# Materials and processing for power electronics packaging and green technologies.


## Abstract:

Water has always been the source of life on planet Earth, and for this reason, it must be protected from potential pollutants. Among these, heavy metals pose a significant threat to both the environment and human health due to their rapid bioaccumulation in living organisms leading to severe consequences. Heavy metal contamination can arise from natural sources, such as extreme weather events that erode rocks containing these pollutants naturally present within the Earth and deposit them into water bodies. Alternatively, heavy metals can be released into the environment through anthropogenic activities, primarily linked to industrial processes. However, traditional laboratory methods for analysing heavy metal contamination involve time-consuming steps like sample collection, transport, and processing. This delay can severely hinder effective remediation, allowing pollution to spread unchecked and cause more damage. To address this critical issue, this research focused on ***developing customized sensors and sensor platforms for the in-situ monitoring of heavy metals in water***, providing immediate, on-site analysis of contamination levels. This rapid detection capability empowers authorities to take swift action, containing pollution and minimizing its impact on human health and the environment. By delivering continuous data and eliminating the lag times inherent in conventional methods, this in-situ monitoring system marks a significant leap forward in environmental monitoring and pollution control.

This objective was achieved through a ***multidisciplinary approach***, integrating expertise in ***chemistry, mechanics, and electronics*** to develop versatile tools for heavy metal monitoring. This synergistic strategy was essential in overcoming the complex challenges of sensor development, resulting in devices capable of accurate and reliable detection. The creation of these sensors involved a comprehensive assessment of design, fabrication, and integration of sub-systems, with a strong emphasis on optimizing key performance parameters such as sensitivity, selectivity, and stability.

The study employed chemical methodologies to create sensor prototypes capable of detecting heavy metals at extremely low concentrations, down to parts per billion (ppb), to safeguard drinking water quality. Specifically, the research targeted arsenic and hexavalent chromium due to their high toxicity even at trace levels. The developed platform of sensors utilizing two different approaches: colorimetric methods through UV-Vis spectrophotometry for chromium and stripping voltammetry for arsenic. The design has been studied to ensure compliance with stringent drinking water safety standards. To this end, after validation and optimization commercial sensors were integrated into a complex hydraulic system to record data on heavy metals monitoring and the essential physicochemical parameters of water. Following validation and calibration within the laboratory, the developed system was installed at two contaminated sites: one in Pietraporzio and the other in Sampeyre, both located in the province

of Cuneo, impacted by arsenic and chromium natural pollution. This real-world context enabled the collection of sensor-generated data and facilitated the validation of maintenance procedures for both the mechanical components and the chemical reagents employed.

Recognizing also the need to monitor industrial wastewater, where heavy metal concentrations can be significantly higher, reaching grams per liter (g/L), the research expanded its scope to include broader applications. This involved developing a prototype sensor for trivalent chromium detection and extending the research to encompass the detection of copper and nickel, common pollutants found in galvanic wastewater. This highlights the dual nature of water preservation in industrial processes: maximizing its efficient use to achieve the desired product quality while simultaneously monitoring for any losses that could be released into the environment. The developed sensor utilizes the principles of UV-Vis spectroscopy based on a colorimetric methodology to monitoring chromium trivalent from grams per liter (g/L) to parts per million (ppm) concentrations. Following laboratory validation, it was deployed for in-line installation within a pilot plant dedicated to process optimization for the galvanic industry.

As a future development of this research area, preliminary experiments have been conducted on the monitoring of cadmium in water intended for agricultural use, using innovative sensors named screen printed electrode able to reach parts per billion (ppb) levels of detection.

The development of the systems mechanical and electronic components has been conducted in collaboration with Microla Optoelectronics. Within the Chilab-ITEM laboratory, supplementary tools, such as dedicated filters to integrated into water monitoring platforms to prevent clogging inside the hydraulic system, ensuring continuous and accurate monitoring, were developed using additive manufacturing techniques.

This research, driven by a ***dynamic exchange between laboratory innovation and real-world industrial needs***, is poised to revolutionize heavy metal monitoring in water. This advancement represents a crucial step towards safeguarding human health and environmental integrity. By providing rapid and accurate detection, it empowers stakeholders with the timely information needed for swift action in the event of contamination. This bridge between academic research and industrial application was made possible through three key projects: TrAcqua, IntelWATT, and Agritech. These projects facilitated the study of diverse water bodies and various heavy metal contaminants, enabling the translation of laboratory innovations into practical tools for real-world use. This ensures that the developed technology is not only scientifically rigorous improvement but also robust and adaptable for diverse real applications in environmental and industrial monitoring for water safeguarding.