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Study of column of flow-rig using radiotracer

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INTRODUCTION

INTRODUCTION

Chemical reactors are the heart of industrial processes

They often do not behave in an ideal way

INTRODUCTION

Residence Time Distribution measurement is one of the most informative **hydrodynamic characterization** methods for **identifying malfunctions**

RTD determined experimentally by **the tracer method**

Dyes

Colorimetry

Electrolytes

Conductimetry

INTRODUCTION

Conventional tracers can only be used at **laboratory scale**

Radiotracers are the most widely used substances for the determination of RTD in **an industrial installation**

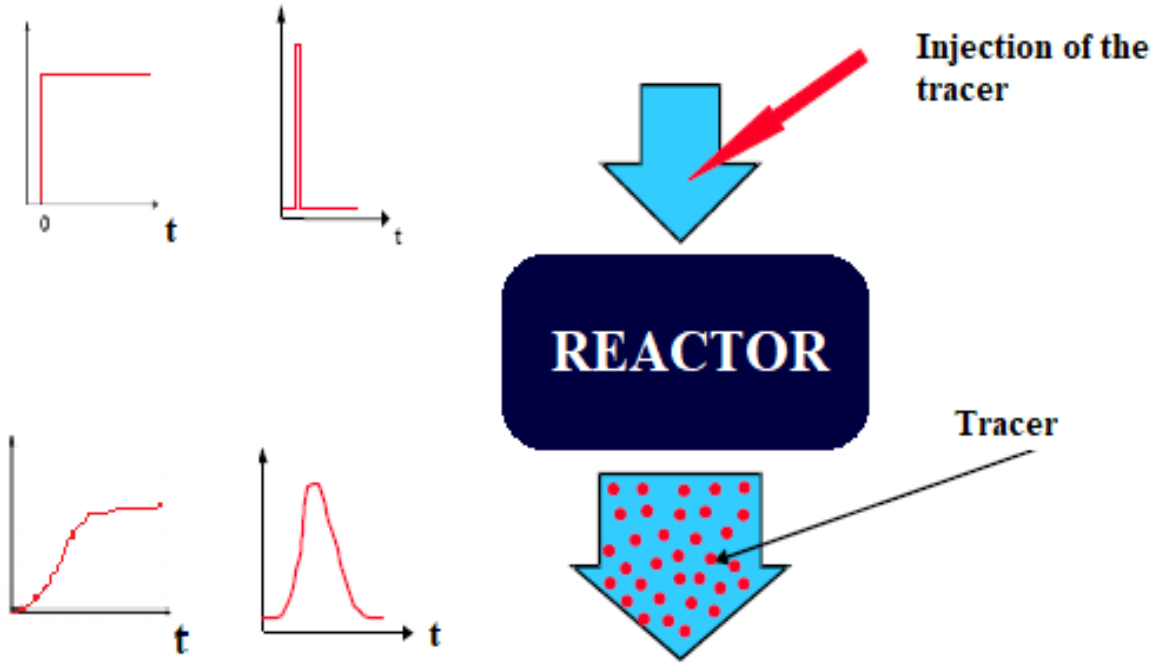
OBJECTIVE

THEORETICAL REMINDERS

THEORETICAL REMINDERS

Residence time distribution (RTD)

Experimental determination of the RTD



- Steady state flow
- Flow that does not involve any macroscopic random processes
- Incompressible fluid
- Flow through the inlet and outlet is only by forced convection
- Small diameter pipes in front of the reactor dimensions

THEORETICAL REMINDERS

Residence time distribution (RTD)

Residence time distribution function **E(t)**

E(t) is the probability that a molecule entering the reactor will reside there for a time t. For a pulse injection, the residence time distribution function is defined as follows:

$$\mathbf{E(t)} = \frac{\mathbf{C(t)}}{\int_0^\infty \mathbf{C(t)dt}}$$

Properties of the function **E(t)**

Variance

$$\sigma^2 = \mu_2 - {\mu_1}^2 = \int_0^\infty (t - \bar{ts})^2 E(t)dt$$

Properties	Formules
Moment of order zero	$\mu_0 = \int_0^\infty E(t)dt = 1$
Moment of first order (**Mean residence time**)	$\mu_1 = \int_0^\infty t\,E(t)dt = \bar{ts}$
Moment of second order	$\mu_2 = \int_0^\infty t^2\,E(t)dt$

THEORETICAL REMINDERS

Residence time distribution (RTD)

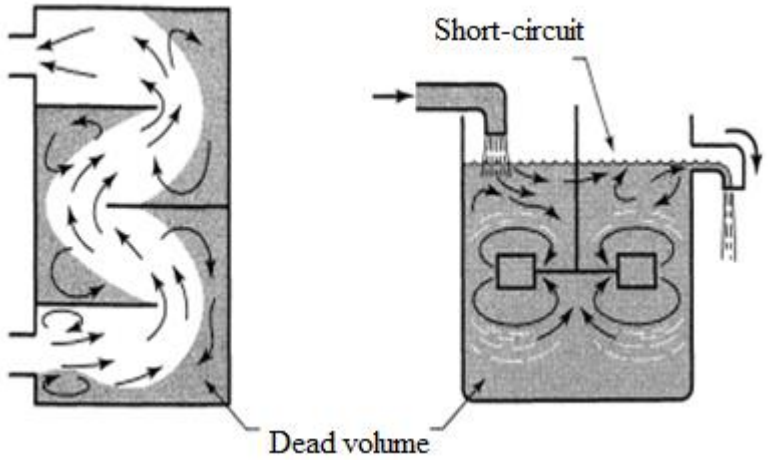
Diagnosis of malfunction

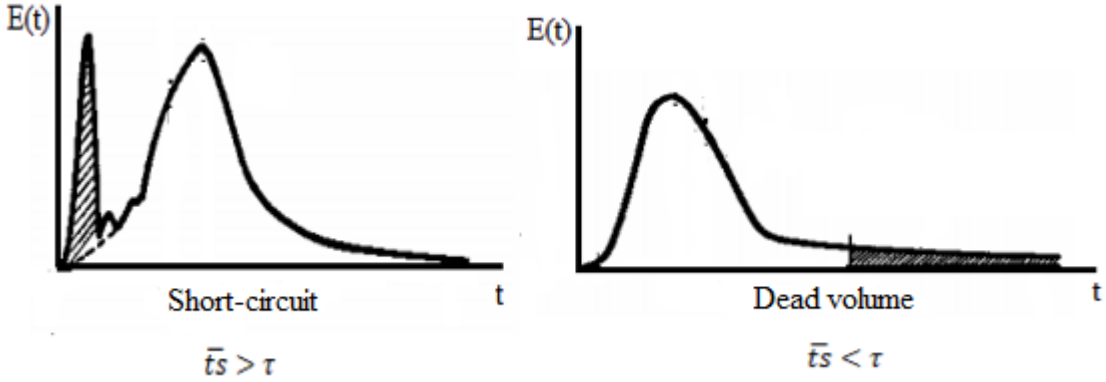
$\bar{t_s} > \tau$ Presence of a **short circuit**

