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

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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.
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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 µg/litre (~0.13 µM). 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.

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