Leakage Detection on Pipelines using IIoT and Edge Computing: A Systematic Literature Review Using PRISMA

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Abstract

Pipelines are principal components for storing and transporting petroleum products be it oil or gas. Automated monitoring and control systems for oil and gas operations that are operative, secure, inexpensive, and transparent are attainable through Edge computing and the Industrial Internet of Things. Pipelines need to span several kilometers to transport these petroleum products and some of such areas might not have internet coverage. Additionally, most Industrial Internet of Things systems are developed based on pressure readings obtained from the sensors mounted on pipelines. This study presents a systematic review, using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines, to identify the various pipeline leakage detection techniques in use. This model helps to improve the reporting of systematic reviews and aids the critical appraisal of published systematic reviews. The study also investigated what other data can be measured, using Industrial Internet of Things, that would indicate leakage in the pipeline. With the initial collection of 41 articles from prestigious databases such as Springer, Multidisciplinary Digital Publishing Institute, Sensors, and Science Direct, a final number of 16 articles were obtained after following the principles laid down in PRISMA. Amongst the publications by countries, China emerged the top publishing country followed by Iran. The parameters most frequently measured for the detection of leakage are pressure and other parameters are temperature, acoustic signals and vibrations around the pipeline. The results indicate that Negative Pressure Wave is one of the most promising methods for pipeline leakage detection.

Keywords: Leakage Detection; Pipelines; IIoT; Edge Computing; Systematic Literature Review; PRISMA

1.0 Introduction

The use of pipelines for the transportation of oil and other fluids over long distances and borders is the most economical mode of transport. The advantages of this means of transportation include speed and low cost, therefore it has become the preferred choice by a great number of oil and gas industries (Korlapti et al., 2022; Yang et al., 2021). In addition, in the last decade, these pipeline networks have been considered the safest means of storage and transportation of oil and gas (Spandonidis et al., 2022). As a result, there is an increase in pipeline installations which has led to a rise in the number of jobs and output thereby affecting the economy positively (Ewing, 2020). The durability of the pipes does not repel damages as ruptures can still occur, causing leakages. Inadvertently, such leakages result in financial losses, energy waste and, most significantly, in immeasurable environmental disasters and possibly human casualties. In some parts of the world, such leakages can arise from vandalization of the pipeline by thugs. Remote monitoring and administration of the oil field operations are vital to the safety of the pipelines. The pipeline is unavoidably affected by natural corrosion, aging, geological disasters, and man-made destruction. Such disasters lead to pipeline leakage which leads to extensive damage to the environment and poses a threat to the health and safety of the population. These pipeline leaks usually lead to a large number of losses for the oil industry. As such, extensive research has been carried out to detect such leakages.

Leakage detection systems have come to the forefront of tackling pipeline leakage. Cutting-edge technologies such as data analytics, artificial intelligence, and IoT have been beneficial to the oil and gas sector and such technologies have been used to increase productivity, promote safety, reduce environmental hazards, and improve security (Ramsey et al., 2023).

The aim of this study is to carry out a systematic review, using the PRISMA guidelines, to identify the various pipeline leakage detection techniques in use. This was achieved through the following objectives: identify relevant literature using varying keywords and search terms; screen the closely related articles that have the full text available by reading through the downloaded articles; extract the relevant features regarding Leakage Detections Systems by judiciously reading through the selected articles; and present a comprehensive report of the reviewed literature using the PRISMA guidelines.

In this review, the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) methodology was used to try to identify as many eligible studies as possible. Out of the total of 41 articles, 16 were selected for review. Considering this output, a possibility exists that if more studies are included, the results would be more explicit.

2. Review of Key Concepts

The following sections contain the discussion of key concepts of the work.

2.1 Edge Computing

Edge computing is an imminent concept in the computing landscape. It brings the services of cloud computing closer to the end user and is characterized by fast processing and quick application response time. The Edge computing model provides low latency, mobility, and location awareness support to applications that are sensitive to delay (Khan et al., 2017). Edge Computing has emerged due to the shortcomings in the computation of large data of traditional cloud computing technologies. The computation is now done on the device network close to the data source (Cao et al., 2020).

2.2 Internet of Things

Internet of Things (IoT) is a technology that connects any possible objects/things, for the basis of communication among themselves to provide better services for users unimaginably, making their life easier. Intelligent things could be a set of sensors, actuators, smartphones, etc. Some of the applications of IoT include smart home, smart city, smart agriculture, smart retail and smart health, etc (Sobin, 2020).

