OVERVIEW OF RADIOTRACER EXPERIMENTS FOR BETTER UNDERSTANDING OF WASTEWATER AND WATER TREATMENT PLANTS IN LIMA (PERU)

UN VISTAZO A LOS EXPERIMENTOS DE RADIO TRAZADORES PARA UN MEJOR ENTENDIMIENTO DE PLANTAS DE TRATAMIENTO DE AGUA Y AGUAS RESIDUALES EN LIMA (PERÚ)

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ABSTRACT

The objectives of this paper are to present an overview of possible applications of the radiotracers for better understanding of water and wastewater treatment plants. Numerous experiments have been carried out in different plants located in Lima. Four processes have been investigated: desanders, flocculators, clarifiers and digesters. Depending on the studied process, the experimental results have been interpreted at different levels of complexity: from simple troubleshooting to the modeling of the flow behavior inside the process.

Keywords: Radiotracers, water treatment plant, wastewater, floccularizers, clarifiers, digesters.

RESUMEN

Se presenta un vistazo a las posibles aplicaciones de los radiotrazadores para un mejor entendimiento de las plantas de tratamiento de agua y aguas residuales. Varios experimentos se han llevado a cabo en diferentes plantas localizadas en Lima. Cuatro procesos se han investigado: desarenadores, floccularizadores, clarificadores y digestores. Dependiendo del proceso estudiado, los resultados experimentales han sido interpretados con diferentes niveles de complejidad: Desde simple solución de problemas a la modelación del comportamiento de flujo en el mismo proceso.

Palabras clave: Radiotrazadores, planta de tratamiento de agua, aguas residuales, flocularizadores, clarificadores, digestores.

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1. Introduction

The supply of water and the treatment of wastewater are of primary importance for the future. This is even more crucial in the developing countries in which a large part of the wastewater flows directly to the rivers without any treatment. Because of this the improvement of the existing water treatment plants and wastewater treatment plants is very important. The objective of this paper is to show through the example of Lima, an overview of the possible applications of radiotracer experiments to understand and to improve the treatment of water and wastewater. The work is mainly focused on the experimental results. Lima, the capital of Peru, is a large city of nearly 8 million inhabitants in which the treated water comes from a big water treatment plant fed by the Rimac river. After treatment the water is distributed to most of the population through the water network system.

The paper presents radiotracer experiments that have been conducted in the water treatment plant to study three of the main stages:

- A desander, which allows removing the high density solid material and which is composed of 12 compartments,
- A set of flocculators,
- The clarifiers located downstream the flocculators.

Unfortunately most of the wastewater is rejected without treatment. In a few places local wastewater treatment plants allow to limit the pollution. They are operated without automatic control system. The knowledge of the flow behavior inside these plants is an elementary step to improve the treatment. The paper also presents results obtained from tracer experiments in an Upflow Anaerobic Sludge Blanket (UASB) digester located in a small treatment plant near the University.

2. Water treatment plant of sedapal

2.1. Desander

The treatment plant, operated by the water company SEDAPAL, is fed by the Rimac river from which the water is continuously pumped. The first treatment, after removing the big objects that may be contained in the water, consists in removing the sediment. The water coming from a large open channel feeds 12 separated tanks in order to remove the sediment (see Fig. 1). The tanks need to be cleaned regularly to remove the sand settling in the bottom. The operators observed that the quantity of settling sediment is different from one tank to another one.

For this reason, tracer experiments have been conducted separately in each tank. A pulse of $3.7x10^8$ Bq (10 mCi) of Indium (^{131m}In) has been injected at the inlet of each compartment of the desander and recorded continuously at the outlet. The mean residence times obtained for each tank are of the same order of magnitude, which reflects the good efficiency of the channel of distribution. However it was unexpected to obtain such large differences in the shape of the curves, as shown by Fig. 2 that represents the response obtained for different tanks. These results have been confirmed by a second experiment. The explanation is not straightforward even if this observation may explain large differences in the solid deposition rate from one tank to another, observed during the cleaning period. It is clear that the observed peaks indicate the presence of short cut with higher water velocity which have been visually observed at the surface of the tank. However since the designs of each tank are similar it is not clear why these short cuts appear.

