Development of Cost-Effective Sensors for the In-Situ Monitoring of Heavy Metals

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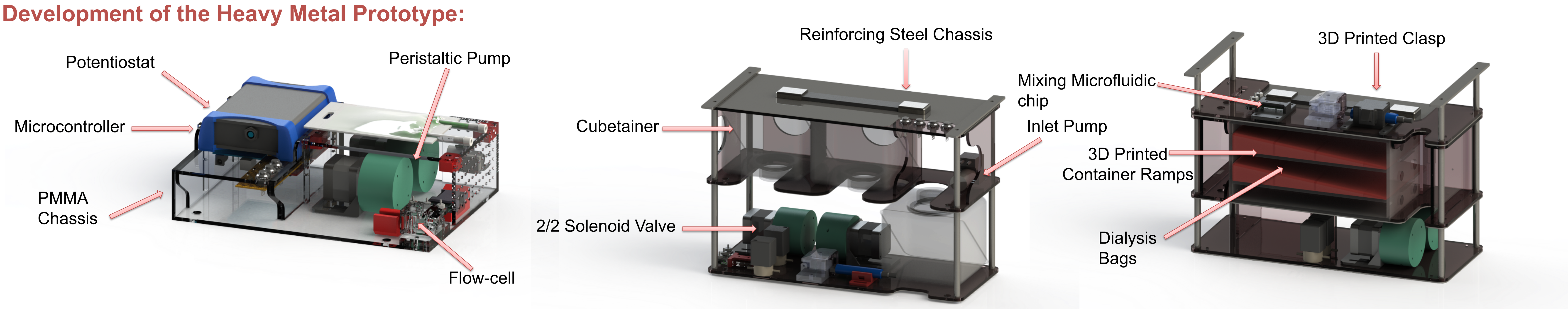
Introduction:

Heavy metals such as lead, mercury, cadmium, zinc and copper are among the most important pollutants because of their non-biodegradability and toxicity above certain thresholds. This work is carried out as part of the COMMON SENSE FP7 project. The COMMON SENSE project aimed to provide a cost effective reliable sensing platform for in-situ measurements of key parameters relating to eutrophication, contaminants, marine litter and underwater noise. Part of the project was to develop a sensor module for the automatic detection of low concentrations of heavy metals in seawater, which can be integrated with other sensors developed in the project. The design and construction of a precompetitive prototype of an electrochemical sensor for the detection of heavy metals made possible through the use of rapid prototyping as the principle manufacturing process. The system includes a microfluidic chip for complete mixing of the buffer and sample, a potentiostat to perform electrochemical measurement, two peristaltic pumps to control the fluidic pathway through the system, a wall-jet flow cell which incorporates a screen printed electrode (carbon-bismuth). The system has been tested on numerous deployments including Ichnussa 2015 Mediterranean Research Cruise (onboard the RV Minvera Uno), Ny-Aselund (Svalbard on the Italian Artic Base) and Sardinia Italy (CNR Italy testing Lagoon).

Development of the Heavy Metal Prototype:



Generation 1:

- 3D printed peristaltic pumps.
- Wall-jet flow cell.
- Mixing microfluidic chip.
- Potentiostat.
- Marinised housing.
- Laser cut PMMA Chassis.
- Electronic control of fluid handling system using a microcontroller.

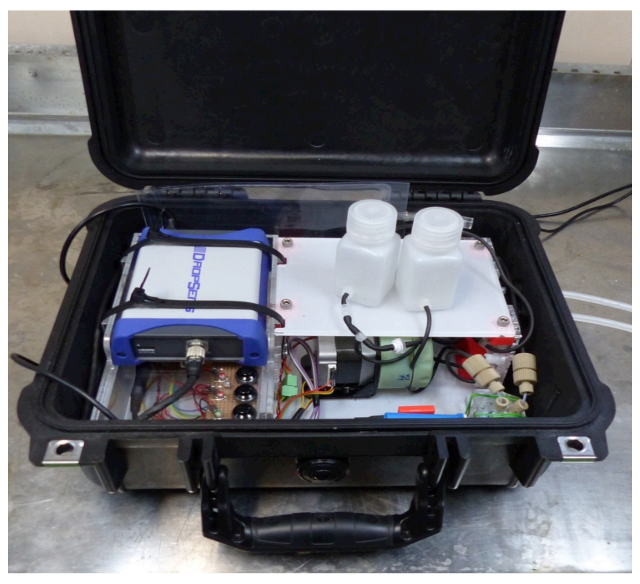


Fig. 1. Rendered image and image of generation 1 Heavy Metals system.

