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A study of residence time distribution using radiotracer technique in the large scale plant facility

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Abstract. As the demand for troubleshooting of large industrial plants increases, radiotracer techniques, which have capability to provide fast, online and effective detections to plant problems, have been continually developed. One of the good potential applications of the radiotracer for troubleshooting in a process plant is the analysis of Residence Time Distribution (RTD). In this paper, the study of RTD in a large scale plant facility using radiotracer technique was presented. The objective of this work is to gain experience on the RTD analysis using radiotracer technique in a "larger than laboratory" scale plant setup which can be comparable to the real industrial application. The experiment was carried out at the sedimentation tank in the water treatment facility of Thailand Institute of Nuclear Technology (Public Organization). Br-82 was selected to use in this work due to its chemical property, its suitable half-life and its on-site availability. NH_4Br in the form of aqueous solution was injected into the system as the radiotracer. Six NaI detectors were placed along the pipelines and at the tank in order to determine the RTD of the system. The RTD and the Mean Residence Time (MRT) of the tank was analysed and calculated from the measured data. The experience and knowledge attained from this study is important for extending this technique to be applied to industrial facilities in the future.

1. Introduction

Chemical, and petrochemical industries are technically complex and generally operates continuously [3]. The radiotracer technique is competitive with other inspection methods in troubleshooting inspection and process analysis of such systems due to its sensitivity and ability to be performed as the process is in operation. Residence Time Distribution (RTD) method using radiotracer has been applied extensively in industry to optimize processes, solve problems, improve product quality, save energy and reduce pollution. The RTD and the mean residence time (MRT) are parameters relevant to the performance of chemical reactors, influencing both the throughput and the quality of the product [1]. As the application of RTD method using radiotracer are mostly applied on large scale industrial plants, knowledge and experience on performing the test and analysis on "larger" than laboratory scale is needed. Therefore, research and hands on work on large industrial-like system shall be conducted to develop the techniques and engineering the operation equipment to be suitable for large and harsh environments in the chemical/petrochemical processes. This paper discusses the experiment at Thailand Institute of Nuclear Technology (TINT) in attempt to develop and analyze RTD and MRT of a large scale system using radiotracer technique. The experiment was conducted at the water treatment facility of TINT at Nakhon Nayok. This paper provides the setup details of the experiment. The

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measured data obtained from the experiment were processed using the recent developed software called preRTD to determine RTD and MRT of the system.

2. Experimental Description

The experiment was carried out for the RTD of the sedimentation tank in the water treatment facility of TINT, Nakhon Nayok. This system was a "larger than a laboratory scale" which could be considered to be comparable to systems in an industrial plant. The measured radiation signals obtained from the experiment were further processed for the RTD and MRT of the sedimentation tank using the preRTD program, originally developed in this work. The details of the experimental setup and the calculation methods are as follows.

2.1. Experimental Setup

The experimental setup consists of three main parts: 1) the water treatment facility, 2) the radiotracer injection and detection system, and 3) the liquid radiotracer. The water treatment facility consists of water supply tanks, a sedimentation tank, an underground storage tank, and pumps and piping systems. The diagram of the experimental setup and the configuration of the sedimentation tank are as shown in Figure 1 and Figure 2, respectively.

