Internet of Things Course
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Anno Accademico 2020-2021

Dr. Roberto Bruzzese

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Group Project Fish Farming Water Monitoring

Course of Internet of Things
Prof.: Ioannis Chatzigiannakis
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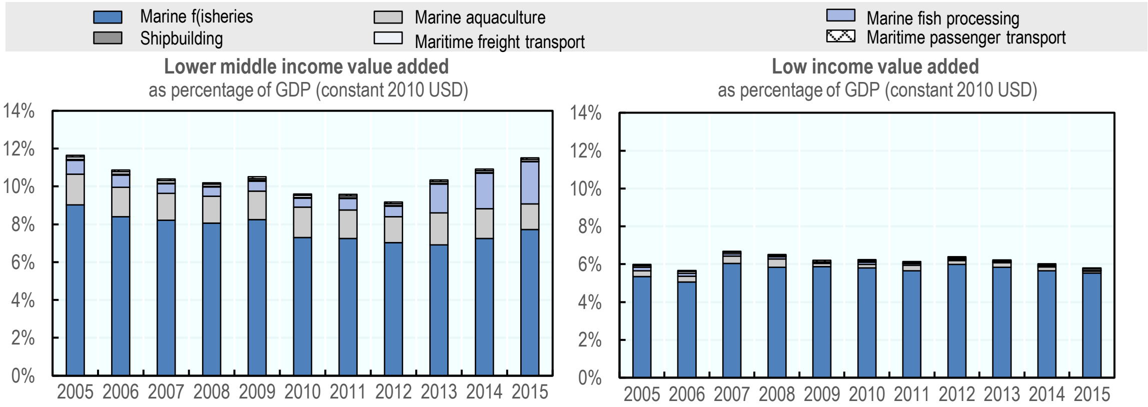
Fish Farming Water Monitoring

Using Spectrophotometer for Underwater Quality Analysis

Share of Gross Domestic Product of value added from six ocean-based industries, by country income groups, 2005-15



Trends in Capture Fisheries & Aqualculture Production

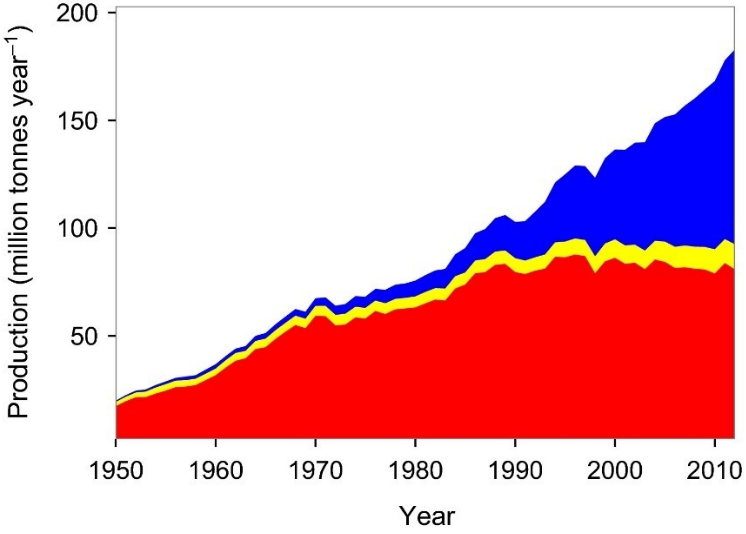


Figure 2: Trends (2016[3]) in global production from marine (red)- and freshwater (yellow)-capture fisheries and aquaculture (blue). Data from FAO FishStatJ (FAO 2015).

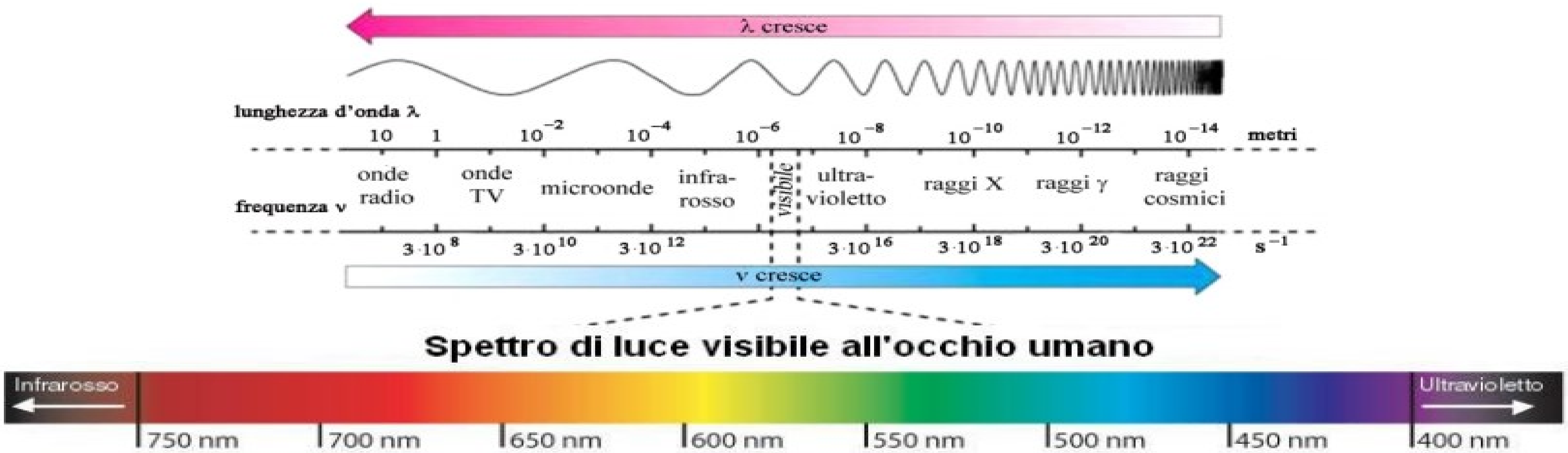
Aquaculture 4.0

- Farmers traditionally performs periodic on site measurements/inspections of water quality
- Traditionally Technical staff are composed by veterinaries, biologists, chemists using hand held instruments
- Aquaculture 4.0 means unmanned 24/24 hours aquaculture monitoring
- Real time data and complete historical data base
- Triggering of alarms when hazardous situations and immediate correction

Water Quality Parameters

- Fitoplankton and Zooplankton
- Oxigene percentage (optimum 80%-120%)
- Ph(6.5 – 9),Salinity (5g/L – 40g/L),Alkalinity(50-250mg/L)
- Waste : Droppings and uneaten feeds
- Oil
- Heavy metals (mercury), Dioxins, Polychlorinated biphenils, Pesticides
- Nitrogen dioxide, Nitrogen Catabolites, Ammonia (0-0.03)
- Turbidity (suspended solids or plankton) less than 1 NTU not more than 5 NTU
- Temperature (optimum 25° C - 35° C)

The Optical Physics Principles : The Spectrum

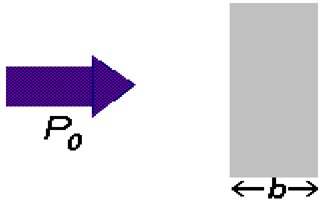


E= hν
E energia associata alla radiazione
h costante di Plank
ν   Frequenza

The Optical Phisycs Principles : Absorbance & Trasmittance

Many compounds absorb ultraviolet (UV) or visible (Vis.) light. The diagram below shows a beam of monochromatic radiation of radiant power P_0, directed at a sample solution. Absorption takes place and the beam of radiation leaving the sample has radiant power P.

