are aging, and safety hazards are prevalent. Moreover, the government supervision and legal systems remain imperfect. This paper adopts a case study approach to examine recent incidents in Jiangxi Province and identify shortcomings in China's oil and gas pipeline transportation. It is clear that China must accelerate the construction of pipeline transportation networks and supporting natural gas peak shaving facilities, promote scientific and technological advancements in pipeline transportation, and adopt a multi-pronged approach to ensure pipeline safety. Only then can China meet the requirements of resource diversification, supply networking, and deployment automation in oil and gas pipeline transportation.

Keywords: Pipeline Transportation, Natural Gas Pipeline, Network System, Accident Disaster

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Introduction

As global economies continue to grow, the demand for oil and natural gas resources has risen, resulting in an increasing need for oil and gas pipelines. These pipelines have proven to be efficient and cost-effective for transportation. In China, pipeline transportation has become the primary method for oil and gas transportation on land, with the establishment of strategic channels that run through southeast, northwest, and connect land and sea. However, 60% of China's existing pipelines are over 20 years old, with some crude oil pipelines in the east operating for more than 30 years. These aging pipelines, coupled with low automation, outdated communication facilities, extended service of storage facilities, among other issues, have led to frequent accidents that require constant adjustment and transformation. Additionally, pipeline safety is threatened by natural disasters and man-made destruction, making the control and operation of pipelines increasingly complex. Therefore, it is crucial to strengthen the safety guarantee of pipeline transportation (Hu et al., 2017; Wang et al., 2018).

The global natural gas supply and demand are changing structurally, with recoverable conventional natural gas resources at approximately 3,671,012m3, and 1,701,012m3 yet to be discovered as of 2018. Major natural gas exporting countries have surplus reserves, with a productivity reserve of over 50 times that can increase reserves and production in the long run. However, the remaining recovered resources are relatively concentrated accounting, with the top ten countries for 77.1% of total remaining recoverable reserves and

60.7% of output (Qi & Zhang, 2009; Gao et al., 2017). China's oil and gas pipeline safety management faces various challenges that hinder its effectiveness. These include: 1) Failure of some pipeline managers to enforce regulations, leading to frequent oil theft and hampering oil management; 2) Inadequate maintenance of long-running pipelines, resulting in oil leakage accidents that threaten lives and the environment; and 3) Potential safety hazards in some pipelines due to construction processes and personnel. To address these challenges, this paper examines case studies in Jiangxi Province and proposes solutions towards achieving zero-accident pipeline transportation.

Literature review

Analysis of pipeline transportation accident types.

1. Natural disasters:

Pipeline accidents can be categorized into primary and secondary disasters, which are caused by natural disasters and man-made accidents. Natural disasters, such as rainstorms and earthquakes, can have a significant impact on China's oil and gas pipelines and facilities. The nationwide oil and gas pipeline network system is vulnerable to environmental changes, and heavy rainfall during the flood season can cause water and soil erosion, leading to pipeline suspension. Water flow and external pressure can also cause pipelines to deform and leak. The impact of earthquakes on ground facilities is mainly affected by earthquake intensity and soil liquefaction.

2. Man-made disasters:

As urbanization continues, infrastructure construction is rampant, resulting in frequent ground-breaking activities. Improper use of diggers or lack of communication with oil and gas network management companies often lead to the inadvertent destruction of oil and gas pipelines and facilities.

Secondary disasters related to oil and gas pipelines include accidental injuries caused by explosion, corrosion, and fire. (Netto, et risks and exacerbate existing hazards.al., 2007) Oil and gas are highly flammable and explosive, and their transportation through pipelines occurs under high pressure. If the quality of the pipeline is poor or welding is inadequate, the pipeline may not withstand the pressure, leading to oil and gas leaks. These leaks can quickly mix with the air and ignite, causing explosions or fires. Pipeline corrosion can occur both internally and externally, and external corrosion is more complex and depends on several factors, including the pipeline's cathodic protection, external coating quality, soil, anti-corrosion measures, service time, current interference, and stress corrosion. Additionally, pipeline construction that deviates from established steps or takes shortcuts can also create potential

How to achieve zero disaster.