Fraction of short-circuit : $\alpha = \frac{Qc}{Q} = 1 - \frac{\tau}{\bar{t_s}}$

$\bar{t_s} < \tau$ Presence of a **dead volume**

Fraction of dead volume: $\beta = \frac{V_m}{V_R} = 1 - \frac{\bar{t_s}}{\tau}$



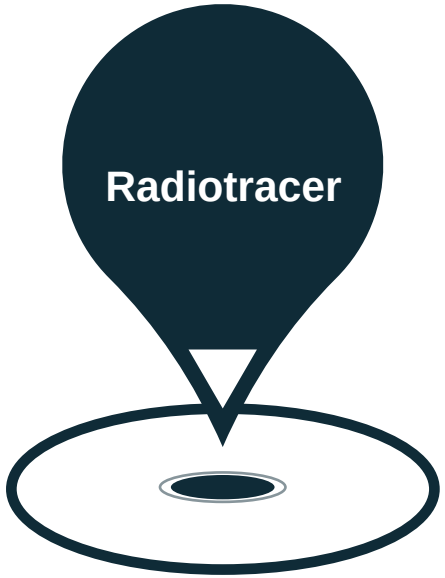


THEORETICAL REMINDERS

Radiotracer

Intrinsic /
extrinsic

Natural /
Artificial



Gamma-ray emitter

