Spectrophotometrical monitoring system, integrated in an Autonomous Underwater Vehicle, for continuous heavy metal detection near offshore sites

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Research context and motivation

The analysis of water quality in the vicinity of oil or gas platforms takes place periodically. Water samples are collected in-situ and delivered to be analyzed in specialized laboratories. Sampling and related delivery does not allow mapping contaminant plumes nor establishing a correlation between the contaminant(s) and a hypothetical source. Thus, it is desirable that the current sampling methodology evolves into a more frequent and refined environmental monitoring approach.

Figure 1. Offshore gas platform in Marina di Ravenna.

Addressed research questions/problems

The offered solution to significantly improve the operational scenario is that of a sensing system capable of sampling daily (or even more frequently) the waters nearby a site of interest to assess any presence of contaminants. A real-time mapping of water quality in proximity of offshore hydrocarbon production sites through AUV (Autonomous Underwater Vehicle) systems is developed.

Novel contributions

The design of the sensing platform mounted on AUV takes advantage of microfluidic (Lab-On-Chip) technologies for the management of the fluids and in-situ analysis of marine water samples. The approach involves a significant reduction of the sample and reagents volumes, prolonged monitoring and a greater areal coverage around platforms without any noticeable loss of performance in terms of sensitivity.

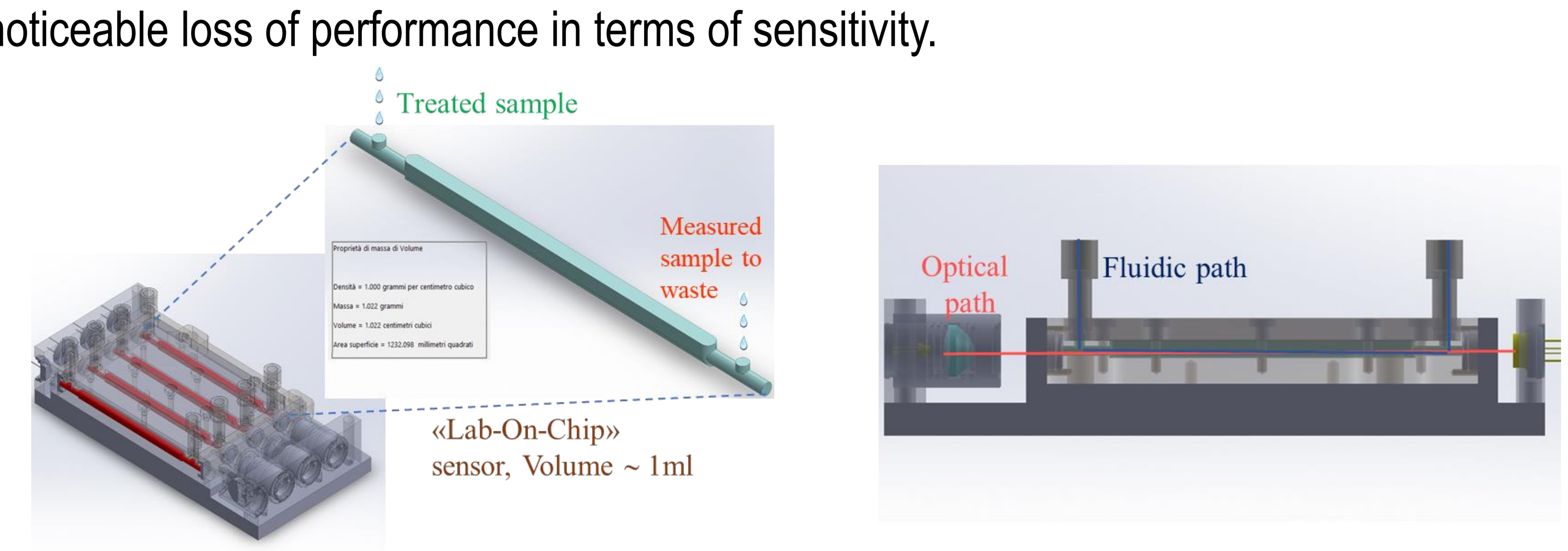

Figure 2. Microfluidic analysis based on Lab-on-Chip technique. Reduction of sample and reagents volumes, energy budget, analysis times. Different chambers for different materials analysis.