In the 1960s, the concept of risk acceptability from sociology was introduced to engineering decision analysis to address the issue of "enough safety is still not safe." (Starr, 1969). Since the 1970s, scholars have studied risk acceptance criteria as a link between risk assessment and decision-making. The book "Acceptable Risk" proposes that risk is acceptable only if the benefits outweigh the potential loss, and it puts forward risk acceptance standards to protect the interests of all parties (Bier, 2010). Pipeline risk acceptance standards fall into two categories: those formulated by operators from an economic perspective seeking to balance safety and efficiency using the ALARP principle and cost-benefit analysis, and those established from a social perspective aiming to protect the lives and environment of surrounding residents (Abrahamsen & Aven, 2012; Ale et al., 2015; Pei et al., 2018). To minimize the wide impact and serious consequences of oil and gas pipeline accidents, it is crucial to accelerate legislation on pipeline safety, enhance the pipeline integrity management system and basic database, conduct thorough research on related safety technologies, and develop widely applicable risk management measures. These efforts aim to ensure the safe, efficient, and cost-effective operation of oil and gas pipelines.

"Zero disaster" aims to reduce the impact of disasters caused by human factors by minimizing and avoiding them through daily work. Pipeline risk management is a continuous improvement process that involves pipeline risk and integrity management, including risk assessment and analysis, risk control and policy support, efficiency testing, and response. By drawing lessons from risk analysis methods used in Europe, America, and other countries for oil and gas pipelines and combining them with the characteristics of China's pipelines, we can gradually identify and assess risks and establish a set of widely applicable risk management methods for oil and gas pipeline transportation.

Research Method

A case study, also known as a case investigation, is a research method that focuses on a particular individual, unit, phenomenon, or subject. This type of research involves extensive data collection, detailed analysis, and sorting of information related to the emergence and development of the research object, as well as the internal and external factors and their relationships. The goal is to form an in-depth and comprehensive understanding and conclusion of relevant issues. Case studies can involve individuals, groups, organizations, events, or specific problems, resulting in case studies of personnel, living units or social groups, media cases, and various social problems.

Through case analysis, we can establish the causal relationship in an accident by analyzing previous experiences from the beginning, through the process, and to the conclusion, thereby achieving the research objective. Case studies have become a valuable tool for disaster prevention because the prevention of disasters and accidents heavily relies on past experiences

Results and discussion

Case analysis

Case 1: Case of the Second Line Project of West-East Gas Transmission

On May 26, 2013, at 7:00 a.m., a gas leakage accident happened in PetroChina's second line project of the West-East Gas Pipeline, which had been operational for less than six months. The incident occurred in the Shangli County branch of Pingxiang City, Jiangxi Province. The pipeline broke, caught fire, and exploded causing five injuries and an economic loss of approximately 7.94 million yuan

Figure 1 Pipeline Repair

The accident analysis revealed the following main causes: (1) Defects in the welding quality of No.19 RW joint, combined with pipeline stress, resulted in the pipeline rupture. (2) The pipeline was not handled using a pipe crane during laying, leading to damage and increased stress. (3) The welding process did not involve the use of an internal aligning device, and quality control was inadequate, resulting in welding defects. (4) The construction team carried out illegal operations and did not follow regulations on the use of special machinery, which led to pipeline damage. (5) The supervision unit did not effectively manage the construction process and lacked expertise, knowledge, and standards for welding and construction. The accident primarily resulted from inadequate pipeline quality and unprofessional construction practices leading to gas leakage.

Case 2: Fengxin branch natural gas pipeline case

The construction of the natural gas pipeline in the Fengxin branch section of Jiangxi Natural Gas Co., Ltd. commenced in April 2011 and was operational by July 2013. The pipeline's design pressure is 6.3MPa, its diameter is 219mm, it is made of L415 material, and 3PE reinforced anticorrosion has been implemented. Currently, the operating pressure is 4.6Mpa, and it transports high-pressure flammable and explosive natural gas. During a routine inspection on June 5th, 2017, the local line patrol of the new line patrol team of Nanchang Management Office discovered that the hydraulic protection foundation of the pipeline on the east side of Shibi Hexi River in Chishi Village, Shibi Town, Anyi County had partially collapsed due to heavy rain and river erosion. The original riverbed's hardened layer was also washed away by the river.

