System for Pollutant Monitoring in Hydric Pathways Associated to Estuarine Areas

Fabrício Ramos da Fonseca, João Pedro Lago, Cledson Akio Sakurai and Caio Fernando Fontana

***Abstract*—** The issues related to the environment in Brazil have been, in the past decades, treated with increasing relevance and narrowing necessaries to the inexorable importance required by the subject. Thus, the development of systems that glimpse the improvement of the efficiency in detection of pollution of the hydric pathways become a priority, given they make possible that the necessary interventions for the ending of pollutant agents' actions take place immediately, lessening the impact cause to the environment. Research in aquatic environments such as estuaries, rivers, and coastal bays presents several challenges to the scientist [1]. This article concerns a study regarding the development of a system for the monitoring of hydric pathways associated to Baixada Santista's estuary region, a region to the south of São Paulo that, in the past decades, has suffered increasing degradation of its aquatic environments. It's expected, with this study, to provide subsidies for the implantation of measurement and analyses' systems of hydric variables in similar contexts.

***Keywords*—** Hydric resources, pollutants' detection, water quality analyses, environmental monitoring, water pollution control, automation.

I. Introduction

THE issues related to the environment in Brazil have been, in the past decades, treated with increasing relevance and narrowing necessaries to the inexorable importance required by the subject. This issues, however, are confronted with an unfortunately inherent characteristic of the country that difficults the actual scenario's quicker reversal: the ineffectual application of environmental legislation [2].

In this context, the automation of the procedures for collection and management of data about the use of hydric resources any materially contribute to its better used, as it permits its follow-up and control [3]. Moreover, the development of systems that glimpse the improvement of the efficiency in detection of pollution of the hydric pathways become a priority, given they make possible that the necessary interventions for the ending of pollutant agents' actions take place immediately, lessening the impact cause to the environment.

Therefore, researches that may aid the adoption of measures in this sense are already part of majorly important activities of sanitation companies, in Brazil and throughout the world.

This article concerns a study regarding the development of a system for the monitoring of hydric pathways associated to Baixada Santista's estuary region, a region to the south of São Paulo that, in the past decades, has suffered increasing degradation of its aquatic environments.

This degradation has a direct correlation with peculiarities regarding the aforementioned region, in which are inserted various vulnerable ecosystems that coexist with intense industrial and port's activities.

The second biggest port in America Latina is located in Santos, and it's responsible, for circulating over 45% of the national GDP [4] (**Fig. 1**). This activities, while contributing to the economic development of this region and of the country, result in intense disturbance of the aforementioned ecosystems, for reason of the associated pollutant potential.

Fig. 1 A view of Santos' bay's entrance and the port's channel (by: Google Maps)

The region in question presents, still, conurbation with the counties of Praia Grande, Guarujá, São Vicente and Cubatão, by the hydric pathways that cut through these cities. These counties are characterized, in Cubatão's case, by intense industrial activity and, regarding the other cities, by evident deficit of housing that possess appropriate sanitation.

Considering the great territorial extension encompassed by the hydric pathways that cross the Baixada Santista, and that require pollutant monitoring, proprieties such as remote supervision, autonomy, and low maintenance demands of dispositives that compose a system conceived for this end become vital, once they enable managing with minimal necessity of human intervention e reduced sustaining costs.

In this context, it's here presented the results of studies that aim the continuous monitoring of hydric pathways, intending that this system complements the laboratorial chemical analyses' procedures used nowadays for detection of pollutant loads related anomalies presents in these pathways.

II. Monitoring Of Hydric Resources' Quality

The quality and quantity of water available for economic development is a matter of concern among politicians, environmental agencies, and the general public because water has a strategic value for the economic and social development of nations, as it can support biodiversity, and human health. During the last decade there has been an increase in the number of Earth observation systems with new sensors' systems. They are designed to collect data and report to a central unit, connected to the Internet or monitored [5].