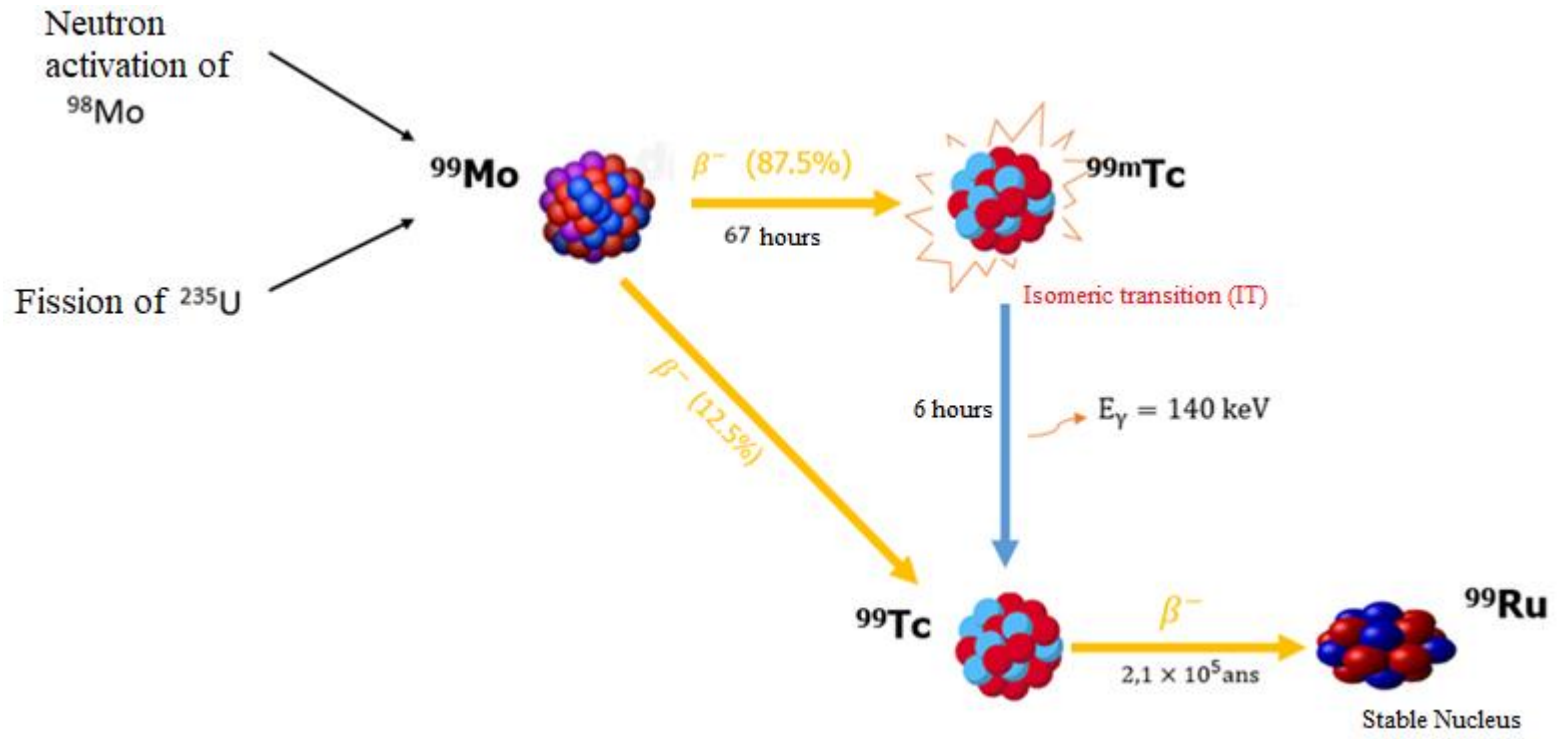
Alpha-ray emitter

Beta-ray emitter

THEORETICAL REMINDERS

Radiotracer

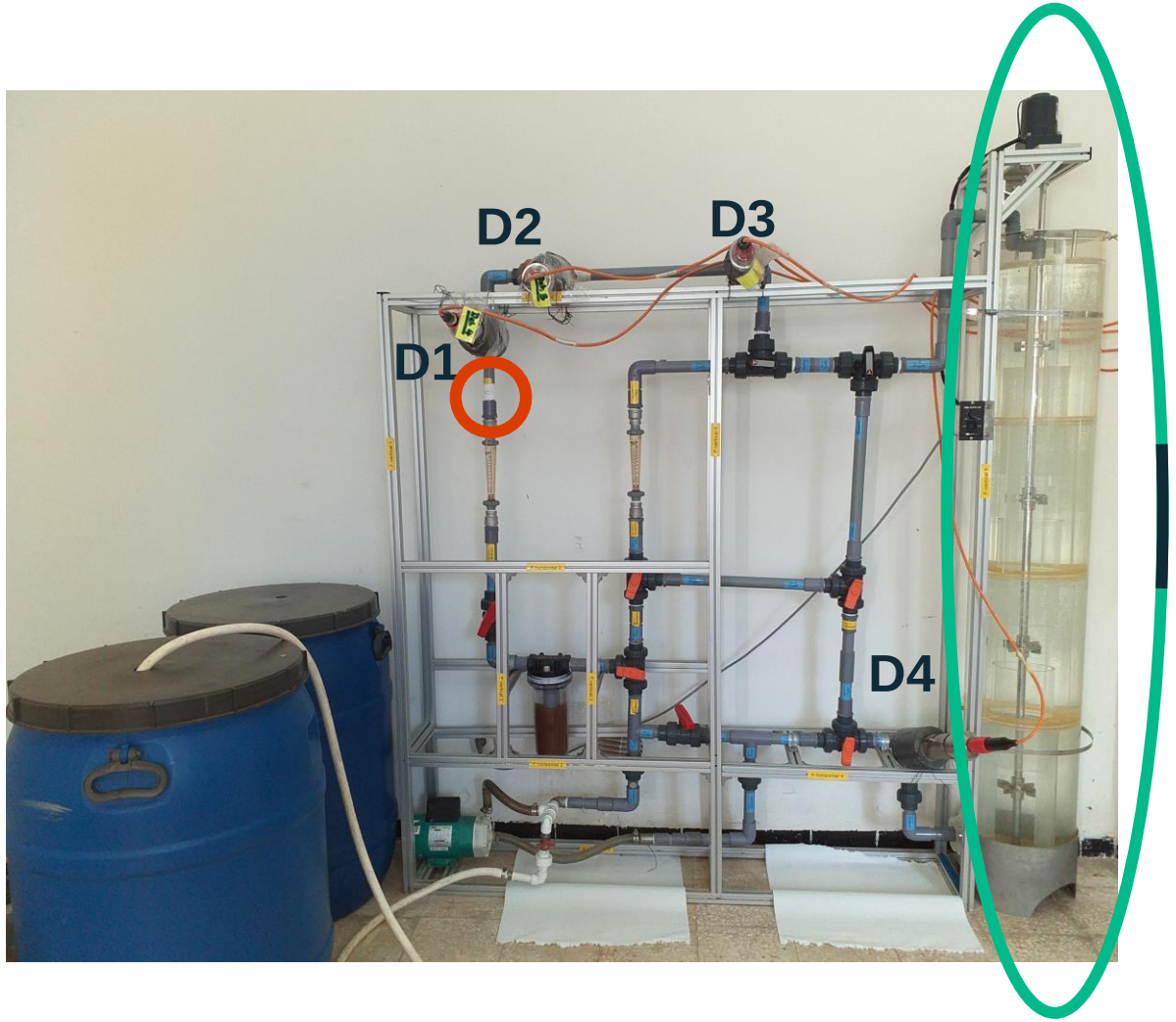
Metastable technetium-99



EXPERIMENTATION

EXPERIMENTATION

Experimental device and acquisition chain



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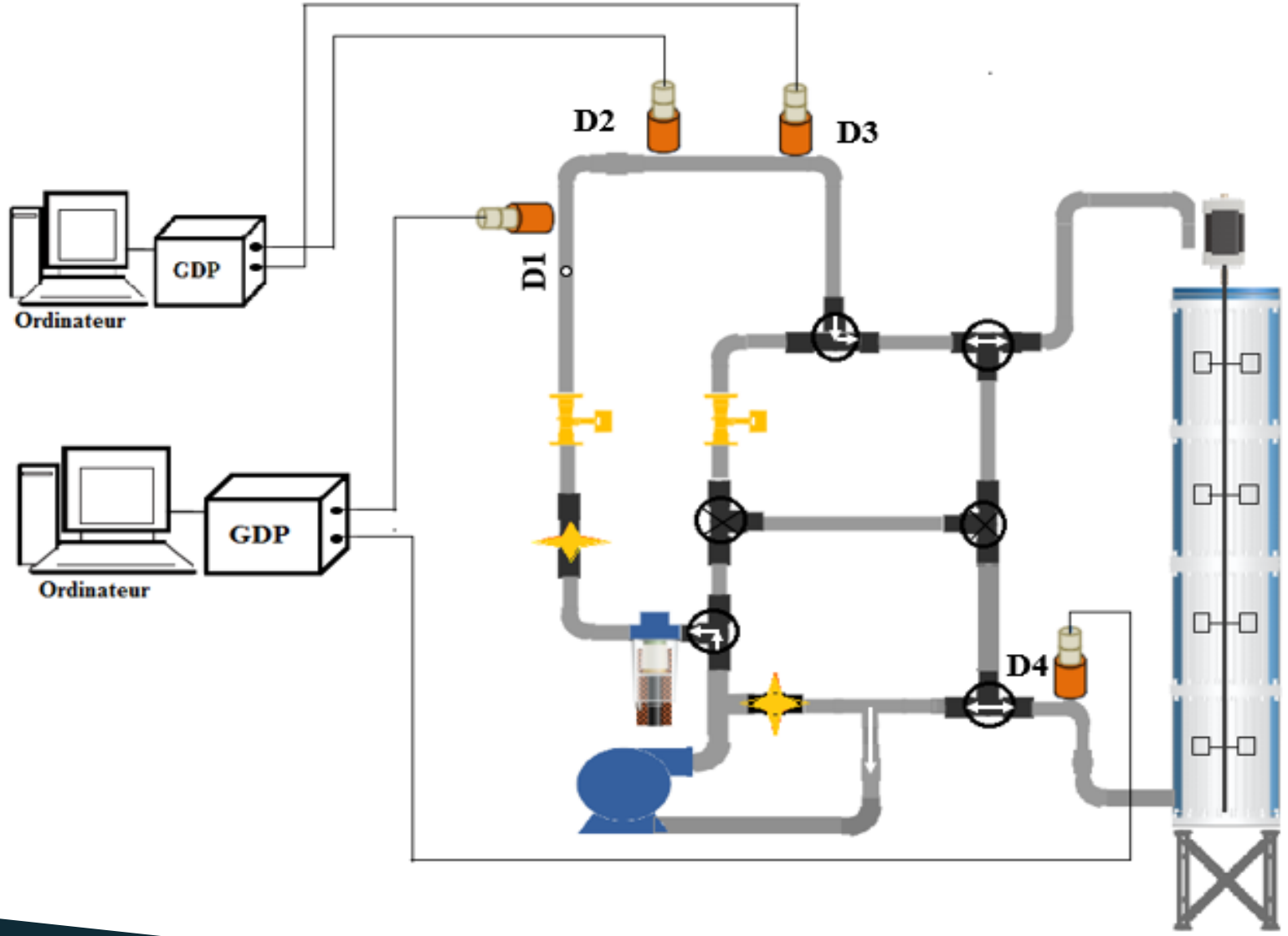
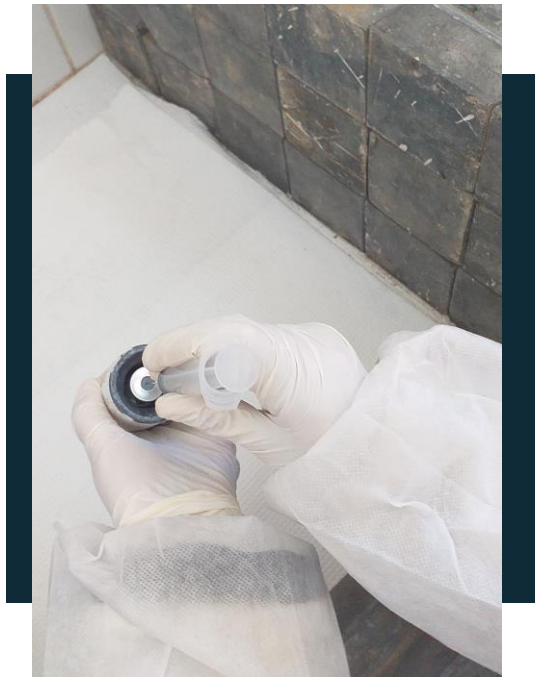