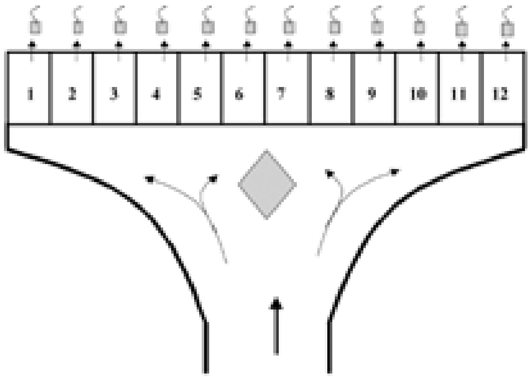

Fig. 1. Scheme of the battery of desanders in the SEDAPAL water treatment plant.

Fig. 1a. Photo of the battery of evaluated desanders.

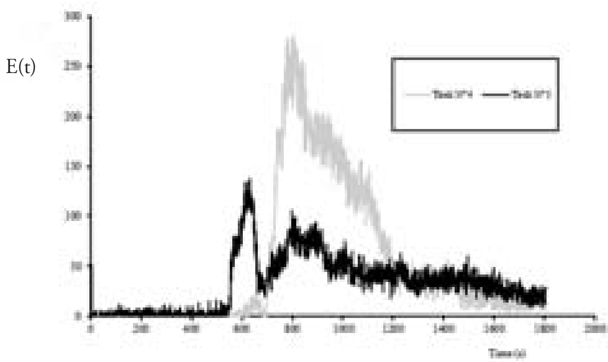

Fig. 2. Typical example of outlet curves obtained for desanders 4 and 5.

2.2. Flocculator

The flocculator of the treatment plant is composed of 2 sets of 2 tanks in parallel. In each tank several baffles allow to increase the length of the trajectory of the water and to improve the settling of the sediment. In order to estimate the efficiency of the flocculator, three parameters are needed: the settling velocity of the sediment, which can be estimated in the laboratory, the fluid velocity, which can easily be obtained by dividing the flowrate by the section of the tank, and the dispersion of the flow induced by the baffles. A pulse of 1.11x10^8 Bq (3 mCi) of Indium (^{131m}In) has been injected at the inlet of the flocculators and recorded continuously at the outlet. The Residence Time Distribution (RTD) has been measured in the flocculator for different water flowrates. As expected, flow behavior is well represented by the plug flow with axial dispersion model characterized by the Peclet number. Table 1 gives the different values of the Peclet number and the dispersion coefficient obtained for different operating conditions. The Peclet number is independent on the flowrate. A correlation giving the dispersion coefficient versus the flowrate is proposed on Fig. 4.

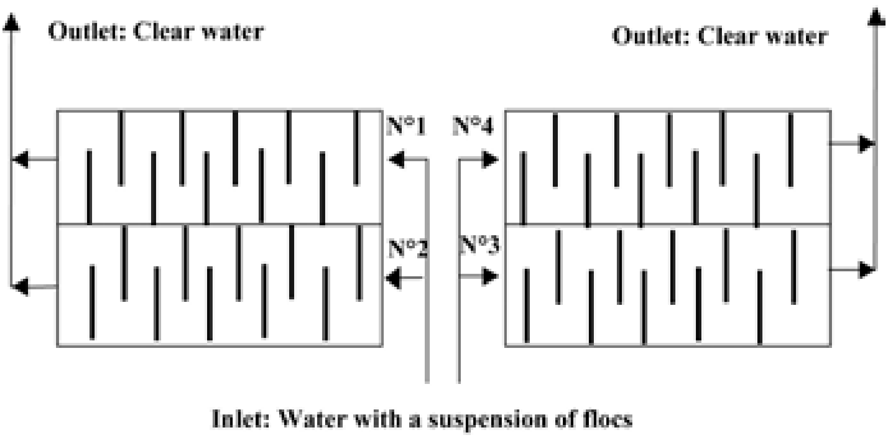

Fig. 3. Scheme of the battery of flocculators at the water treatment plant.