Transmittance, $T = P / P_0$



Absorbance can be calculated from percent transmittance (%T) using this formula:
Absorbance = 2 – log(%T)

Transmittance (T) is the fraction of incident light which is transmitted. In other words, it's the amount of light that "successfully" passes through the substance and comes out the other side. It is defined as T = I/Io, where I = transmitted light ("output") and Io = incident light ("input"). %T is merely (I/Io) x 100. For example, if T = 0.25, then %T = 25%. A %T of 25% would indicate that 25% of the light passed through the sample and emerged on the other side.

Absorbance (A) is the flip-side of transmittance and states how much of the light the sample absorbed. It is also referred to as "optical density." Absorbance is calculated as a logarithmic function of T: A = log10 (1/T) = log10 (Io/I).

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The Optical Phisycs Principles: Absorbance & Trasmittance

The transmittance, T, of the solution is defined as the ratio of the transmitted intensity, I, over the incident intensity, I_0 and takes values between 0 and 1.

$$T = \frac{I}{I_0}$$

$$T(\%) = 100\,\frac{I}{I_0}$$

The absorbance, A, of the solution is related to the transmittance and incident and transmitted intensities through the following relations:

$$A = \log_{10}\frac{I_0}{I}$$
$$A = -\log_{10} T$$

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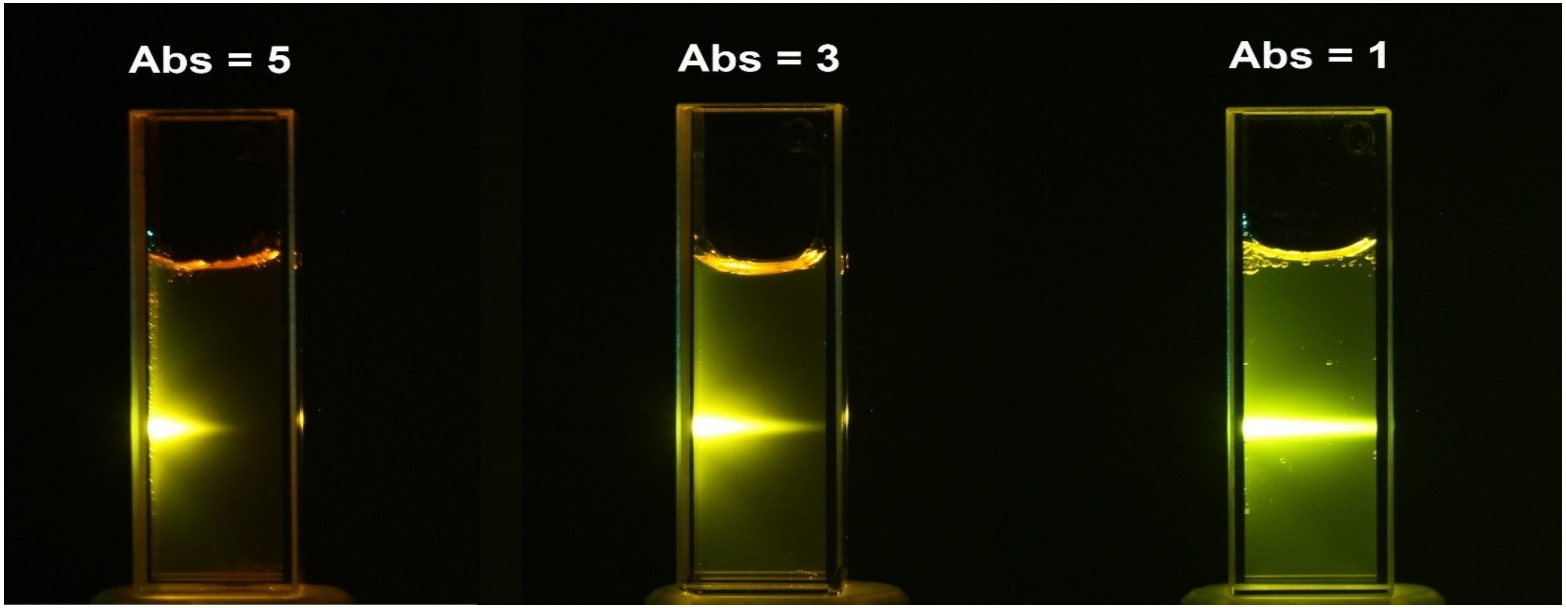
The Optical Phisycs Principles: Absorbance & Trasmittance

The absorbance has a logarithmic relationship to the transmittance; with an absorbance of 0 corresponding to a transmittance of 100% and an absorbance of 1 corresponding to 10% transmittance. Additional values of transmittance and absorbance pairings are given in Table 1. A visual demonstration of the effect that the absorbance of a solution has on the attenuation light passing through it is shown Figure 2, where a 510 nm laser is passed through three solutions of Rhodamine 6G with different absorbance.

Table 1: Absorbance and Transmittance Values:

Absorbance	Transmittance
0	100%
1	10%
2	1%
3	0.1%
4	0.01%
5	0.001%

The Optical Phisycs Principles: Absorbance & Trasmittance



What is the Beer-Lambert Law ?

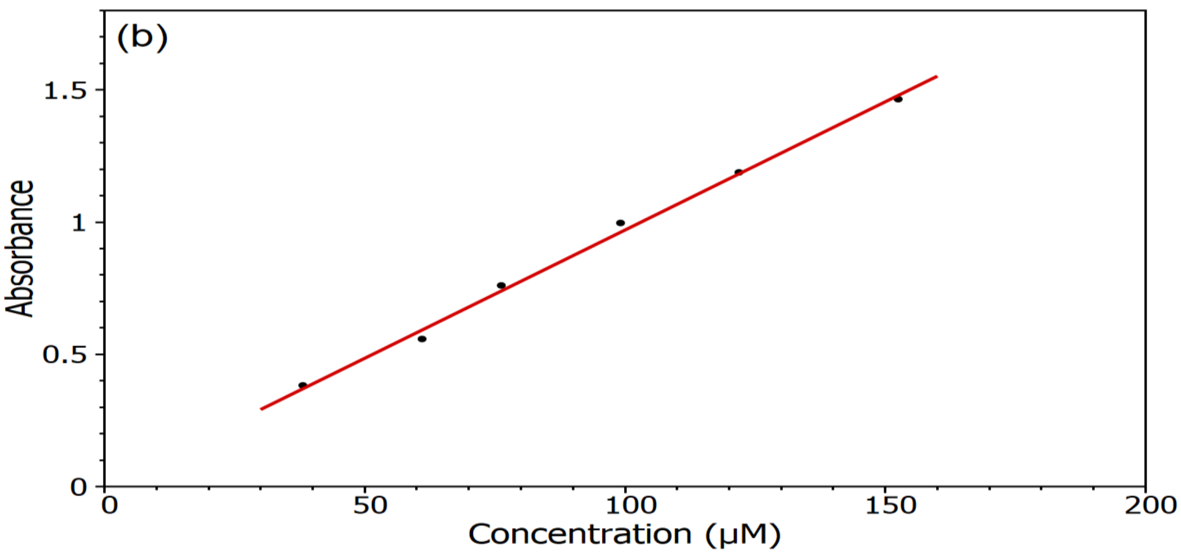
The Beer-Lambert law is a linear relationship between the absorbance and the concentration, molar absorption coefficient and optical coefficient of a solution:

$$A = \varepsilon c l$$

A	Absorbance	
ε	Molar absorption coefficient	$M^{-1}cm^{-1}$
c	Molar concentration	M
l	optical path length	cm

What is the Beer-Lambert Law ?

The Beer-Lambert law states that there is a linear relationship between the concentration and the absorbance of the solution, which enables the concentration of a solution to be calculated by measuring its absorbance.



La mole è l'unità di misura della quantità di sostanza.

