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CORIA UMR 6614 — INSA Institut National des Sciences Appliquées Rouen Normandie — SEGULA Technologies

Phenomenology of a bubble plume From the leak of an underwater storage tank to the seawater surface

C. Deberne[a,b], J.C. Brändle de Motta[a], M.-C. Renoult[a], T. Neu[b], J.-B. Blaisot[a], D. Guyomarc'h[b]

[a] INSA Rouen Normandie, Univ Rouen Normandie, CNRS, Normandie Univ, CORIA UMR 6614, F-76000 Rouen, France

[b] SEGULA Technologies, 1 rue Charles Lindbergh, Bouguenais, France

Context and Objectives

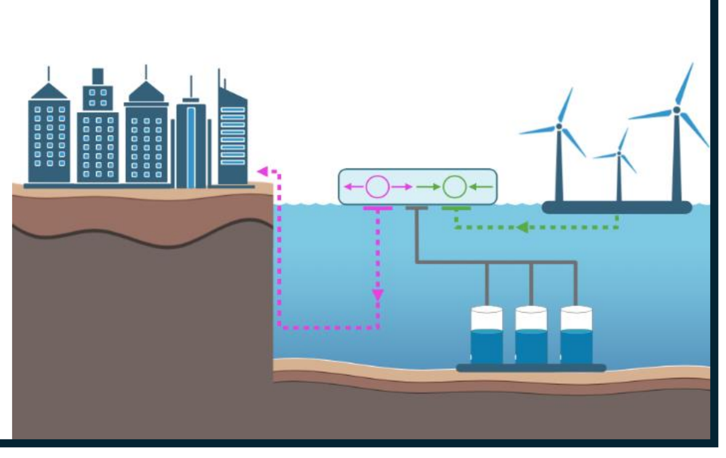
Helping designing an underwater compressed air energy storage system (UWCAES)

- Predicting the impacts induced by a massive leak of compressed air into seawater
- Implementing a suitable risk analysis study

Application

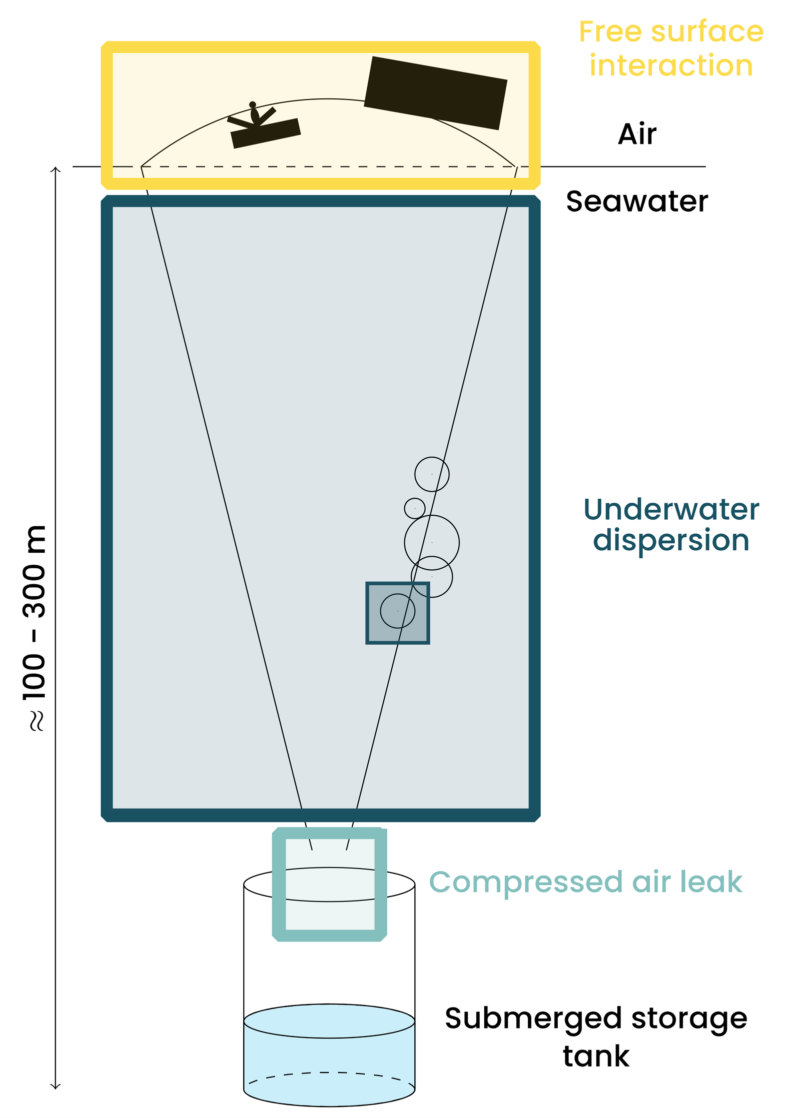
UWCAES system configuration

- Submerged at 200 m depth
- Cylinder tank initially filled with 15 000 kg of compressed air
- Leak orifice of 30 cm diameter



