

BUBBLES DYNAMICS UNDER POOL SCRUBBING CONDITIONS FOR IODINE COMPOUNDS TRAPPING APPLICATIONS

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OUTLINE

Context

Materials & methods

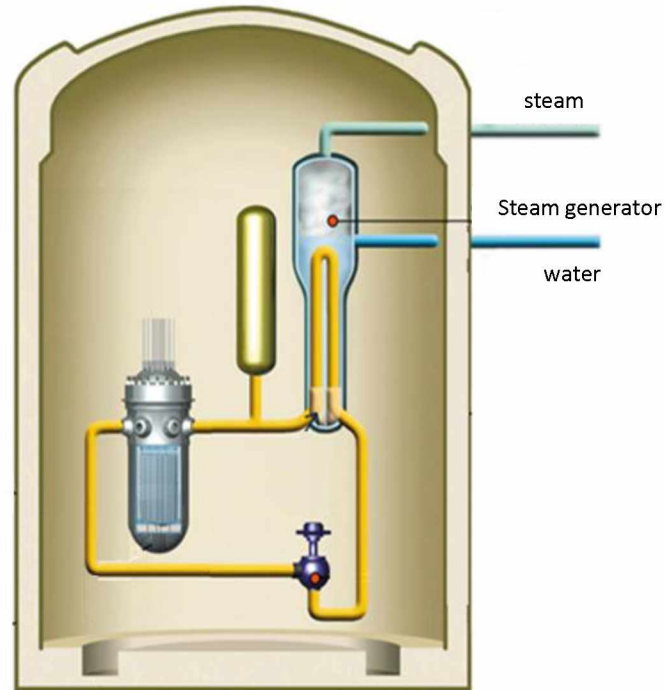
Hydrodynamics

DF measurements

$$DF = \dot{m}_{in} / \dot{m}_{out}$$

Conc. & Perspect.

Pool scrubbing

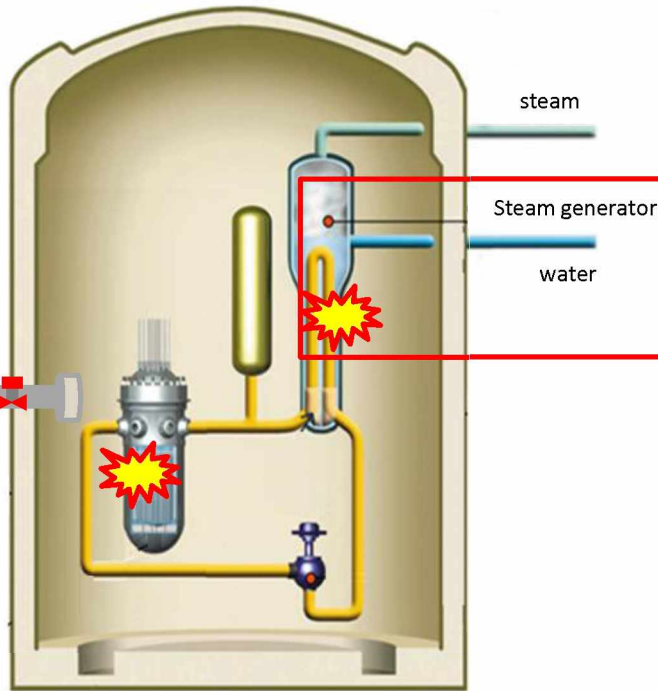


Containment building of PWR

Pool scrubbing



Filtered containment venting system
(FCVS)



Containment building of PWR

MITIGATION OF THE RELEASED
FISSION PRODUCTS:

WET FCVS

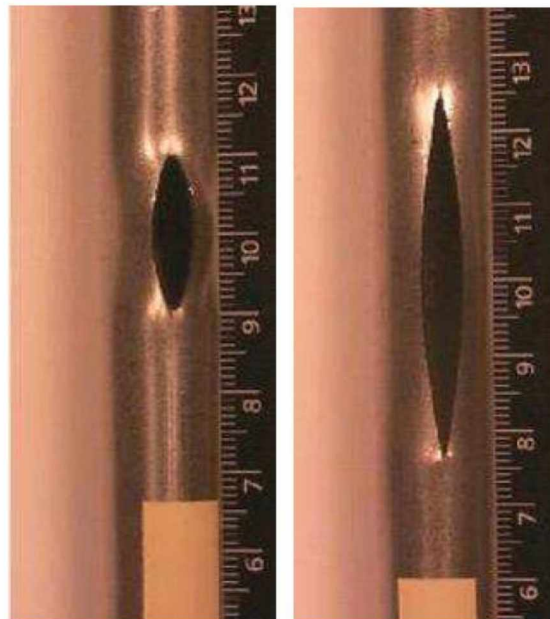
STEAM GENERATOR TUBE RUPTURE
(ACCIDENTAL SITUATION SGTR)

Pool scrubbing



Filtered containment venting systems

Ref: <https://www.idom.com/en/project/design-of-the-filtered-containment-venting-system-in-asco-and-vandellos-ii-nuclear-power-plants/>