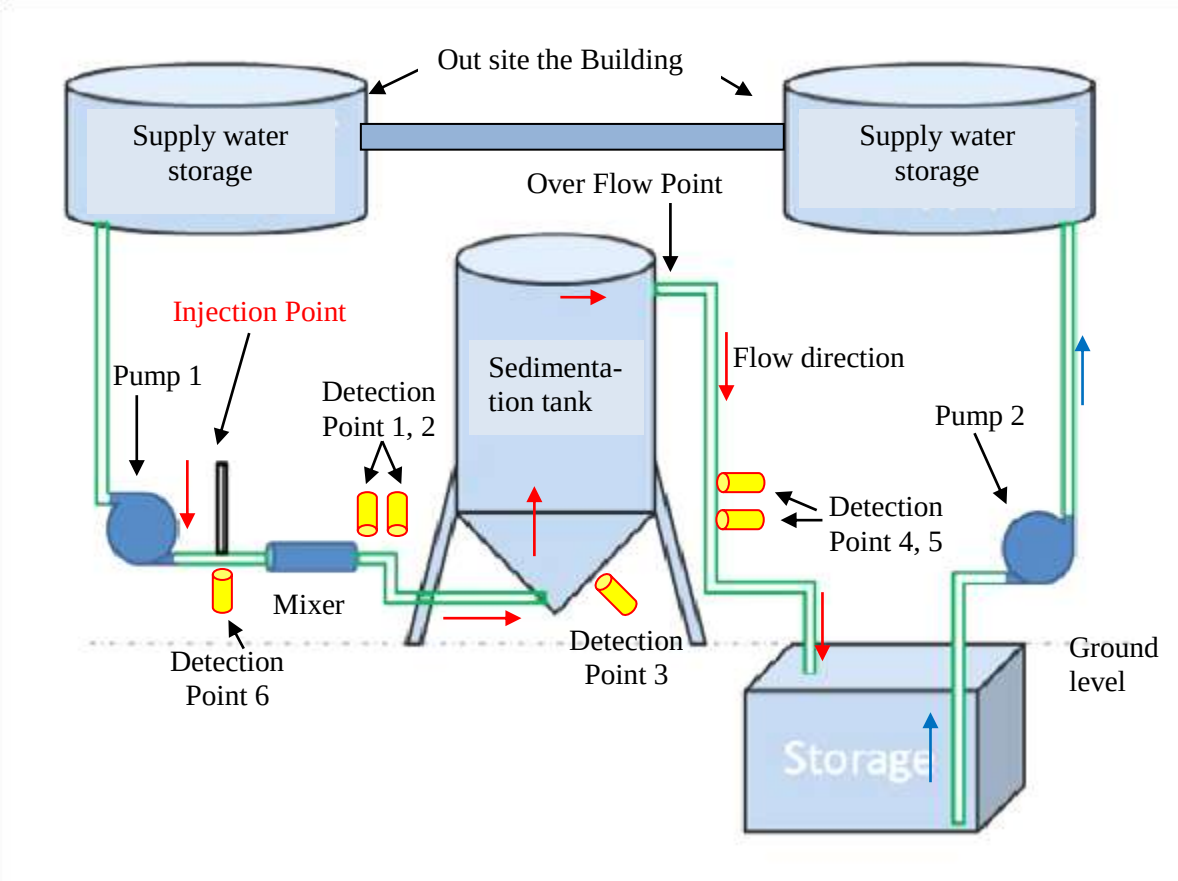

Figure 1. Layout of the experimental setup



Figure 2. Sedimentation tank configuration

The radiotracer, Br-82 (approximately 2 R/h at contact), in the form of NH_4Br aqueous solution was injected into the test system at the injection point as shown in Figure 3 . Six NaI detectors were placed along the pipeline and at the sedimentation tank to measure the radiation signals (see Figure 3). The first two detectors were located at the inlet of the sedimentation tank as redundancy to measure signal of the radiotracer at the inlet. The third detector was setup at the tank wall in order to detect the radiotracer in the tank. The fourth and fifth detectors were set, as redundancy system, at the outlet of the tank for the RTD measurement of the radiotracer inside of the tank. The last detector, detector #6, was located close to the injection point to ensure the injection of the radiotracer into the test system.