EXPERIMENTATION

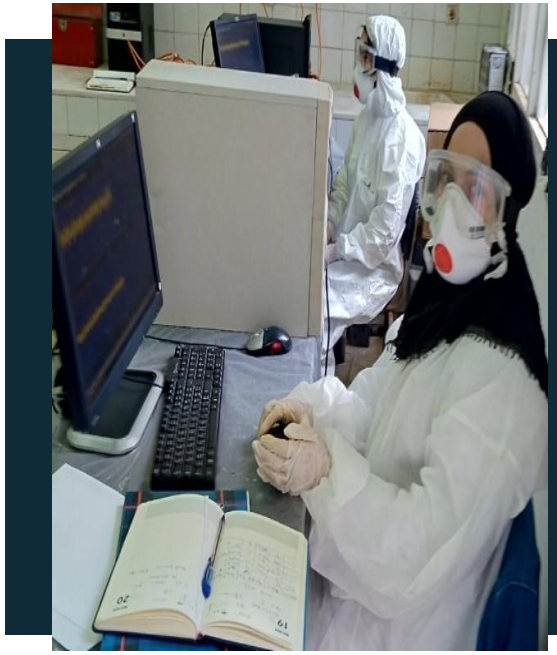
Experimental device and acquisition chain



Dilution of radiotracer

Injection of radiotracer

(4mL of ^{99m}Tc of 2 mCi)



