

# Polyvinyltriazole-functionalized SWCNT ink for printed Arsenic (III) chemistors for drink water monitoring applications

Leshan USGODARACHCHI<sup>1,2</sup>, Balakumara VIGNESH M<sup>1,3</sup>, Benoit PIRO<sup>2</sup>, Senthilmurugan SUBBIAH<sup>3</sup>, Eric CLOUTET<sup>4</sup>, Bérengère LEBENTAL<sup>1,\*</sup>

*1 Université Gustave Eiffel, COSYS/IMSE, 14-20 boulevard Newton, Champs sur Marne, 77447 Marne-la-Vallée Cedex 2, France*

*2 Université Paris Cité, ITODYS, CNRS, F-75006 Paris, France*

*3 Water and Energy Nexus lab - Department of Chemical Engineering, Indian Institute of Technology, Guwahati*

*4 University of Bordeaux, CNRS, Bordeaux INP, LCPO, UMR 5629, F-33600 Pessac, France*

\* berengere.lebental@univ-eiffel.fr

## ABSTRACT

Arsenic contamination in drinking water, which mainly results from natural sources and human activities, poses a significant health risk globally. Simple field-based detection methods are crucial for monitoring water sources; a transduction method using functionalized single-walled carbon nanotubes (SWCNT) shows promise. Polyvinyltriazole (PVT)-functionalized SWCNT sensors offer better sensitivity (0.77%/ppb) and detection range compared to pristine SWCNT sensors. Further research aims to improve sensitivity and widen the detection range by understanding the interaction between PVT and SWCNTs. Stoichiometry studies suggest a ratio of 1.2:1 PVT:SWCNT for monolayer adsorption, indicating potential for enhanced detection capabilities.

## INTRODUCTION

Arsenic contamination in water sources poses a severe threat to human health globally, as it is a potent carcinogen and toxicant even at low concentrations. The World Health Organization (WHO) has set a provisional guideline value of 10 ppb for arsenic in drinking water and currently, approximately, 230 million people worldwide are affected by arsenic toxicity. Water sources can become contaminated with arsenic through natural processes and human activities, such as natural geological processes, industrial activities, agricultural practices, urban and industrial surface runoff, geothermal activity, and poorly managed waste disposal. Arsenic exists in various environmental forms, primarily as inorganic and organic forms. Organic arsenic is less toxic in natural environments compared to inorganic forms. Inorganic arsenic compounds are further categorized into two main oxidation states: arsenite (As(III)) and arsenate (As(V)). The accurate determination of total arsenic concentration in water demands many techniques are already exist. These techniques encompass a wide range, including atomic-absorption spectrophotometry (AAS), atomic-emission spectroscopy (AES), inductively coupled plasma mass spectrometry (ICP-MS), high-performance liquid chromatography (HPLC), anodic stripping voltammetry (ASV) and differential pulse voltammetry (DPV) [1]. Despite their effectiveness (high selectivity and sensitivity) in laboratories, most existing methods consume significant time for analyses and capital investment for multi-sample analysis, and well-trained people who carry out the analysis and instruments have to carefully monitor and maintain. Consequently, there is a demand for the development of rapid, cost-effective, reliable, and portable As (III) detection sensors that can be used on-site.

Existing sensors for the detection of As (III) primarily rely on electrochemical or optical methods due to their high sensitivity, selectivity, and suitability. These sensors utilize various nanomaterials to enhance performance, including transition metal nanoparticles, nanorods, graphene and carbon nanotubes, metal-organic frameworks (MOFs), gold nanoparticles (Au NPs), quantum dots (QDs), and polymer nanocomposites [2], [3]. Polymer molecules can be synthesized and polymerized by targeting specific analyte probes that are present on the polymer chain, those probes can be referred to as the binding sites in the polymer chain. The selection or modification of existing polymers can be used for Arsenic sensing. Similarly, incorporating polymers into SWCNT matrices enhances the specific binding sites, which may improve the sensitivity and selectivity [4]. The development of a low-cost, user-friendly transduction method for detecting As (III) ions would allow on-site testing and real-time monitoring of water sources. Our transduction strategy is based on functionalized SWCNT chemistors (chemo-resistors). We developed a printable ink composed of SWCNT functionalized by polyvinyl triazole (PVT) and printed it by dispensing printing (DP) on interdigitated electrode arrays made on a flexible strip. For the sake of comparison, pristine SWCNT and PVT-functionalized SWCNT sensors were evaluated. PVT-functionalized SWCNT sensors demonstrated; in tap water, a limit of the detection (LOD) of 5 ppb, a dynamic range from 5 to 50 ppb, and a sensitivity of 0.77 %/ppb. Pristine SWCNT sensors demonstrated the same LOD but a much-reduced sensitivity of 0.33 %/ ppb. Based on these preliminary results, kinetics and isotherms studies were conducted to better understand how PVT-118 and

