UNCONVENTIONAL WATER MONITORING AND EARLY WARNING SYSTEM

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ABSTRACT: The paper presents an unconventional system for the monitoring of water quality. The system is unconventional, as it comprises light emitting diodes for the detection of fluorescent compounds of dissolved organic matter. The system can be operational through a microcontroller incorporated within, and can perform on-line measurements, without human assistance for several hours. Also, through internet connection, the proposed system can deliver early warning messages to a remote host, in case of accidental microbial contaminations, based on the calculated fluorescence ratios of dissolved organic matter components.
KEY WORDS: water monitoring, early warning, dissolved organic matter

1. INTRODUCTION

Water quality monitoring can be a tedious task, especially in urban and rural area affected by uncontrolled discharges domestic wastes. At the moment, surface water bodies are monitored by sampling water and taking it to specialized laboratories, for measurement of specific water quality parameters. However, some of the most persistent measurements, with respect to the quality of the surface water systems, such as the biochemical oxygen demand, or the dissolved organic carbon, are long-time, expensive measurements. In the attempt to offer an alternative to these standard measurements, several studies have confirmed that they correlate very well with spectroscopic measurements, such as steady-state fluorescence, which is a much rapid, cost-effective method, does not require laborious pre-treatments of the investigated water samples and correlates very well with standard parameters [1,2].

The aim of this paper is to present an unconventional system for the real-time monitoring of natural water bodies, offering high quality data at low operational and maintenance costs.

2. SPECTROSCOPIC ANALYSIS OF AQUATIC DISSOLVED ORGANIC MATTER

Having in mind the need to simplify water quality analysis, many researches have addressed the problem of developing new methods and systems for the monitoring of water quality, through various methods, basically based on the use of electromagnetic radiation [2-9]. Most studies imply using fluorescence spectroscopy to identify the endogenous fluorophores found in water systems. The main chromophoric constituents in water samples are the protein-like and the humic-like fractions of the ubiquitous aquatic dissolved organic matter. The protein-like fraction is represented principally by tryptophan, and is representative fir highly microbially contaminated waters [3]. Humic-like matter found in water samples mostly consists of humic acid, derived from plant decay or from geological activities [4]. Freshly produced organic matter can also be an indicator of the anthropogenic influence on water systems, reflecting the evolution of the dissolved organic matter. Each of these components has specific excitation wavelengths and emission domains, making them useful in the fluorescence analysis of natural water systems.

Early researches have proposed using a single wavelength for the excitation of the samples [5]. However, contaminated waters represent a highly complex mixture, which cannot be generally characterized by using a single excitation wavelength, which can only provide limited information regarding the fluorophores in the sample. Additionally, the method proposed by Alfano, implies lower operational costs, but there is a need for a data base containing many standards.

Powers and Lloyd [6] have proposed a method for evaluating the quality of natural aquatic media, based on the detection of microbes in liquids, air and surfaces. Their method uses different wavelengths of electromagnetic radiation to detect specific microbes. The contamination of natural water bodies often implies not just some specific microbes, but an overwhelming mixture of microbes and pollutant products.

Other researchers have tried to use fluorescence markers [7], which can offer a wider range of detectable pollutants, but can increase the operational costs and duration.

Hoang [8] presented an apparatus for the measurement of active fluorescence in liquid samples, using solid state components. The method refers only to the detection of photosynthetic material and can offer erroneous information, due to light entering from the saturation LEDs used or from the room.

Recently, Chekalyuk [9] proposed an advanced laser fluorometer for the spectral and temporal laser fluorescence analysis of natural aquatic environments. However, the use of lasers implies higher acquisition costs, as different wavelength lasers would be needed in order to excite more fluorescent components from the analyzed samples.

The first attempt of continuous water monitoring was performed by Carstea et al. [10]. The researchers improvised a setup based on a bench-top fluorimeter in a van. They successfully managed to perform a two-weeks continuous monitoring, but their system cannot be transformed into an *in situ* monitoring equipment, due to the large dimensions of the setup.