Acquisition

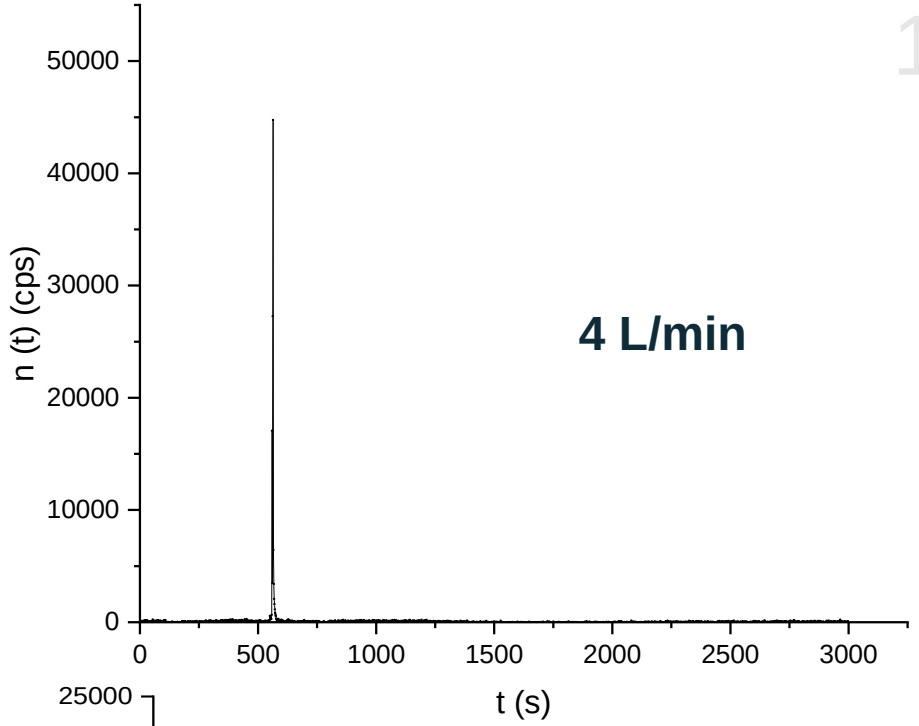
4

RESULTS AND DISCUSSION

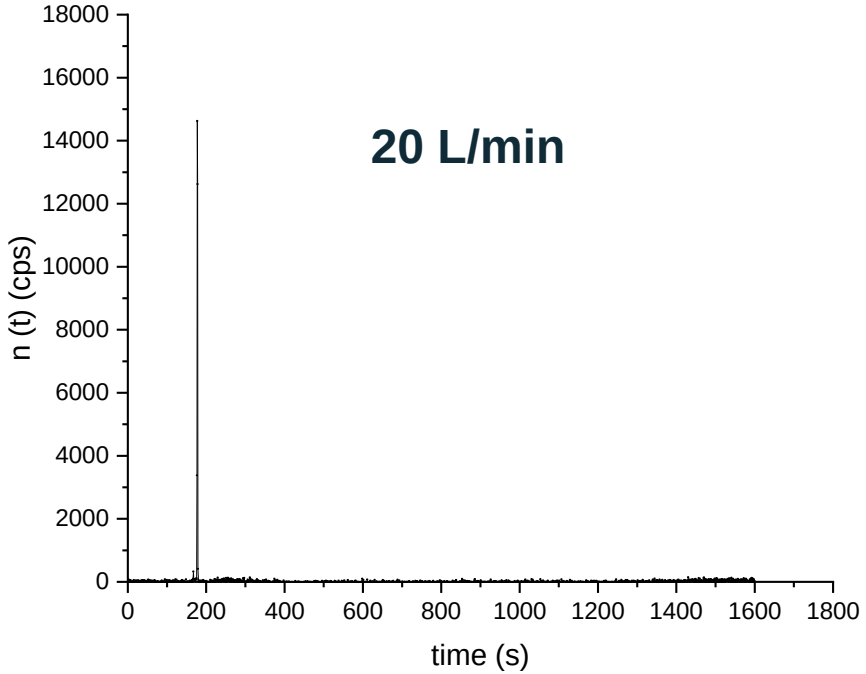
RESULTS AND DISCUSSION

Impulse injection

Flow (L/min)	t_{inj} (s)	τ(s)
4	**3.46**	**1800**
12	**3.78**	**600**
20	**3.15**	**360**