Ruptures of tubes SG

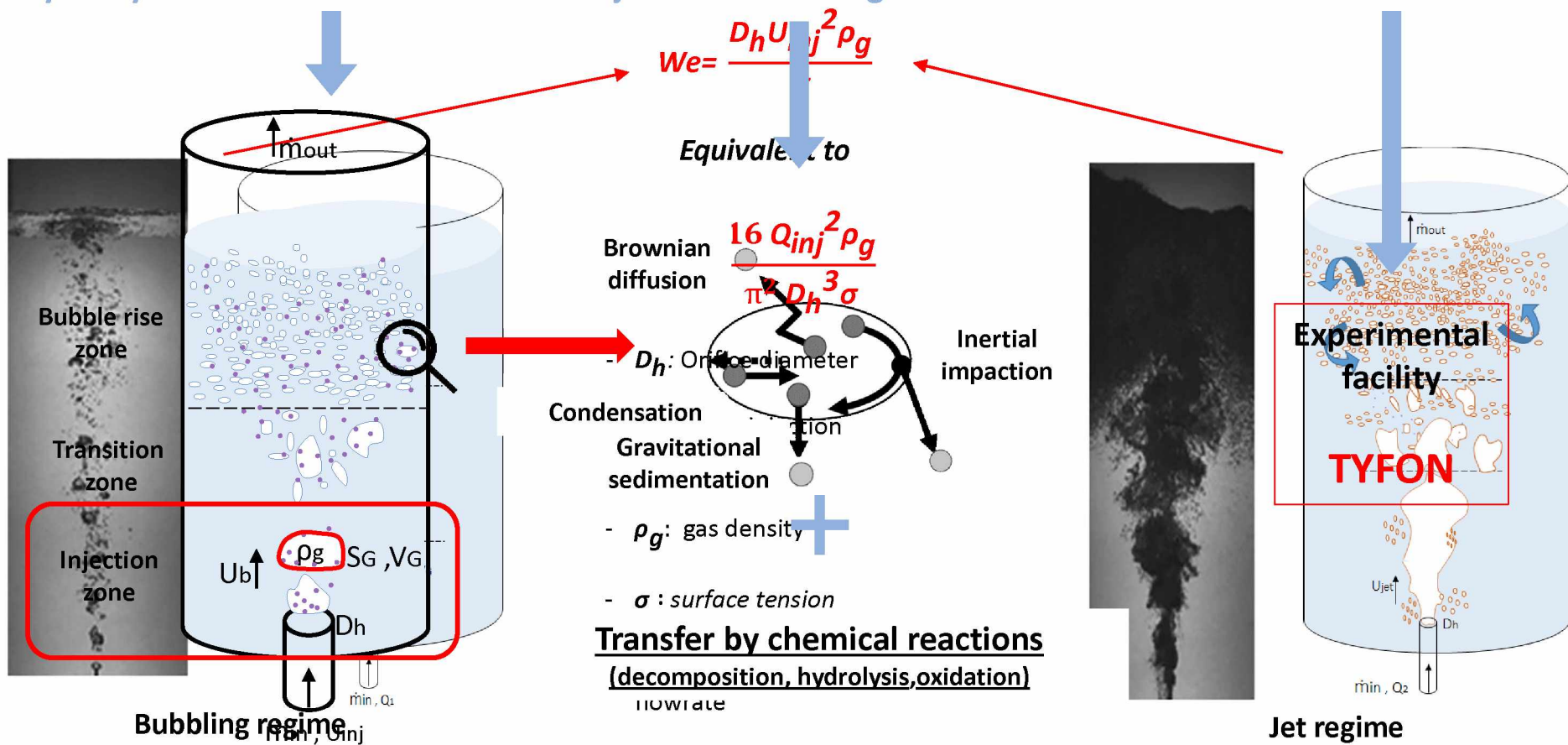
Ref: Cartonnet, A. (2013). *Contribution à l'étude du rejet à l'environnement de l'iode radioactif lors d'une séquence accidentelle de type RTGV* (Doctoral dissertation, Thesis).

State of art, uncertainties, and objectives

- Experimental databases haven't yet characterized the overall phenomena encountered in the pool scrubbing.
- Conventional theoretical models and assumptions for the descriptions of pool scrubbing are implemented in codes.
- The code's validity extends only over the range of conditions encompassed by the data they were based on.

Establishing advanced experimental database → ASTEC code

Hydrodynamic characterization in the injection zone and global decontamination factor measurements



MATERIALS & METHODS



Experimental setup: TYFON



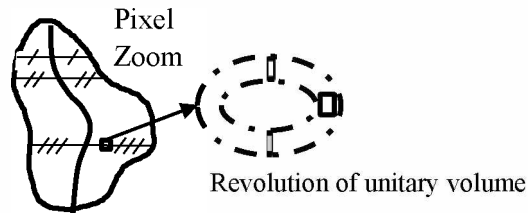
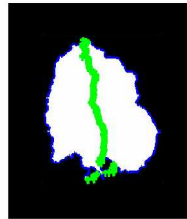
Data treatment & analysis



Image processing



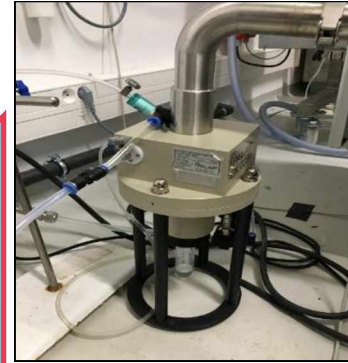
Tracking and characterization of globules formation



Globule volume computation

Physical aspects

Chemical aspects



Aerosol generator
AGK 2000 Palas



ICPMS

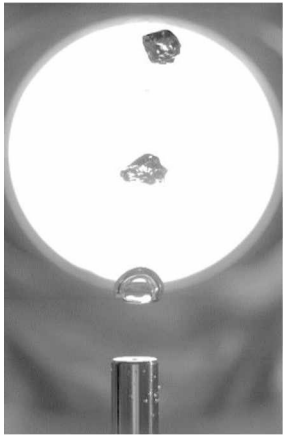
Analysing liquid
samples
quantification of
trapping