2.3 Industrial Internet of Things

The Industrial Internet of Things (IIoT) emerged as a result of several interoperable issues from IoT, including a large number of heterogeneous IoT gadgets, tools, software, sensing, and processing components all connecting to the Internet, despite the deficiency of communication protocols and standards (Hazra et al., 2021). Industrial Internet of Things (IIoT) is a significant component of future industrial systems. It offers interconnection and intelligence to industrial systems through sensors and actuators with ubiquitous networking and computing abilities (Yu & Guo, 2019). A definition coined by Boyes et al. (2018) reads, “IIoT is the use of certain IoT technologies – certain kinds of smart objects within cyber-physical systems – in an industrial setting, for the promotion of goals distinctive to the industry.” (p. 3)

It is seen that IIoT is an extension of IoT and it is specifically for the industry. Pipelines need to span several kilometers to transport these petroleum products and some of such areas might not have internet coverage. Additionally, most IIoT systems are developed based on pressure readings obtained from the sensors mounted on the pipelines (Ramsey et al., 2023). This study seeks to investigate what other data can be obtained from the sensors that would indicate a leakage in the pipeline. The study will critically evaluate the IIoT and Edge computing solutions for automated oil leakage detection on pipelines.

3. Review of Related Work

Spandonidis et al. (2022) developed a low-cost, high-performance wireless sensor network for the rapid detection of leaks in metallic pipeline systems carrying gaseous and liquid petroleum products in loud industrial settings. To reduce interference in the piping system, they used an approach that is based on analyzing the spectrum of vibration signals that arise in the pipeline walls as a result of a leakage effect. To extend the range of the sensors and hence lower cost, low frequencies were employed to identify and analyze leakage. The smart sensor system was developed for signal gathering and data processing. The signals obtained by the accelerometers positioned on the pipeline wall were utilized to extract spectrograms, which were then classified using a 2D-Convolutional Neural Network (CNN) model. To gather data from the accelerometers and give an unsupervised leakage detection method, Long Short-Term Memory Autoencoders (LSTM AE) were used. In such environments, the environmental sounds can produce vibrations that could impact the accuracy of the vibrations sensed due to pipeline leakage.

Khan et al. (2017) proposed an IoT architecture that could detect anomalies in the oil and gas industries to ensure faster remedy. The architecture is deployed to make data collection from connected objects simple, secure, robust, reliable, and quick. It is also deployed for monitoring various operations of the upstream, midstream, and downstream sectors of the oil and gas industry. The proposed IoT-based modular architectural design comprises three modules namely; module of a smart object, a module of a gateway and a module of a control center (server). Each module has layers (including sensing, networking and application layers) and tackles specific functions to support monitoring of the interconnected oil field environment.

Gao et al. (2021) investigated methods used for oil and gas pipeline leakage detection. To solve the problem of low accuracy, the Particle Swarm Optimization (PSO) algorithm optimized Support Vector Machine (SVM) was introduced. For experimentation, negative pressure wave signals under varying working conditions were collected. Denoising and data preprocessing precede the statistical operation extracted from the signals to form eigenvector samples, which were used as input for the SVM. Four working conditions were taken as output namely: normal, leakage, rise, and fall. The performance of the PSO-SVM algorithm was better than conventional SVM and can be trusted for deployment in leak detection of oil-gas pipelines.

Ramzey et al. (2023) deployed Industrial Internet of Things (IIoT) and Edge Computing (EC) framework for smart real-time and remote monitoring and controlling of crude oil production exploitation. The system was simulated and implemented in an oil field using real data. The architecture has the device layer which comprises electrical submersible pump (ESP) and complementary sensors, the IIoT-EC layer which comprises a Raspberry Pi board, Modbus interface board, MIFI (standing for "my WiFi," which is a mobile hotspot device), and power bank, the cloud monitoring and design layer which comprises the servers and the enterprise control system and this layer is responsible for monitoring and controlling the ESP remotely through the industrial dashboard introduced by the cloud as an enterprise control system. The IIoT gateway was used to gather information about the IIoT measurement values of the ESP well, then, it sends it to Adafruit IO via a transaction. The implementation was tested on Adafruit IO. The results were overall satisfactory for the wells operation crew compared to the SCADA system. However, the implementation still needs some improvement regarding the electrical metrics which should be added to the dashboard, and proactive tips need to be introduced to the smart system on the software side to minimize electrical blackouts.

Anwar et al. (2019) designed the invasive sensors with time stamp (ISTS) algorithm a framework for possible oil and gas pipeline anomaly localization detection. The framework designed was to be applied to tasks of monitoring pipelines and to provide a framework for anomaly localization using Cooja open-source java-based wireless sensor network simulator and geographical information systems that can also be used in pre-disaster management scenarios. Among the available localization techniques, the negative pressure wave and the pressure point analysis methods were used since they are recognized as state-of-the-art techniques. The invasive sensors with time stamp (ISTS) algorithm were implemented and the outcome was compared with the other two above-mentioned methods. From the results they obtained, the ISTS algorithm superseded the other two. Its accuracy was not affected by pipeline transient flows and type of material. Time synchronization was also not an issue as the clock is maintained by the invasive sensor. Minimal fluid loss can be achieved through preventive measures which can be taken before an anomaly occurs. This can be achieved through scheduled monitoring. This is not possible with the other two techniques. However, it incurs high implementation costs on existing pipeline infrastructure. On the other hand, Pressure Point Analysis (PPA) and Negative Pressure Wave (NPW) incur low implementation costs but are unreliable in anomaly localization and detection for transient flows. With PPA, the occurrence of multiple anomalies at different locations at the same time cannot be detected or localized.

