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Use of a hand-held thermal imager in addition to chemical and microbiological analyses of bathing waters

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Abstract

The use of remote sensing, carried out with a helicopter-flown hand-held infrared (IR) camera has proved a useful tool for monitoring coastal waters, in addition to the routine chemical-microbiological monitoring. Such technique has been used to check the direction of plumes of water effluents and thus their impact on bathing areas, in some sites along the Apulia coast (Southern Italy). Such sites are undergoing an epidemiological study, aimed at checking the impact of water quality on the onset of gastro-enteric pathologies.

For a thorough standardisation of the results, besides thermal images, data on the direction of surface coastal currents, and on tides and prevailing winds have been collected in order to forecast, in different environmental conditions, the possible diffusion of pollutants in the areas being studied.

This approach can be a sound and effective tool in managing seaside resorts, that would allow to base the provision of bathing permissions and prohibitions on the actual environmental situation present.

While the investigation was being carried out, a document concerning the proposal for a new Directive on bathing waters was issued by the E.U. Commission. Therefore, the data and images obtained by the investigation have been assessed and discussed in the framework of this new document.

1. Introduction

Inappropriately processed urban, livestock and industrial waste are responsible for the emission of pathogenic micro-organisms into the sea. The population can be exposed to these micro-organisms by eating fish products (especially molluscs) and bathing. Such exposure can give rise to different forms of pathologies, particularly gastro-enteritis.

The PRISMA2 project -Conservation of the Adriatic Sea- Human Health Subproject has pinpointed that for certain etiologic, gastro-enteric agents an important epidemiological role is played by the consumption of raw or improperly cooked seafood in the onset of these pathologies (Ferrara and Funari 1999, Arcieri et al. 1999, Ripabelli et al. 1999).

The recovery and protection of the quality of the coastal environment should represent a general objective for the primary prevention of pathologies in humans. The recent Directive 2000/60/CE establishes the framework for E.U. initiatives in the field of waters. In setting such objective, the proposed Directive indicates a new structure that will be responsible for its achievement, i.e. the *hydrographic district*. This comprehends one or more catchment basins, including the respective coastal waters.

1.1 Proposal for a New EEC Directive on Bathing Waters

At present, a new European Directive on bathing waters is being drawn up. Such Directive is very innovative compared to the previous one, which dates back to 1976, and is now dated, even though the latter contributed to a considerable improvement in this sector. The new Directive proposed should curtail the number of parameters to monitor and introduce new and more effective instruments and parameters. The new Directive won't only concern water quality monitoring, but also the way to deal with pollution sources, in particular with waste water and farming waste. (Moreover, it also intends to improve the information for citizens, which is now insufficient.)

Among other things, the Directive envisages that the *beach profile* for every bathing area be traced. The *beach profile* will have to be drawn after a careful study on the existence of possible contamination sources in the hinterland, on the meteorological and climatic characteristics of the site, on the possible occurrence of particular events (downpours, flooding, overflowing, etc.), and anything that may contribute to alter the quality of bathing waters (nearby water discharges, waterways, maritime routes, etc.).

Once the necessary data have been collected, it will be possible to develop a plan to monitor the beach and prepare the most rational measures for its correct management, since the stated aim of the proposed Directive is to go from an "a posteriori" management to a preventive one. This entails that all the possible hazardous situations for bathing be known, so that when an accident occurs, it will be possible to take immediate action to protect the bathers' health.

In order for the "Beach Profile" to be drawn, a valid contribution can be given by the use of Remote Sensing techniques, in particular by the use of satellite high-resolution images and thermal images taken with a thermographer from low altitude. The former allow to know the detailed situation present on the territory surrounding the beach at the moment of filming, the latter visualise possible discharges, as well as the extension and area of impact of their plumes. The recent availability of satellite images having 1m resolution allows to know and follow over time the development of land use with previously unthinkable precision.

The use of highly detailed thermal images taken from low altitudes (Catena and Palla 1981, Catena 1994, Catena 2000) allows to visualise water discharges into the sea and to follow their plumes in the different conditions of wind, tidal and surface marine currents. Therefore, such images help to create an image database that can be used when the different situations reappear.