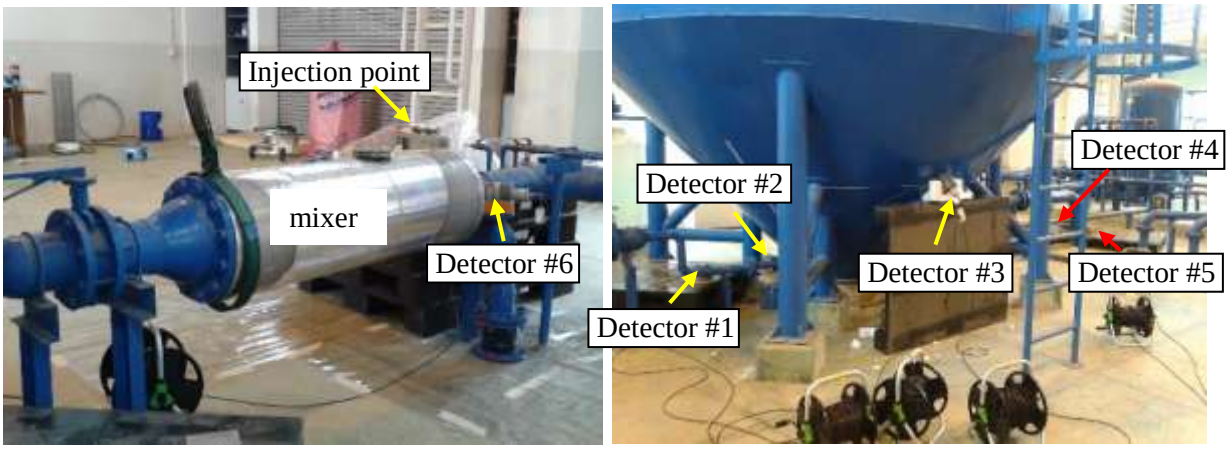

Figure 3. Injection and detection points

2.2. Calculation method

The radiation signals obtained from the experiment were further processed to determine RTD and MRT of the system of interest, the sedimentation tank. The measured signals were input into the preRTD program for computing RTD and MRT of the tank. The signal treatments of the experimental

response curve in the preRTD program include background correction, radiation decay correction, signal smoothing, and normalization of the area of experimental tracer curve. After the treatments, the system RTD and MRT were computed from [1], [2]

$$RTD = E(t) = \frac{n_c(t)}{\int_0^\infty n_c(t)dt}$$

$$MRT = \int_0^\infty tE(t)dt$$

Where $n_c(t)$ is the corrected count rate after the signal treatments.

3. Results and Discussion

The radiation signals obtained from all detectors are shown in Figure 4. At the beginning, the signals from all detectors were approximately constant due to the background radiation, influenced from the radiotracer source, at each measured locations. The levels of the background radiation depend on the distance between the measured point and the radiation source at the injection point. The level of radiation from detectors #1-#5 behaved similarly as they increased when the radiotracer reached the detection points and decrease as the radiotracer passed by. The signal from the detector #6 behaved differently as it only decreased during the injection time. This result may come from the configuration of the system at the injection point (valve and bends of the system) that caused significant accumulation of the radiotracer around that location. The accumulative radiotracer near the detection point cause high radiation level almost at all time for the detector #6.