HYDRODYNAMICS

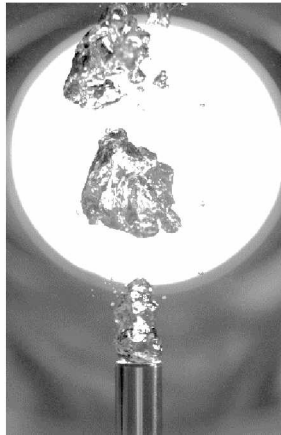
Hydrodynamics

- Hydrodynamic measurements of globules formation in the injection zone
- Examination of influences :
 - Carrier gas contamination
 - Orifice size
 - Injection flowrate
 - Water level (submergence)

$D_h = 2 \text{ mm}$



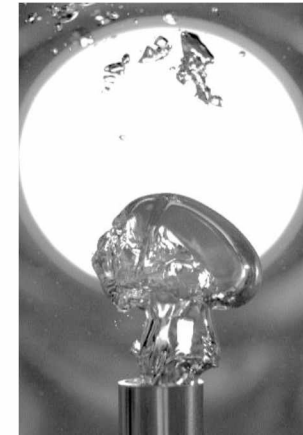
$D_h = 5 \text{ mm}$



$D_h = 10 \text{ mm}$



$D_h = 20 \text{ mm}$

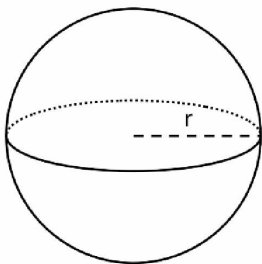


Globule volume

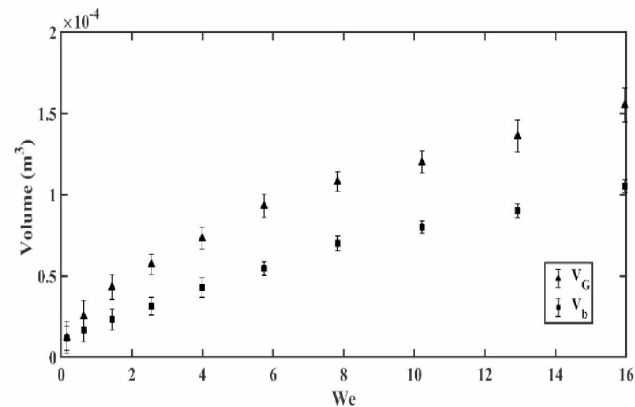
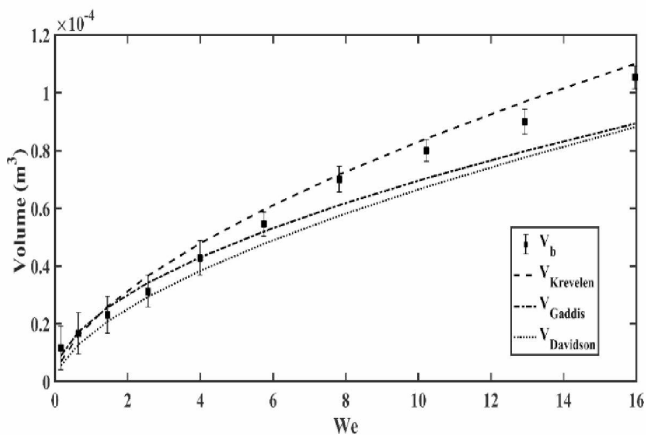
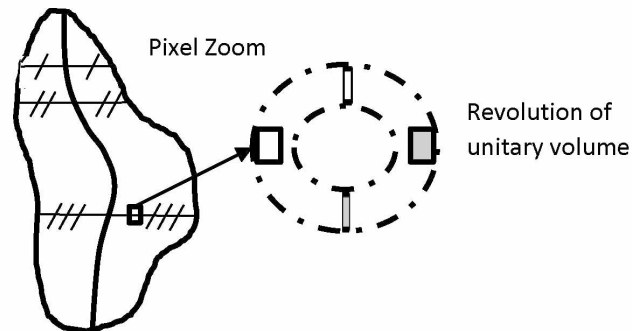
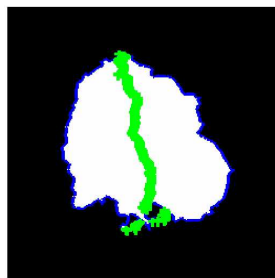
- Mohamad Farhat, Maxime Chinaud, Philippe Nerisson, and Olivier Vauquelin. "Characterization of bubbles dynamics in aperiodic formation." *International Journal of Heat and Mass Transfer* 180 (2021): 121646.

