International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 2 Issue 1, January- 2013

Discharge Measurements using Radiotracer Techniques

Dr. Mostafa A. Abu Zeid,

Chairman of Mechanical & Electrical Department, Ministry of Water Resources & Irrigation, Cairo,

1. Introduction

Radiotracer techniques are widely used for accurate measurements of various process parameters including discharge rates in pipelines, open channel and canals. Radiotracer techniques have many advantages such as physico-chemical compatibility, high detection sensitivity, in-situ detection, availability of a number of radiotracers for different phases; do not degrade in harsh industrial environment and limited memory effects, over conventional tracer techniques. In radiotracer applications, the radioactive material in a suitable physico-chemical form similar to that of the process material is instantaneously injected into the system at the inlet and its passage is monitored at the outlet or along the system at strategically selected locations using collimated radiation detectors. The monitored tracer concentration data is plotted as a function of time and interpreted to obtain information about process parameters, hydrodynamic behavior of the system and occurrence of malfunctions, if any.

2. Radiotracer Investigations

There are two methods i.e. pulse velocity method and dilution method for measuring flow rates using radiotracers. The transit time method is generally suitable for measuring discharge rates in closed conduits such as pipes where volume of the test section is accurately known. Whereas, the dilution technique, is usually used for measuring discharge rates in systems such as open channels, rivers, pipes and conduits of irregular shapes and does not require volume of thetest section to be known. Both the methods i.e. Pulse velocity method and Dilution methods were applied to measure discharge rates.

2.1. Pulse Velocity Method

The method is most suitable for applications in close conduits where the volume of the test section is known, such as pipelines and closed conduits. In this method a gamma-emitting tracer is instantaneously injected at a selected cross section of the pipe and its passage is monitored at two downstream locations using externally mounted radiation detectors. The first detector is mounted at sufficiently downstream location from the injection point to allow complete lateral mixing of the tracer. The mean transit time of the tracer pulse between the two detectors is determined from the difference of first moments (centeriods) of the tracer distribution curves recorded at two locations. The first moment of a tracer distribution curve is given as:

$$\bar{t}_i = \frac{\int_0^t tC(t)dt}{\int_0^t C(t)dt} \qquad (1)$$

The mean transit time is given as: $t = t_2 — t_1$. where, i: 1 and 2 for first and second detection point, respectively. The geometric volume (V) between the two detection points is determined from the distance (L) and the cross sectional area (A) of the pipeline. Knowing the geometric volume and the mean transit time, the volumetric flow rate is calculated from the following simple relation:

$$Q = \frac{AL}{\bar{t}} = \frac{V}{\bar{t}} \qquad (2)$$

The accuracy of the measurements depends mainly upon (i) complete or sufficient lateral mixing of tracer between the injection point and first detection point, (ii) accuracy in measurement of volume of the test section. The method is well established and accuracy level of the order of 1%, in practice, can be achieved.

A straight section of uniform dimensions of the canal was chosen to measure flow rate using pulse velocity method. The experimental setup used in pulse velocity method is shown in Fig. 1. About 150 mCi of Iodine-131 as NaI was diluted in 800 ml of inactive KI solution and instantaneously injected at the suction end of the pump (Pump No. 4) using a PVC pipe and aplastic funnel. Prior to the injection of radiotracer, sufficient quantity of KI solution was prepared and injected into the injection pipe to minimize loss of radiotracer due to adsorption on inner surface of pipe. The radiotracer was monitored at three different locations i.e. Bridge-1 (B1), Bridge-2 (B2) and Bridge-3 (B3) along the straight section of the canal as shown in Fig. 1. At a particular location, three detectors i.e. Detector D1, D2 and D3 were used to monitor radiotracer concentration at right bank, centre and left bank of the canal. The mean depth of water at all the three monitoring locations was about 4.8 m. All the three detectors were dipped in water and protected with high density polyethylene (HDPE) pipes and kept at desired depths. All the three detectors were connected to a computer controlled data acquisition system set to record radiotracer concentration at a present time of 20 seconds. All the detectors used for monitoring tracer concentration at three locations were calibrated to provide identical response prior to the experiments.