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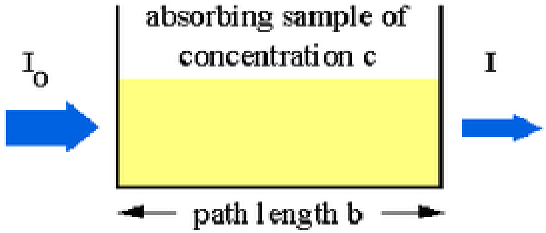
What is the Beer-Lambert Law ?

Experimental measurements are usually made in terms of transmittance (T), which is defined as:
$T = I / I_0$
where I is the light intensity after it passes through the sample and I_0 is the initial light intensity. The relation between A and T is:
$A = -\log T = -\log (I / I_0)$.

Absorption of light by a sample



Modem absorption instruments can usually display the data as either transmittance, %-transmittance, or absorbance. An unknown concentration of an analyte can be determined by measuring the amount of light that a sample absorbs and applying Beer's law. If the absorptivity coefficient is not known, the unknown concentration can be determined using a working curve of absorbance versus concentration derived from standards.

La mole è l'unità di misura della quantità di sostanza.

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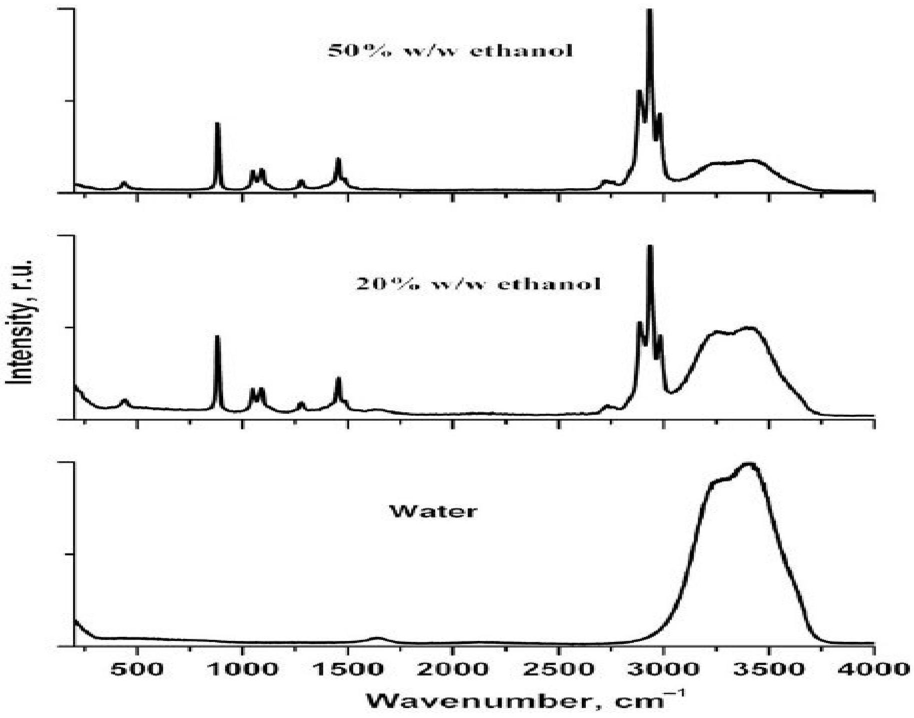
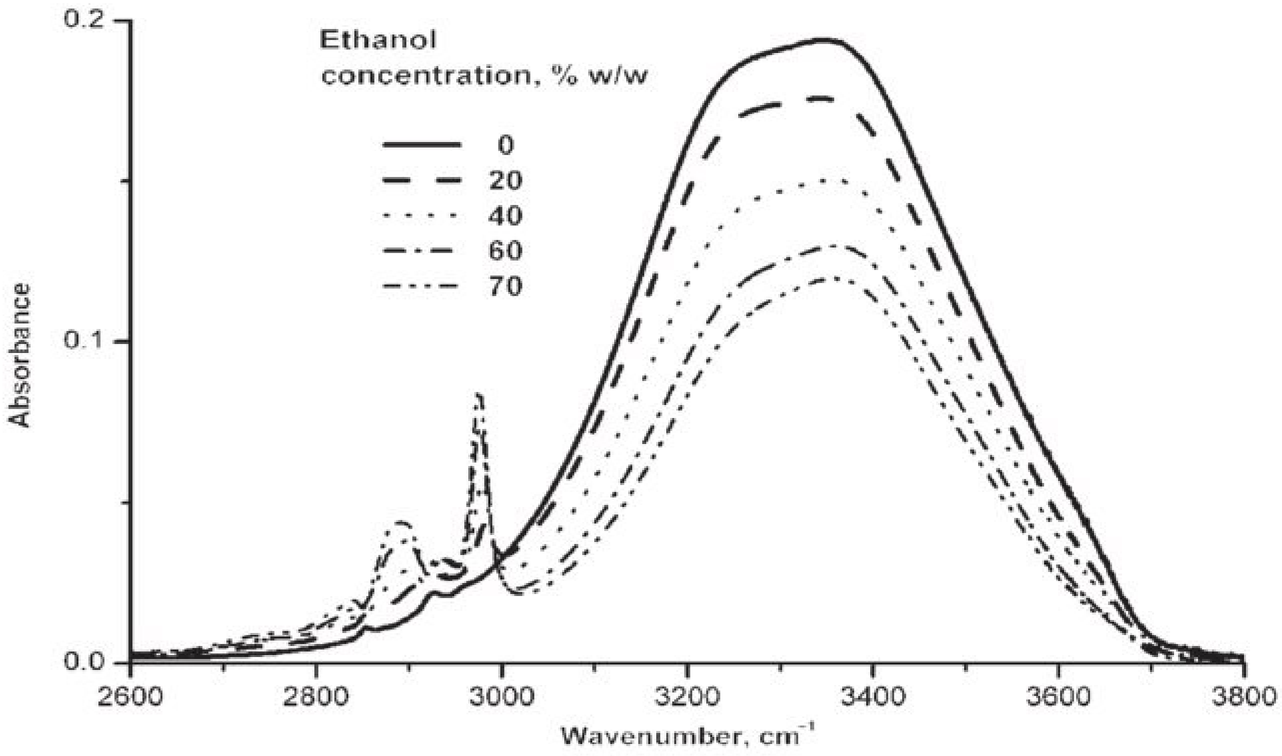
Spectrum Intensity distribution on water composite samples