This method of investigation has been recently used in the study of bathing areas in some sites of the Apulia coast (Southern Italy, on the Adriatic Sea), where an epidemiological study is underway to assess the impact of water quality on the onset of gastro-enteric pathologies.

The introduction of the data relative to the territory, to the meteorological and climatic conditions, and the chemical and microbiological analyses of bathing waters in a Territorial Information System (**TIS**) will permit to carefully manage the territory and forecast possible worsening in the hygienic conditions of the coastal sites, thence giving considerable advantage for public health. In fact such sites could be reached by polluting loads, the source of which could be located either at sea or in the hinterland. Also the establishment of forecasting models could contribute to a better and more modern management of public health.

2. Materials and Methods

The prevention-based management of bathing waters entails the perfect knowledge of the territory, of possibly occurring environmental, meteorological and climatic conditions and the

water discharges present. As far as the knowledge of the territory is concerned, it is to be borne in mind that it cannot be acquired once and for all, but it has to be continuously updated. Nowadays, the actual knowledge can be obtained and updated through the periodic collection of images having a ground resolution of 1m, such as the images taken from the Ikonos satellite.

In order to detect in detail water discharges and the direction of their plumes in the different meteorological, climatic and tidal conditions, it is necessary to make use of flown multi-channel scanners or portable high-resolution IR cameras, since the satellites equipped with a thermal sensor besides providing for low-resolution thermal images do not have a revisit time compatible with the dynamics of the phenomena.

For this investigation an AVIO TVS 610 camera having a geometric resolution of 1.4mrad (at 100m it can show objects bigger than 14cmx14cm) and a thermal sensitivity of 0.1°C has been used. The images obtained are directly stored on a videocassette-recorder or a PCMCIA Compact Flash card, which allows their successive processing with a computer. Once the necessary documentation for the knowledge of the territory concerned has been gathered, it is possible to proceed with the investigation by using a flown IR camera, which permits to visualise the plumes present. In colour images plumes are visualised in a colour different from the one of the water body, into which they flow or in a different shade of grey, in black-and-white images.

The filming was carried out from an Agusta A109 helicopter, at 150-350m from the ground at about 60 knots.

The collection of data on wind speed and direction, on the tidal condition and direction of surface marine currents present when the shooting was carried out allows to relate the images to their causes: the repetition of the filmings when other conditions important for the single locations are given will provide for all the images and data that will make it possible to manage them in different conditions.

The *hydrographic district* envisaged by the proposed Directive will have to use the data available to manage the coastal area at best. Such district supposes the existence of a pyramidal structure with a person entrusted with the management and the Territorial Information System, which is the only way to permit an effective and timely management of a wide territory.

3. Results

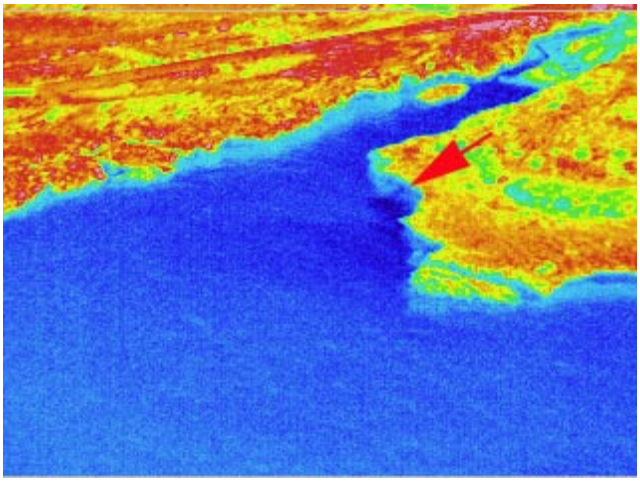
Some visual and thermal images are shown hereafter. They concern coastal sites near Brindisi (Apulia), taken on 16th September, 2000 during an investigation planned in the framework of the PRISMA2 programme. The filmings have been made with high tide, with NE wind at 5 knots; the surface marine current without wind tends to go towards the Ionic Sea, except differences due to the coast conformation.