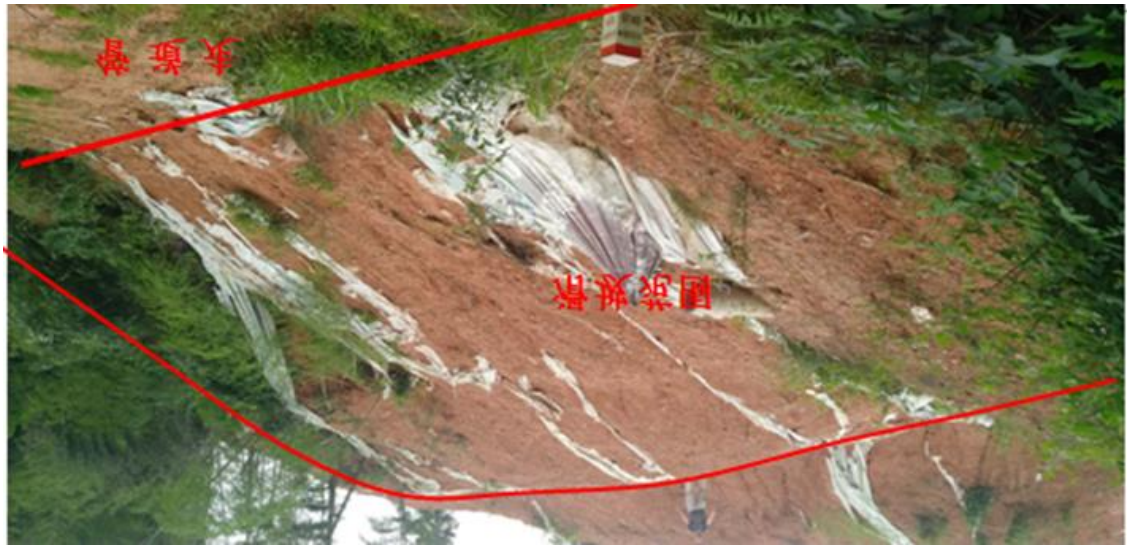

Figure 2 Schematic Diagram of Landslide Surface of Geological Disaster

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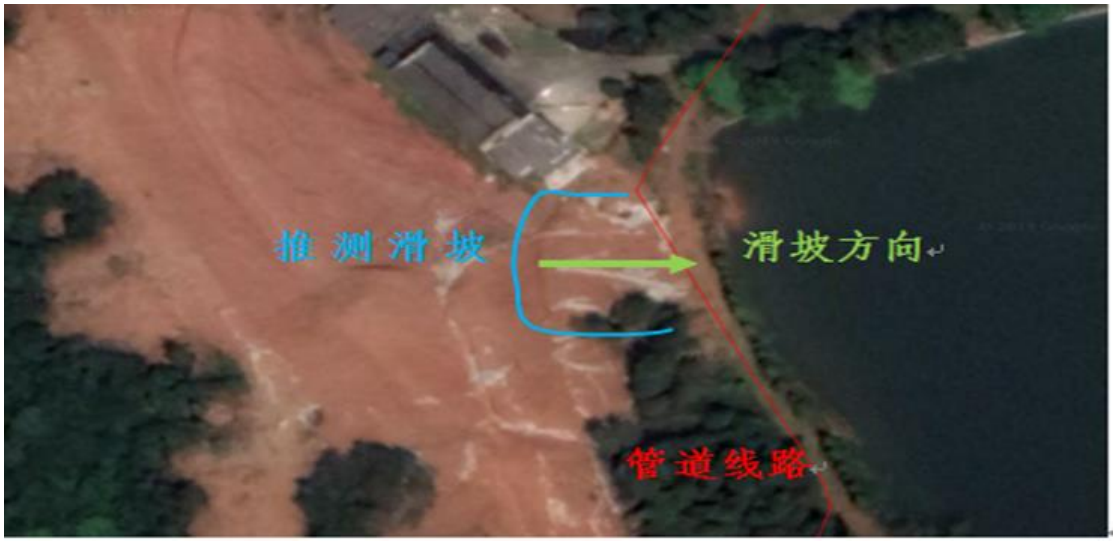