Spectrum Intensity distribution on water composite samples



Spectrum Intensity distribution on water composite samples

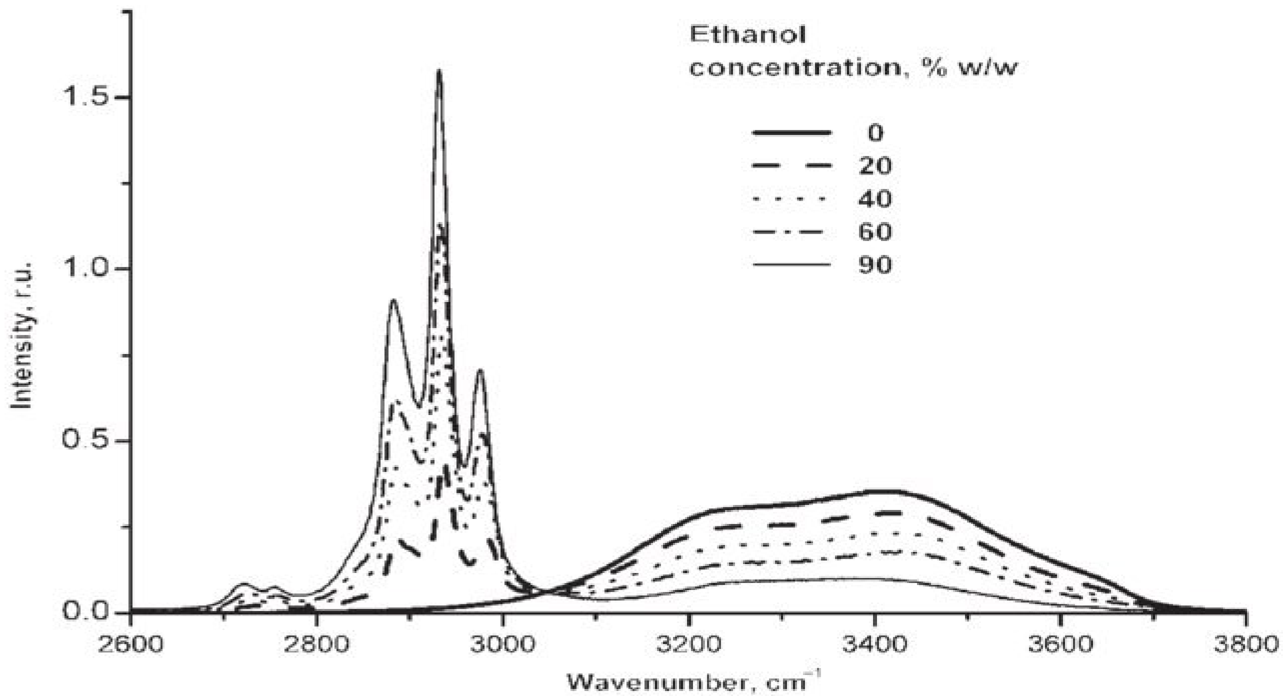


Figure . Raman scattering spectra of water and ethanol solutions with various ethanol concentrations within the region of CH and OH stretching bands.

Near Infrared spectroscopy

Some of the biggest advances in the food industry are being made possible by technological innovations such as near-infrared spectroscopy, which can identify certain compounds like fat, sugar, water, and proteins in food, leading to information about calorie content, freshness, and quality of food that can help consumers make better choices. By analyzing the absorption spectrum of an unknown material and matching this measurement with a database of known molecules, it is possible to determine the presence and quantity of certain ingredients—for example, the percentage of cocoa in a chocolate bar.

La mole è l'unità di misura della quantità di sostanza.

Near Infrared spectroscopy

Quantitative and qualitative analysis

Infrared (IR) light stimulates the molecules in a material, causing them to vibrate; due to resonance, an atomic compound with a certain binding energy is stimulated by a photon with the same energy. Depending on the type of atomic bond, certain fundamental vibrations, harmonics, and combination vibrations can be measured in the IR range. A characteristic atomic connection thus occurs in several wavebands, depending on whether it is a fundamental or a harmonic vibration. In the near-infrared (near-IR), usually only harmonics are found.

In terms of food analysis, one of the goals is to determine the percentage of corresponding ingredients, such as sugar, fat, or water content. This method is called **quantitative spectroscopy**. However, in most cases, the object to be analyzed does not consist of a laboratory-pure mixture. As a result, the identification of the ingredients in complicated and unknown substances can be difficult to pinpoint because the individual oscillations can overlap in the overall spectrum. In contrast to the quantitative analysis mentioned above, this is a **qualitative analysis**. The mathematical models used here are much more complex and have to be geared to a reduced target quantity in order to achieve meaningful results.

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On the path of mobile spectroscopy

As a result, there has not yet been a release of a handy spectrometer that consumers can carry in their pockets to get an immediate, detailed analysis of every piece of food they eat. Fortunately, however, the first steps toward this reality are now being made. In the near future, a mobile handheld spectroscope could ultimately be used to scan a wide range of materials—food, medicine, even the human body—and analyze them in real time.

A spectrometer consists of four main building blocks: a light source, a detector, optics, and a statistical mathematical model (so-called **chemometrics** https://www.laserfocusworld.com/test-measurement/spectroscopy/article/16562702/chemometrics-software-from-bw-tek-adds-new-algorithm), which derives meaningful information from raw data. The photoresponse of silicon-based detectors extends to just over 1000 nm; for longer wavelengths, sensors based on gallium arsenide are needed. The 780–1000 nm spectral region crystallizes out as a meaningful measuring range because it shows measurable characteristic curves for almost all key substances.

Chemometrics

Chemometrics is the science of extracting information from chemical systems by data-driven means. Chemometrics is inherently interdisciplinary, using methods frequently employed in core data-analytic disciplines such as multivariate statistics, applied mathematics, and computer science, in order to address problems in chemistry, biochemistry, medicine, biology and chemical engineering.

Chemometrics in Spectroscopy, **Book** • Second Edition • 2018

BWIQ is a multivariate analysis software package that analyzes spectral data to find internal relationships between spectra and response data or spectra and sample classes. It combines traditional chemometric methods like Partial Least Squares Regression (PLSR) and Principal Component Analysis (PCA) with a new proprietary adaptive iteratively reweighted Penalized Least Squares (airPLS) algorithm.

The case of compound water samples

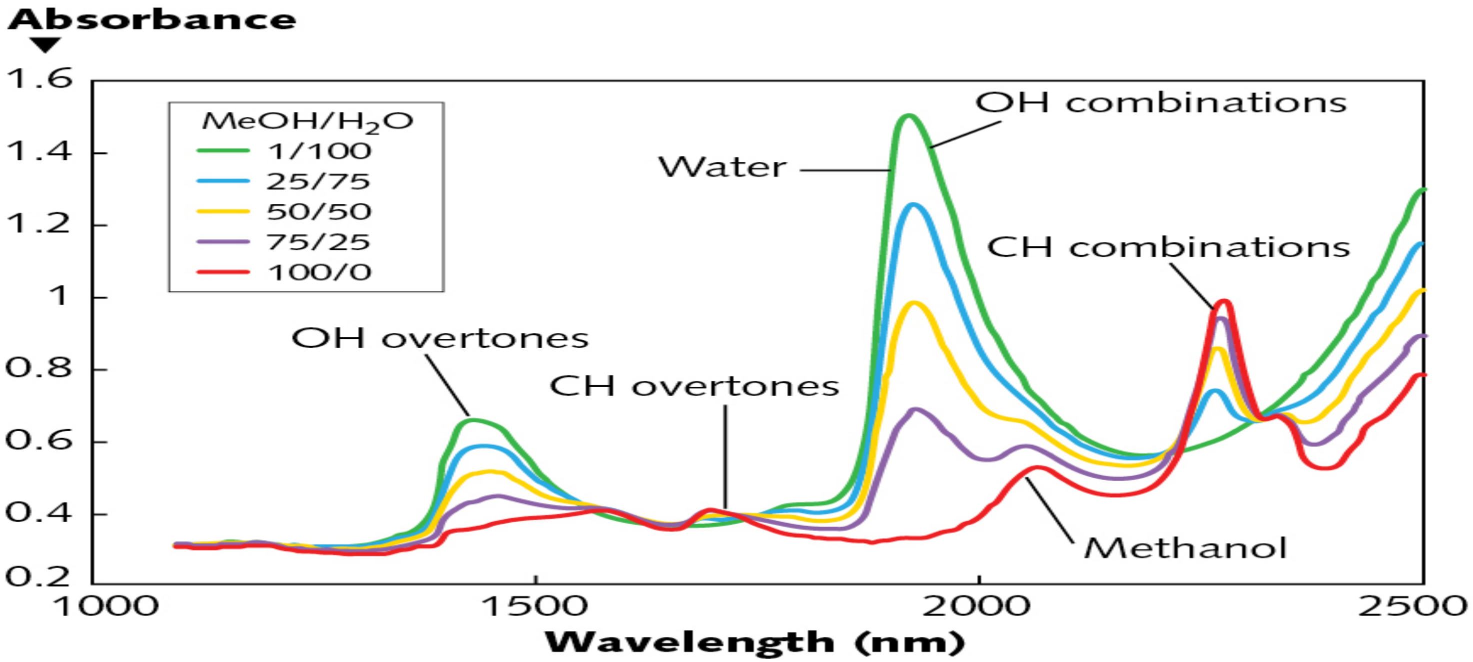

FIGURE 2. Absorption spectra of water and methanol under different mixing ratios.