Yas & Qassab (2023) developed a system for detecting pipeline leaks using pressure and water-flow. An accelerometer and voltage sensor coupled to an Arduino mega microcontroller with BLYNK IoT platform was used for real-time monitoring. It is obvious from the data that the Oil Pipe Monitoring System is capable of displaying pipeline flowrate, pressure, and acceleration. When a leak occurs or an event occurs during operation, a message is delivered to the responsible technical individual indicating which pipe is leaking. The authors were able to build a system that successfully established an Internet of Things (IoT) platform to monitor pipeline events in real-time.

Fereidooni et al. (2021) proposed a hybrid model-based method for leak detection in large-scale water distribution networks. The authors employed the use of simple and cost-effective flow sensors installed on each junction in the pipeline network. Hydraulic equations like Hazen–Williams, Darcy–Weisbach, and pressure drop were used to demonstrate how influential features for leak detection would be generated while Decision Tree, KNN, random forest, and Bayesian network were used to locate leaks and their pressure in the pipeline. The Vitens company data set of the open challenge 2015 that describes the water distribution networks of Leeuwarden City in the Netherlands was used which contains data on flow, pressure, temperature, turbid, conductivity, and acidity. Water GEMS water distribution modeling application was used for simulation. Eight (8) scenarios were used to try out the proposed model and each obtained accuracies between 72.00% and 99.15% with the highest obtained using the Random Forest algorithm.

Sun et al. (2011) designed an underground pipeline network monitoring network using magnetic induction-based wireless sensors (MISE-PIPE). It is low-cost and real-time leakage detection and localization for underground pipelines. The network was able to detect and localize leakage on the pipeline by jointly utilizing the measurements of different types of sensors that are located both inside and around the underground pipelines like the pressure sensors, the acoustic sensors, and soil property sensors. The Magnetic Induction waveguide technique was adopted and the measurements of different types of sensors throughout the pipeline network were reported to the administration center in real-time. MISE-PIPE highly depended on two types of wireless communication needs: the communication between soil property sensors and the processing hubs, and the communication between the processing hubs and the remote administration center.

Wang et al. (2016) proposed a pipeline leak detection system using fiber Bragg grating (FBG) pressure sensors based on negative pressure wave (NPW). It was evaluated using a pipeline leakage test platform that was established and experimented on to verify the performance of a system using this FBG-based approach. The results obtained show that the system can accurately determine the pressure change trends along the pipeline and also allow the calculation of the NPW velocity online. In comparison with traditional NPW detection techniques, the novel detection system was able to achieve a higher leak-location accuracy and detection with smaller leakage volumes. This was a result of the FBG-based system allowing a large number of sensors to be multiplexed along the pipeline. The corresponding output signals generated gave a very satisfactory, high signal-to-noise ratio which makes it efficient, especially in response to extraneous signals and thus disturbances caused by the pump starting or stopping. The design of the system was to minimize the instances of false alarms.

Yang et al. (2022) proposed a novel ensemble model of a one-dimensional convolution neural network (1DCNN) and support vector machine (SVM) to improve the detection accuracy in the process of pipeline leakage detection. As the first step, 1DCNN was developed and used to extract data features. Variable Amplitude Particle Swarm Optimization (VAPSO an improved particle swarm optimization (PSO) algorithm) was proposed to decrease the risk of trapping into local optimum in the training process. The optimized algorithm was developed by adjusting the variable amplitude vibration to enhance the parameter combination in SVM thereby decreasing the local optimum trap during training. The pipeline data were collected from a reconstructed pipeline at the Artificial Intelligence Energy Research Institute at Northeast Petroleum University. The classification was carried out by feeding the mined data features into the improved VAPSO-SVM. Compared with the existing models, results show that the developed ensemble model can extract the features of pipeline data faster and more accurately. There was a significant improvement in the classification accuracy, overcomes the disadvantage of traditional pipeline leakage detection, and the model has better robustness in the process of pipeline leakage detection.

Shaer & Shami (2022) proposed a multi-step Machine Learning (ML) pipeline for pipe leakage detection in an industrial environment. This environment contains a lot of interference from background noises, which complicates the accurate identification of leaks. For the proposed ML pipeline, feature selection was first carried out to reduce the data dimensionality and then time-based features were extracted. These served as input to a Support Vector Machine (SVM) of low complexity that generalizes well to a small amount of data. For the experiment, two datasets were used: one with background noise and the other without to ascertain the validity of the model. These datasets were gathered in an industrial setup. Tuning of SVM hyper-parameters and parameters specific to the pipeline steps was done to obtain the best models from the dataset with industrial noise and leaks. Results obtained show that the proposed model produced excellent results with 99% accuracy and an F1-score of 0.93 and 0.9 for the respective datasets.