Figure 3. Layout definition to minimize dead volumes. The system is designed to be embedded on an Autonomous Underwater Vehicle (AUV).

Adopted methodologies

The first contaminant analyzed was Chrome(VI). The main process parameters of the standard method were optimized to be moved to a miniaturized and portable device where reagents and samples will be dosed in continuous by a microfluidic electronical system able to manage minimum volumes of liquids. Methods for Zinc, Nichel and Copper were optimized too.

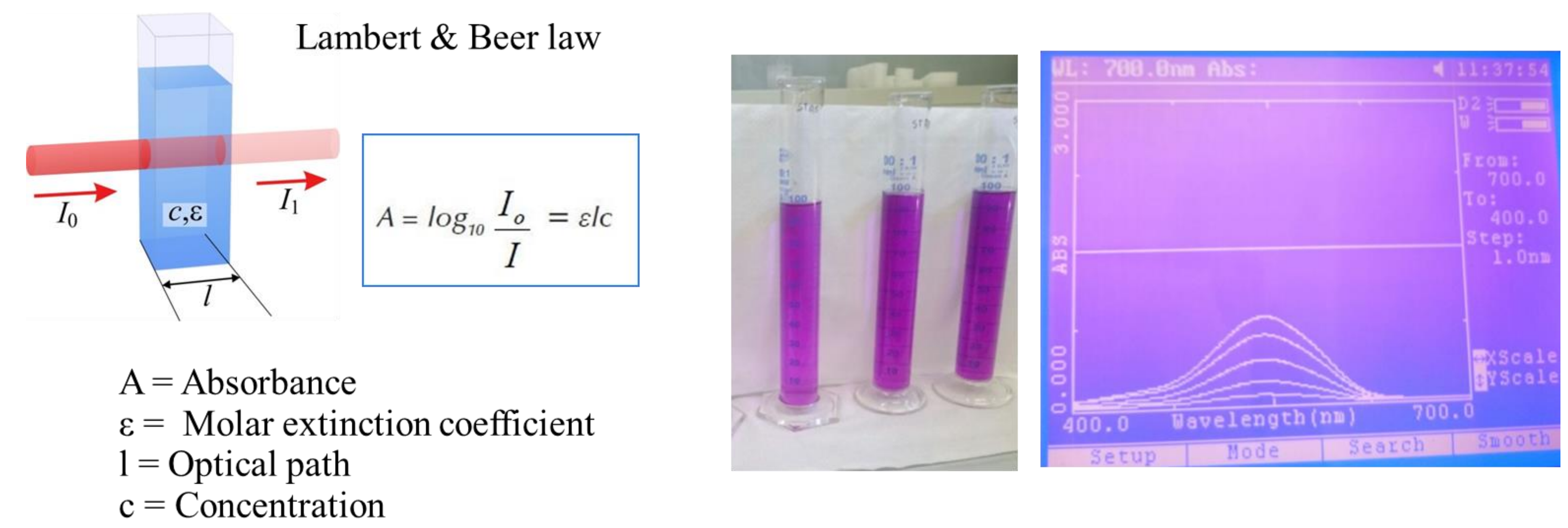

Figure 4. Spectrophotometric analysis allows to accurately determine traces of heavy metals in water. The method presents high selectivity and sensitivity, making it competitive with respect to more sophisticated and expensive techniques (ex: ICP - MS).

Many tools are involved in characterization and development of the optical system for absorption detection

1) Ray tracer for optical design and beam shaping,
2) CAD programs for structures design,
3) Optical devices for laser beam characterization (Beam profiler, power meter).