Figure 3 Schematic Diagram of Landslide Surface of Geological Disaster

Figure 4 Hydraulic protection and restoration

The main cause of the accident was due to the partial collapse of the hydraulic protection foundation of the pipeline on the east side of Shibi Hexi River, which was caused by continuous heavy rain and river erosion. When pipelines cross waterways, the foundation of the pipeline bottom may be partially hollowed out by the hydrodynamic force, creating a suspended pipeline section, which can result in the pipeline breaking, leaking, and even exploding. This is a common issue that can occur in such situations, and in this case, due to the geographical environment, the bottom of the pipeline was further hollowed out, leading to the gas leak

Case 3: Ganzhou Deep Combustion High Pressure Natural Gas Pipeline

On August 30, 2016, during the engineering geological survey project (No.QZK176, third contract) of Yingbin Avenue in downtown Ganzhou, Jiangxi Province, a sub-high pressure natural gas pipeline belonging to Ganzhou Shenran Natural Gas Co., Ltd. (406×7.1 in specification, 1.6MPa in design pressure, and 1.5MPa in operation pressure) was drilled through, causing gas leakage. There were no reported casualties, but the incident resulted in a loss of 2.53 million yuan (according to the original data source on construction safety).

Figure 5 Construction near the pipeline

Case analysis: Gas leakage occurred due to illegal operation by Ganzhou Municipal Engineering Company, the construction unit, during the excavation of the street lamp base, resulting in the cutting off of the gas pipeline. Improper construction practices by the unit led to the rupture of the pipeline and subsequent gas leakage.

Discussion

The main reasons for this study are discussed in the following table.

Table 1 Analysis and prevention methods of each case

	Name, time and place	Characteristics	Disaster loss situation	Prevention and cure method
Case 1 Case of the Second West-to-East Gas Pipeline Project	At 7: 00 a.m. on May 26, 2013, a leakage accident occurred in the second line project of PetroChina's West-East Gas Pipeline, which was put into operation for less than half a year. The natural gas pipeline located in Shangli County, Pingxiang City, Jiangxi Province, was broken, caught fire and exploded.	primary disaster	Five people were injured and the economic loss was about 7.94 million yuan.	1. Governments at all levels shall specify the competent departments or institutions of natural gas pipelines. 2. When the government makes urban planning, it should give full consideration to cross-construction, and increase the punishment for those units that build at random and construct savagely. 3. Pipeline enterprises should inform the relevant departments of the geographic information of pipelines for the record in time, and at the same time, they should strengthen the supervision and management of their own pipelines, and make 24-hour on-site monitoring during the third-party construction.
travel to watch industry Fengxin Branch Natural Gas Pipeline Case	On the morning of June 5, 2017, the hydraulic protection foundation of the pipeline on the east side of Shibi River was partially collapsed due to continuous heavy rain and river erosion, and the hardened layer of the original riverbed was also washed away	primary disaster	without	1. According to the collapse danger of the hydraulic protection part, start the emergency plan, and organize the construction unit to reinforce the collapsed part with sandbags. Due to the rapidity of the river, two full-time line patrol members of the line patrol team will be arranged at the scene to inspect the reinforcement every hour in the evening to ensure the safe and stable operation of the pipeline.

	by the river, which was prone to gas leakage.			2. According to the site conditions, formulate the protection construction scheme here, determine the slab culvert to protect the pipeline, and reinforce the hydraulic protection of the pipeline in the form of concrete retaining walls on both sides of the riverbank.
Case 3 Case of Ganzhou Deep Combustion High Pressure Natural Gas Pipeline	On August 30, 2016, engineering geological survey projects such as Yingbin Avenue, downtown Ganzhou City, Jiangxi Province, and related intersections led to gas leakage.	primary disaster	No casualties, loss of 2.53 million yuan.	1. The construction administrative departments of counties (cities, districts) earnestly perform their duties, benchmark the tables, and resolutely do it together, investigate and punish the gas safety accidents caused by illegal excavation and brutal construction. 2. To urge Natural Gas Company Limited to strengthen the daily management of line patrol personnel and strengthen the construction of emergency repair team. 3. To strengthen the daily safety supervision of pipeline construction projects.