Kim et al. (2018) performed an anomaly detection for Edge Computing in Industrial Internet of Things (IIoT) on labeled time series data obtained from the University of California Irvine machine learning repository (UCI). The authors proposed a Squeezed Convolutional Variational AutoEncoder (SCVAE) which are compressed neural networks that make up for the compute and memory-intensive nature of well-performing networks. The proposed model was applied to the UCI dataset to evaluate its performance and on real-life data as a basis for comparison. Results indicate that there was a reduction in the size of the model and inference times yet the performance levels were preserved.

In their paper, Giro et al., (2022) focused on the detection of leaks from pipeline transport systems using a peculiar acoustic noise produced by the exit of fluid from a hole in a pressured pipeline which is known as jet noise. Pressure signals, measured by vibroacoustic sensors on the pipeline were used in the experiment. Several controlled spills utilizing nozzles of varying shapes and sizes were used in the experiment and these data were collected for over a month. In their results, it was noted that there is a relationship between the acoustic noise produced by the leaking whole, the volume of the leaking fluid, the pressure gradient at the exiting point, and the cross-section of the hole. All the analyzed spillages were detected which poses a workable solution to leakage detection.

Agbolade et al., (2023) proposed a LoRaWAN-based approach for detecting and localizing leakages in pipelines. Authors used an experimental setup that simulated a pipeline network with pressure and flowrate sensors attached. The flow rate and pressure data were transmitted through LoRaWAN to a receiver, which was uploaded to a cloud server using a cellular network. The flow rate reading from all the monitoring nodes attached to the pipeline network were compared to determine whether a leakage exists and to localize the leakage area. The resolution of the leak detection is dependent on the number of monitoring nodes on the pipeline network. Authors concluded that the pressure readings were found to be insufficient to provide reliable evidence of leakage on the pipeline.

Zhang et al. (2021) used the Gaussian Mixture Model based Hidden Markov Model (GMM-HMM) for pipeline leakage detection and crack depth using lead zirconate titanate (PZT) transducers to spot the negative pressure wave when a leakage occurs on the pipeline. Sensors were placed on the pipelines in the experimental setup built at the University of Houston, to gather data for two states: leaking and not leaking. The data was fed into the model for training and testing and it yielded a testing accuracy of 92.51%.

Doshmanziari et al. (2020) proposed a general leak detection and localization method for high-pressure gas pipelines using sensor fusion under-based fault detection. The transient pipeline flow was proposed for their work and is completely described by momentum and continuity equations which are a set of first-order nonlinear hyperbolic partial differential equations. The model was derived under the following assumptions. The pipeline is considered straight without any slope or branches. The fluid is Newtonian and compressible and the pipe cross-section, diameter, fluid density, and wave velocity along the pipeline were constant. Extended Kalman Filter was implemented as a state observer in the proposed model-based fault detection technique. The Fisher method was implemented as a data fusion method in sensor array applications to improve the estimation accuracy. A realistic high-pressure Gas pipeline was simulated by OLGA (version of 2017.2.0) and PVTSIM (version of 20). Simulation results demonstrated satisfactory leak magnitude and location estimations.

4.0 Methodology

This review was designed using the Preferred Reporting Items for Systematic Reviews (PRISMA) guidelines. Systematic reviews often present a lack of awareness of shared guidelines that make them replicable and scientifically adequate. The PRISMA objective is to assist authors of systematic reviews, and scoping reviews, among others, to generate a document free of bias. Its first version was published in 2009 and its latest version was released in 2020, due to developments in terminology and methodology. This report reflects methodological advances in classifying, selecting, and summarizing different studies (Page et. al., 2021). The PRISMA guidelines were originally designed to assess studies and documents relating to the health sector. Nevertheless, due to its remarkable ingenuity, it has been employed in several other fields such as engineering and social sciences. This guide predominantly suffices as a means to ensure that all the information relevant to the topic under study is correctly itemized and summarized (Naranjo et al., 2022).

4.1 Data Sources and Search Strategies

This review focused on conducting a systematical search of several prestigious electronic databases to which the authors have access such as Arxiv, Core, MDPI, ResearchGate, Science Direct, Sensors, Springer, Tailor and Francis Online, and Google Scholar. The articles were between the years 2011 and 2023. According to Salazar-Moya & Garcia (2021), documentation should be included, regardless of age, as long as it provides relevant data to the research being conducted. To identify as many eligible studies as possible, search terms were used and expanded where necessary. Boolean operators were used to modify the search terms as follows: (“oil pipeline leakage” AND (“detection” OR “monitoring”)); (“pipeline leakage” AND “pipeline monitoring); (“pipeline leakage” AND (“IoT” OR “IIoT” OR “Edge Computing”)). The reference lists found in the eligible articles selected and included in this review were also manually searched.

4.2 Paper Selection

The process of paper selection was done in three phases: Identification, Screening, and Included. In the first phase, 41 articles were found as shown in Figure 1.

The second phase was divided into two steps. The first step of the second phase was to determine the eligibility criteria.