The case of compound water samples

The challenge is to derive from this information a quantitative model that allows one to measure a spectrum and then calculate the mixing ratio.

The limits of this project work : the unknown water sample

We must consider that our water analysis does not have to consider only one concentration level , but a very composite mixture od chemical components at different level of concentrations. Nevertheless it is not here the context in which the collection and set up of data collection should be set up , but in an advanced machine learning context. It is true that the parameters important for us are predefinite and well identified.
What could be done in this project is right a sample data collection obtained by simulating and inducing variation of the important quality parameters by some additive of our choice. For example some bicarbonate or vinegar can variate the Ph level .We could try to add artificially oxygen to the water sample, or salt for testing the salinity. That's all. There will be a very simple set of data that will be transmitted to the Amazon AWS Iot Cloud, and elaborated by machine learning module. It will not be built a model since this will be a work to be done in an Advanced Machine Learning Course. Our monitoring level should be limited to assessing if the parameter under observation are within the accepted range of values, or if any of them has passed the boundaries.

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The Triad spectroscopy Sensor AS7265x

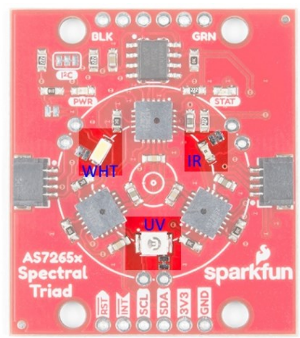

FIGURE 1. LEDS (WHITE, IR, UV) .

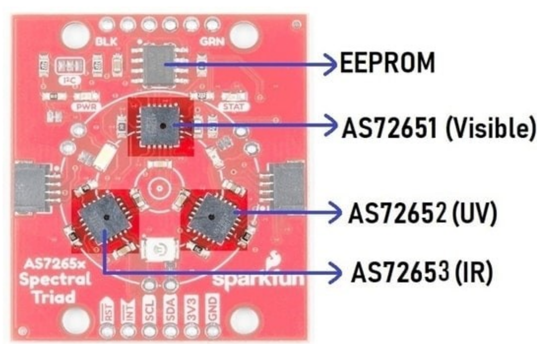

FIGURE 2. SENSORS (VISIBLE, IR, UV) .

Each sensor can detect six frequencies in different ranges of light spectrum.

Wiring of Arduino BlackBoard with AS7265x Spectrometer Sensor

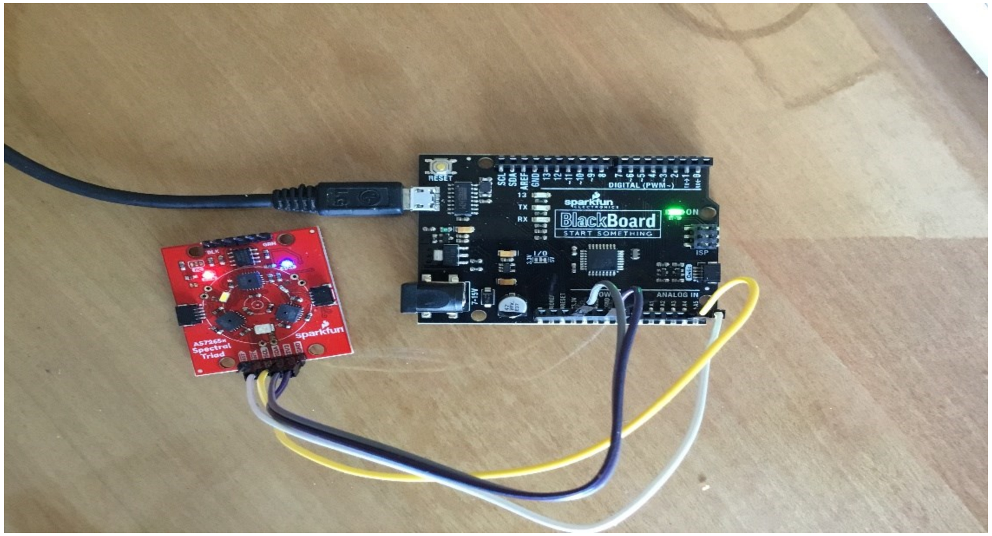

Figure 5: Wiring of BlackBoard to Spectrometer Sensor .

First Arrangement of the experiment test measurement

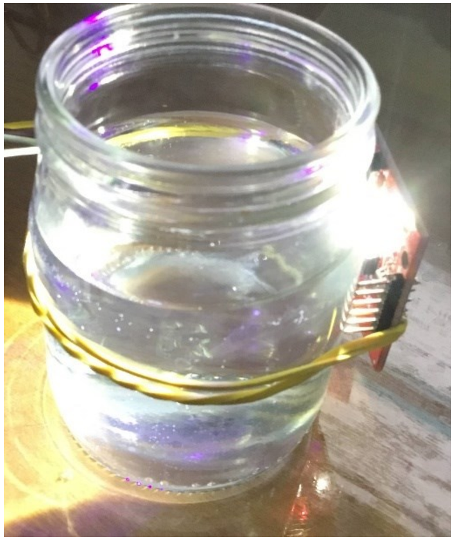

Figure 6 : Open space arrangement of spectrometer sensor

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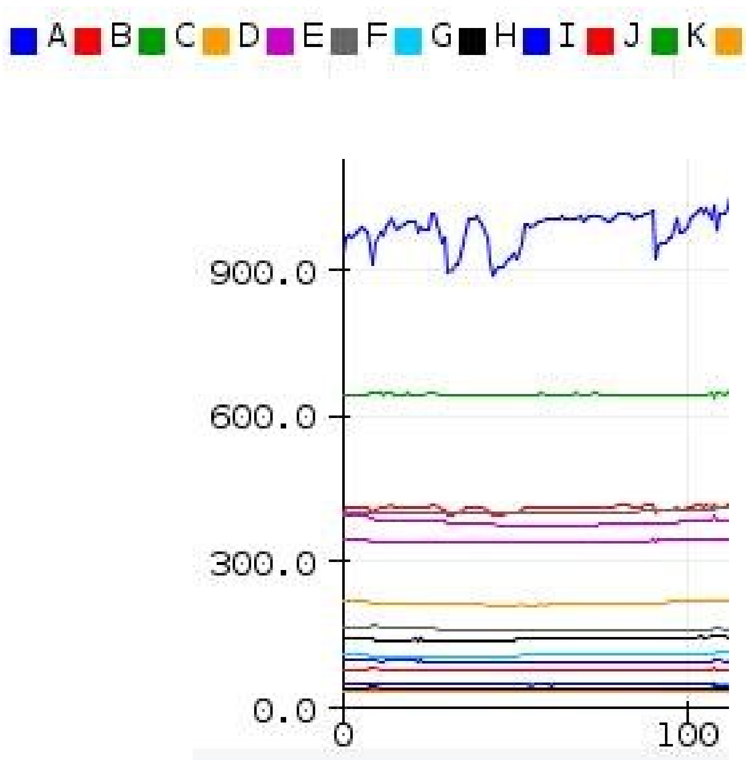
Reflectance Measured from water sample in open space



Device	Channel	Center λ (nm)
AS72653	A	410
AS72653	B	435
AS72653	C	460
AS72653	D	485
AS72653	E	510
AS72653	F	535
AS72652	G	560
AS72652	H	585
AS72651	R	610
AS72652	I	645
AS72651	S	680
AS72652	J	705
AS72651	T	730
AS72651	U	760
AS72651	V	810
AS72651	W	860
AS72652	K	900
AS72652	L	940

FIGURE 7 : Graphical Plot of pure water sample (drinkable water without additions).