Classical approach

$$d_b \approx \sqrt[3]{\frac{6 * V_b}{\pi}}$$

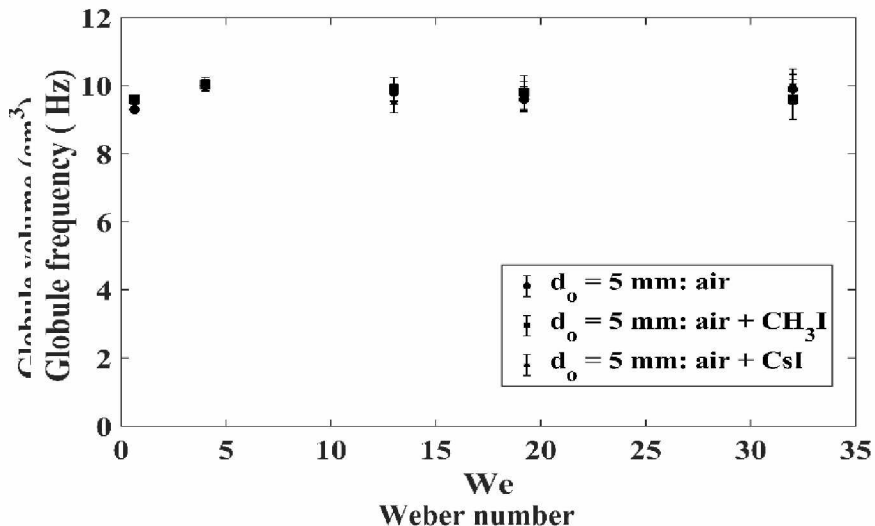


Phenomenological approach



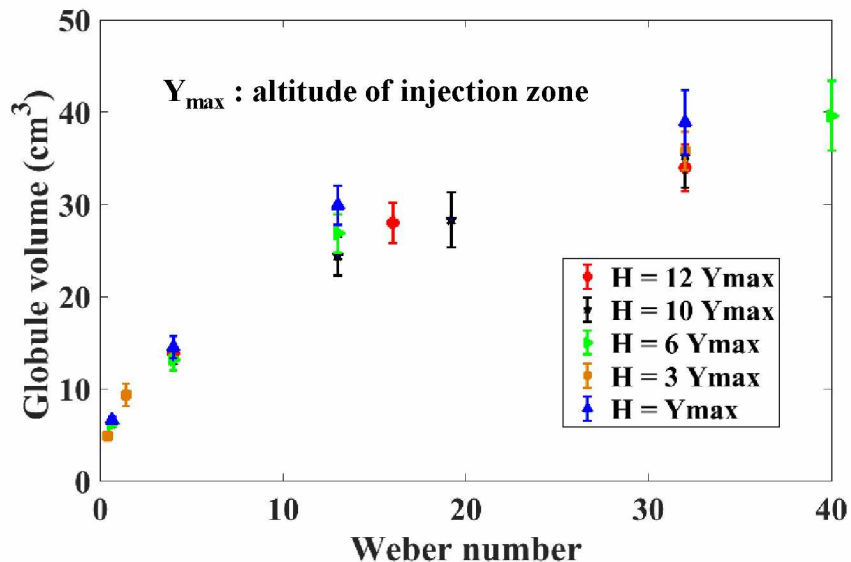
Hydrodynamics

Carrier gas contamination



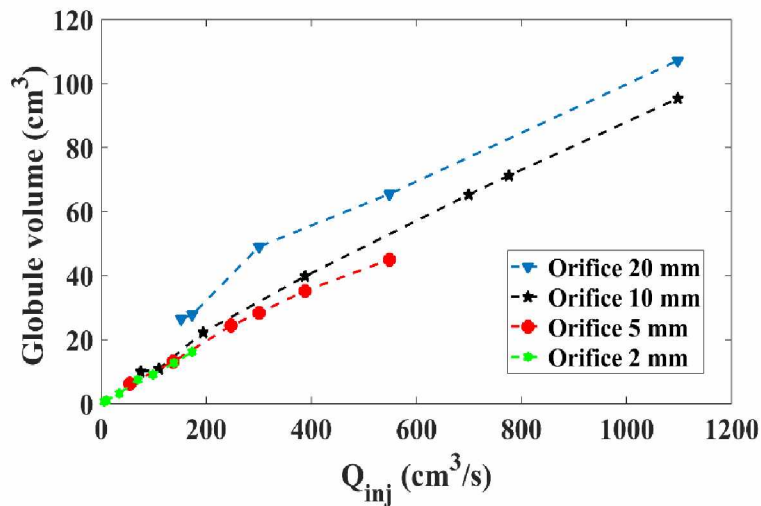
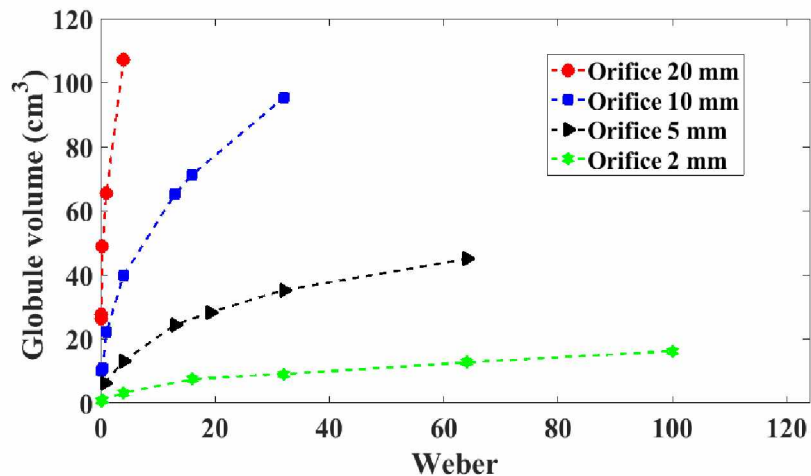
- No influence on the formation process of globules
- Negligible influence on globule volume with the variation of submergence.