SWCNTs interact, so to as be able to further lower the LOD, widen the dynamic range and increase the sensitivity. The stoichiometry yielding monolayer adsorption of PVT-118 on the SWCNTs was found to be 1.2:1 PVT:SWCNT.

## METHODOLOGY

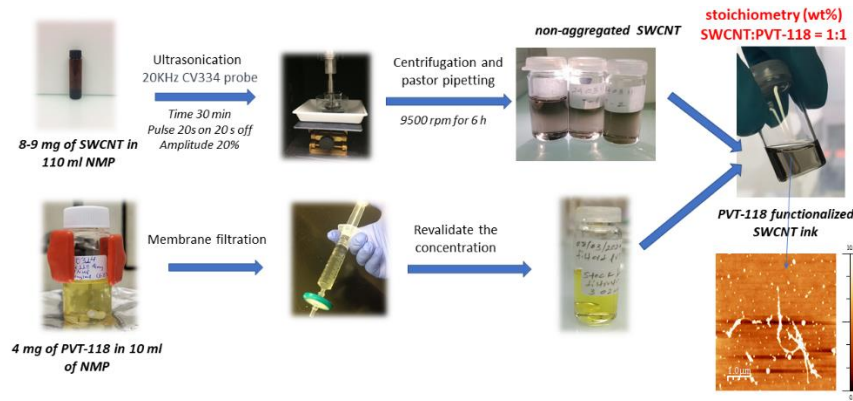


FIGURE 1. Graphical representation of the simplified methodology for the fabrication of composite ink

## RESULTS

The sensors were characterized using a square wave with a duty cycle of 50 and an excitation current of 1.28  $\mu\text{A}$ . The characterization was also carried out in tap water in the presence of the active chlorine ( $\text{ClO}^-$ ) along with the minor impurities of other ions ( $\text{Na}^+$ ,  $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$ , etc.). The PVT functionalized SWCNT chemistor offers a minimum detection limit of 5ppb. As shown in figures (b) and (c), the addition of As (III) increased the resistance of the device and also showed reversibility (return to the initial resistance) with the addition of fresh tap water. The relative response was calculated using Eq 1 and the variation of the relative response as a function of As (III) concentration is shown in Figure 2 (c). The PVT functionalized SWCNT chemistor exhibited a dynamic range of 5 to 50 ppb and a sensitivity of 0.77%/ppb with a linear regression coefficient of 0.98. The SWCNT chemistor acted as a reference sensor to compare the performance improvements due to functionalization and exhibited a dynamic range of 1 to 20 ppb with a sensitivity of 0.33%/ppb and a linear regression coefficient of 0.98.

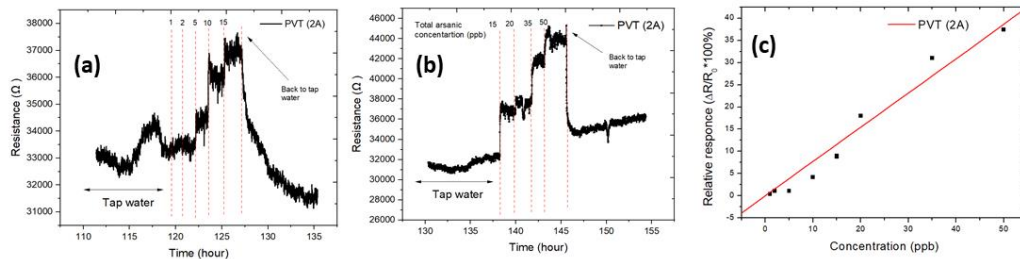


FIGURE 2. Variation of the resistance as the function of time for PVT functionalized SWCNT chemistor with the addition of As (III) from (a) 1 ppb to 15 ppb, (b) 15 ppb to 50 ppb and (c) Variation of the relive response as a function of As (III) ion concentration

$$\frac{\Delta R}{R_B} \% = \frac{(R_m - R_B)}{R_B} * 100\% \quad (1)$$

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