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BROMIDE AS CHEMICAL TRACER TO MEASURE THE LIQUID EFFLUENT FLOW AT IPEN-CNEN/SP

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ABSTRACT

Due to recent changes in CONAMA Resolution 357, which occurred through the publication of Resolution 430, on May 13, 2011 that now set standards about the effluent release, IPEN-CNEN/SP initiated several actions to improve the Environmental Monitoring Program (PMA-Q) of stable chemical compounds. Besides various parameters (physical and chemical) established by CONAMA, the submission of an annual pollution inventory report became necessary. The liquid effluent flow measurement is required to implement this inventory. Thereby, this paper describes a study that uses bromide as a chemical tracer. This paper presents the results of 6 tracer releases in IPEN wastewater collection network between 2011 and 2012. Two tracer releases designs were performed: single pulse and continuous releases performed with 1 to 6 hours duration, done by using one single piston pump manufactured by DIONEX. After the release, one fraction of the effluent was collected every 15 minutes at IPEN effluent monitoring station. The tracer concentration in the effluent was analyzed by ion chromatography and flow was calculated considering the dilution in the system and pump flow set up for the release. The flow values were measured in 6 events were determined and evaluated as per Brazilian regulation requirements. Experimental designs to be implemented during 2013 monitoring were also discussed in this paper, contributing to legal compliance and to improve IPEN´s Environmental Monitoring Program for stable chemical compounds (PMA-Q).

1. INTRODUCTION

IPEN planned and implemented various activities in order to achieve and demonstrate correct environmental performance. These actions are described on its Environmental Monitoring Program (PMA-Q) of chemically stable compounds, which includes monitoring the liquid effluent release in public sewer system and the groundwater quality. Since 2006, the Environmental Monitoring Plan of Chemical Compounds Stable of Nuclear and Energy Research Institute - IPEN has been going through various improvement proposals that can provide IPEN technical documentation required for compliance with existing environmental legislation and that were requested by Term of Conduct Adjustment-TAC established with IBAMA, referring to its facilities.

These improvements intended to meet the CONAMA Resolution #430 requirements, which deal with the liquid effluent release. One critical aspects of this new resolution is to establish the pollutant load. In order to achieve the pollution load released by IPEN in the sewer system is needed to measure the liquid effluent flow.

The chemical wastewater composition generated varied on time and is dependent on the operating schedule, on the production line and process characteristics, products and services, raw material and equipment.

Effluent flow is a parameter that once associated with effluent composition allows the pollution loads measurement. All these conditions (composition, flow and load) are essential to define the kind of treatment required to attend to environmental laws and guidelines, and also to estimate the water stream self-purification capability. [9]

Despite the fact that chemical tracers are used to measure liquid effluent flow, tracers are widely used in several areas such as environmental monitoring shaft agent and in wastewater treatment efficiency studies [6]

Today tracers are used in almost every science fields, such as medicine, biological sciences, chemistry, agriculture, geosciences and engineering, with great technological relevance.

Chemical tracers are non-radioactive compounds such as halides (iodides, bromides) or organic anionic molecules that are detectable by chemical analysis. Tracer chemical analysis can be performed by high performance liquid chromatography, nuclear magnetic resonance and mass spectrometry. Alkali metal halides such as potassium iodide and potassium bromide are widely used as tracer, since they have smaller tendency towards interact in the formation reservoir [9].

In this paper, bromide was used as a chemical tracer to measure the liquid effluent flow released by IPEN. Accordingly to NBR ABNT 13403, tracer methods performed by concentration or by speed have many common requirements. Tracer methods performed by speed are based on time measurements; with this method the intention is to know how long the tracer takes to flow through a well-known distance. In this case, the tracer is applied intermittently.

In the method based on concentration measurements, the dilution factor is evaluated and a comparison is made between the initial and final tracer concentrations. Wirth this model the tracer is applied continuously. [1].

Some characteristics are mandatory in order that a chemical substance be efficient as a tracer [10]. As per [8], the chemical substance must present the following properties in order to be used as a tracer:

- It must be sufficiently conservative,
- It must not be adsorbed or retained in the soil by any other process,
- It must not be degrade chemically or biologically;
- It must be "exotic" environment study, or
- It must not exist in measurable quantities or
- It must not be any close source of this substance near the study site [8]

Presenting these characteristics, bromide is widely used as an ion tracer in various environmental studies that characterize solutes and water movements. Bromide is also identified as inert from the chemical or biological point of view. It also has an additional

Advantage once its natural concentration in soils and waters are usually low (ug.L^{-1}) which allows movements detection with very small amounts of this ion. [8], [6].

So the Bromide tracer method based in concentration measurements was selected for being appropriate to employ in a closed system with gravity flow. Chemical tracer allows measurements in that kind of flow lines even when there is no knowledge of the duct cross section. It is also described as a low-cost and a simple operation method, depending solely on the used substance [9]. Other methods that use ionic tracers to measure the electrical conductivity do not consider the total concentrations change and required temperature correction. The chemical tracer's choice is also based on the fact that, differently of the conductivity ones, is not required any temperature correction [4].

2. METHODOLOGY

A sodium bromide solution (10 g $Br.L^{-1}$) was used as a chemical tracer to perform effluent flow measurements. Six bromide launches were performed at IPEN´s effluent collection system, from 2011 to 2012. The releases are listed in Table 1.

Table 1 – Bromide release summary.

Release date	Average flow ($m^3.h^{-1}$)	Standard Deviation ($m^3.h^{-1}$)	Number of measurements	Release site
Feb-2011	2.2	1.7	5*	CQMA
Aug-2011	10.5	3.2	13	CQMA
Oct-2012	9.7	2.0	4	Bloco A
Oct-2012	35.8	6.2	12	DIRF,Post-Graduation Building
Nov-2012	18.0	4.9	4	Restaurant
Dec-2012	23.9	2.1	4	Post-Graduation Building

* Single pulse release, no initial flow measurement.