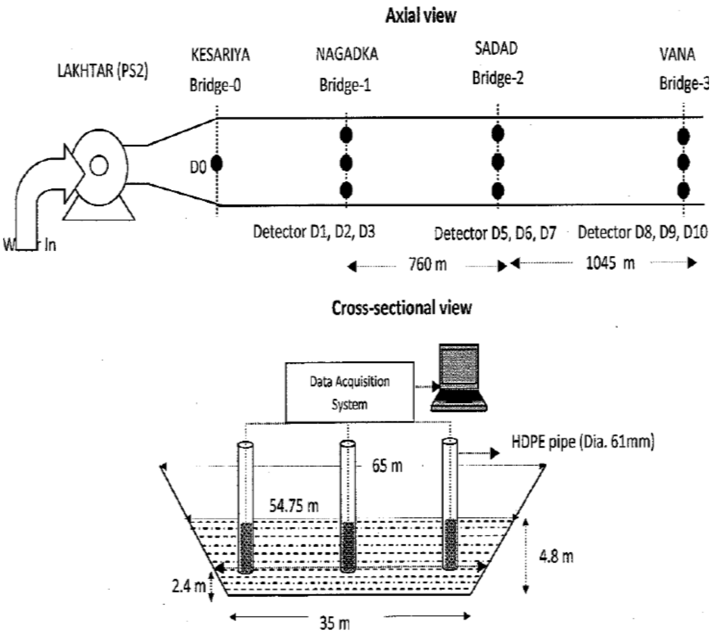

Fig.1. Experimental setup for pulse velocity method

All the three data acquisition systems were synchronized and turned on at the same time prior to the injection of radiotracer. The acquired data was saved for analysis. The data recorded at location B3 could not be saved due to malfunctioning of computer connected to data acquisition system and hence not utilized for discharge measurements.

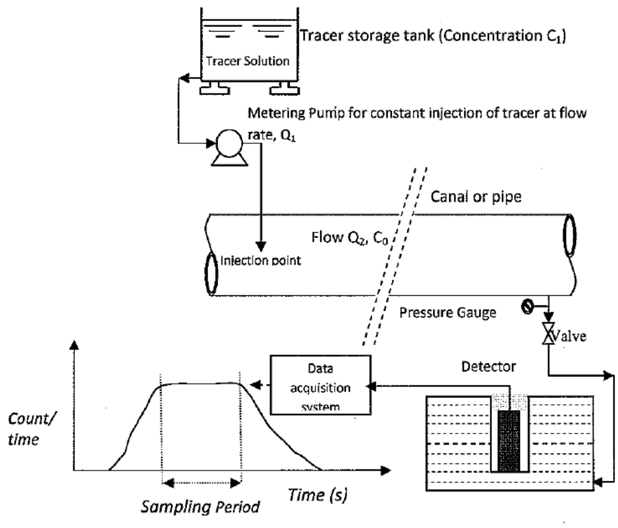

Fig. 2. Principle of dilution method

2.2.Dilution Method

Principle of dilution technique is shown in Fig. 2. In dilution method, a suitably selected radiotracer of known concentration C_1 is continuously injected into the flow stream at a constant rate (Q1). The tracer concentration C2 of diluted radiotracer is measured at downstream location where complete radial mixing of tracer is achieved. If Q2 is the unknown discharge rate of water stream, then one can write the tracer balance equation as:

Q1C1 + Q2C0 = (Q1+ Q2) C2 **4**

Therefore,

$$Q2 = Q1\,[(C1-C2)/ (C2-C0)]$$

Since C1>>>C2 and C2>>>C0, above equation can be written as:

$$Q2= Q1\,(C1/C2)$$

The method is independent of velocity and volume of the water stream between injection and measuring location.

