Real- Time Monitoring of the Venice Lagoon

The Magistrato alle Acque Develops a Monitoring Network to Study the Evolution of the Venice Lagoon Ecosystem

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Satellite image of the Venice Lagoon, along with the position of the 10 Magistrato alle Acque real-time monitoring stations.

The Venice Lagoon is about 550 square kilometers, and is the largest and most famous lagoon of northern Italy. The lagoon was formed about 6,000 years ago by the counteracting effects of the sediment transport of the rivers that feed into the lagoon and the force of the sea, causing the formation of sandy littorals between the mainland and the sea.

The lagoon communicates with the sea by means of three mouths, which allow for the periodic renewal of the lagoon waters by tidal exchange, and represent access to the port of Venice. The mean depth of the lagoon water is less than one meter, but there are many canals which make it possible to navigate inside the lagoon.

In the middle of the lagoon lies the city of Venice, one of the most ancient and historical Italian cities, visited by many millions of tourists every year. Due to its particular urban structure, the city of Venice is not served by a modem sewage system, and the city's sewage is treated by individual plants (septic tanks and small biologic treatment plants). In the middle of the 20th century, one of the largest Italian industrial areas was developed at the northern edge of the lagoon. Several industrial activities sprang up in that area, such as the naval industry, metallurgical industry, refineries, petrochemicals plants, fertilizers and power-production plants. This highly industrialized area caused the extensive contamination of the water in the lagoon and of the other environmental matrices (sediments and biota). Furthermore, the diffuse pollution from agriculture produces a high load of nutrients (mostly nitrates) from the numerous rivers which flow into the lagoon from the mainland draining basin and cause the eutrophication of the lagoon. For all these reasons, the lagoon suffers from numerous pressures that can cause negative impacts such as abnormal growth of macroalgae, algal blooms, anoxic status, and loss of biodiversity and habitats.

Features of the Network

The Magistrato alle Acque, the Venice Water Authority, is currently

(Above) View of the Ocean Seven **316** *multi-parameter. probe installed in each station.*

(Left) Image of one of the monitoring stations.

taking a series of measures to counteract the degradation of the lagoon, including the dredging of the contaminated sediment, clean-up of contaminated sites inside the lagoon, pollution prevention from the industrial discharge and wetlands reconstruction. In order to control the status of the ecosystem, and to verify both the short and long-term effects of the initiatives taken to counteract the degradation of the lagoon environment, the Magistrato alle Acque has set up a real-time system to monitor the quality of the water of the Venice Lagoon.

The monitoring system is composed of 10 stations placed in different parts of the lagoon. The system covers the most significant areas of the lagoon such as the area surrounding the city of Venice; the portion of the lagoon directly influenced by the industrial area of Porto Marghera; the southern of area of the lagoon close to the city Chioggia, an important economical center for fishing activities; various areas close to the outlet of the main rivers that flow into the lagoon; and undisturbed areas.

Each station consists of a housing unit constructed entirely out of plastic, devoid of any metallic parts that might interfere with trace-metal measurements. All stations are equipped with Ocean Seven 316 multi-parameter probes from Idronaut (Milan, Italy) that measure the depth of the water column, temperature, pH, salinity, dissolved oxygen, redox potential, turbidity and chlorophyll. The stations have been designed to contain other instruments for the future monitoring of other parameters, such as voltammetric probes for determining trace metals, both in the totally dissolved form and in the free ion form, and nutrients such as nitrogen, phosphorus and silica.

Due to the limited depth of the water in the lagoon, the measurements of the different parameters are referred to a depth of about one meter. Data are automatically measured every 30 minutes and transmitted to the headquarters of the Magistrato alle Acque, where they are stored, validated and elaborated. Each station is equipped with an automatic sampling system which can be operated by a remote position to collect water samples at any time and with different frequencies. All of the stations are self-operating, the power being supplied by solar panels. Each station is also equipped with static sampling systems for the collection of both wet and dry atmospheric deposition, which is periodically analyzed for the evaluation of the pollution load from inorganic and organic pollution due to atmospheric fall-out.

The stations are equipped with a set of two probes-one operating and the other kept calibrated in the laboratory-by using certified reference materials and standards. Every one to two weeks, according to the period of year or when anomalous data are measured, the operating probe is substituted with the calibrated probe and brought into the laboratory for routine maintenance and calibration. This way, it is possible to perform continuous measurements of all the parameters with limited risks of signal drifts and unreliable data due to sensor fouling. Nevertheless, because of dirt or bio- fouling, which can attach to the probes in a natural system with high productivity or turbidity, such as the Venice Lagoon, unreliable data can be measured.

Such problems became particularly evident with oxygen measurements, due to the difficulty of obtaining stable signals over a long period of time.

An accurate value of the dissolved oxygen concentration is of paramount importance in estimating the status of the aquatic environment.

The early detection of faults in the probe is of great importance to real time monitoring activities since it can prevent misunderstandings in the system analysis and permit the optimisation of maintenance of the monitoring network. This problem has been addressed by using deterministic and statistical models that connect the information from the time series concerning independent variables, or from the time series that are collected at different sampling stations in the monitoring network. Furthermore, the dissolved oxygen (DO) anomalous data can be corrected by the corresponding pH measurements, a strictly related parameter which has been revealed to be a much more stable signal. In fact, it is well known that DO concentration is linearly correlated with pH. The application of these models and corrections allows for a recursively correct series of temporal data, which are affected by errors due to bio-fouling or anomalous functioning of the sensors.

The results obtained over a two-year period confirm the reliability of the system and the possibility of using the results to describe both the short and long-term evolution of the Venice Lagoon ecosystem. All of the measured parameters appear to be directly influenced by the tidal cycle. In general, DO decreases in low-tide conditions and increases when the tide is growing, confirming that the seawater is more oxygenated in comparison to the lagoon water. Seawater represents a thermal reservoir for the lagoon, being colder in summertime and warmer in winter, thus mitigating the thermal stress of the lagoon environment. The salinity shows higher values in the stations that are more influenced by the seawater and, conversely, lower values in the stations that are closer to the mainland and directly influenced by the fresh water from the rivers flowing into the lagoon. Other interesting aspects are related to the turbidity, which is dependent on sediment resuspension due to maritime traffic, fishing activities and meteoric factors. Chlorophyll and DO are strictly related, the higher values of chlorophyll correspond to the periods in which DO showed high over saturation.

Another interesting aspect is the different range of variability of the main parameters typical of the different stations.
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Conclusions and Future Work

The real-time monitoring system of the Magistrato alle Acque is producing an enormous amount of environmental data, which can be useful for the local and international scientific community interested in studying the Venice Lagoon ecosystem. Furthermore, the ministry believes that the environmental information from this network must be shared with the local community, who has the right to know the status of the ecosystem where they are living. The ministry is developing graphics software that allows, through chromatic animation implemented on a geographical basis, an effective and easy-to-understand real-time representation of the status and the evolution of the Venice Lagoon ecosystem.

Acknowledgements

We would like to acknowledge the president of the Magistrato alle Acque, Eng. Maria Giovanna Piva, for funding this project; Dr. Roberto Pastres of the University of Venice for his scientific support; and Flavio Graziottin and Fabio Confalonieri of Idronaut for their technical support

References

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