How to compare an unknown sample to a known one

A,B,C,D,E,F,G,H,I,J,K,L,R,S,T,U,V,W

1054.53,405.61,676.10,198.37,343.88,435.63,107.24,140.40,86.75,34.79,32.33,28.21,347.31,155.94,43.59,37.58,42.00,74.59,

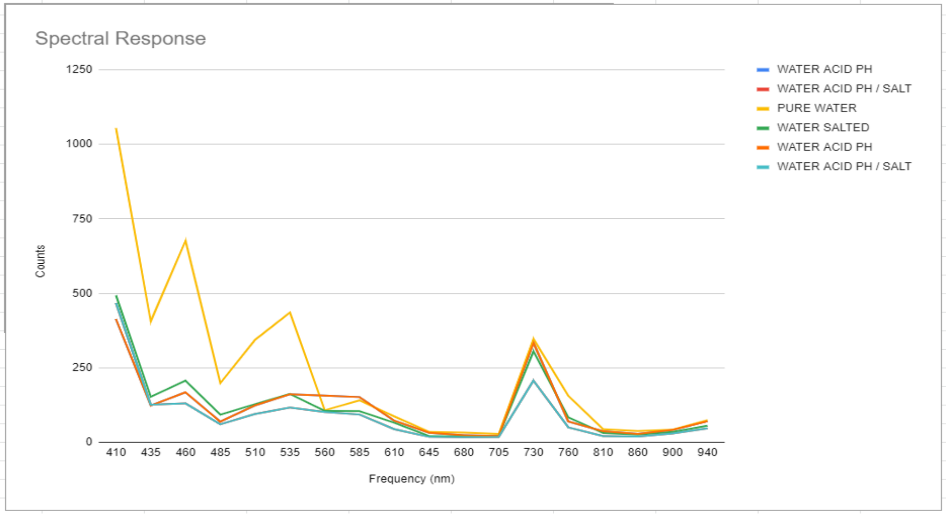


FIGURE 2. Absorption spectra of water and methanol under different mixing ratios.

Second Arrangement of the experiment test measurement

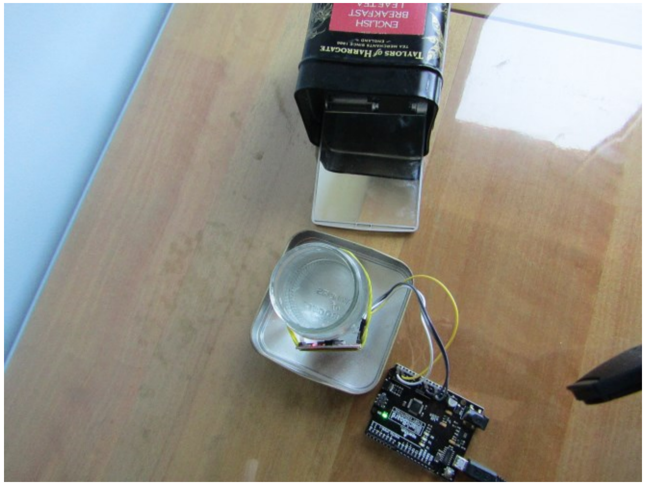


FIGURE 7 : Graphical Plot of pure water sample (drinkable water without additions).

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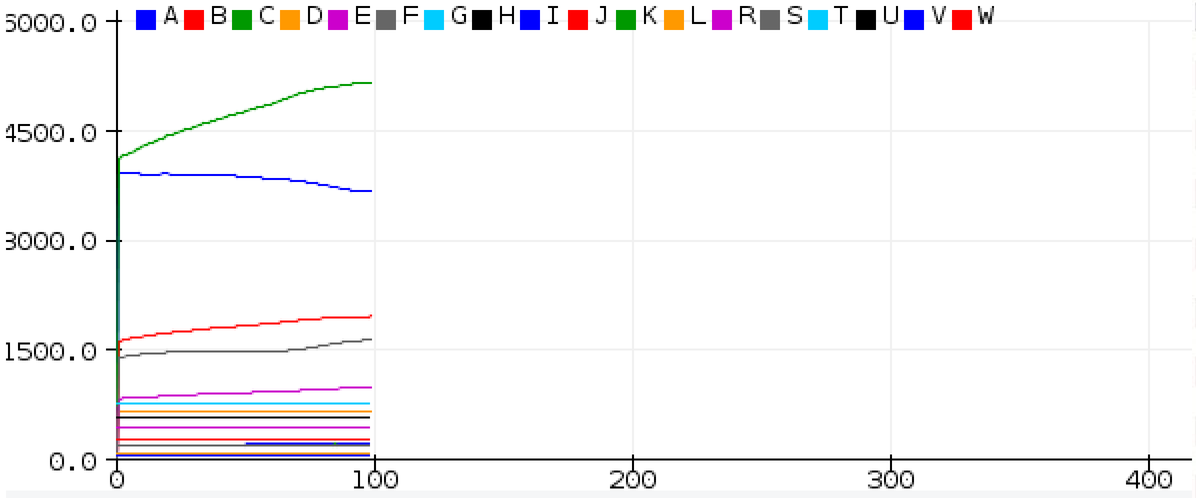
Trasmittance Measured from water sample in closed space



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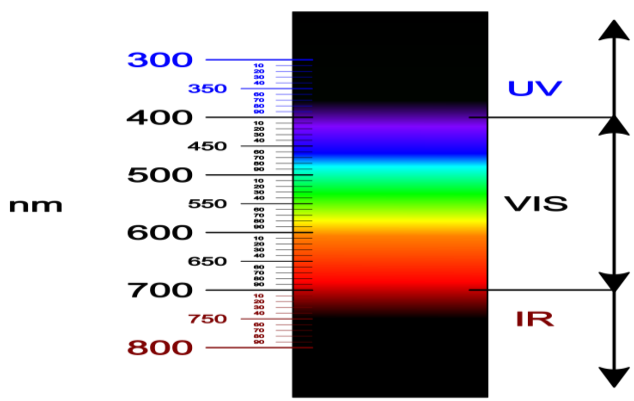
AS72651	R	610
AS72652	I	645
AS72651	S	680
AS72652	J	705
AS72651	T	730
AS72651	U	760
AS72651	V	810
AS72651	W	860
AS72652	K	900
AS72652	L	940



Optimal Arrangement of the experiment test measurement

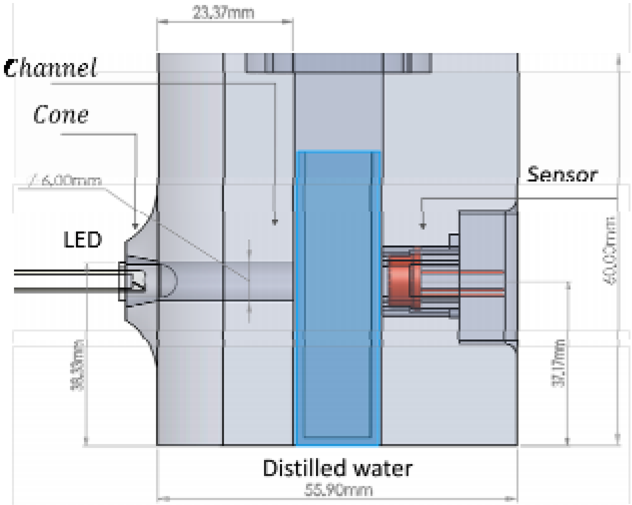


FIGURE 2. Absorption spectra of water and methanol under different mixing ratios.