Submergence



Hydrodynamics

Orifice size & injection flow rate



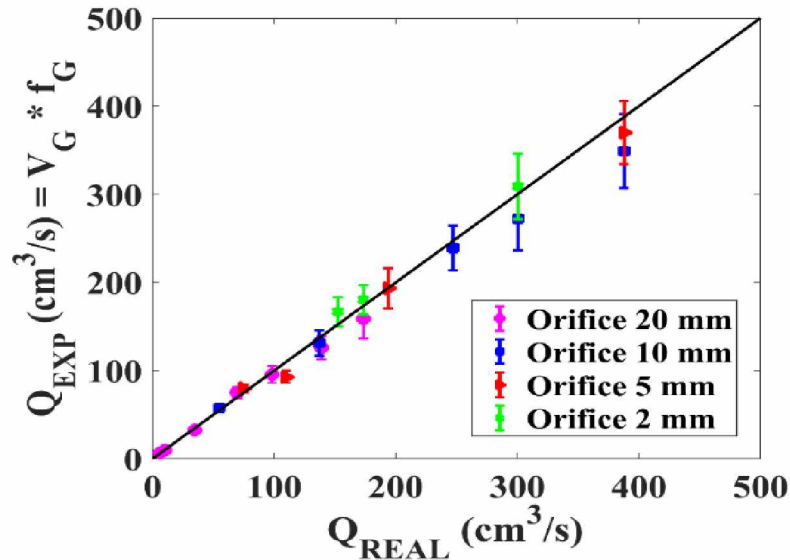
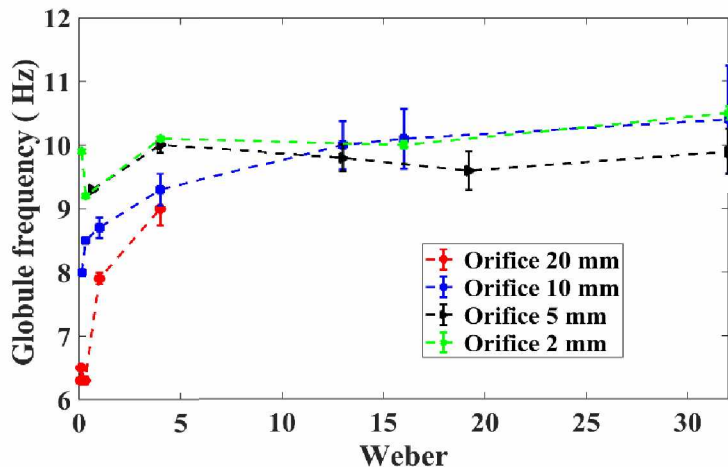
$$We = \frac{16 Q_{inj}^2 \rho g}{\pi^2 D_h^3 \sigma}$$

- Implication of orifice size into Weber number → divergence of globule volumes as function of Weber
- Comparable globule volumes with different orifices at same conditions → frequency ?

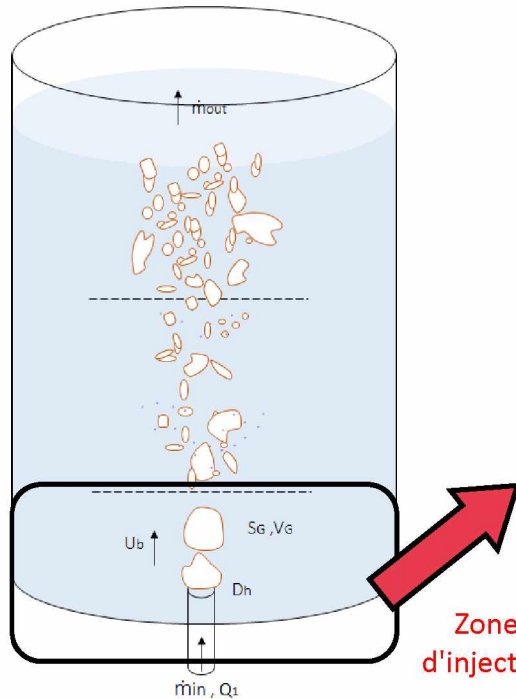
Hydrodynamics

- Mohamad Farhat, Maxime Chinaud, Philippe Nerisson, and Olivier Vauquelin. "Characterization of bubbles dynamics in aperiodic formation." *International Journal of Heat and Mass Transfer* 180 (2021): 121646.

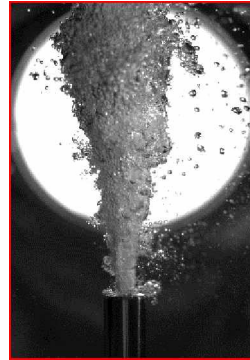
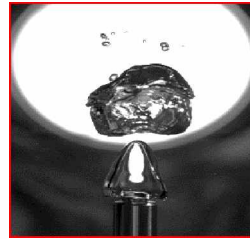
■ Globules frequency and validation of globule characterization



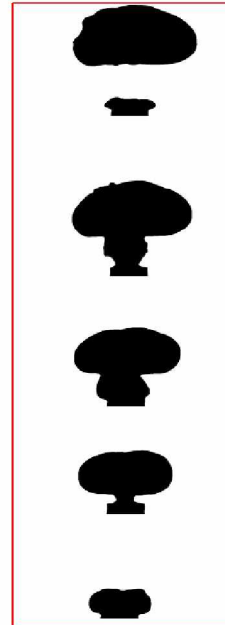
- Stable frequency, maximum frequency up to a certain flowrate (**Dh= 20 mm**).
- Validation of globule approach by comparing experimental to real flowrate



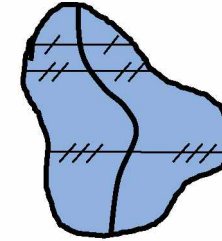
Zone
d'injection



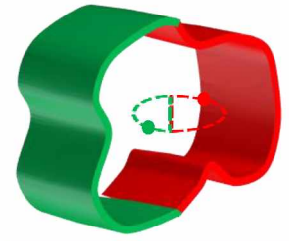
Morphology
Bubbling - Jet



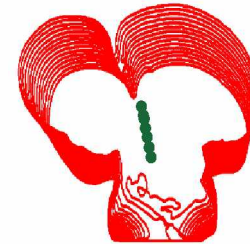
Formation
frequency



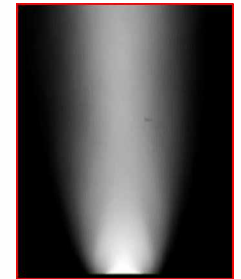
Volume



Surface area



Formation
velocity



Void fraction

*Références

- Mohamad Farhat, Maxime Chinaud, Philippe Nerisson, and Olivier Vauquelin. "Characterization of bubbles dynamics in aperiodic formation." *International Journal of Heat and Mass Transfer* 180 (2021): 121646.
- Farhat M. Etude expérimentale de l'hydrodynamique du barbotage pour différents régimes : application au piégeage des iodes. Rapport d'avancement de première année de thèse. Rapport IRSN/2020-00691, 2020.

