

## Recent progresses in optical detection and discrimination of pollutants in remote ground water and environment: a review

Bernard Dussardier, Charlotte Hurel, Marie Adier, Dominique Vouagner,

Anne-Marie Jurdyc

### ▶ To cite this version:

Bernard Dussardier, Charlotte Hurel, Marie Adier, Dominique Vouagner, Anne-Marie Jurdyc. Recent progresses in optical detection and discrimination of pollutants in remote ground water and environment: a review. International Conference on Fiber Optics and Photonics - PHOTONICS- Delhi-India 2018, Dec 2018, New Delhi, India. hal-02054441

## HAL Id: hal-02054441 https://hal.science/hal-02054441

Submitted on 1 Mar 2019

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers. L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

# Recent progresses in optical detection and discrimination of pollutants in remote ground water and environment: a review.

Bernard Dussardier, <sup>1,\*</sup> Charlotte Hurel,<sup>1</sup> Marie Adier,<sup>2</sup> Dominique Vouagner,<sup>2</sup> and Anne-Marie Jurdyc<sup>2</sup>

<sup>1</sup>Université Côte d'Azur – CNRS – Institut de Physique de Nice UMR7010 – France

<sup>2</sup> Université Lyon 1 – CNRS - Institut Lumière Matière, UMR5306, Villeurbanne, France bernard.dussardier@unice.fr

**Abstract**: Against threats to populations by water pollution, it is critical to remotely, continuously and unambiguously identify and quantify pollutants in surface and ground water. This fast evolving field shall benefit increasingly from optical technologies. We propose a tentative review of the state of art and some promising ideas.

OCIS codes: (060.2370) Fiber optics sensors; (280.0280) Remote sensing and sensors; (240.6695) Surface-enhanced Raman scattering; (010.7340 Water.

### 1. Context:

Pollutants released by industries, mines, intensive farming, heavy irrigation by groundwater threaten ecosystems and human health. Ground- and surface-water are carriers of naturally- and anthropogenically-sourced toxic elements. Intensive farming use ground-water as a primary source of irrigation at an increasing rate, causing overconcentration of pollutants in crops. Pesticides enter soils and filter down to water tables. Industry and mining are also important causes of pollution.

Even higher concern relates to drinking water. It was estimated that in 2015, 29% of the global population (2.1 billion people) lacked "safely managed drinking water"— meaning water at home, available, and safe [1]. Types of pollutants in water are many, to name a few: polychlorinated bi-phenyls (PCBs)[2], heavy metals and metalloids in various species (i.e. chemical compounds or forms) [3].

One of the iconic toxic elements is inorganic arsenic, even at trace level, and its most current ionic species, arsenate and arsenite. It is considered to be a major water pollutant due to its toxicity, being mainly responsible for human cancer, DNA hypomethylation, arsenicosis [4], and is associated to cardiovascular disease and diabetes, as well as to negative impacts on cognitive development and increased deaths in young adults.

Arsenic is naturally present at high levels in the groundwater of a number of countries worldwide [4,5,6]. The most important action in affected communities is preventing further exposure to pollutants. It is crucial for health security to carefully monitor the seasonal and/or accidental variations in pollutants concentration in surface water (rivers, lakes) as well as in ground water (water tables, seashores areas, water catchments, springs). The World Health Organization (WHO) recommendation for inorganic total metal arsenic in drinking water is less than 10  $\mu$ g/litre (~0.13  $\mu$ M). Available on-field testing kits based on chemical analysis lack of reliability, sensitivity and precision. Many other strong toxins merit attention. All those harmful at trace level (<< 1 ppm) require established laboratory methods, like mass-spectroscopy. They are costly, time intensive and laboratory bound [7].

In order to increase effectiveness and reduce costs of surveying programs, a great improvement would be the development of systems able to detect, speciate and quantify trace level pollutants. Ideally, surveys shall be remote and continuous, as opposed to scheduled sampling, to allow for fulltime survey and potential forewarning towards authorities and populations. To this aim, new technologies must be developed to access difficult locations (deep wells, water tables) to simultaneously probe at several depths, for example. Also, industrial pollution over extended zones (rivers, estuaries, lakes) shall be tracked, ideally with automatic networked sensing systems, where the sensing heads are sturdy, easily laid out with minimal footprint and environmental impact. Low cost and low energy consumption are also important choice parameters.

### 2. What can optical technologies offer to remotely detect trace level pollutants in water?

Optical technologies shall contribute to offer interesting alternatives to timed sampling and time-delayed chemical analysis of trace pollutant in ground- and surface-water. Sensing heads based on optical fiber and physical chemistry technologies shall be advantageous for small footprint, low cost and low environmental disturbance and impact. Distant interrogation of the sensing heads shall also be provided by guided wave optics and optoelectronics.

Several useful principles for sensing include absorption and vibrational spectroscopy, plasmonics and enhanced phenomena [8], surface plasmon resonances, surface enhanced Raman spectroscopy (SERS) [9], engineered

chemical interactions between pollutants and nanostructured substrates [10], colorimetry [11], etc. A great deal of literature reports on applications toward pollutants detection [12,13], including microfluidics [14,15].