Optimal Arrangement of the experiment test measurement

This arrangement could be feasible with a little modification of the sensors. The three external bulbs can be added to the sensors and placed in the front of the sensors, and in the middle should be placed the water sample. The total absence of light during the sampling is a strong desiderata since the light interferences can disturb the sampling and make sampling unreliable and difficult to identify for

Intervallo di trasparenza:

- Silice 150-3000 nm
- Vetro 375-2000 nm
- Plastica 380-800 nm

NOTE : The use of glass is uninfluent since the lowest frequencies detected by the spectrometer is 400 nm.

Optimal Arrangement of the experiment test measurement

This arrangement could be feasible with a little modification of the sensors. Three external bulbs can be added to the sensors and placed in the front of the sensors, and in the middle should be placed the water sample. The total absence of ambient light during the sampling is a strong desiderata since the light interferences can disturb the spectrometer measurements and make sampling unreliable and difficult to identify for the machine learning since the data collected cannot depend on the external and environmental variability.

In my initial experiment I have used a glass jar which is transparent to almost all wavelengths of interest. The most appropriate cell must be transparent to its wavelength so that it will not interfere with the results. Also the geometry should be regular and definite. The path must be constant.

Optimal Arrangement of the experiment test measurement

Intervallo di trasparenza:

- Silice 150-3000 nm
- Vetro 375-2000 nm
- Plastica 380-800 nm

NOTE : The use of glass is uninfluent since the lowest frequencies detected by the spectrometer is 400 nm.

The Law of conservation of Energy how does affect the experiment

Consider a layer of absorbing medium where only part of the total incident radiation I_λ is absorbed, and the remainder is either transmitted through the layer or reflected from it (see Figure 3.1). In other words, if a_λ, r_λ, and τ_λ represent the fractional absorptance, reflectance, and transmittance, respectively, then the absorbed part of the radiation must be equal to the total radiation minus the losses due to reflections away from the layer and transmissions through it. Hence

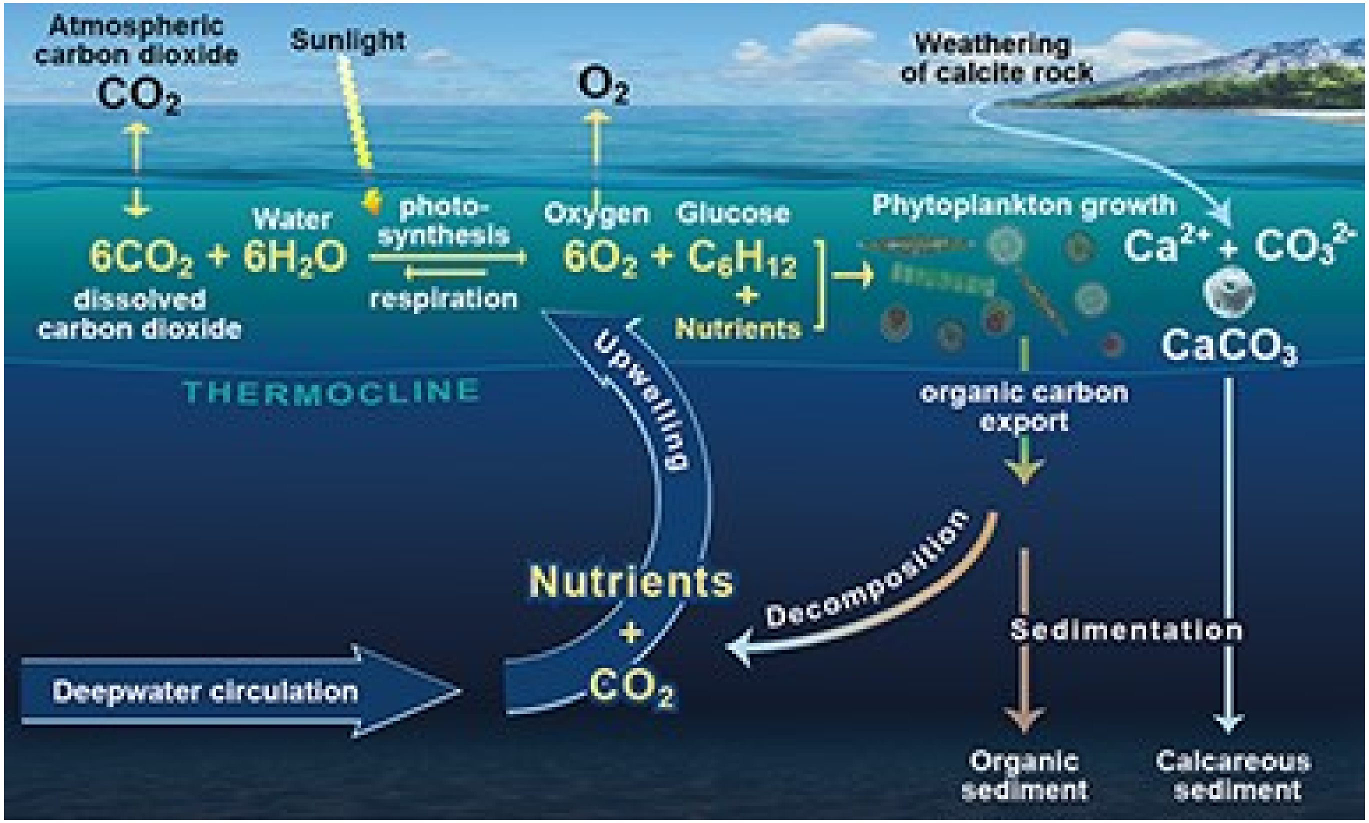
$$a_\lambda I_\lambda = I_\lambda - r_\lambda I_\lambda - \tau_\lambda I_\lambda \ ,$$

or

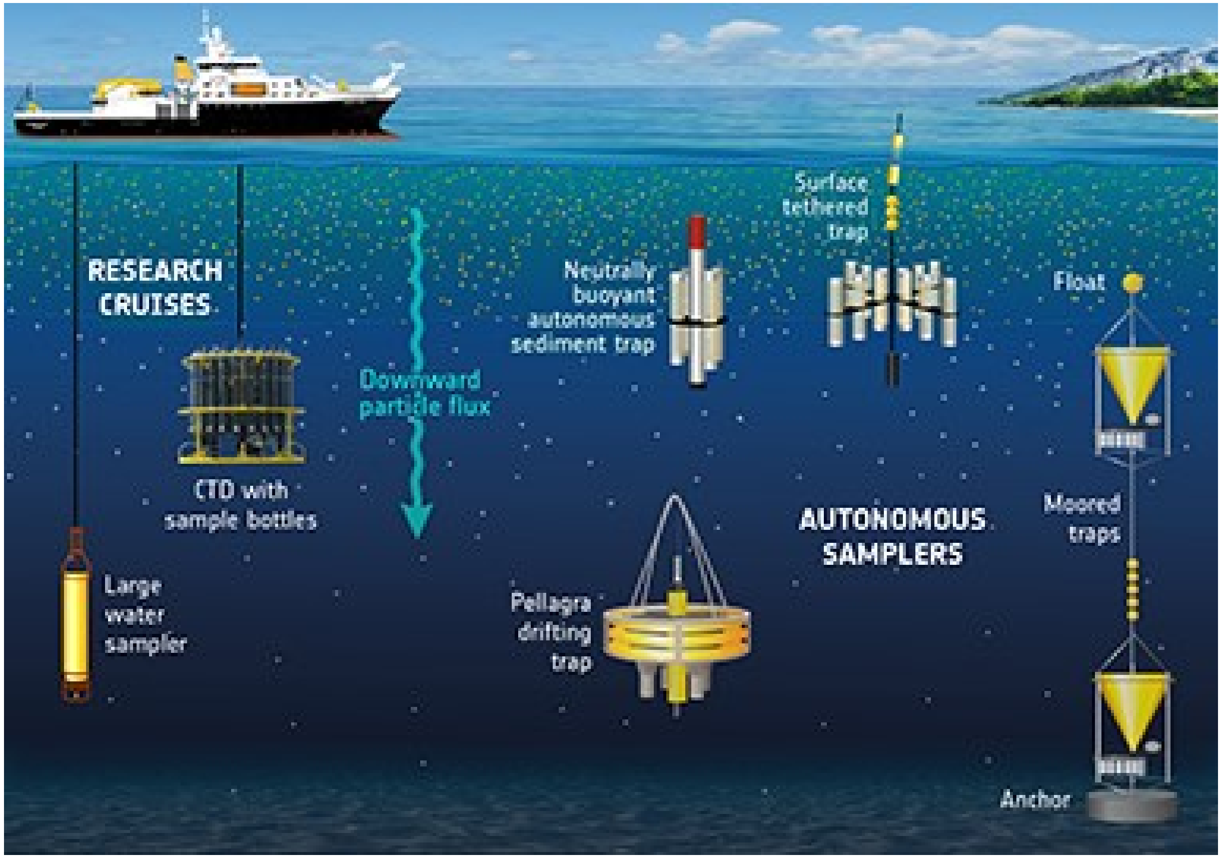
$$a_\lambda + r_\lambda + \tau_\lambda = 1 \ ,$$