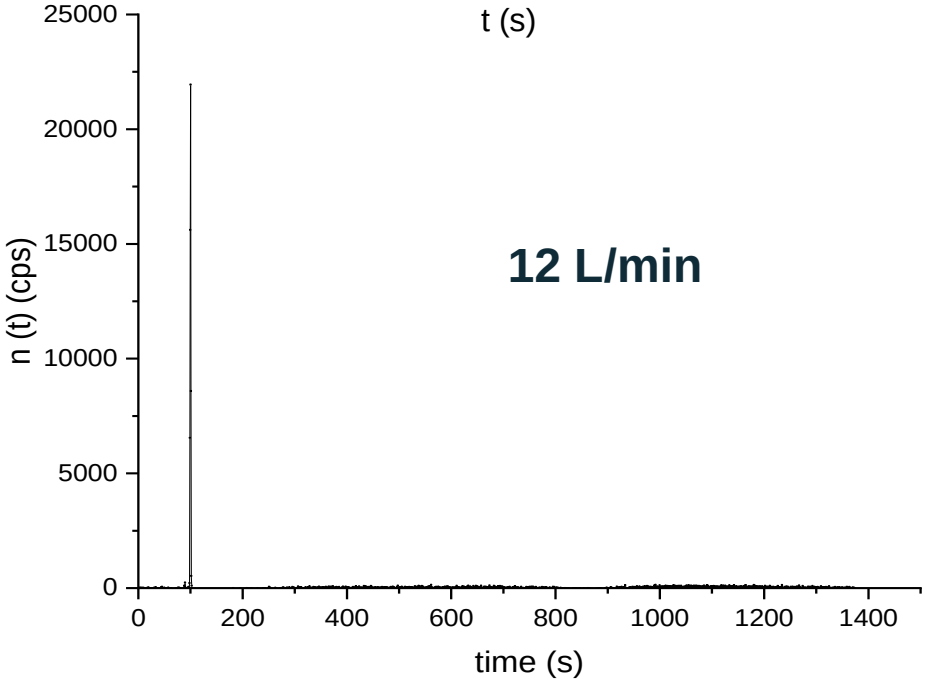
4 L/min



20 L/min

$t_{inj} < 0.01\ \tau$

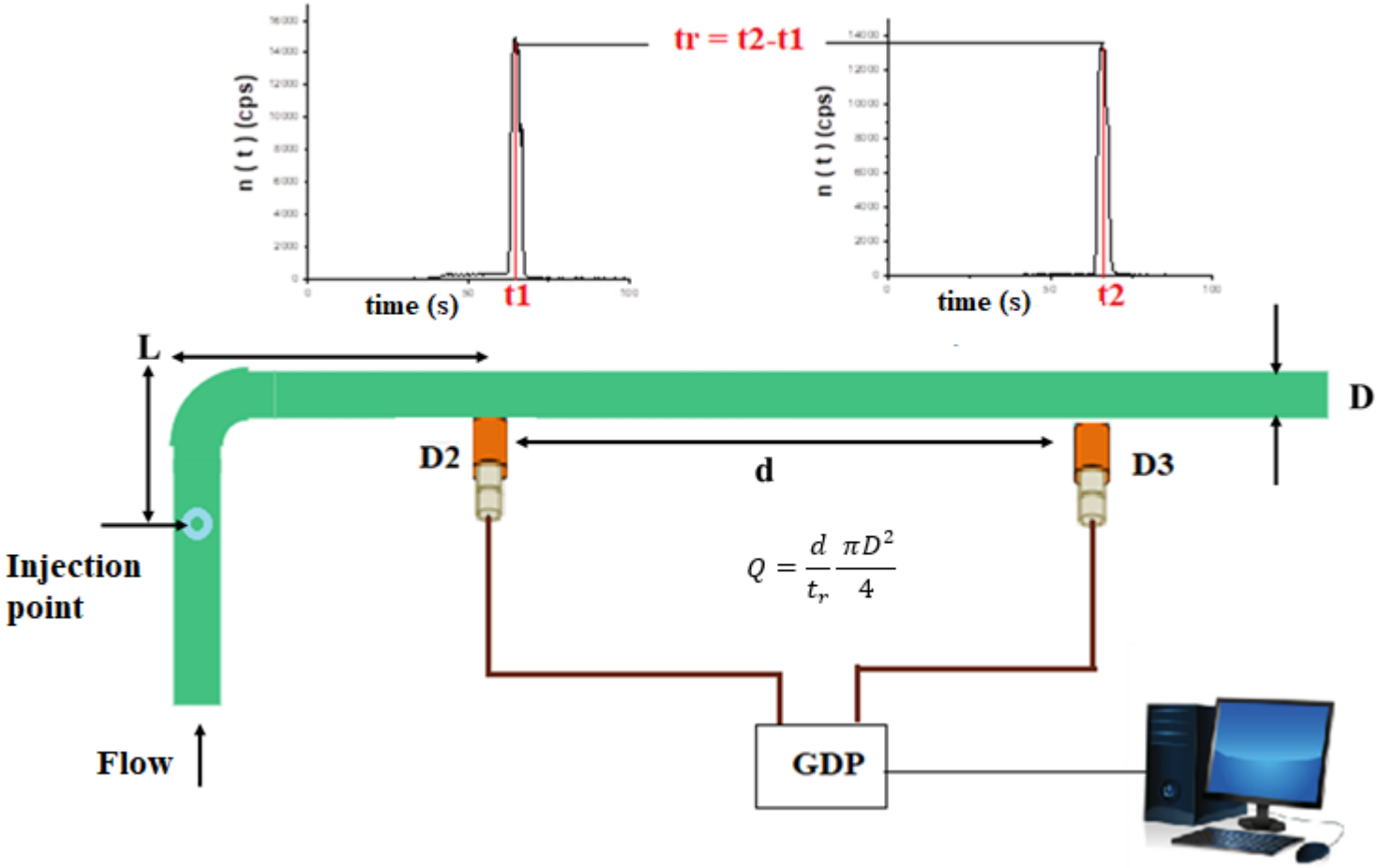
Impulse injection

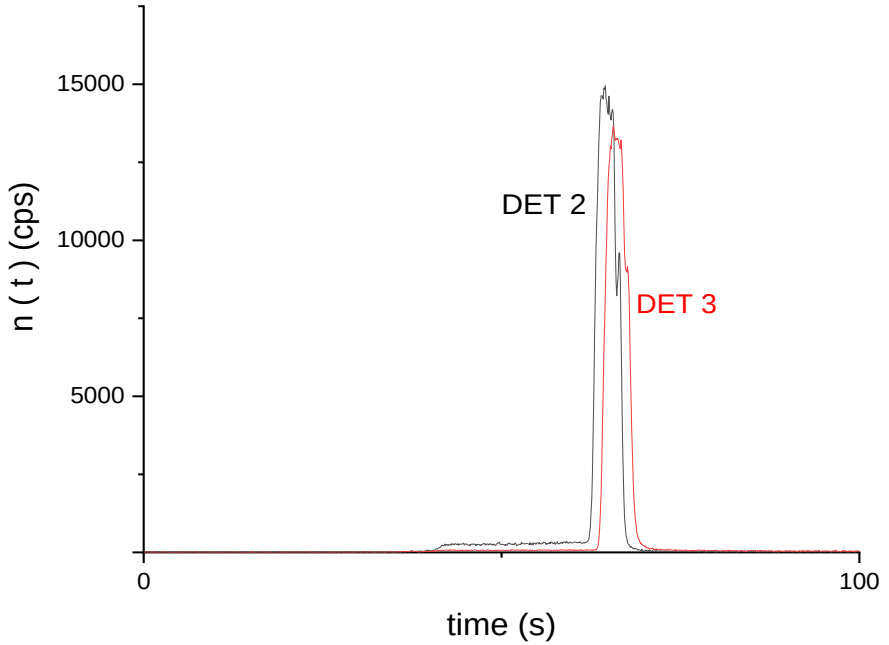


12 L/min

RESULTS AND DISCUSSION

Flow measurement