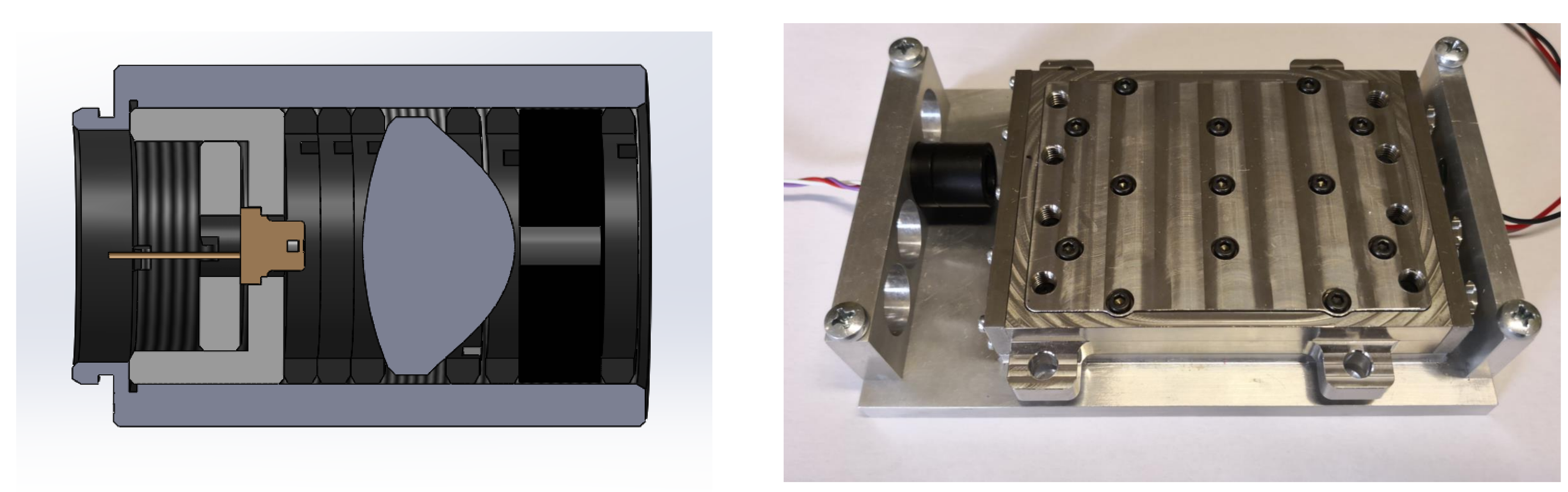

Figure 5. a. Optical system design, **b.** Measure chamber with the optical system,

Conclusions

In this study we perform the optimization of different methods for the detection of several metals and other contaminants in seawater, and the design of optical systems for absorption analysis. Test on the bench prototype confirmed the results obtained at laboratory scale, moreover, test on the field have demonstrated the validity of the system and its complete automation.

	Chrome	Zinc	Nickel	Copper
Reference method	Diphenylcarbazide	Zincon® at pH 8	Zincon® at pH 9	Zincon® at pH 4
Linearity	10-0.1 ppm 100-5 ppb	10-0.1 ppm	10-0.1 ppm	10-0.1 ppm
Wavelength	520nm	638nm	600nm	665nm

Figure 6. Four different contaminants and their reference methods.

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References

[1] F. Catania, A. Piscitelli, S. Ferrero, M. Cocuzza, C. F. Pirri, L. Scaltrito, M. Periolatto Cr(VI) in Water: Continuous, on Site Spectrophotometric Determination Laboratory test preliminary to microfluidic device prototyping. International Journal of Applied Science and Environmental Engineering. -pp. 265-270, 2018.

[2] M. Cocuzza et al "Innovative technologies for offshore platforms safety and environmental monitoring", Geoingegneria Ambientale e Mineraria, Anno LIV, n. 3, pp. 7-16, 2017

[3] F. Ferrero, C. Tonetti, M. Periolatto, "Adsorption of chromate and cupric ions onto chitosan-coated cotton gauze", Carbohydrate Polymers, Vol. 110, pp. 367-373, 2014

[4] R. C. Demey, R. Sinclair, "Visible and Ultraviolet Spectroscopy", John Wiley and Sons, New York, 1987

[5]J. Fries, H. Getrost, "Organische Reagenzien fur die Spurenanalyse", E. Merk Darmstadt, pp. 115-118, 1975

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