Fig. 3a. Photo of the battery of evaluated flocculators

TABLE 1. MEAN RESIDENCE TIME, PECLET NUMBER AND DISPERSION COEFFICIENT IN THE FLOCCULATOR FOR THE DIFFERENT OPERATING CONDITIONS.

N°	Q(m^3/s)	Volume (m^3)	t (s)	Pe	D ($m^2.s^{-1}$)
1	1	1666	1661	32.6	0.0658
2	3.144	1611	512	33.1	0.204
3	1.724	1608	933	37.5	0.0986
4	2.754	1625	590	33.63	0.1756

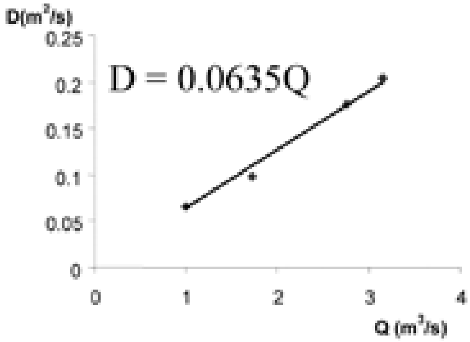

Fig. 4. Dispersion coefficient versus liquid flowrate.

2.3. Clarifiers

The plant has three similar clarifiers. Each clarifier is composed of several basins as shown by Fig. 5. The water inlet pipe located in the center of the clarifier is divided into many smaller pipes, which feed the bottom of each small basin. The clear water goes to the two main canals by overflowing in a smaller channel, which separates each basin. A radiotracer experiment has been made using several detectors. Two of then have been installed at the outlet of two small basins to investigate the behavior of one basin. Four of them have been placed at the four main outlets to model the behavior of each part and to estimate whether the flow is well distributed in the different parts of the clarifier.

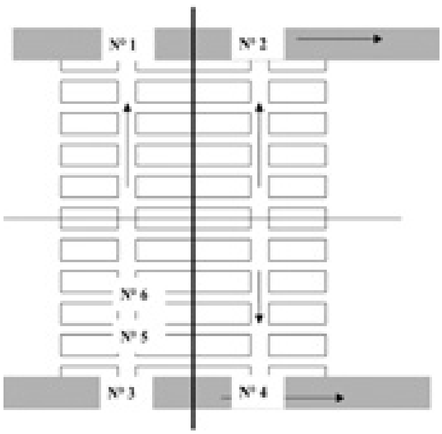

Fig. 5. Scheme of the clarifier at the SEDAPAL water treatment plant.

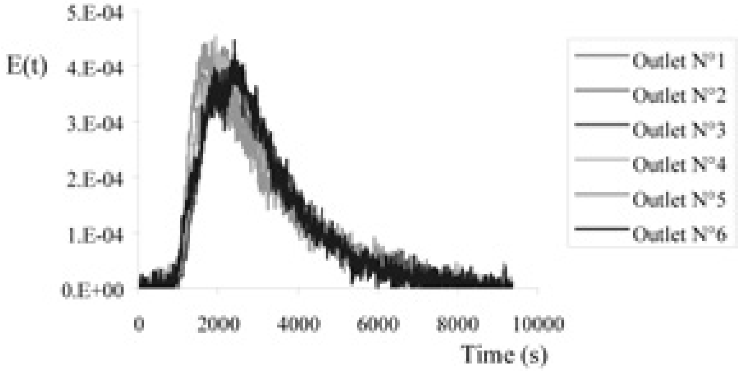

Fig. 6. RTD curves obtained in the different outlets of the clarifier.

Fig. 6 represents the different RTD curves that have been obtained for each outlet. They are purposely represented in the same graph to show that the RTD curves are similar. This result demonstrates that the flow rate is well distributed with a similar dispersion whatever the outlet. Table 2 that gives the mean residence time and the variance for each curve also confirms this.