Generation 2:

- Cubetainer sample, buffer and waste reservoirs.
- 2/2 solenoid vales.
- Redesigned layout.
- Larger Marinised housing.
- Water jet cut marine grade stainless steel (316L) chassis.
- Isolated and protected electronics.

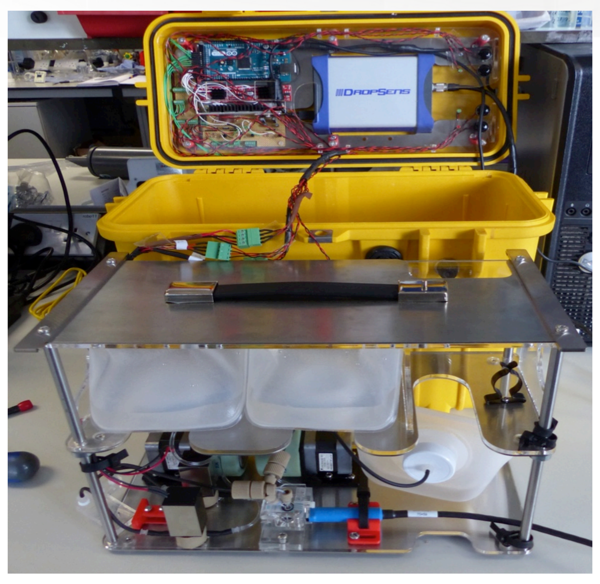


Fig. 2. Rendered image and image of generation 2 Heavy Metals system.

Generation 3:

- Dialysis bag sample, buffer and waste reservoirs.
- Fused Depositing Modelling 3D printed container ramps.
- PolyJet 3D printed electrode adaptor clasp.
- Redesigned layout for ease of operation.
- Touchscreen control of fluid handling system.
- Variable flowrate and purge operations.

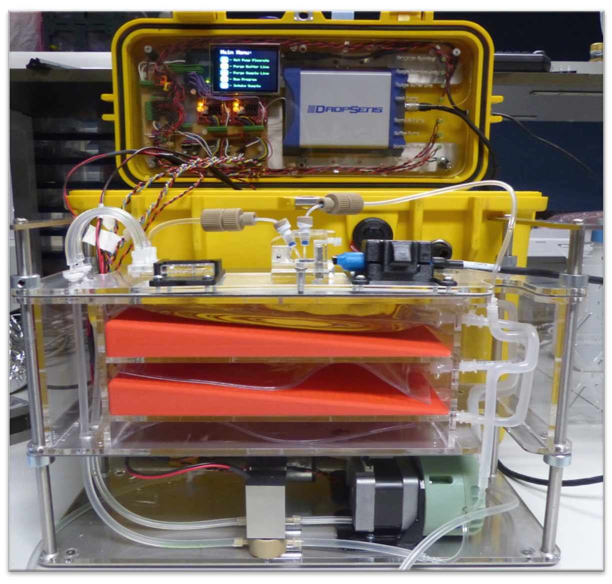


Fig. 3. Rendered image and image of generation 3 Heavy Metals system.

Precompetitive prototype:

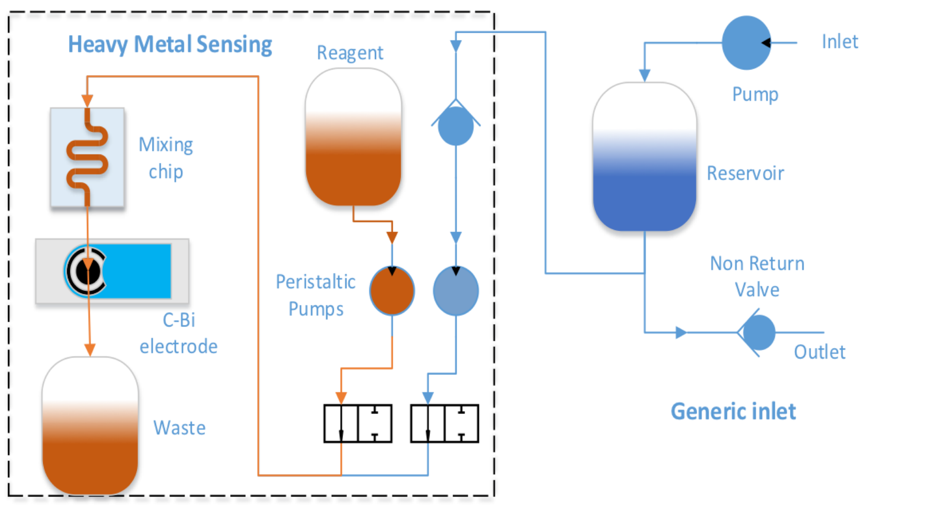


Fig. 4. Fluidic schematic of the heavy metal system

Operator Interface:

- Touchscreen allowing operator to vary flowrate over electrode, purge individual fluid pathways, intake sample and analyse sample.
- LED lights to indicate which operation is currently occurring and which electrical components are operating.