3. PROPOSED EQUIPMENT

For the purpose of real-time monitoring of surface water quality and early warning in the event of a microbial contamination, we have envisaged an unconventional setup, using three light emitting diodes (LEDs) of different wavelengths, a detector, a pump, a portable computer and a microcontroller, as illustrated in figure 1. The wavelengths of three LEDs, generically denoted by LED1, LED2 and LED3, were chosen so as to excite the major fluorescent fractions of the dissolved organic matter fraction, ubiquitous in all water systems, which are related to the quality of surface water bodies. LED1 is 250 nm emitting diode, used for the excitation of humic acid, LED2 has central wavelength of 280 nm, so as to excite the tryptophan residues in the samples, and LED3 is a 330 nm diode, for the detection of recently produced organic matter.

The three LEDs are connected to a microcontroller, which automatically triggers, consecutively, at predefined time intervals, the three light sources.

The light from the LEDs is guided through a three-way input optical fiber towards the sample to be analyzed. The sampling geometry involves a 90° angle between the excitation and the emission paths. In order to eliminate the exciting radiation from the collected signal, an optical cut-off filter is placed before the fiber optic enters the detector. The spectra are then processed using a portable computer.

The sample is placed in a cuvette, inside a closed, black housing, which eliminates the errors associated with stray light.

Water is pumped into the cuvette using an automated peristaltic pump, which fills and voids the cuvette through two hoses, when receiving the triggering signal from the microcontroller.