TABLE 2. MEAN RESIDENCE TIME AND VARIANCE FOR THE SEVERAL DETECTORS LOCATED AT THE OUTLETS OF THE CLARIFIER

Detector	1	2	3	4	5	6
Mean residence time (s)	3029	3036	2930	3110	2990	2975
Variance (s^2)	1.90 10^6	2.37 10^6	1.78 10^6	1.77 10^6	1.82 10^6	1.79 10^6

3. Troubleshooting and modeling of a USBA digestor

Wastewater coming from a small group of habitations located close to the Engineering National University is treated by a small treatment plant. After removing the bigger objects, the wastewater is supplied to a USBA reactor of 356 m^3 through two entrance chambers, each of them receiving half the flow. From each chamber 12 pipes covering a surface of 2.7 m^2 each conduct the water to the bottom of the reactor. The reacting zone is estimated to 263 m^3 The biogas is collected in two pipes fixed to the gas chamber and is burned in a flare. The clear water flows from the top of the digester to the bottom of two 37 m^3 settlers. The dead volume below the gas chamber is estimated to 56 m^3. Excess sludge can be released to a sludge drying bed located close to the USBA by 4 valves that allow to take the sludge from 4 different heights (1 m, 1.5 m, 2 m and 2.5 m). Up to now, no excess sludge has been removed. The maximum surface-load (at the max. flow of 10 L/s) is 0.55 m/h.

Using tracer experiments, leakages have been detected. A more complex compartment model has correctly represented the leakages and the flow behavior. An experiment has been conducted in the UASB reactor. The reactor has been modeled by perfect mixers in series with back mixing and a short cut, which may be due to some broken inlet pipe. Fig. 7 shows the model and the different parameters, Fig. 8 compares experimental and calculated RTD curves. The volume obtained using the model is 30 % lower than the geometrical one, which reflects a very important dead volume due to the low flowrate in the inlet pipe that is not sufficient to guarantee mixing.

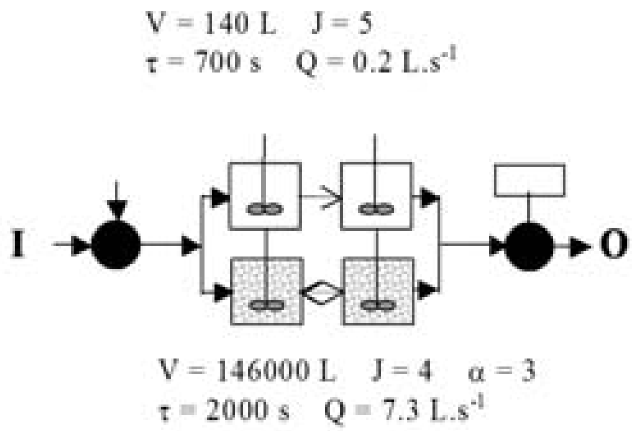

Fig. 7. Model of the flow behavior inside the digester.

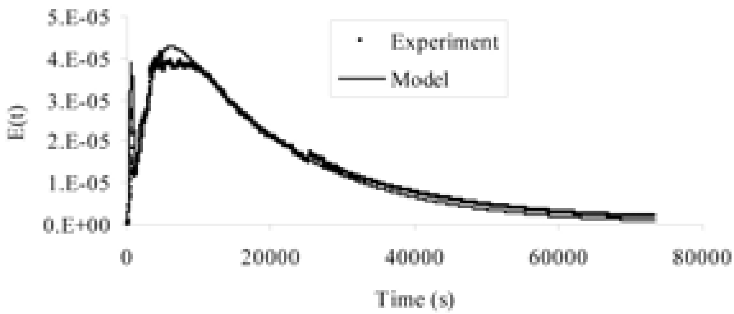

Fig. 8. Comparison between experimental RTD and simulation obtained with the model represented by Fig. 7.

Conclusions

This paper presents an overview of several applications of radiotracer experiments for a better understanding of water and wastewater treatment plants. It shows that radiotracer experiments may be used for in the different steps of the treatment to investigate numerous problems. The results present new applications that complement the numerous previous studies [1,2] in this field of applications.

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