Traditionally, environmental analyzes are conducted through sampling followed by laboratory analysis. Recent technological advances (such as 3G networks made possible that the Internet turns into the widest network used for data communication [6]) enable fully automation and integration with a flow-based delivery systems and wireless communication technology [7] (**Fig. 2**).

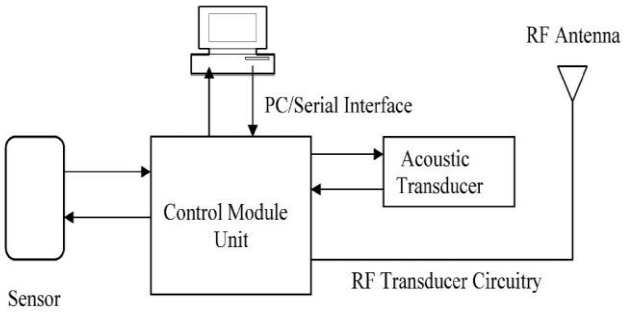

Fig. 2 Aqueous sensor setup incorporating an rf transceiver and acoustic tranducer [7].

Many are the reasons for the deficiencies found in urban sanitation. Many of these, however, are converging on a common reason: a lack of planning in the implementation and expansion of sewage and therefore a deficit in monitoring incorrect evictions in watershed areas and coastlines, an issue which, unfortunately, is recurrent and independent of the size of the treatment and disposal systems, they are applied to small, medium or large municipalities.

In this context, there is an urgent need to implement systems that will reduce the rate of water pollution which, in Brazil, affects more than 26% of municipalities with funding surface water. Moreover, in 14.24% of them were found contaminations by dumping of domestic sewage and industrial waste by 16.22% [8].

III. Methodology

The development of this work was oriented towards describing an automatized system for the monitoring of the hydric pathways of Baixada Santista's estuary regions, may they be natural, such as rivers and streams, or artificial, such as rainwater collection channels (Fig. 3), besides the Santo's bay itself.

It is understood, as previously stated, that this monitoring shall complement the laboratorial chemical analyses' procedures conducted by Balneability Control Center of Santos' Prefecture and Company of Environmental Sanitation Technology (CETESB), that occurs in a punctual manner, thrice a week, through samples collected in seven locations of the Santo's shoreline, one of the ways to get faster results is the use of handheld probes while sampling is performed (Fig. 4).

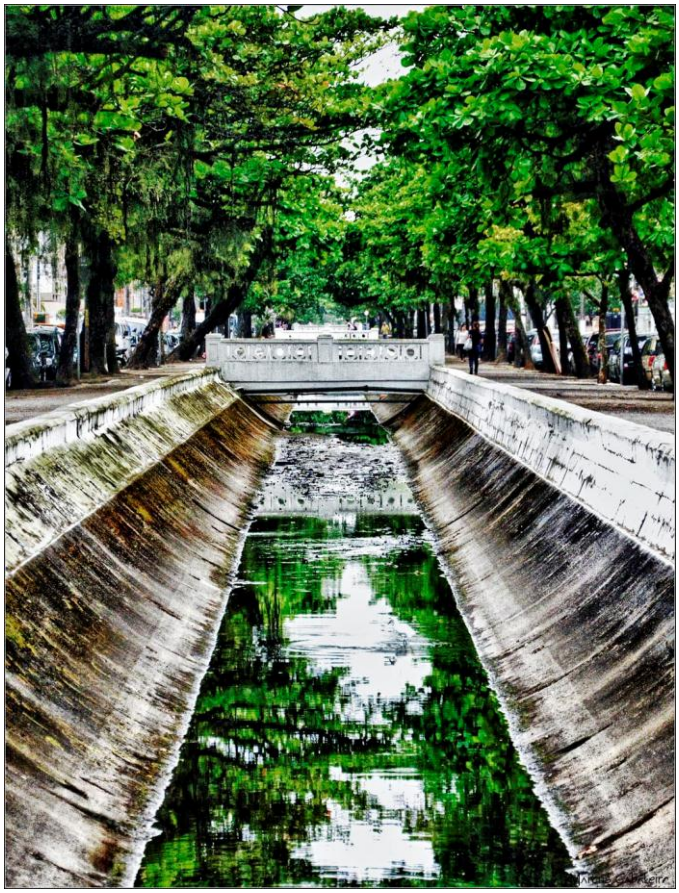

Fig. 3 Rainwater channel [9]

