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Turbidimeter and RGB sensor for remote measurements in an aquatic medium

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ABSTRACT

The present article describes a turbidimeter based on nephelometric scattering measurements, which operates with an infrared source. The device also includes an RGB sensor to obtain information about the color of the sample. The basis of operation and process of calibration of the device are described. The turbidimeter was tested during two months offshore in a bay of northwestern Spain obtaining a periodic turbidity daily signal from the water. On the other hand, the RGB sensor pointed out that the marine suspended particles were primarily green. These data demonstrated that the apparatus detected the diel vertical migration of phytoplankton.

1. Introduction

The measurement of water turbidity gives us insight into the way dissolved matter and suspended particles affect its optical clearness. The dispersed materials can be either microorganisms, organic matter or inorganic substances. Measurement of sea water turbidity accounts a great interest in biological marine studies and water-quality analysis. It has been demonstrated that the variations of turbidity strongly modify the aquatic ecosystems [1]. For instance, photosynthetic organisms can be blocked by shadows which prevent them from obtaining energy from the sun, and consequently the whole food chain can possibly result affected. As for what concerns fish, they can experience a vision reduction and may also find trouble to breathe. It is on this context where the turbidity measurement has gained its major interest.

There are few classical methods to measure turbidity, most of them based on transmission of light through water. Among them let us cite the Jackson candle turbidimeter [2] which works pouring water progressively into a tube under which there is a candle. The measurement is taken just at the moment when the candle stops being visible from the top. This is a low cost method and needs no calibration but it is unuseful to measure low turbidities and does not allow automatic nor remote measurements. Another method is the Secchi disk [3,4] which consists in immersing a black and white disk into the water up to a depth where the disk becomes invisible. This low cost method does not require consumables and needs no calibration. However, it is less accurate than the former, it cannot be used in shallow waters nor swift currents and it is not applicable to small samples. Additionally, it is unable to measure low turbidities and does not allow remote measurements either. A combination of the both methods described above is the so-called turbidity tube or transparency tube [5]. In this device, the disk is placed on the bottom of a tube and water is added up to the point where the disk becomes invisible from the top. Turbidity is then read as the level reached by the water on the tube scale. This makes the procedure useful for many water sources but it still has the drawbacks of the above

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described methods. Modern turbidimeters are based on transmission or scattering of light coming from a source like a bulb or LED and result more accurate, suitable for small turbidity measurements, and allow working with small samples. In the present work we describe one of these turbidimeters, specially designed to take remote measurements from natural environments.

When light encounters random irregularities in its propagation medium (such as small particles), rays are deflected in different directions. This phenomenon is known as scattering. Fundamentally, the monitoring of turbidity is based on optical methods such as backscattering measurements, 90-degree scattering, forward transmission and forward scattering [6,7]. Due to its low dependency on the particle size, the here described sensor is based on the 90-degree scattering also known as nephelometric method [8]. Nowadays, there is a wide variety of commercial sensors on the market, useful to control the turbidity of a sample. However, most of them lack a RGB sensor which could allow to obtain not only an estimation of the color of the liquids, but also may aid the identification of the immersed particles responsible for it. Possible applications of this device can be: pollutants detection [9] (e.g. oil), wastewater quality evaluation [10], filter monitoring in diverse processes [11], industrial waste treatment control and limnological studies [12,13].

In the following sections we will describe the operating principles of the device (Section 2), as well as its design and characteristics (Section 3). Subsequently, we detail the process of calibration for the turbidity and color scales (Section 4). Next, we present the measurements and analyze the results for the different tests carried out (Section 5).

2. Operating principles

When measuring the scattered light in a suspension we have to take into account that a number of factors can alter the received signal. For instance, the properties of the dissolved solid (like size, shape, concentration and absorbance) can play an important role. We are unable to control those factors, but we can choose an appropriate design so that their impact is minimized. Concerning the particle size, it modifies the distribution of the scattered light in the different directions. When the dimensions are larger or equal than the incident wavelength a larger forward scattering will be sensed, whereas the perpendicular scattering is barely changed [14]. This way, fixing the receiver at an angle of 90° respect to the emitter will reduce the effect of the particle size [see Fig. 1(a)].

Light scattering is also influenced by the absorbance of the solid, which depends on the wavelength of the incident light. In order to have a more accurate measurement we decided to use an 890 nm infrared (IR) emitter, avoiding in such a way the need of color compensation. This source is a light emitting diode (LED) with a radiation power of 1 mW and a spectral FWHM (full width at half maximum) of 80 nm. In order to get information on the color of the solid, also a triple (red, green and blue, RGB) LED source was installed on the device to get measurements on these three components. A unique phototransistor is used as detector for all IR and RGB sources oriented in such a way that it receives the scattered radiation into a 90-degree angle respect to the direction of both sources. For this, an arrangement as the one illustrated in Fig. 1(b)–(d) is used. Both sources and the detector are placed at the apexes of an equilateral triangle and properly bent to form the requested 90-degree angle between every source and the detector.

Regarding the mechanics of the equipment, sources and detector are attached to a copper piece. This material was selected in order to minimize the corrosion of salty water and the fouling. Fouling is the accumulation of organic or inorganic matter on a surface. It has a negative effect since it impedes the correct functioning of an underwater device [15]. It has been demonstrated that copper produces a film, composed of oxychloride, that diminishes this effect [16]. The copper piece was pierced to place the IR and RGB LEDs at the desired position, both forming a 90-degree angle respect to the phototransistor as explained above. The copper plate is integrated on the bottom of a commercial buoy to be placed offshore or into the water ecosystem to test (lakes, rivers or seas) in such a way that it lays

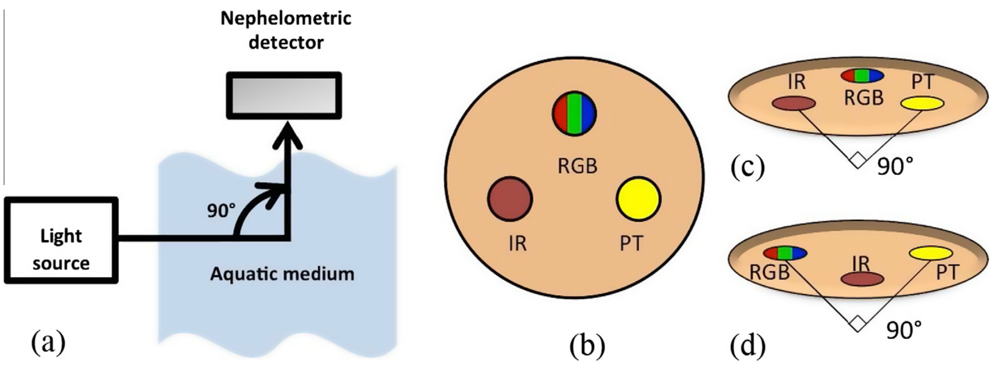

Fig. 1. (a) Scheme showing the operating principle of a nephelometric sensor, based on detecting the 90-degree scattered radiation. (b) Sketch of the arrangement of sources (IR and RGB) and the phototransistor acting as a detector on the copper piece attached to the bottom of the buoy. (c and d) Detail of the orientation of both sources and detector to fulfill the 90-degree angle layout. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)