Papers are selected using the following criteria:

a) *Study design:* All studies relating to pipeline leakage detection and monitoring were included, excluding literature reviews and comparative studies.

b) *Years considered*: Publications from 2011 to 2023 were reviewed. Although there are papers from previous years, a decision was made to limit the search in this way to present fresher information.
c) *Language*: The search was strictly for English papers as there are a more significant number of publications in English.
d) *Publishing region*: Papers from all regions of the world were reviewed.
e) *Publication status*: Only papers published by indexed journals were considered. Articles with DOI (Digital Object Identifier) were first considered before those without, making it a decisive factor for acceptance.

In the second step of the second phase, the documents were sorted by title, method, dataset, parameter measured, and keywords. In this way, it was possible to analyze them effectively. Finally, in the third phase, the 16 selected articles were reviewed again. Again, the information shown in the introduction, results, and conclusions were further reviewed to ascertain whether the article provided the necessary data to support the review.

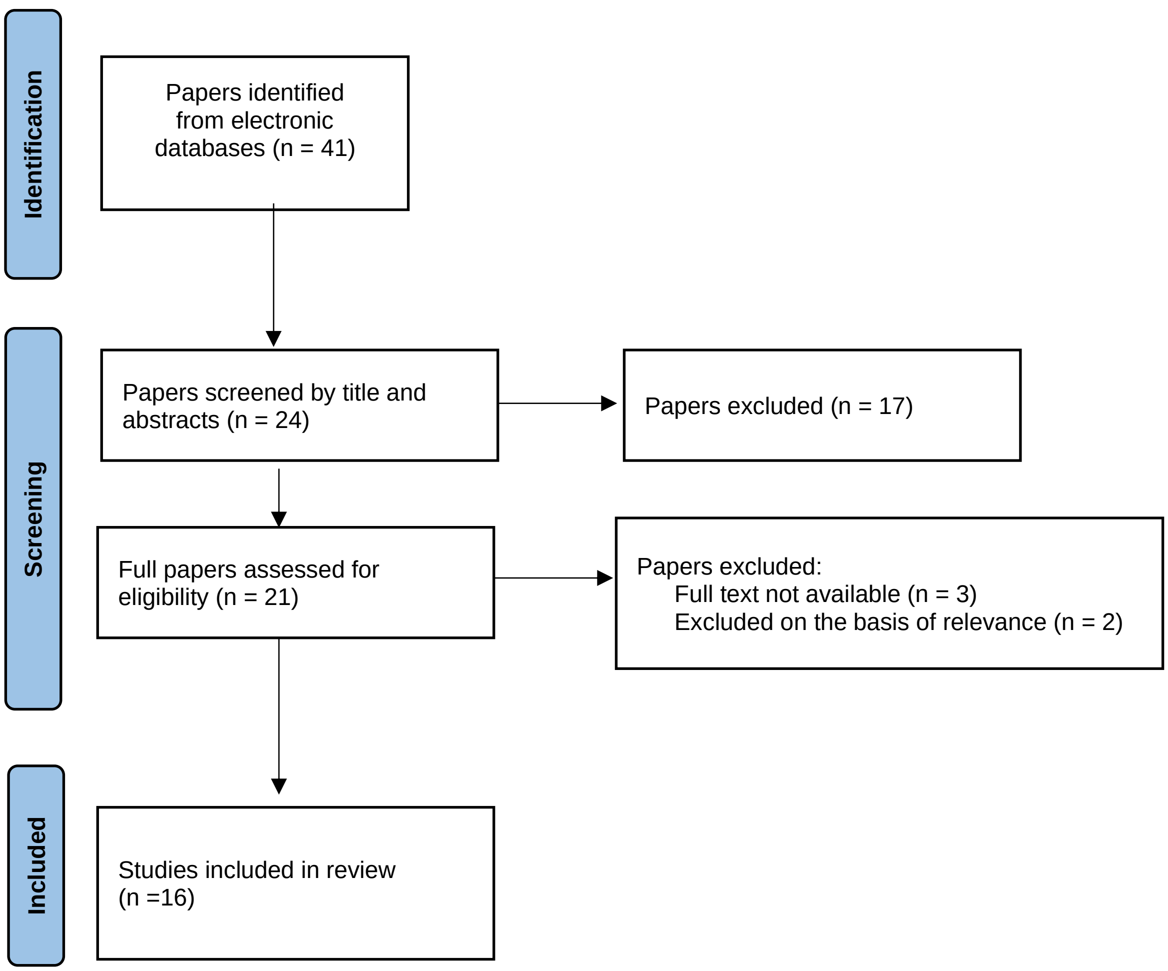

Figure 1: Prisma Flow Diagram. Reporting Items for the Systematic Review

4.3 Characteristics of the Included Articles

The year with the most studies that were found in the search is 2022, as depicted in Figure 2.