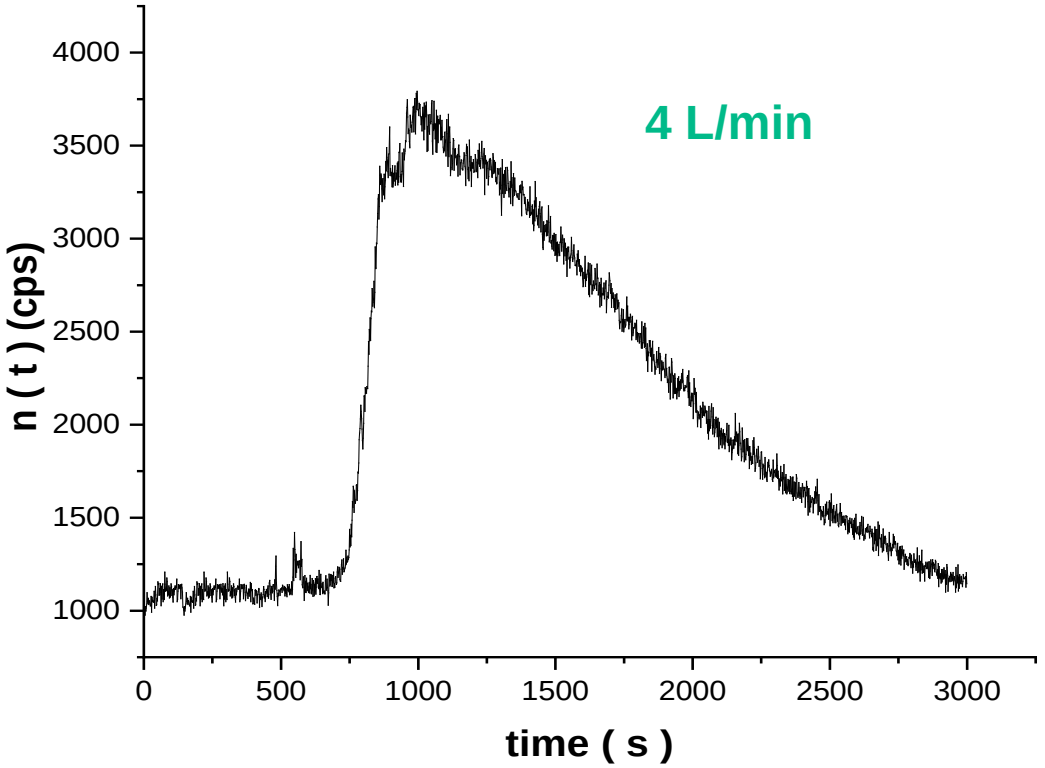


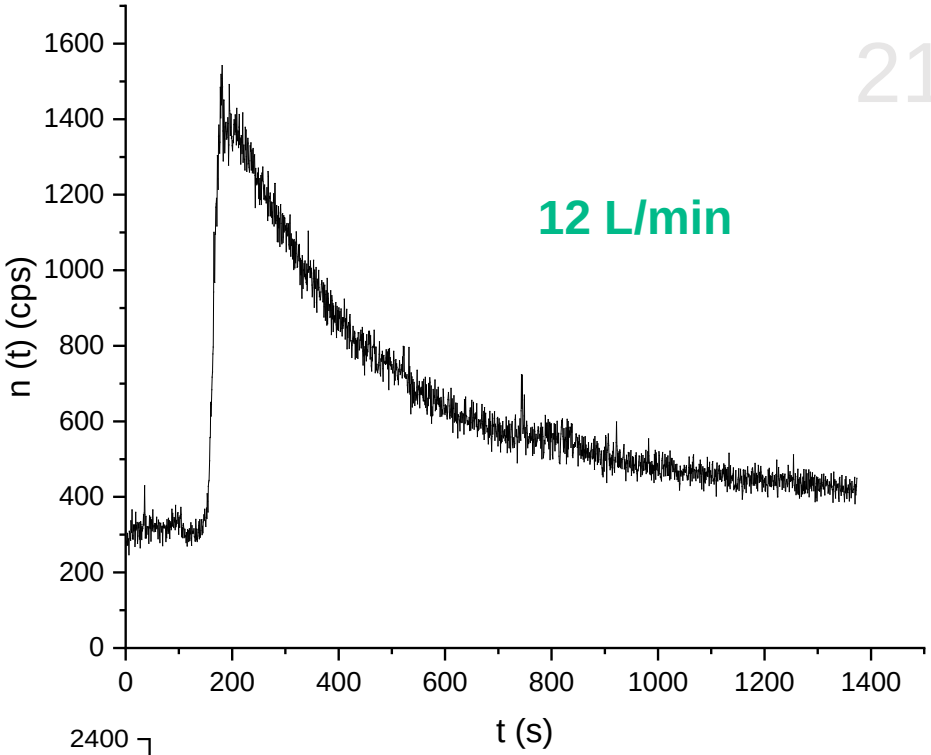
Parameters	Values
Delivered flow(L/min)	**12.000**
D (m)	0.032
L (m)	0.510
d (m)	0.550
t_r (s)	2.150
Calculated flow (L/min)	**12.344**
Relative error(%)	**2.787**