The immediate detection of pollutants in these pathways possibilities the pollutant agent's tracking and the immediate intervention for its ending, preserving the spring's and rainwater channel's water quality, as well as the balneability's index of the littoral coasts they flow into.

Some mechanisms for the contention of pollutants, in case their immediate detection is enabled, are already available in some hydric pathways that interact with Santos' estuary. Out of the seven rainwater collector channels that cut through the city, six contain automatized flood-gates that may be put in action, from their complete openness position to their complete shutting, in a period of twelve minutes tops.

This flood-gates remain usually closed, and the contents of the aforementioned channels are continuously directed towards a Preconditioning Sewage Station (PSS) to be, subsequently, released five kilometers off-shore through an emissary submarine [10]. However, in periods of greater rain levels, the EPC hasn't the capacity of bombarding enough to compensate for the rise in hydric water volumes present in all rainwater collection channels, in such a manner that, under this circumstances, it's necessary for all flood-gates to be open, causing the release, in the sea, of rainwater contained in the

channels alongside an eventual pollutant load present in these waters caused by some irregular dumping.

A system of continuous pollutant detection, such as proposed in here, would propitiate, amongst other possibilities, the perception of which channels present some pollutant load that could compromise estuary water quality, enabling, thus, the decision of closing only these channels flood-gates, in such a way as to increase the competency of PSS's bombs usage.

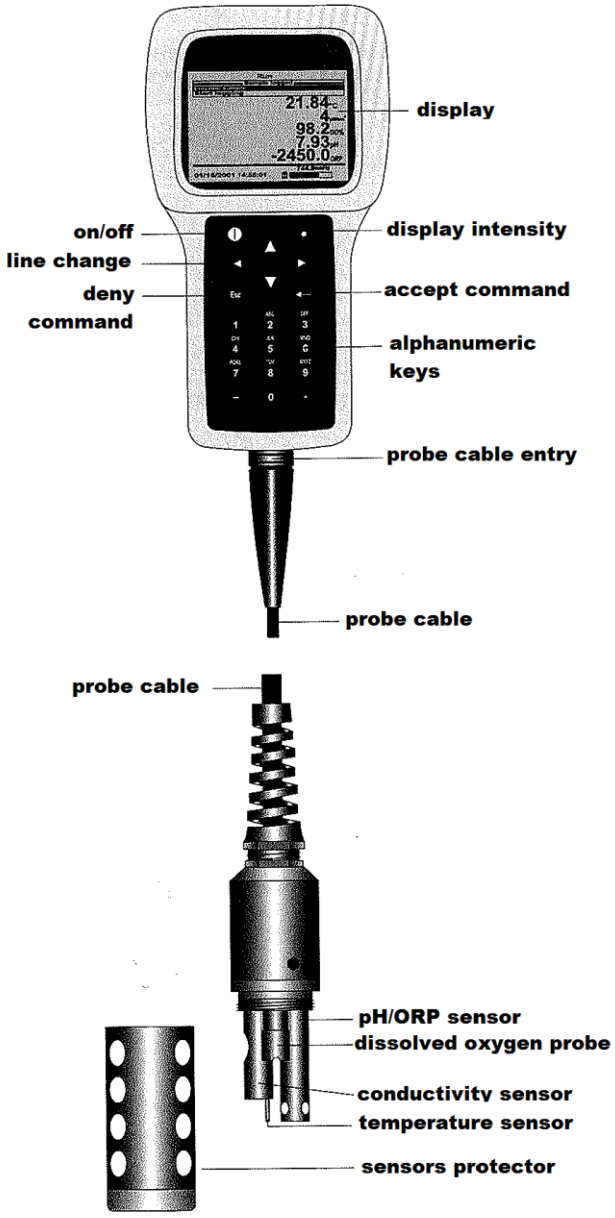

Fig. 4 YSI handheld probe model 556 (Adapted from Yellow Spring Instruments Manual).