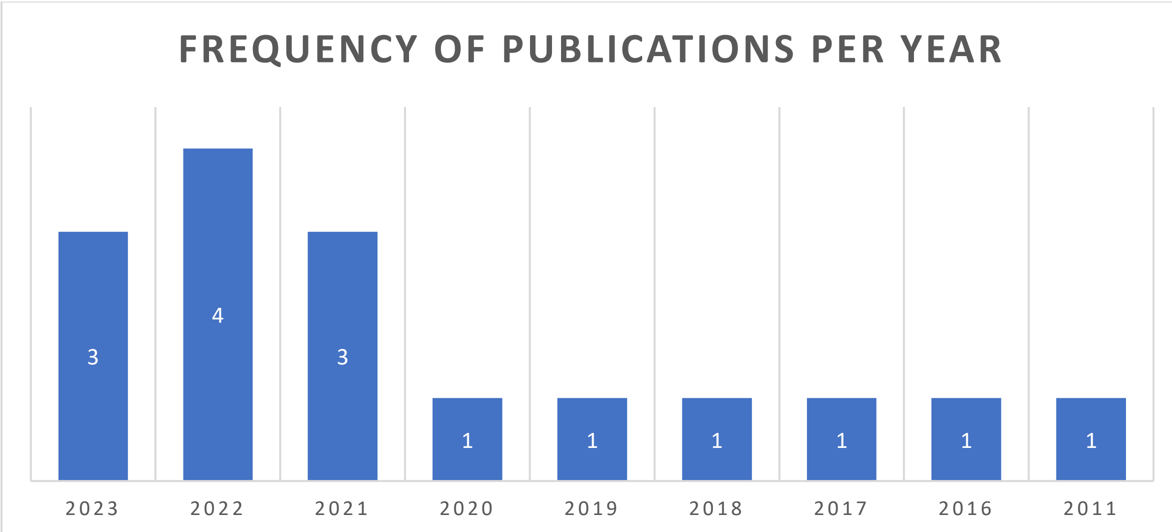

Figure 2: Frequency of Publications Per Year

The country that had the greatest number of originating research in pipeline leakage is China. The United States of America, Iran, and Saudi Arabia are the next three countries with the most relevant research. For China, there are three articles, while for the USA and Saudi Arabia, there are two articles each. As seen in Figure 3, a smaller number of the selected articles can be seen belonging to countries such as Canada, Korea, Egypt, Nigeria, Italy, Iraq, and Greece.

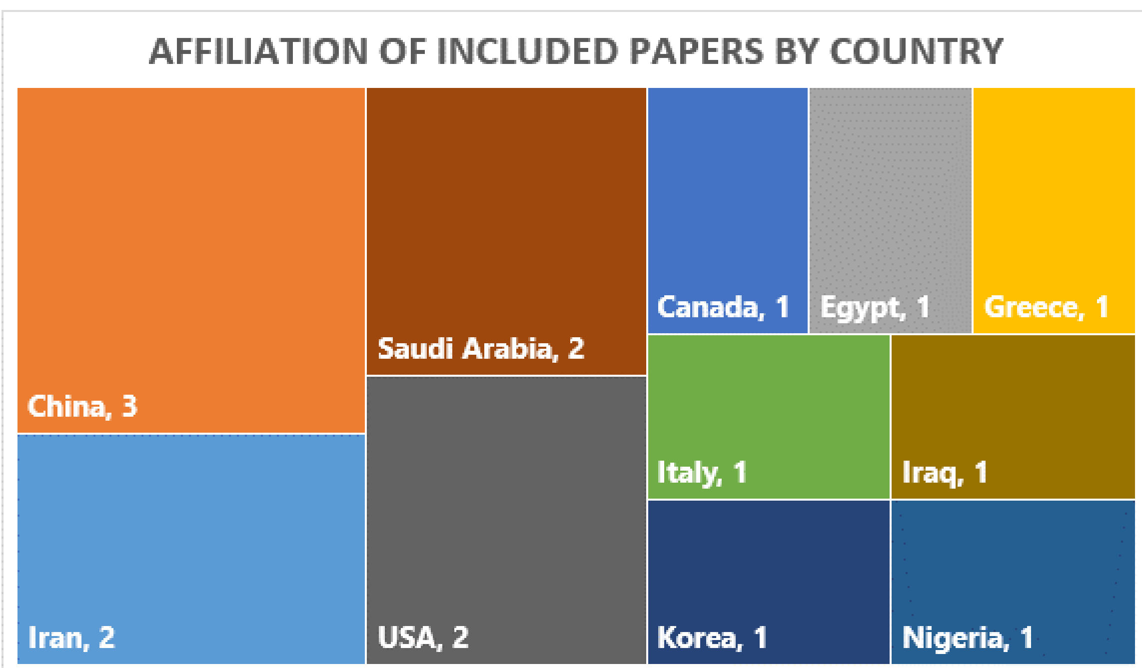

Figure 3: Affiliation by Countries

The articles found have been summarized to better visualize their span. This is depicted in Table 1.