DF MEASUREMENTS

DF measurements of CsI

- Hydrodynamics: No impact of aerosols contamination.

$$DF = \dot{m}_{in} / \dot{m}_{out}$$

- The tests covered bubbling and jet regimes ($0.07 < We < 1000$).

- Effects:

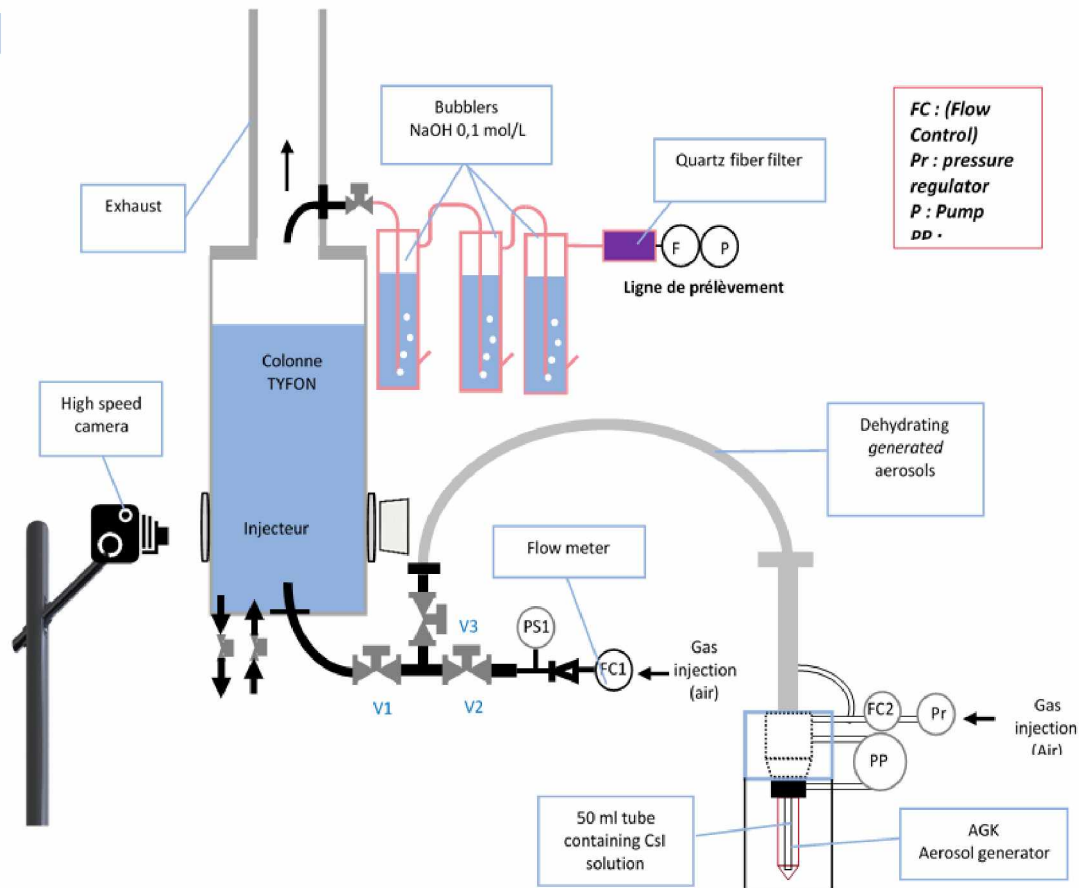
- Injection flowrate (We)