For this referred monitoring, two crucial points of the automation system were studied, looking for optimal solutions for its implantation: the subsystems responsible for continuously measuring and analyzing of the hydric pathways and the resultant data transmission subsystem of this analysis. This article refers to the first subsystem mentioned.

A. Criteria for measuring and analyses subsystem specification

Automation systems for water monitoring are, basically, used to collect, concentrate and analyze the process information using data technology. Based on these results, autonomous systems may be used so that containment measures are taken, in case the monitored variables present divergence in relation to pre-defined standards. These measures can, for example, constitute the generation of warnings or the automatic acting in one or more final control elements.

The analyses subsystem is responsible for the obtaining of water samples to be analyzed, conditioning of this sample, the analyses itself and availability of an instrumentation standard sign sent towards a monitoring center, or a data logger registry. The range of substances that are potential pollutants of hydric pathways that flow into the estuary of Santos region is very extensive, in such a way that the implementation of a system whose function is monitoring the entire range of substances is impossible. Also, not all substances may be detected through usage of continuous analyzers.

Another aspect considered for the specification of this subsystem was its cost. Certain analyzers have high cost and, considering the system predicts the implementation of remote analyses stations in various locations distributed along the hydric pathways to be monitored, the necessary investment, in case these of use of this equipment, would be prohibitive.

Therefore, some of the criteria that guided the definition of monitoring parameters and of equipment to compose the measuring and analyses subsystem were as follows:

- Which are the potential contaminants of the region's hydric pathways?
- Amongst these pollutants, which ones may be directly detected, or have their presence inferred through substances detected by continuous analyzers?
- Which if the identified analyzers enables the detection or the presence's inference of the biggest range of pollutant substances or of physical and chemical water inconsistencies that may characterize the presence of this substances?

It was also considered the costs involved in the analyses' system installation in the conditions presented by the hydric pathways, taking in account the fluid's conditioning system to be analyzed and the electrode's and transducer's service life.

These assumptions conduced to the selection of the following parameters for analyses or measuring, once it is understood they enable the detection of the greatest of number possible of contaminants without making the project unviable because of its cost of acquisition, installation and maintenance.
Chemical parameters:

- *Hydronium ions potencial (pH);*

- *Dissolved oxygen;*
- *Ammonium;*
- *Nitrate;*
- *Chlorite.*

Physical parameters:

- *Conductivity*
- *Depth* (channel's water level)
- *Temperature*

Biological parameters:

- *Dissolved Organic Matter*

Calculated parameters:

- *Salinity*: calculated by the conductivity and temperature
- *Total Dissolved Solids*: calculated by the conductivity and temperature
- *Oxygen demand (chemical and biochemical)*: calculated by the Dissolved oxygen and Dissolved Organic Matter

Based on these selected parameters, researches regarding continuous analyzers with potential to be installed in hydric pathways available on the market have been conducted. This researches resulted in the selection of multisensory equipment, integrated to a computer interface based on bluetooth wireless technology, RS-485, and USB output options with signal output adapter (SOA); RS-232 & SDI-12 with DCP-SOA.

This kind of equipment, commonly named Conductivity, Temperature, Depth measure device (CTD – Fig. 5) works in a depth rating between 0 to 250m, its battery life is about 90 days long, has a data memory of 512 MB total, which means more than 1,000,000 logged readings, and also operates in temperatures from -5° to 50°C without compromising its sensors. It is a common tool used in oceanography to obtain vertical profiles of water.