Table 1: Summary of pipeline leakage detection papers

Name	**Year**	**Dataset**	**Parameter** Measured	**Algorithm** Used
Sound event classification in an industrial environment: Pipe leakage detection use case.	2022	Locally generated	Acoustic data	SVC
Oil and Gas Pipelines Monitoring Using IoT Platform	2023	Locally generated	Pressure, flowrate, vibration	IoT architecture
Squeezed convolutional variational autoencoder for unsupervised anomaly detection in edge device industrial Internet of things.	2017	UCI and real-world data	Manufacturing data	CNN-VAE
Jet noise characterization for advanced pipeline leak detection	2022	Locally generated	Pressure and flow rate	Equation
Hidden Markov models for pipeline damage detection using piezoelectric transducers.	2021	Locally generated	NPW	GMM-HMM
A reliable Internet of Things-based architecture for oil and gas industry	2017	Nil	Acoustics, temperature, flow, pressure level, and vibration	IoT architecture
A LoRaWAN-based IoT System for Leakage Detection in Pipelines	2023	Locally generated	Pressure	IoT architecture
Research on oil-gas Pipeline Leakage Detection Method Based on Particle Swarm Optimization Algorithm Optimized Support Vector Machine	2021	Locally generated	Pressure wave signals	PSO-SVM
I2OT-EC: A Framework for Smart Real-Time Monitoring and Controlling Crude Oil Production Exploiting IIOT and Edge Computing	2023	Locally generated	Temperature, pump discharge and intake pressure, run status, motor frequency	I2OT-EC Architecture
A framework for single and multiple anomalies localization in pipelines	2019	Locally generated	NPW and PPA	Framework
MISE-PIPE: Magnetic induction-based wireless sensor networks for underground pipeline monitoring	2011	Locally generated	Pressure, acoustics, temperature, humidity	Framework
A hybrid model-based method for leak detection in large scale water distribution networks	2021	Vitens company dataset	Pressure drop, flow rate	Decision Tree, KNN, Random Forest, and Bayesian network
Novel negative pressure wave-based pipeline leak detection system using fiber Bragg grating-based pressure sensors	2016	Locally generated	NPW	Novel LDS
Novel leakage detection by ensemble 1DCNN-VAPSO-SVM in oil and gas pipeline systems	2022	Locally generated	Temperature, flow rate, pressure, frequency	1DCNN-VAPSO-SVM
A Combined Semi-Supervised Deep Learning Method for Oil Leak Detection in Pipelines Using IIoT at the Edge.	2022	Locally generated	Vibration signals	CNN, LSTM-AE
Gas pipeline leakage detection based on sensor fusion under model-based fault detection framework	2020	Locally generated	Pressure, flow rate	Framework

5.0 Results and Discussion

The literature reviewed contains enough information to extract scientific criteria regarding LDSs. These systems, when built using IoT and/or edge computing, the size of the model should be considered. The chosen model size should be small enough to be used in the edge devices and should have a short inference time for real-time processing. This gave rise to small-sized algorithms such as SqueezeNet and SCVAE. Other lightweight models such as SVM and DT for leak detection are recommended for edge computing (Kim et al., 2017; Gao et al., 2021; Spandonidis et al., 2022).

Datasets for LDSs are not generally and readily available. Two out of the fourteen articles discussed in Table 1 used readily available and labeled datasets to conduct their experiments. Eleven articles from the fourteen included generated their datasets as seen in Figure 4. The researchers either built an experimental setup in a laboratory or did a simulation of a pipeline. The experimental setup allowed the authors to gather their own data using sensors (Zhang et al., 2021; Spandonidis et al., 2022; Ramsey et al., 2023; Gao et al., 2021; Yang et al., 2022).