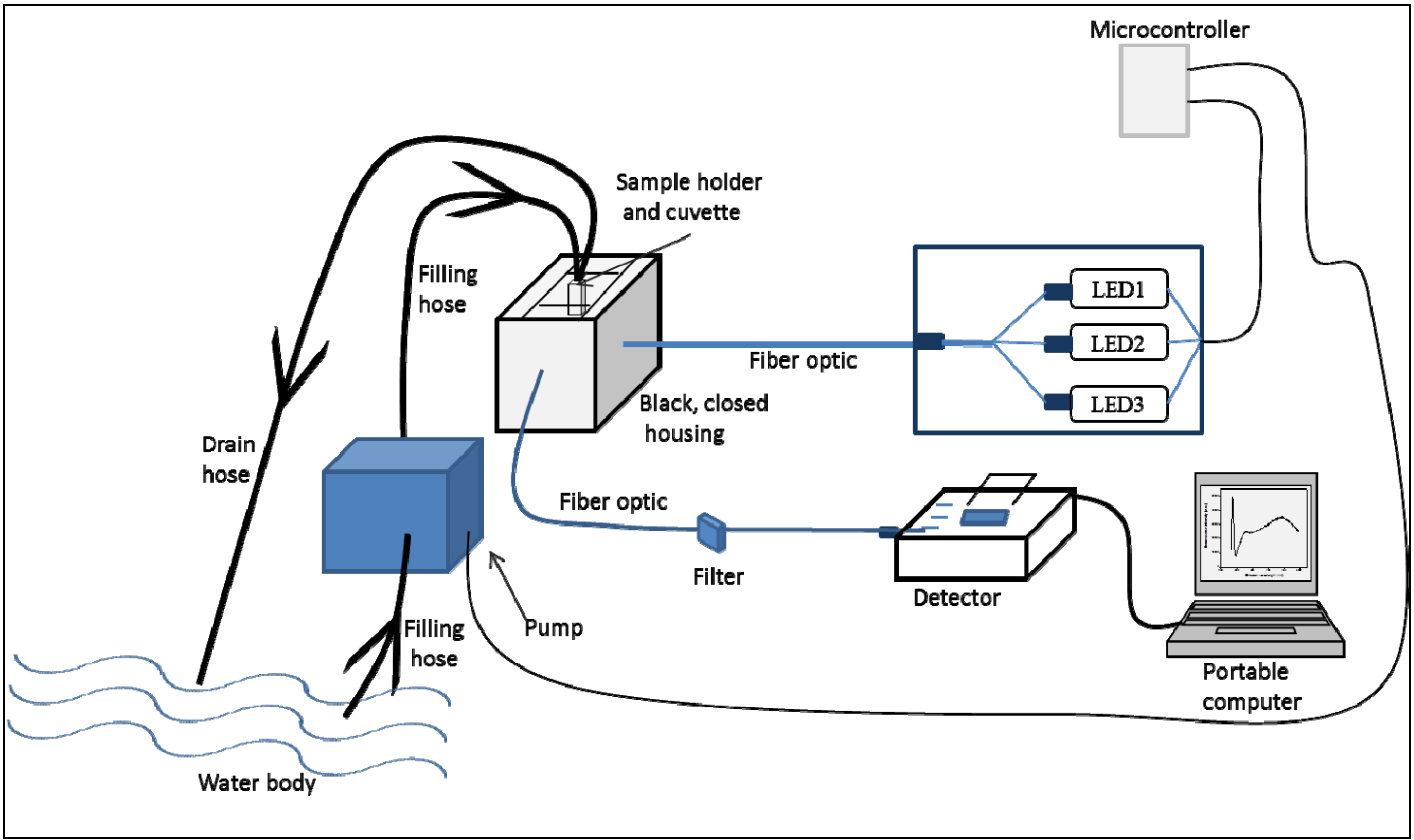

Figure 1. Experimental setup of the equipment for monitoring the quality of natural aquatic systems [11]

One end of the filling hose is placed into the water body and the other is connected, through the pump, to the cuvette inside the closed housing. After measurements, water is guided abut of the cuvette, trough the drain hose, into the water body. Figure 2 illustrates the conceptual method for monitoring water quality using the above described system.

The operational method has several steps:

- The microcontroller triggers the peristaltic pump, so as to fill the cuvette with water;
- The microcontroller triggers LED1, with central wavelength of 250 nm;
- the emission spectra is recorded;
- LED1 is turned off;
- From the acquired emission spectra, the area of a predefined interval is calculated. The selected interval corresponds to the emission maximum given by the humic acid. The calculated value is designated by Area1;
- LED2, of 280 nm, is turned on;
- The emission spectra is acquired;
- The microcontroller send the signal to turn off LED2;
- The area of a predefined interval, corresponding to the emission of tryptophan, is calculated. The value is denoted by Area2;
- LED3, with central wavelength of 330 nm, is turned on;
- The emission spectra is registered;
- LED3 is turned off;
- Area3 is calculated, from a predefined wavelength interval, corresponding to maximum emission generated by the recently produced organic matter;
- The ratios Area2/Area1 and Area3/Area1 are calculated; the ratio between tryptophan and humic matter fluorescence emission, Area2/Area1, is useful in identifying microbial contamination, whereas the ratio Area3/Area1, can signal the increase of the humic-like dissolved organic matter concentration, through the input of freshly produced organic matter.
- If any of the two values is higher than 1, a warning message is displayed on the portable computer.
- If both ratios are below 1, then the next step is to void the cuvette;
- The system waits for a predefined time interval, and then starts the cycle over again, for the measurement of a new water sample.

Such equipment has the advantage of offering several hours of functioning autonomy. Thus, it can be left for hours to perform continuous, on-line measurements and can be cleaned at the end of each day.