which says that the processes of absorption, reflection, and transmission account for all the incident radiation in any particular situation. This is simply conservation of energy. For a blackbody $a_\lambda = 1$, so it follows that $r_\lambda = 0$ and $\tau_\lambda = 0$ for blackbody radiation. In any window region $\tau_\lambda = 1$, and $a_\lambda = 0$ and $r_\lambda = 0$.

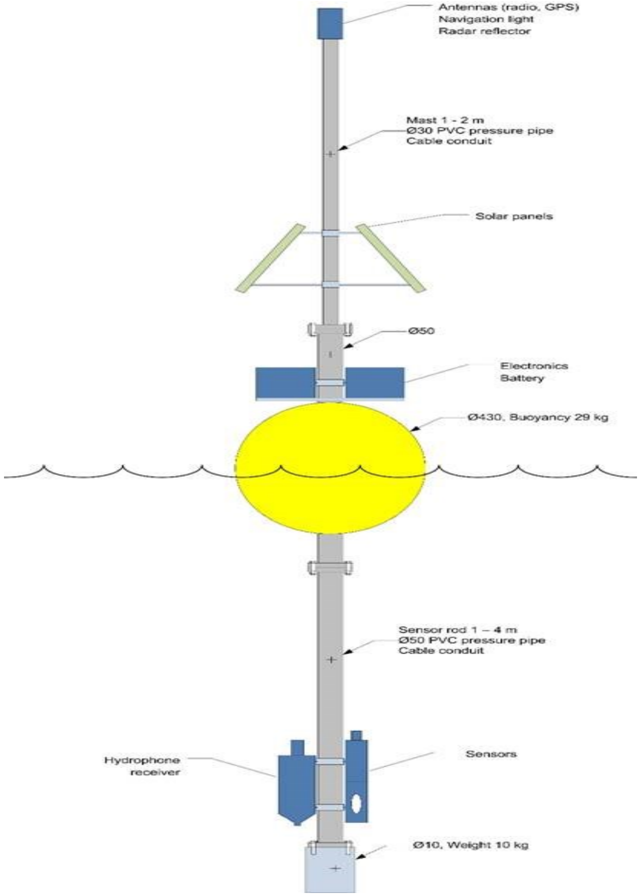
Which water sample should be analysed



Which water sample should be analysed



The Smart Buoy: the site where all the instrumentation will be placed

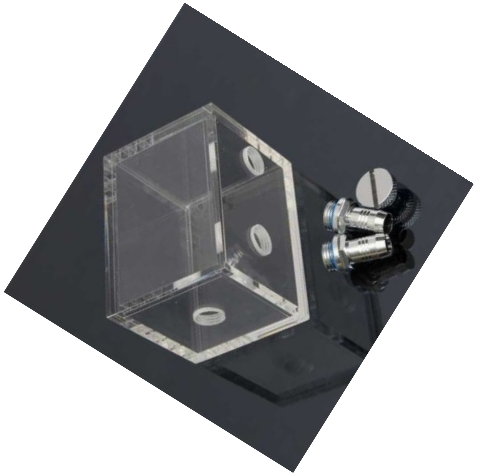


This model may be subject to changeI

Other equipment used

Pompa Acqua Miniatura 1 PZ Pompaggio

- Diam interno : 10mm/0,4"";il diametro esterno : 12mm/0,47""
- sourcingmap



Water Cooling Reservoir2. Size: 80 * 60 * 60mm3. Capacity: 160ml4.

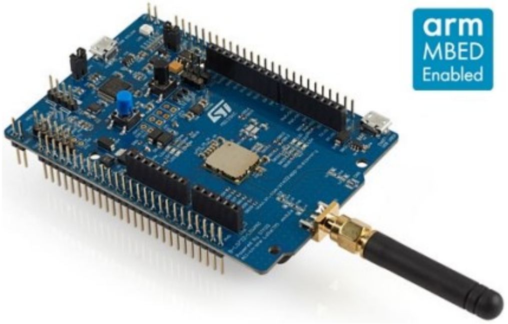
- Dimensioni circa 8,5 * 7 cm

Elettrovalvola valvola controllo elettronico Piccolo scarico valvola sfiato DC 5V DC6V

Other equipment to be used : ordered

fotovoltaic device

battery based on Lithium Ion

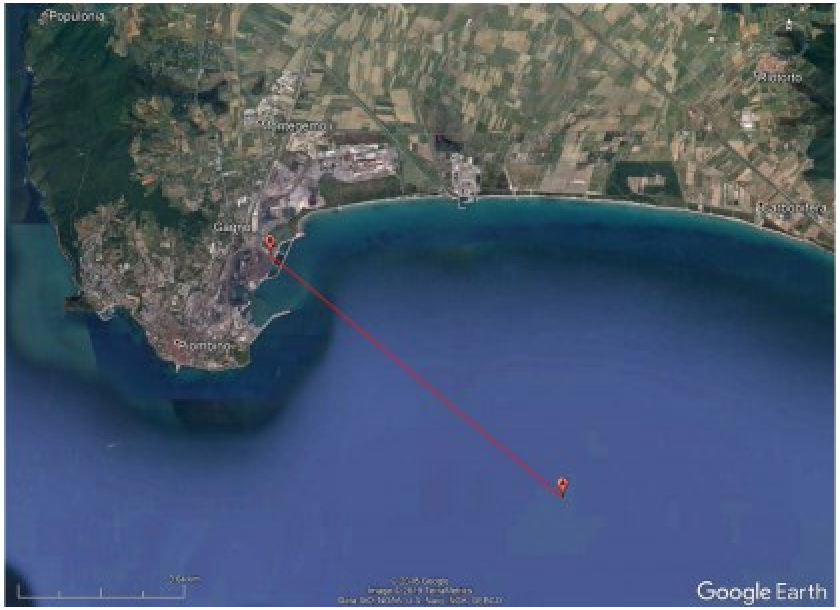


ST B-L072Z-LRWAN1

iC880A-SPI - LoRaWAN Concentrator 868 MHz

Raspberry Pi 2 Model B v1.2, Quad-Core-CPU, 1GB RAM, 40 GPIO-Pins, HDMI-Anschluss

The need for LoraWAN concentrator: the site of aquaculture may be distant from the coast and from the Gateway



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Grazie per la Vostra Attenzione!

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