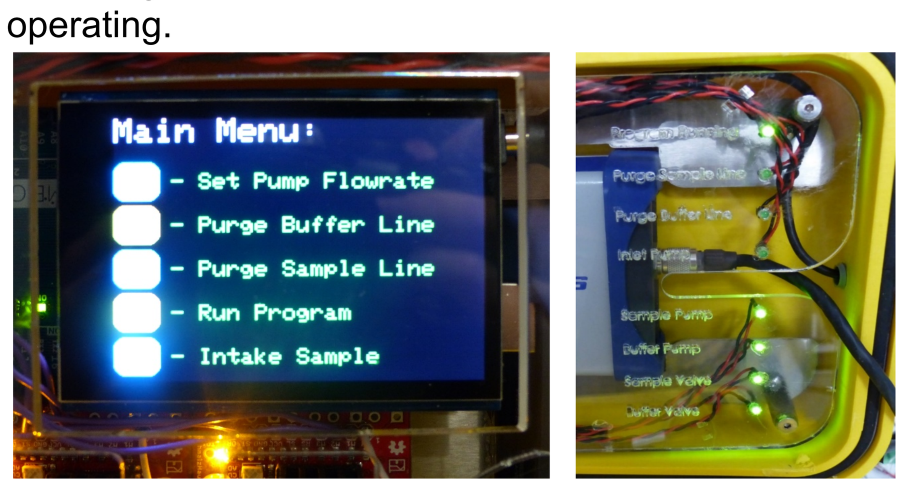


Fig. 5. A) Touchscreen operation selection B) LED component/operation indication

Fluid Handling:

The heavy metal system incorporates a diaphragm inlet pump, highly compliant dialysis bags, two peristaltic pumps, 2/2 solenoid vales, a mixing microfluidic chip and a wall-jet flowcell.