Conclusions and suggestions

According to the results of the above case analysis, some suggestions are put forward:

Pipeline transportation is vulnerable to various uncertainties and risks due to the complex geological environment it spans. Soil erosion, landslides, floods, collapses, debris flows, and earthquakes are among the natural and human factors that lead to countless accidents every year (Liu & Cheng, 2017; Alvarado-Franco et al., 2017; Li et al., 2017).

1. Establish and improve the basic database related to oil and gas pipelines.

(1) Establish the basic database of oil and gas pipeline accident cases.

Examine both domestic and foreign incidents involving oil and gas pipelines, draw upon the best practices of international pipeline management, and create a foundational database of pipeline accidents tailored to the unique characteristics of China's pipeline infrastructure.

(2) Establish the database of environmental background value of oil and gas pipeline crossing area. Conduct surveys and monitor the environmental background values of surface water, groundwater, atmosphere, soil, environmental noise at stations along the pipeline, and equipment noise in the pipeline crossing area. Develop a database of pipeline environmental background values based on the collected data.

(3) Establish a database of potential environmental risks in oil and gas pipeline crossing areas.

Analyze and identify potential hazardous events and the severity of their consequences during oil and gas pipeline crossings. Establish a dynamic database of environmental risks and evaluate identified hazardous factors using scientific methods. Develop corresponding control measures for unacceptable risks.

2. Formulate and run the integrity management plan for oil and gas pipelines.

To face the constantly changing factors, pipeline companies must identify and evaluate risk factors in oil and gas pipeline operations. Through monitoring, detection, and inspection, they obtain information on pipeline integrity and combine this with professional management to formulate corresponding risk control measures. They continuously improve identified adverse factors to maintain pipeline operation within a reasonable and acceptable risk level. This circular process of inspection, risk identification, evaluation, and risk reduction is necessary to prevent accidents and ensure the safe and economically feasible operation of pipelines. Regular inspections and risk evaluations must be conducted at certain intervals to sustain the integrity management of the pipeline.

3. Strengthen safety technology research related to oil and gas pipelines.

To reduce the risk of failure accidents of oil and gas pipelines, research on geological disasters, earthquakes, meteorology, and other factors that have a significant impact on long-distance pipelines needs to be strengthened. The change of natural environment can cause external interference and become a critical cause of pipeline failure accidents. Therefore, conducting research on the above-mentioned natural environmental factors and establishing a database of their dynamic changes can effectively reduce the failure risks that pipelines face.

4. Strengthen the research on relevant detection technologies of oil and gas pipelines and improve the detection capability and level. Regular internal and external inspections and evaluations of pipelines should be conducted, and pipeline integrity management should be promoted and implemented as soon as possible. It is essential to develop an intelligent detection system for oil and gas pipelines that is suitable for the actual situation of Chinese pipelines, based on the digestion and absorption of foreign pipeline corrosion detectors. This will enable comprehensive detection and safety evaluation of existing Chinese oil and gas pipelines.

Through this research, we have gained a deeper understanding of the challenges faced by China's pipeline transportation and identified corresponding solutions. These findings can help to promote the development of China's pipeline transportation industry, increase the exploration and development of oil and gas resources, ensure the growth of reserves and output, and diversify import channels to mitigate over-reliance on foreign sources. Currently, natural gas has a better safety record compared to oil due to its more recent development and diversified sources. We calculated the Herfindal index for China's natural gas industry, which

suggests that the overall situation of China's natural gas security is still relatively loose, with a diversification level comparable to major EU countries (Wang et al., 2017; Huang, 2011); Zhao, et al., 2018).

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