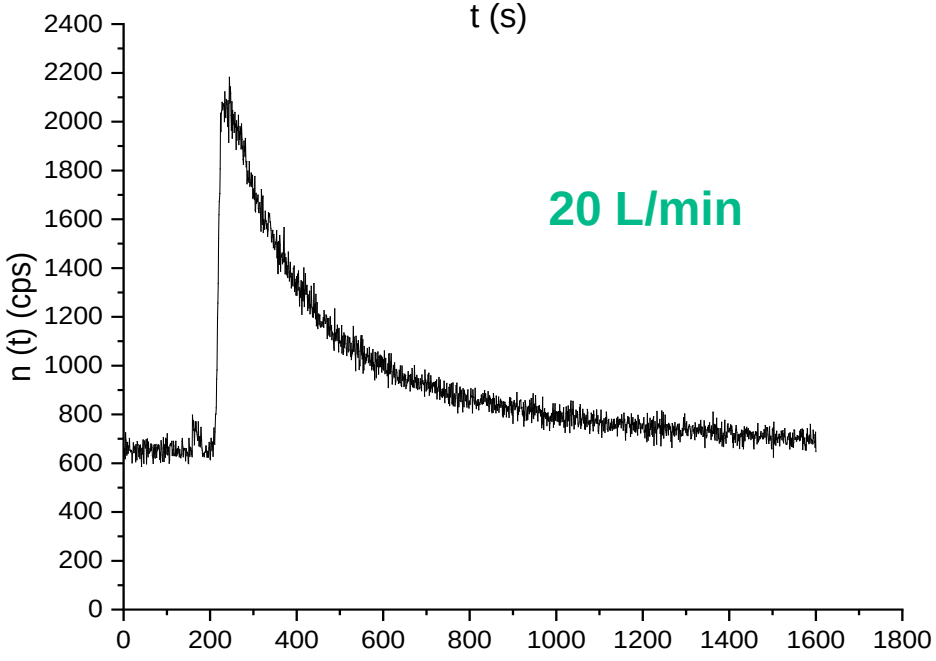
The flow meter is well calibrated

RESULTS AND DISCUSSION

Hydrodynamic characterization and effect of flow

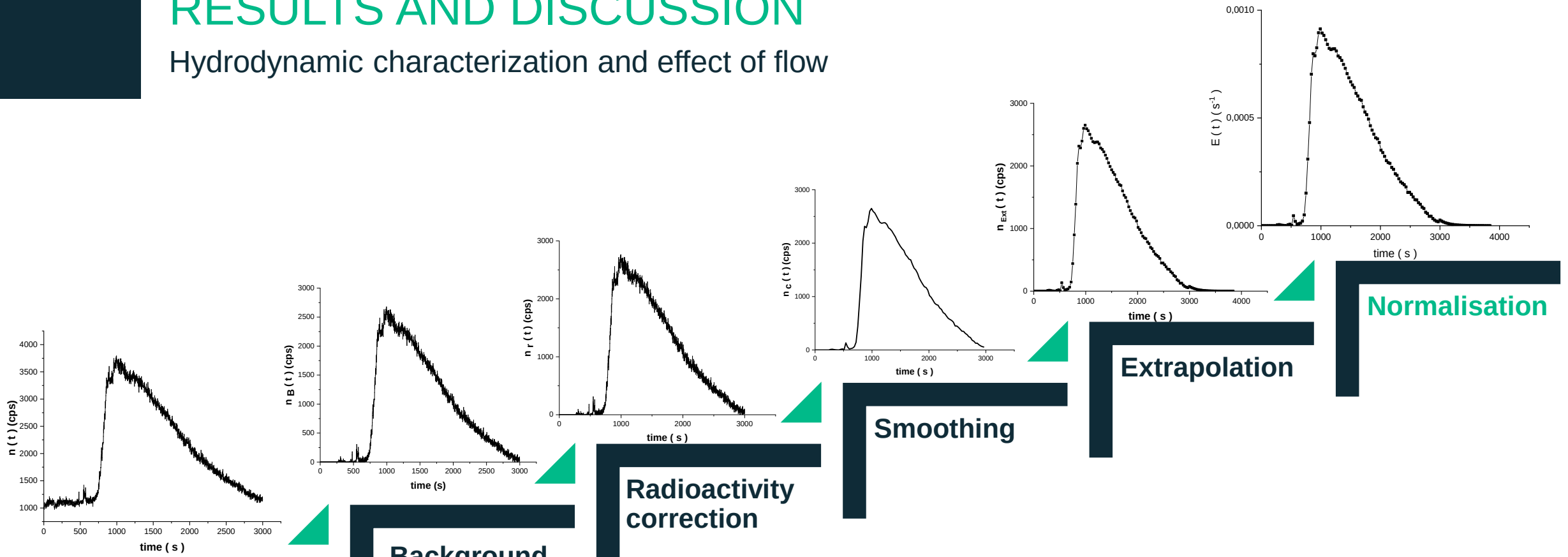






RESULTS AND DISCUSSION

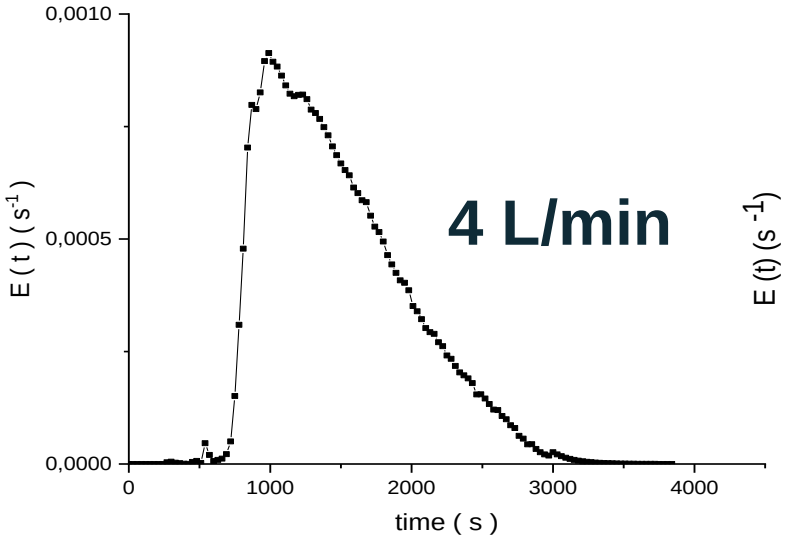
Hydrodynamic characterization and effect of flow



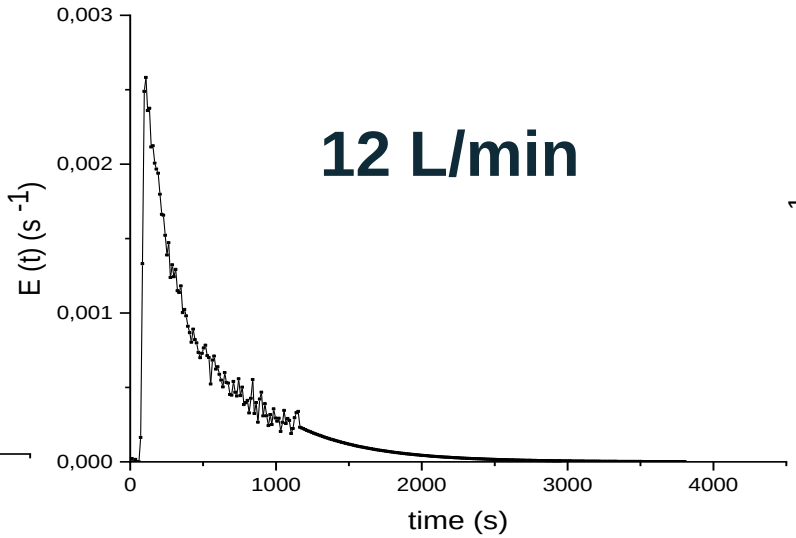
Spectrum processing

RESULTS AND DISCUSSION

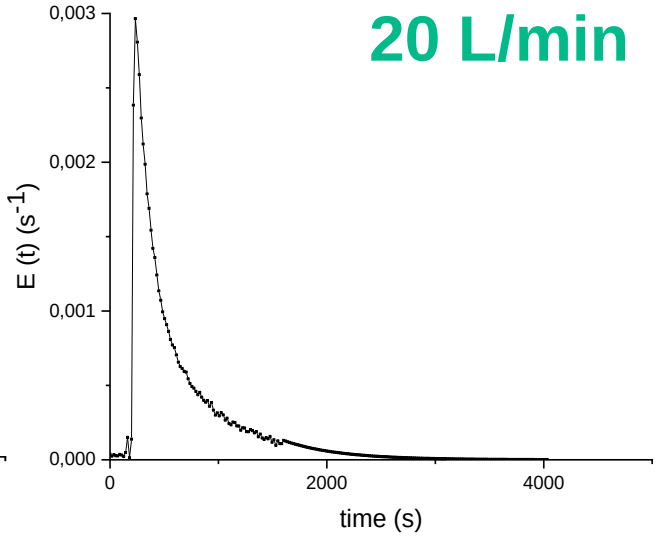
Hydrodynamic characterization and effect of flow



4 L/min



12 L/min



20 L/min

σ^2 (min 2)

93.39

70.36

72.05

RESULTS AND DISCUSSION

Hydrodynamic characterization and effect of flow

Flow (L/min)	t_s(min)	τ (min)	Mulfunction	α (%)	β (%)
4	**24.52**	30	**Dead volume**	-	**18.27**
12	**9.29**	10	**Dead volume**	-	**7.15**
20	**10.80**	6	**Short-circuit**	**44.46**	-

A very high flow rate can cause a major short circuit

CONCLUSION AND OUTLOOK

CONCLUSION AND OUTLOOK

The main objective of our study was the evaluation of a flow rig column using technetium-99m as radiotracer by modifying a very important parameter which is the flow rate.

The experiments were performed successfully. The experimental RTD curves as well as the mean residence time showed the presence of dead volumes for low flow rates (4 L/min and 12 L/min) and a short circuit for a high flow rate (20 L/min).

In addition to the characterization of the column, the use of radioactive tracers allowed the verification of the injection and the verification of the flow rate by the transit time method, which cannot be done with conventional tracers .

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THANK YOU!