Method

Different scales ... ... Different tools



C. Correlation for the sea surface flux [3]

B2. Population balance model of the bubble plume [2]

B1. DNS of single rising bubbles

A. Mathematical modelling of the gas flow rate [1]

Results

A. Tank empties in less than 4 minutes

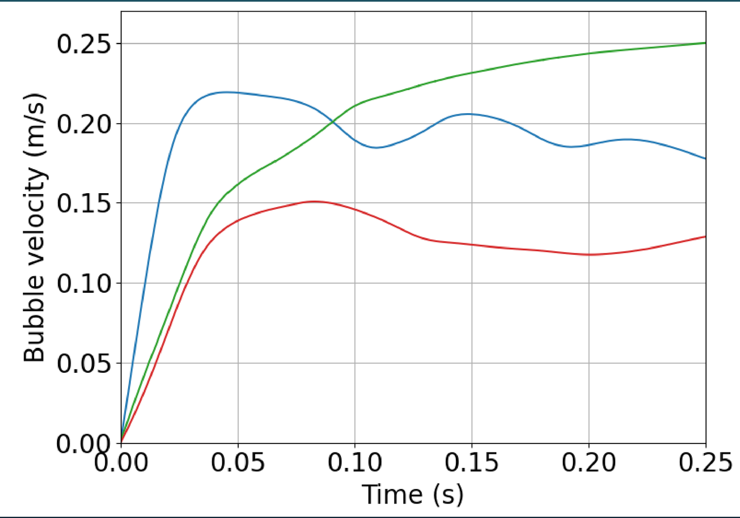
Initial gas flow rate is 136 kg/s → Jetting flow regime

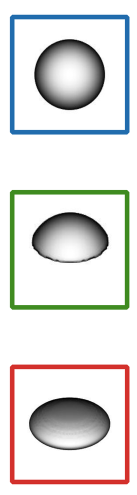
- Leak behaviour depends on tank dimension

B1. Gas density has no effect on bubble dynamics

Dynamics is driven by bubble height h

- Initial shape influences bubble velocity

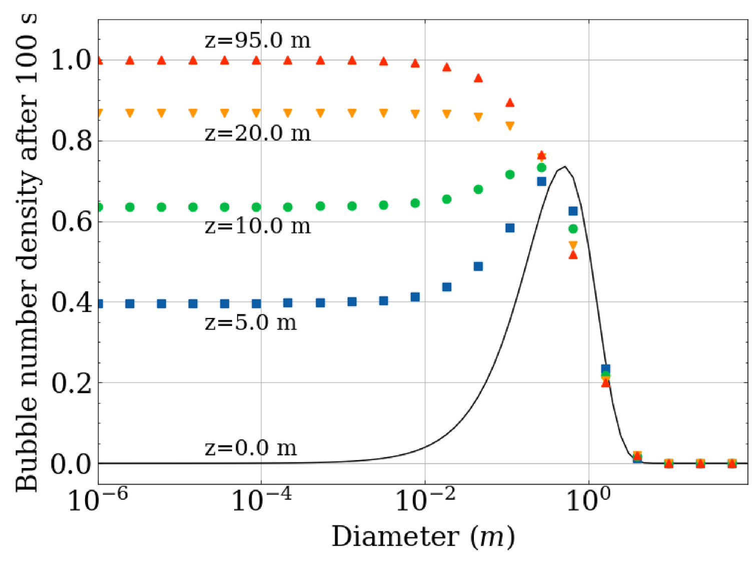




Sphere $h=0.016$ m

Spherical cap $h=0.008$ m

Spheroid $h=0.004$ m



B2. Expansion rate is negligible compared with bubble rise velocity

Bubbles increase in number but decrease in size

- Fragmentation prevails over coalescence and expansion

C. Seawater surface fountain is 1 m high and 42 m wide

- Fountain width increases with immersion depth

Conclusion and Perspectives

Using multiple tools to study an air bubble plume offers a deeper insight into its dynamics.

Greater accuracy could be achieved by considering the interaction between plume and seawater

DNS have been realized with in-house code ARCHER

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camille.deberne@coria.fr

[1] Deberne, C., Renoult, M. C., Blaisot, J. B. (2023) « A mathematical model describing an unsteady leak of compressed air from an open underwater storage tank ». Journal of Energy Storage, 81 (110318)

[2] Solsvik, J., Jakobsen, H. A. (2015) « The Foundation of the Population Balance Equation : A Review ». Journal of Dispersion Science and Technology, 36:4, 510-520

[3] Friedl, M. J., Fanneløp, T. K. (2000) « Bubble plumes and their interaction with the water surface ». Applied Ocean Research, 22, 2