In dilution technique, about 1.5 Ci of Iodine-131 as sodium iodide was used as radiotracer. The tracer (Vol.:8 ml) was homogeneously mixed in 15 litre of potassium iodide solution and filled in a graduated cylinder. Two samples of 20 ml volume, one from top surface and second from bottom of the cylinder, were drawn to measure concentration of radiotracer (C1) in injected solution.The homogeneously mixed tracer solution was injected at a constant rate (Q_1)

i.e. 135 ml/minute at the suction end of the pump using a pre-calibrated peristaltic pump. In order to check, uniformityin injection rate of radiotracer, the amount of volume of tracer solution pumped was noted at a pre-decided time interval. A plot of volume pumped versus time was plotted at the end of the experiment and injection rate was estimated. The injection rate was calculated to be 135 ml/minute. This confirmed the uniformity of injection rate of radiotracer during the experiment. In dilution method also, it was decided to take samples for measurement of concentration radiotracer after from three locations i.e. B1, B2 and B3. Similar monitoring setups, as used in pulse velocity method and as shown in Fig. 1, were used to know start of appearance of plateau or constant concentration of radiotracer at the three locations. As soon as radiotracer concentration became constant, three samples of 20.5 litres were drawn from right bank, centre and left bank of the canal during the plateau region of the curves. The samples were drawn from a depth of about 1 meter and similar sampling procedure was adopted at each location. After collection of samples, the concentration of radiotracer, C2 (counts/2 minutes) was measured in each sample using a specially fabricated sampling vessel (20 litre) and data acquisition system. Identical detection geometry and conditions were maintained during measurement of concentration of radiotracer in all the samples and in injected solution are given in Table 2.

3. Results

The results of discharge measurements using pulse velocity and dilution method are given in Table 1 and Table 2, respectively.

Table 1. Flow velocity and discharge rate between location B1 and B2 measured using pulse velocity method

Sr. No.	Distance between B1 and B2. (m)	V, Volume between B1 and B2 (m^3)	Mean residence time (s)	Velocity (m/s)	Q, Flow rate (m^3/s)
1	760	166159	7575	0.1	21.9

Table 2: Results of discharge rate measurements using Dilution

Sample No.	Q1 (ml/min)	C1 (Counts/2 Mins.)	(Counts/2 Mins.)	Q2 (m^3/s)	Mean Q_2 (m^3/s)
Location 1 (Bridge 1)					
B1-S1-R	135	5.662×10^{10}	6260	20.3	20.13
B1-S2-C	135	5.662×10^{10}	6304	20.2	
B1-S3-L	135	5.662×10^{10}	6407	19.9	
Location 2 (Bridge 2)					
B2-S1-R	135	5.662×10^{10}	6275	20.3	20.3
B2-S2-C	135	5.662×10^{10}	6306	20.2	
B2-S3-L	135	5.662×10^{10}	6244	20.4	
Location 3 (Bridge 3)					
B3-S1-R	135	5.662×10^{10}	6306	20.2	20.4
B3-S2-C	135	5.662×10^{10}	6184	20.6	
B3-S3-L	135	5.662×10^{10}			

(B: Bridge, Sample: S, R:Right bank, C: Centre of canal, L: Left bank of canal)

Overall mean discharge rate (Q_2)=20.27 m^3/s

4.Conclusions

Following conclusions were drawn from radiotracer investigations carried out.

- The value of discharge measurement between location 1 (Bridge 1) and location 2 (Bridge 2) with operation of only pump no. 4 was measured to be 21.9 m^3/seconds using pulse velocity method.
- The values of discharge rates with operation of only pump no. 4 and measured using dilution method at three locations i.e. Bridge-1, Bridge-2 and Bridge-3 were estimated to be 20.13, 20.3 and 20.4 m^3/s, respectively. Thus mean discharge rate using dilution technique was found to be 20.27 m^3/s. The dilution technique is independent of volume of the canal between tracer injection and monitoring locationsand thus is more accurate than pulse velocity method.

- It is concluded that discharge rate measured by both the methods are in agreement with each other. The pulse velocity method is equally suitable for measurement of discharge rates in canal, provided volume of test section is accurately known.

References

- PotentialEconomic Benefits from Use of radioisotopes in flow measurement through High Head Turbines and Pumps- EDMUND BARBOUR
- Radiotracer technology as applied to Industry - IAEA
- ISO 2975/1, III, VII - Measurement of water flow in closed conduits - Tracer methods
- Flow Rate Measurements using radiotracer techniques - Dr. H.J. Pant

.