- Submergence

- Gas temperature

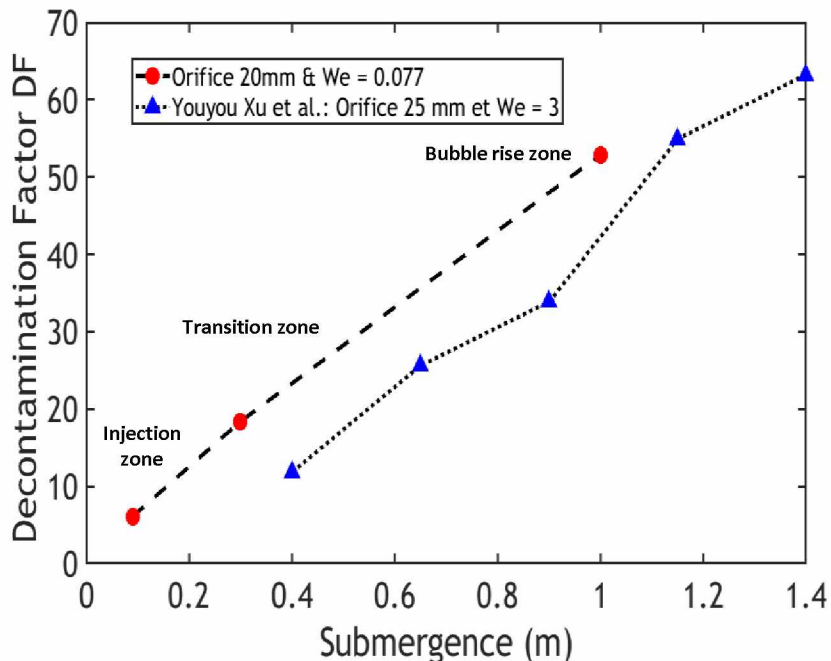
- Pool temperature

- pH

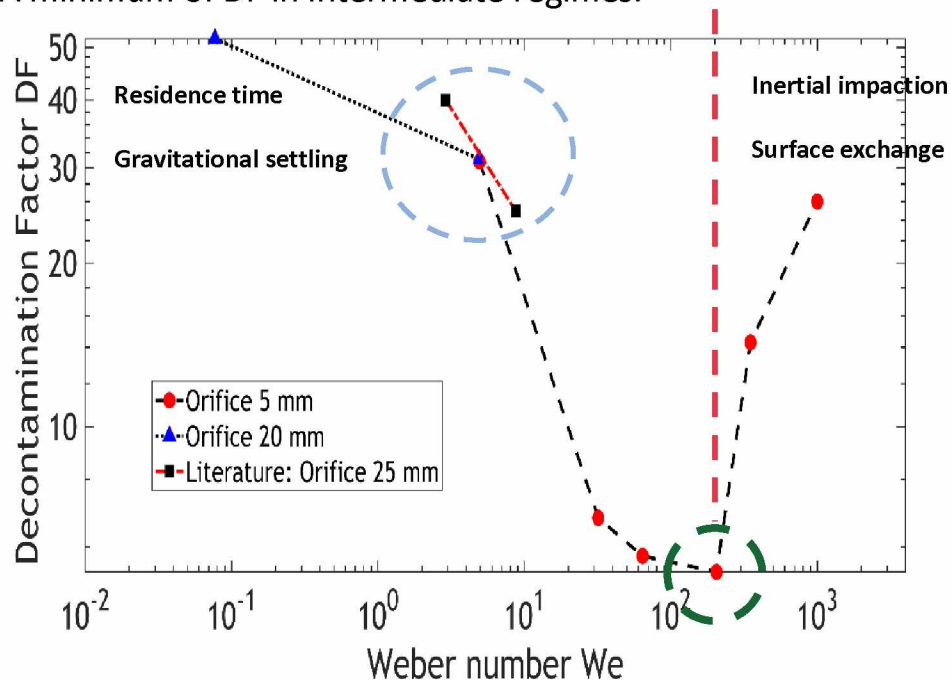


Some results

- DF vs submergence.



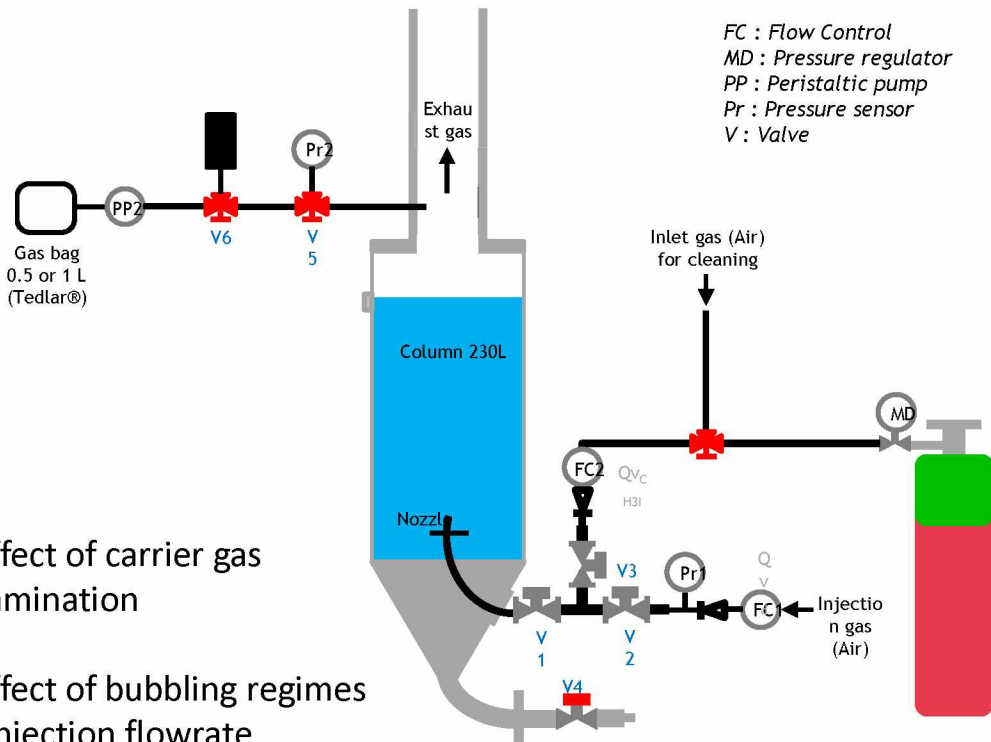
- A minimum of DF in intermediate regimes.



- Capability of Weber, comprising the variation of orifice's size and injection flowrate, in characterization of DF.

Ref: Xu, Youyou, et al. "Experimental study on aerosol behavior in water pool scrubbing under severe accident conditions." *International Journal of Advanced Nuclear Reactor Design and Technology* 2 (2020): 111-116.

DF measurements of CH₃I



- No effect of carrier gas contamination
- No effect of bubbling regimes and injection flowrate ($0.07 < We < 3000$).