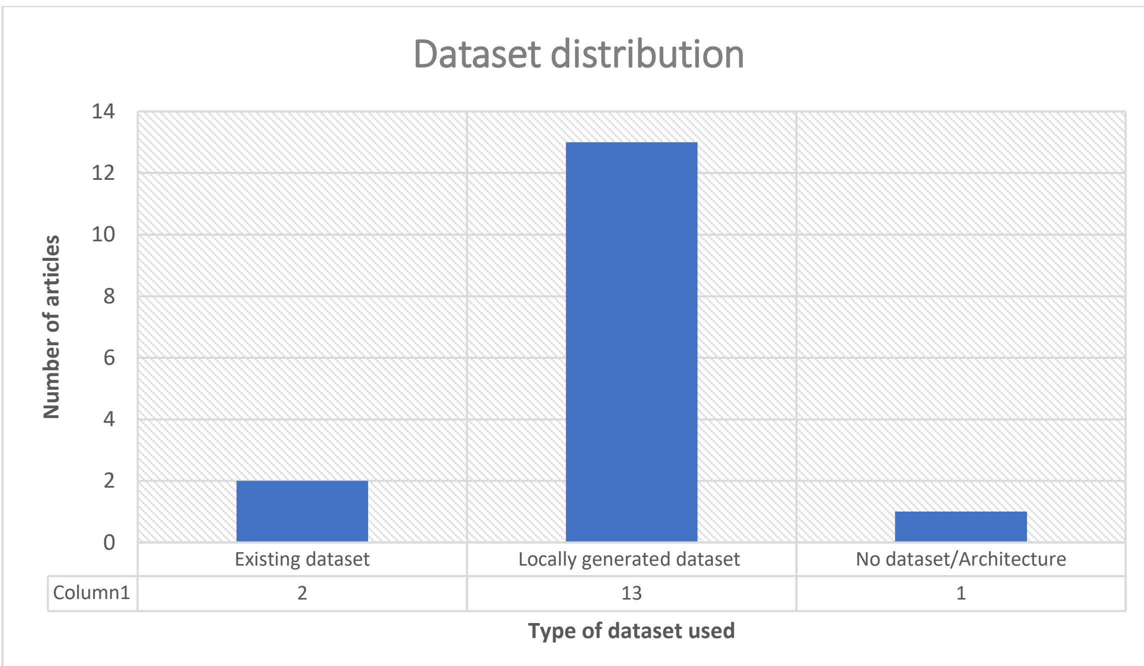

Figure 4: Distribution of Datasets Used.

The parameters measured by the sensors used in the experiments range from acoustic signals to the humidity of the soil. Other parameters include frequency, temperature, vibration, flow rate, and run status. The most predominant is the pressure reading; be it for the pump or the pipeline. Out of the 16 articles included in the review, ten of them, which accounts for 60%, used pressure rate to detect oil leakage in the pipeline, amongst other parameters such as flow rate and temperature. Figure 5 shows the distribution of parameters measured. The promising method for leakage detection is the Negative Pressure Wave as stated by Zhang et al. (2020). Alongside NPW, Pressure Point Analysis (PPA) is seen to be an emerging method for anomaly detection and localization of pipeline leakage (Anwar et al., 2019).

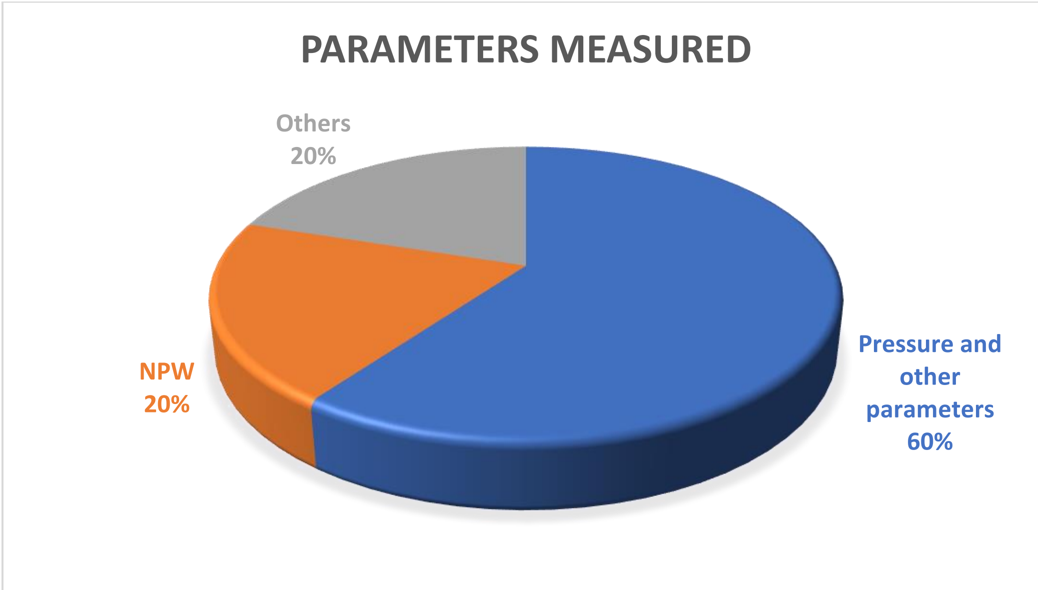

Figure 5: Distribution of the Parameters Measured

The choice of algorithms used largely depended on the type of data generated by the experiment. When time series data were generated, the algorithms used were mostly CNN and LSTM including its hybridization and optimization (Kim et al., 2017; Shaer & Shami, 2022; Spandonidis et al., 2022). For signals such as frequency and acoustics algorithms such as SVM and HMM were employed (Zhang et al., 2021; Fereidooni et al., 2021; Gao et al., 2021).

6.0 Conclusion

Pipeline leakage has been an area of concern over the years and a thriving area of research over the past decade. This review sought to identify the different methods used for detecting leakage in pipelines using IoT and Edge Computing spanning over a decade. It was seen that the measurement of pressure in the pipeline is generally used for leakage detection. Lightweight algorithms are most preferred when using edge devices and neural networks for time series data. As a majority of the data used in the experiments were locally generated, there is a need to make such datasets publicly available for other researchers to have access. This will encourage more research in leakage detection and stimulate authors to find optimal algorithms for LDSs.

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