Two tracer releases design were applied:

- In ***single pulse*** releases a known volume is launched in single instant that corresponds to start time (To). The final time (Tf) corresponds to the moment the bromide is detected in the collection site. This test intended to measure the tracer residence time in the outflow line.

- In ***continuous mode***, the tracer is released continuously from 1 to 6 hours, using one single piston pump manufactured by DIONEX, adjusted for an initial flow rate of 2.5 mL min^{-1}, calibrated before and after the assay.

From the start time (To), a fraction of the effluent was collected every 15 minutes at IPEN effluent monitoring station, which corresponds to the exit point of the entire liquid effluent released by IPEN in public sewer system. Bromide concentration in the effluent was analyzed by ion chromatography.

Flow rates were calculated considering the dilution factor occurred in the system and pump flow as per equation 1:

$$Q = q.C / c \qquad (1)$$

Where:

Q -is the flow to be measured,
q -is the tracer release flow corresponding to the launching pump flow,
C -is the initial tracer concentration that corresponds to10g $Br.L^{-1}$,
c -is the final tracer concentration at the collection point.

3. RESULTS AND DISCUSSION:

Table 1 presents the bromide tracer releases summary from 2011 to 2012, with the average flow, standard deviation, number of measurements performed in each test launch and the tracer release site.

Considering all flow measurements achieved in 6 tracer releases (Table 1), the single pulse release when 1L bromide solution was released once at start time To, that corresponded to the lowest flow measured. Single pulse value differs from all subsequent tests performed by continuous release and also differs from the reference values proposed by [7]. This lowest flow value is related with a higher tracer concentration as per Equation 1. To release a discrete tracer volume, in a small mixing zone, with laminar flow, could be the origin of this effect, preventing the tracer dispersion through all effluent pipelines. Sudden variations must be avoided in flow measurement tests, especially with industrial effluent that also suffers with temperature changes that impact in the mixture conditions (Brazil, 1995). Without enough time and tracer displacement, many potential errors could occur due to an uneven and inhomogeneous collection zone and samples

The individual flow rate measured in a continuous bromide release is presented in Figure 1. These values were applied to evaluate the daily effluent flow rate. Similar flow rates with similar behavior were observed in all continuous bromide releases performed from 2011 to 2012.

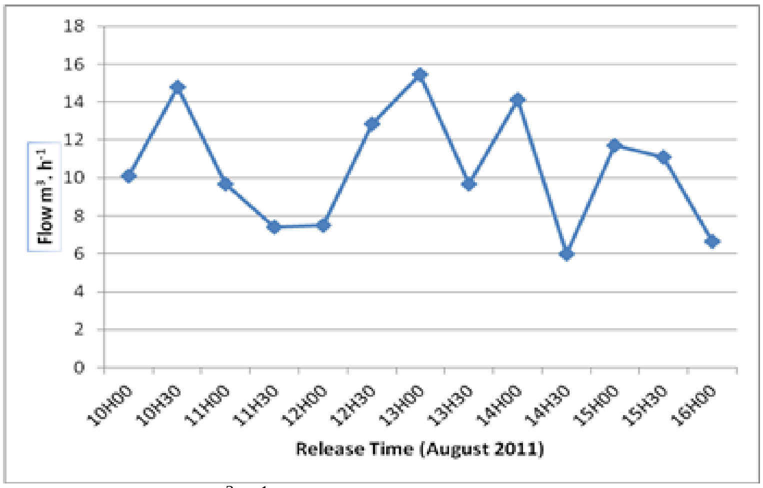

Figure 1 – IPEN´s effluent flow rate ($m^3.h^{-1}$) measured in a bromide continuous release performed in August, 2011.

By all bromide continuous release, IPEN´s effluent flow rate also agreed with other previously measured valued where radioactive tracers were applied [7]. The previous values estimated in 2009 in two separate releases, corresponded to 10.9 ± 0.9 m^3. h^{-1}. These measurements allow us to estimate each monitored substances pollution load. With the average flow rate of 10.5 ± 3.1 $m^3.h^{-1}$ it was possible to estimate an individual liquid effluent equivalent average of 85 L/person/day, considering an average of 3000 people circulating in IPEN, including employees, students and outsourced workers. Average values measured in offices usually varies from 35 to 75L /person/day and at schools and educational institutions these average values varies between 57 and 115 L/person/day [5], [7].

4. CONCLUSION

There is bromide trace technical was demonstrate good results for the measures effluents in closed system, this is chemical allows make an estimate annual pollution for improve the Environmental Monitoring Program the IPEN. Also have a low-cost and a simple operation method.

Since 2006, IPEN´s liquid effluent released is evaluated constantly. Improvements are implemented every year. This paper presented an effluent flow rate method using bromide as a chemical tracer. The average flow rate was estimated at 10.5 ± 3.1 $m^3.h^{-1}$ which implies in a liquid effluent production average equivalent to 85 L/person/day. This method to measure the effluent flow rate was assessed as effective and appropriate for IPEN´s effluent characterization. With the flow rate values, the following actions must be programmed and implemented in the future:

- The flow rate values will be compared with IPEN´s water consumption by month;
- It will be possible to establish individual consumption goals per IPEN´s administrative centers;
- To establish effluent discharge reduction targets;
- The flow rate values will be used in the pollution load and that will be compared with IPEN´s chemical consumption of monitored substances;
- Flow rate values will be used in a database to ensure the legal compliance the institution.

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