On optical fibre sensing heads in particular, a rich literature reports on a variety of configurations and characteristics : fibre type and configuration [16,17], fibre coating [18,19], addition of gratings implementing surface plasmons [20,21,22,23]. Interesting applications in other fields than pollutant detection is also inspiring, in life sciences [24,25,26], food industry [27].

In this talk we will discuss some recent advances that would allow for the improvement of sensing heads, and for their remote interrogation.

### 3. References

- [1] World Health Organization (http://www.who.int/water\_sanitation\_health/monitoring/coverage/monitoring-dwater/en/)
- [2] Ross G. "The public health implications of polychlorinated biphenyls (pcbs) in the environment". *Ecotoxicology and Environmental Safety* **59**(3) 275–291 (2004).
- [3] S. A. Baig, et al., "Arsenic Removal from Natural Water Using Low Cost Granulated Adsorbents: A Review," *CLEAN Soil, Air, Water* 43, 13-26 (2015).
- [4] K. Jomova, et al., "Arsenic: toxicity, oxidative stress and human disease," J. Appl. Toxicol. 31, 95-107 (2011).
- [5] World Health Organization : "Arsenic" (http://www.who.int/news-room/fact-sheets/detail/arsenic)
- [6] A. Barats, et al., "Naturally dissolved arsenic concentrations in the Alpine/Mediterranean Var River watershed (France)," Sci. Total Environ. 473–474, 422-436 (2014).
- [7] M. Singh and M. del Valle, "Arsenic Biosensors: Challenges and Opportunities for High-Throughput Detection", in *Handbook of Arsenic Toxicology*, S.J.S. Flora, ed.(Elsevier, 2015), Chap 25.
- [8] P. Strobbia, et al., "Recent advances in plasmonic nanostructures for sensing: a review," Opt. Eng. 54, 100902 (2015).
- H. Lai, et al., "A review of the preparation and application of magnetic nanoparticles for surface-enhanced Raman scattering," J. Mat. Sci. 53, 8677–8698 (2018).
- [10] E. Priyadarshini and N. Pradhan, "Gold nanoparticles as efficient sensors in colorimetric detection of toxic metal ions: A review," Sens. Actu. B: Chem. 238, 888–902 (2017).
- [11] G.-H. Chen, et al., "Detection of Mercury(II) Ions Using Colorimetric Gold Nanoparticles on Paper-Based Analytical Devices," Anal. Chem. 86, 6843–6849 (2014).
- [12] D.-W. Li et al.,"Recent progress in surface enhanced Raman spectroscopy for the detection of environmental pollutants," *Microchi. Acta* 181, 23–43 (2014)
- [13] J. Hao, et al., "SERS detection of arsenic in water: A review", J. Environ. Sci. 36, 152-162 (2015)
- [14] H. Pu, et al., "SERS-microfluidic systems: A potential platform for rapid analysis of food contaminants," *Trends Food Sci. Technol.* **70**, 114–126 (2017).
- [15] Q. Zhou and T. Kim, "Review of microfluidic approaches for surface-enhanced Raman scattering," Sens. Actu. B: Chem. 227, 504–514 (2016).
- [16] I. Latka, et al., "Fiber optic probes for linear and nonlinear Raman applications Current trends and future development," Las. Photon.Rev. 7, 698–731 (2013)
- [17] L. Mescia and F. Prudenzano, "Advances on Optical Fiber Sensors (review)," Fibers 2, 1-23 (2014)
- [18] C. Elosua, et al., "Micro and Nanostructured Materials for the Development of Optical Fibre Sensors," Sensors 17, 2312 (2017).
- [19] M. Hernaez, et al., "Optical Fibre Sensors Using Graphene-Based Materials: A Review," Sensors 17, 155 (2017).
- [20] C; Silva et al., "Fibre Sensing System Based on Long-Period Gratings for Monitoring Aqueous Environments," in *Fiber Optic Sensors*, M. Yasin, Sulaiman W. Harun, and Hamzah Arof, eds. (InTech, 2012). Chap 13.
- [21] J. Albert et al., "Tilted fiber Bragg grating sensors," Las. Photon. Rev. 7, 83–108 (2013).
- [22] B. Gupta, et al., "Surface Plasmon Resonance-Based Fiber Optic Sensors Utilizing Molecular Imprinting," Sensors 16, 1381 (2016).
- [23] C. Wang, et al., "Review of optical fibre probes for enhanced Raman sensing," J. Raman Spectr. 48, 1040–1055 (2017).
- [24] D. W. Shipp, et al., "Raman spectroscopy: techniques and applications in the life sciences," Adv. Opt. Photon. 9, 315 (2017).

- [25] X. Wang and O. S. Wolfbeis, "Fiber-Optic Chemical Sensors and Biosensors (2013–2015)," Anal. Chem. 88, 203-227 (2016).
- [26] F. Chiavaioli, et al., "Biosensing with optical fiber gratings," Nanophotonics 6, 663–679 (2017).
- [27] S. Kumar, et al., "Flexible and robust SERS active substrates for conformal rapid detection of pesticide residues from fruits," *Sens. Actua.B: Chem.* 241, 577–583 (2017).