Pool scrubbing of IodoMethane

TYFON	Conditions				DF
	Matrix	Temp. gas	Temp. pool	Weber	
PIM 1	Alcaline (pH = 12)	25 °C	25 °C	0,077	1,3
PIM 2	Alcaline (pH = 12)	70 °C	70 °C	0,077	2,4
PIM 3	Alcaline (pH = 12)	25 °C	25 °C	64	1,0
PIM 4	Alcaline (pH = 12)	70 °C	25 °C	350	1,2
PIM 5	Alcaline (pH = 12)	70 °C	70 °C	350	1,6
PIM 6	Alcaline (pH = 12)	70 °C	25 °C	1000	1,1
PIM 7	Alcaline (pH = 12)	25 °C	25 °C	1000	1,0
PIM 8	Alcaline (pH = 12)	25 °C	25 °C	3000	1,1
PIM 9	Alcaline (pH = 13)	70 °C	70 °C	0,077	5,6

CONCLUSION & PERSPECTIVES

Conclusion

1 – Hydrodynamics

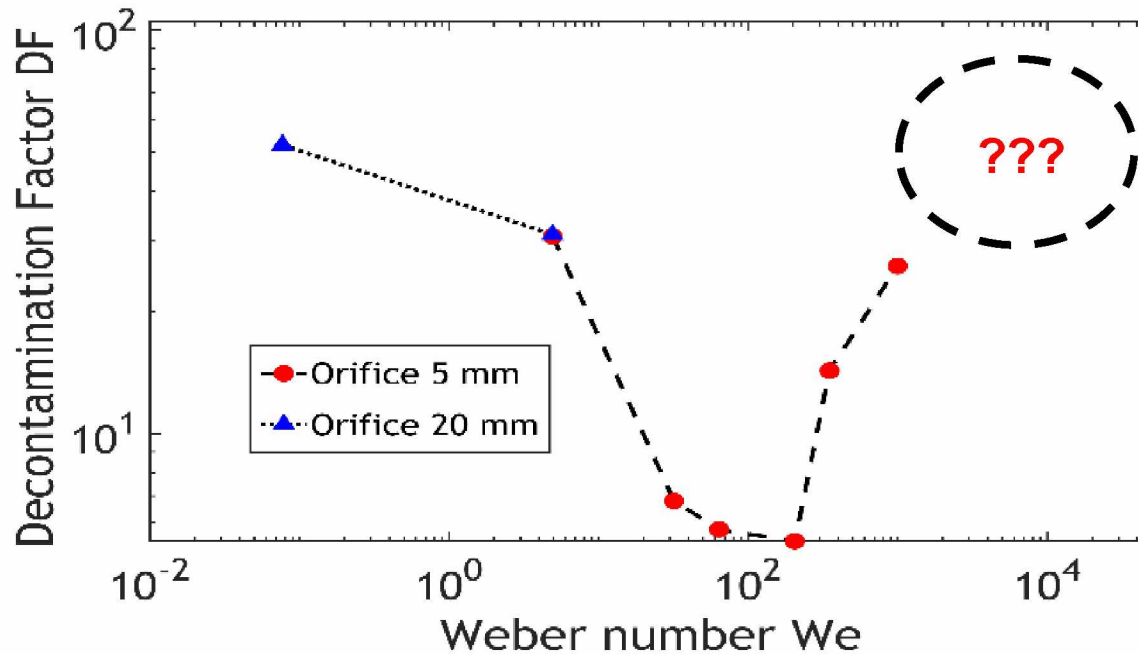
- Capability and validity of phenomenological approach in characterizing globule volumes in the injection zone
- Negligible influence on the globule dynamics due presence of CH_3I or CsI aerosols in the composition of the carrier gas
- Negligible influence of pool submergence (level of water in the pool)
- Globule volumes is mainly affected by the gas flow rate as the frequency of formation is independent at high flowrates

2 – DF measurments

- Pool scrubbing trapping CsI aerosols is affected significantly by hydrodynamic aspects & weak retention of CH_3I
- Competition of aerosol removal mechanisms and existence of a minimum trapping
- Capability of Weber number in characterizing the DF

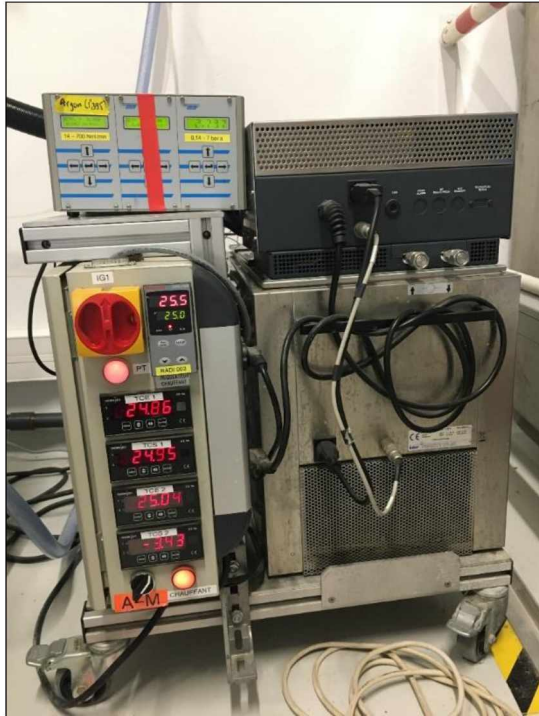
Perspectives

DF measurements on Csl at high Weber number: $We > 10^4$



Perspectives

Trapping of elemental I₂



I₂ generator



IRSN

INSTITUT
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ET DE SÛRETÉ NUCLÉAIRE

Questions are welcomed !

