Detecting Pipeline Leakage in Long-Distance Water Transmission: Case Study in Liaoning Province, China

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ABSRACT

Pipeline leakage inevitably occurs in the long-distance water transmission process. If a leak cannot be identified and processed promptly, it can cause severe economic losses or environmental pollution. This paper proposes a method to evaluate pipeline leakages in long-distance water transmission. The pipeline located in Liaoning Province was selected; it is 63.97-km long and runs from west Shenyang to Liaoyang city. Flowrate time-series data were obtained from two flowrate stations; the data were measured using ultrasonic flowmeters. The variance and mean values of flowrate time-series data were determined and used to evaluate whether pipeline leakage occurs. A Chi-Square test was used to test if the variance of a flowrate time-series was equal to a specified value.

The results indicate the following: (1) the method of variance test can be used to evaluate whether the pipeline operation is abnormal or not; (2) when the variance test on time series data of flowrate is abnormal for more than two days, the pipeline leakage situation can be evaluated; (3) the combination of the variance test and the mean value analysis can help locate the leak position, which provides a reference for site personnel. The method proposed in this paper can detect pipeline leakage in a timely manner, and further ensure normal water transmission operation in many cities downstream.

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Study area

The pipeline located in Liaoning Province was selected; it is 63.97-km long and runs from west Shenyang to Liaoyang city.

Method

Mass conservation

$$\Delta Q = Q1 + Q2 - Q3 - Q4 - Q5 \qquad (1)$$

in which
Q1 and Q2 are inflow rate measuring at west Shenyang ;
Q3 is outflow rate measuring at west Shenyang;
Q4 and Q5 are outflow rate measuring at Liaoyang city.
$\Delta Q > 0$ may come from pipeline leakage, measuring error of flowmeter or flowing liquid contained bubble in pipeline, etc.

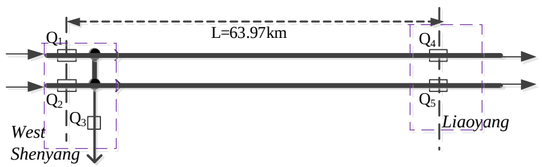

Figure 1. Schematic diagram of pipeline in the study area

The measuring error from flowmeter and the flowing liquid contained bubble in pipeline were excluded in this study. 0.05 cms < ΔQ <0.05 cms was regarded as no leakage in analysis.

There are three steps to evaluate pipeline leakage

Step1: Data collection of flowrate

The flowrate time-series data of Q1, Q2, Q3, Q4, and Q5 were collected from ultrasonic flowmeters, and ΔQ can be obtained form Eq.(1).

Step2: Determination of critical value

The variance values

$$\chi^2_{0.05}(n-1)=42.56$$

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Step2: Evaluation of pipeline leakage

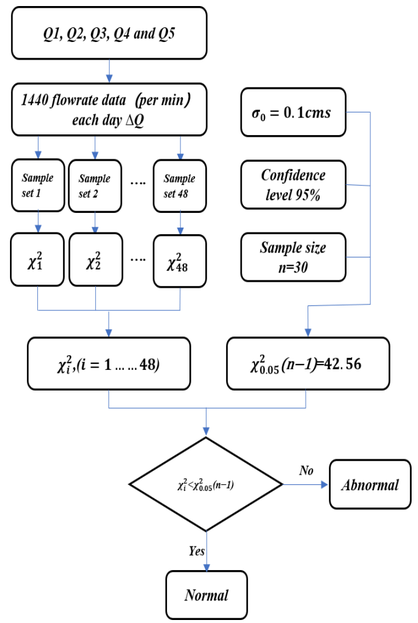
A Chi-Square test was used to test if $\chi 2$ (the variance of ΔQ) was smaller or greater than the critical value.

χ^2 < 42.56 : normal state, no pipeline leakage

χ^2 > 42.56 : abnormal state, pipeline leakage

Table 1. Time-series data used in this study

Sampling interval from flowmeter	*per minute*
Statistic test on flowrate per 30 min.	*30 samples in each test*
Analysis on one-day flowrate data	*A total of 48 test data one day*



The procedure of variance test

Results

Assumes that there is no pipeline leakage occurs before ***April 26, 2015.***

1) No pipeline leakage

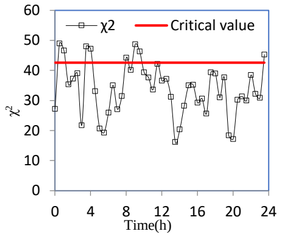


Figure 1: χ^2 distribution on April 26, 2015

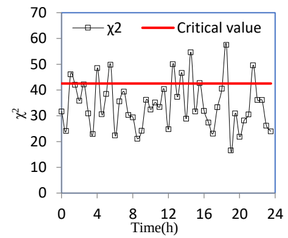


Figure 2. χ^2 distribution on April 27, 2015

2) Pipeline leakage

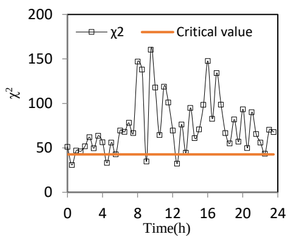


Figure 3: $\chi 2$ distribution on Feb. 05, 2016

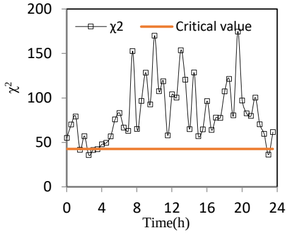


Figure 4: $\chi 2$ distribution on Feb. 12, 2016

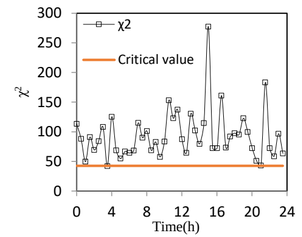


Figure 5: $\chi 2$ distribution on Feb. 28, 2016

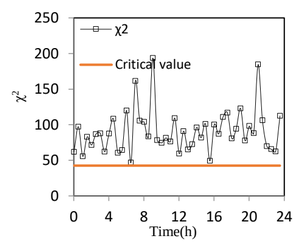


Figure 6: $\chi 2$ distribution on Feb. 29, 2016

The pipeline leakage was successfully detected by the proposed method and it is consistent with field investigation.