The multisensor equipment proposed for this project is in harsh conditions, a practical alternative to the traditionals CTDs. The functioning of the CTD is based on the electrical measurements principle, aimed primarily at measuring physical parameters [11]. It's proposed, therefore, the incorporation of multisensor probes in order to add, in this equipment, resources for measurement of selected chemical and biological variables.

Electrical sensors allow remote deployment with a near-real time monitoring capacity. The consequence of these developments is a way to represent a manner of knowing the water conditions in real time, and, based on that, have the ability to detect any changes due to pollution or human impacts almost automatically.

For a simple example, using the voltammetry or conductivity sensor's reading to infer a possible metal contamination and determination of trace metals [12]. If the readings have a significant increase we could say that a metal contamination is running on, or if readings have a significant drop, it could mean that alkaline chemicals were dumped in water.

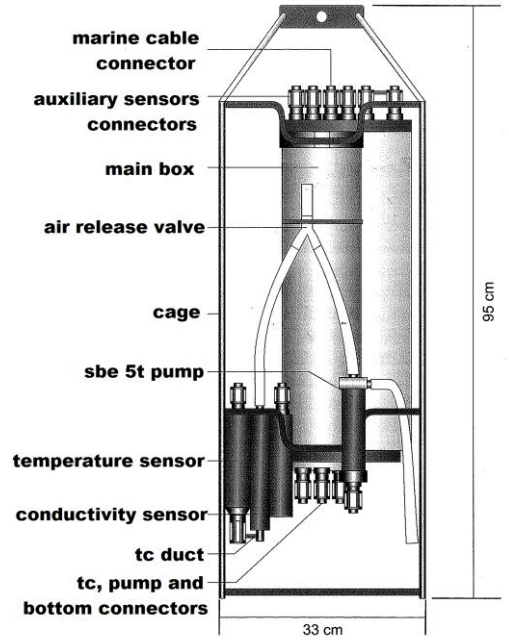

Fig. 5 CTD SBE 9 plus (adapted from Sea-Bird's Electronics Inc. catalog).

It's known that suspended particulate matter can be a harmful pollutant in freshwater environments [13]. Through monitoring sensors, we can detect dissolved solids or solids in suspension, and track the status of particles per cubic meter of water, and, if necessary, initiate preventive or remedial measures to its increase.

Moreover the suspended particulate matter influences the turbidity of the water, which impacts on photosynthesis, leading to a decrease in primary productivity at these sites, which in turn impacts all subsequent trophic levels

IV. Conclusion

The importance of divulgating solutions and technical knowledge related to hydric resources monitoring relates, as well, to the constant and increasing evolution of the natural applicability of techniques involved in systems of this nature and to the diversity of possible configurations, technologies and architectures for its implementation.

In this context, it's important to search for mechanisms that enable the development of researches for this area, in such a way that the developed solutions and the implemented techniques can be divulgated and released, constituting a set of technologies that, if correctly utilized, imply greater efficiency in hydric pollution monitoring.

The evolution of such technologies is becoming increasingly faster, and the arrival of new techniques and equipment enables more and more options for the integration of large systems and for the reduced proportion, as those present in small cities.

Technologies that are already a reality in hydric variables analyses and measuring, such as multivariable probes e

biological sensors, have their applicability scarcely explored, and may constitute the motivation of new researches regarding their usage in monitoring the quality of hydric resources monitorin in urban environments.

Besides the technologies in themselves, the development of deepen methodologies that contemplate the planning of their integration with pre-existent systems, guided in the prioritization of this system's more critical parts, constitutes a fertile land for the realization of more research work.

It's proposed, therefore, the execution of new researches related to the development of sensors and analyses methods for continuous monitoring of hydric environments, in such a way as to make possible a broader detection of chemical or biological substances that may constitute aquatic environment's pollutants

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