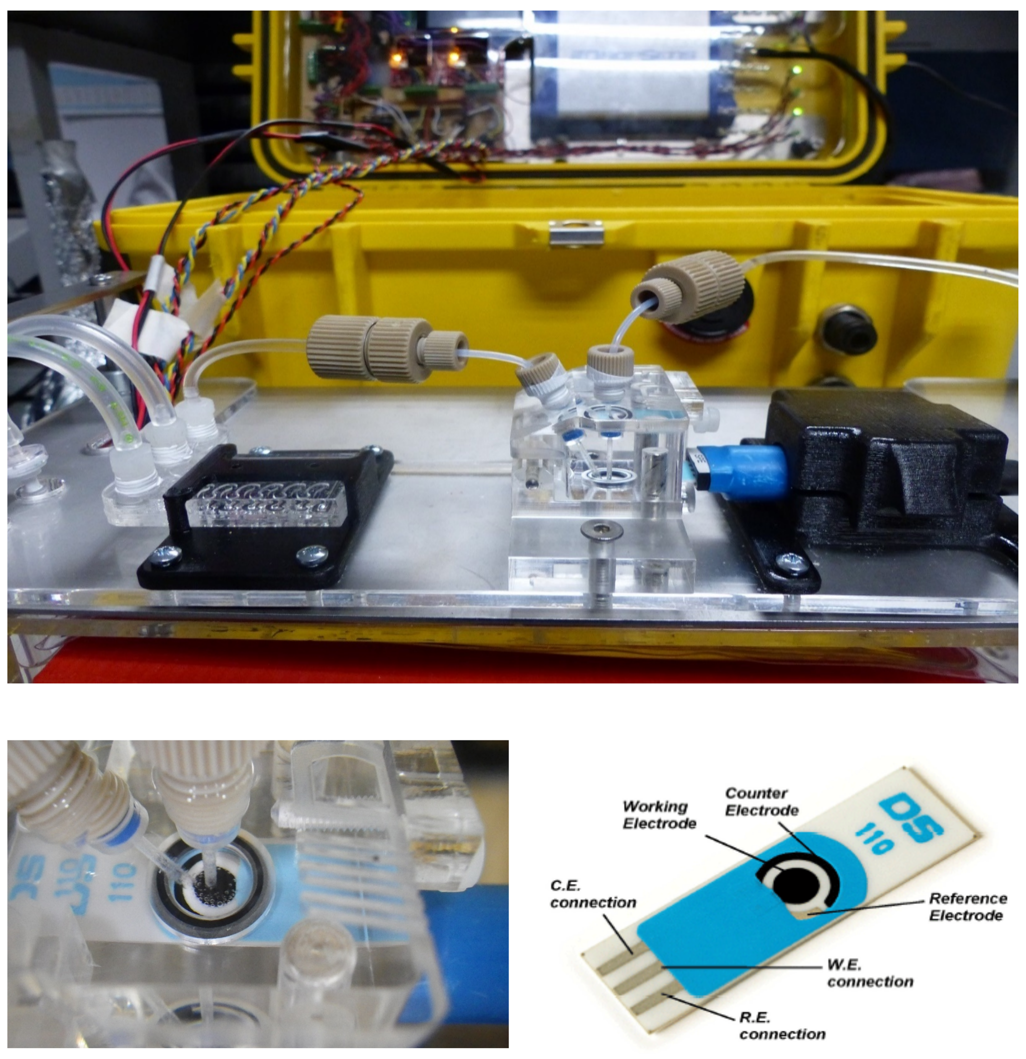


Fig. 6. A) Mixing chip, flow cell, electrode and clasp B) Sample and buffer flowing over electrode C) C-Bismuth electrode

Detection:

- Buffer and sample are delivered to the mixing microfluidic chip by the peristaltic pumps and mixed in a 1:1 ratio.
- The mixture enters the flowcell and passes over the Carbon-Bismuth screen printed electrode.
- The electrochemical data is then received by the potentiostat through the electrode adaptor
- The square wave anodic stripping voltammetric signals were recorded in acetate buffer solutions with different concentrations of Pb(II) and Cd(II) from bottom to top 25, 50, 75, 100 ppb, respectively. Shown in the figure below.

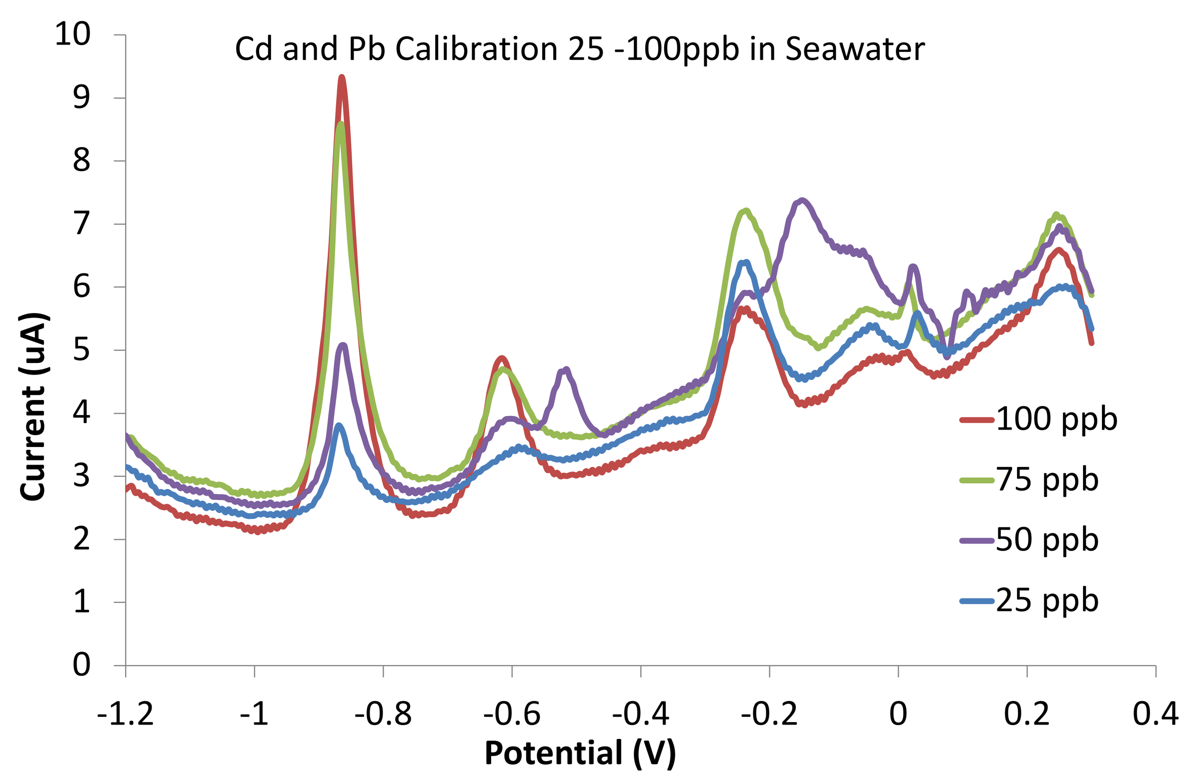


Fig. 7. The square wave anodic stripping voltammetric signals were recorded in acetate buffer solutions with different concentrations of Pb(II) and Cd(II) from bottom to top 25, 50, 75, 100 ppb, respectively

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