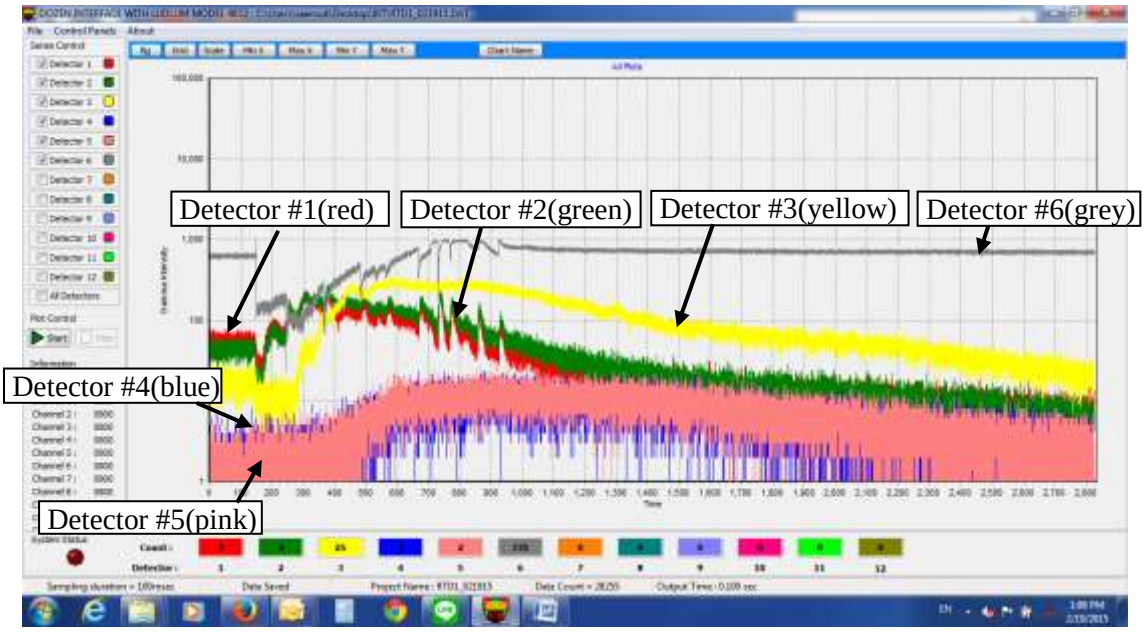

Figure 4. Radiation signals from six NaI detectors

The signals from detector #4 and #5, which were measured at the outlet of the sedimentation tank, can be used to calculate the RTD and MRT of the system. Signals from detector#2 (inlet signal) and from detector#4 (outlet signal) were selected for RTD and MRT analysis. The signals were treated with background and radiation decay correction. Unwanted noise was filtered out by median filter with n=500. The signals after treatments by the preRTD program were shown in Figure 5. The calculated MRT of the sedimentation tank is approximately 16 minute.

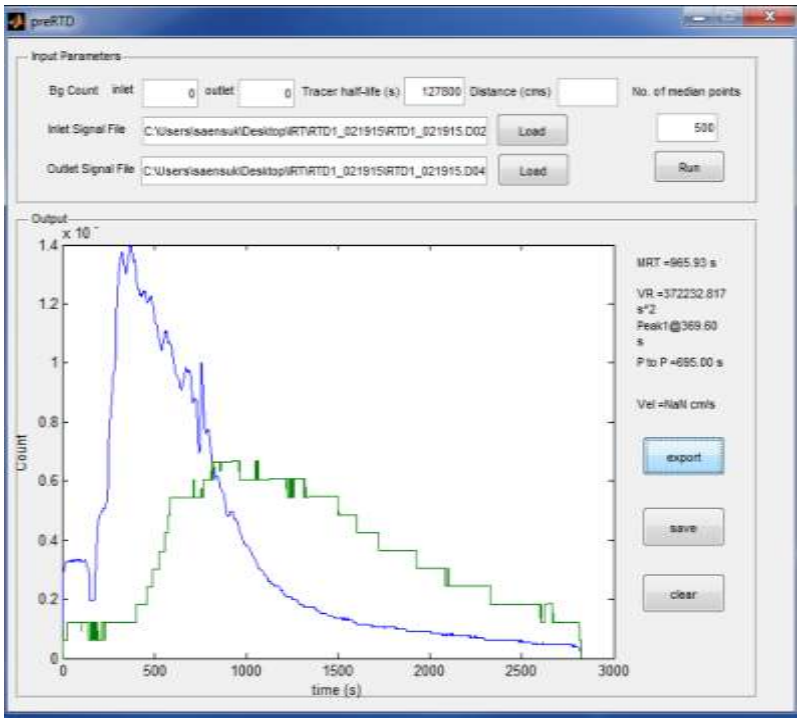

Figure 5. Corrected signals from preRTD program

4. Conclusions

The study of RTD in a large scale plant facility using radiotracer technique was performed at TINT water treatment facility. Br-82, in the form of NH_4Br aqueous solution, was used as a radiotracer in this study. The MRT of the system of interest, the sedimentation tank, computed by preRTD program was approximately 16 minute. As the plant is quite large, the high dose rate radiotracer has to be employed in this work. In order to perform the experiment safely and successfully, various aspects have to be considered at all steps including before, during, and after the experimental time. These include preparation for the experimental procedure, production and transportation of the high dose rate radiotracer, remote radiotracer injection system and detection setup, data collecting process, data analyzing, radiation protection procedure, emergency preparedness, site preparation, and site clearing after completing the experiment. The success and safe operation of this experiment raises the confidence of applying this technique to the large scale facility. The experience and knowledge attained from this study is important for extending the technique to be applied to industrial facilities in the future.

References

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