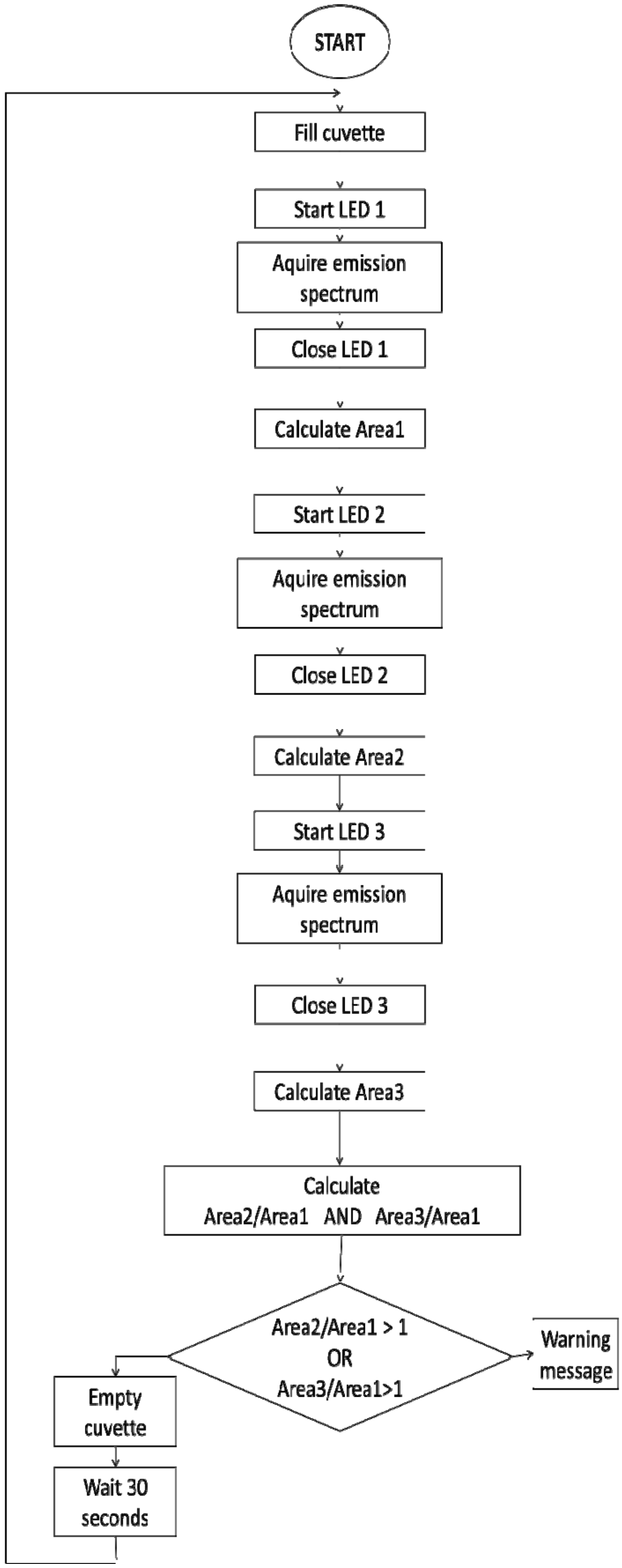

Figure 2. Schematic diagram of the process steps [11]

The setup needs a power source and can be inserted into a protection housing and placed on the shore of the investigated water flow.

An internet connection can be useful for the transmission of the warning messages to a remote host, in the case of microbial contamination of the water system or even in the case of potential system errors, which need human intervention, such as software malfunction or clogging of the filters or hoses.

Optionally, the electronic control system can be programmed to perform time measurements, by triggering several times the same LED, when there is a need to investigate the time evolution of just one of the main fluorescent fractions of dissolved organic matter.

4. CONCLUSIONS

The paper presented an innovative equipment for the monitoring of surface water bodies. The system is based on the unconventional use of three light emitting diodes, to excite the major fluorescent fractions of the aquatic dissolved organic matter, linked to water quality. The use of LEDs reduces the manufacturing cost and still covers a wide range of the water quality parameters. The system is able to deliver warning messages in case of contamination, revealed by the calculated fluorescence ratios. It can offer several hours of operational autonomy, thus eliminating the need for constant human supervision. It can be designed to continuously monitor the water quality parameters, but can also be programmed to perform time measurements. A wireless internet connection can be used, which makes it a useful tool for the remote monitoring of water bodies.

5. ACKNOWLEDGEMENTS

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