From the aerial multi-spectral photograph shown in picture 1 it is possible to immediately understand the situation in the area adjacent to the Lama d'Antelmi canal, the outlet of which is shown by the arrow on top. Urban areas, coastal parcels, big farms present on the hinterland (the trees are mainly the monumental olive trees that make Apulia famous), road infrastructures, various waterways can be recognised. The arrow on the right bank of the Lama d'Antelmi canal shows the water-treatment plant of the nearby city of Ostuni. The big arrow on top indicates the North.

Picture 1. Aerial multi-spectral photograph of the area sorrounding the Lama d'Antelmi canal, the outlet of which is shown by the arrow on top. It is possible to recognise all the structures and features of the territory. The arrow on the right side of the canal shows a water-treatment plant The big arrow on top indicates the North

Picture 2 shows the outlet of the Lama d'Antelmi canal into the sea. In such canal the waters coming from the above mentioned water-treatment plant are usually discharged during autumn and winter. The relative thermography shown in picture 3 indicates how the plume rendered in dark blue moves to the right in the picture (NW), because of wind blowing from NE, and is pushed towards the shore because of the high tide. If the thermography is observed well, a small plume can be noticed. It originates in the point shown by the arrow: it is a submarine freshwater spring that has nothing to do with the canal.

Picture 2. The outlet into the sea of the Lama d'Antelmi canal



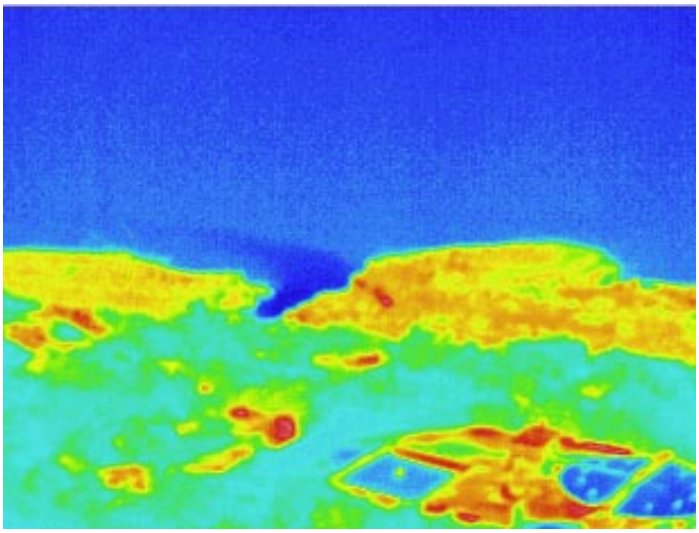
Picture 3. Thermography of the area shown in picture 2. The arrow shows a submarine freshwater spring. The blue colour of the two plumes allows to recognize how they are deviated by wind and the high tide present at that time

The thermography in picture 4 shows the presence of a plume near a watertreatment plant belonging to a holiday village nearby. The settling tank of such plant is shown at the bottom on the right of the image. This plume too moves towards NW and is pushed towards the shore. This is not, as it could be thought, the emissions of the above mentioned plant which are dumped a few hundred metres further down, but a submarine spring the existence of which was unknown also to the technicians tasked with the analyses of coastal waters.

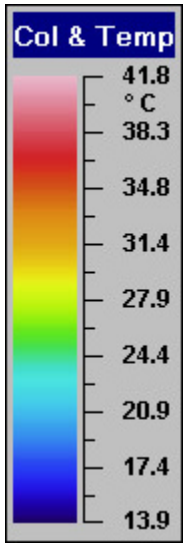
In the thermography in picture 5, the chromatic scale which allows to assess the different temperatures present in the thermal images is shown: almost all the thermographies have been taken in this temperature interval which is expressed in degrees Celsius. The more the colour at the bottom the lower the temperature.

The photograph in picture 6 shows the outlet (arrow) of the drainage canal of a protected area: in the background it is possible to see the ancient Guaceto Tower after which the oasis was named. The assessment of the thermography (picture 7) which was taken from a position opposite to the one from which the photograph was taken, indicates how the plume which is always pushed towards the shore because of the high tide has a direction opposite to that of the other emissions which have been revealed during the same flight and therefore in the same wind and tidal conditions.

The data obtained from the investigation have been considered very useful by those entrusted with the management of bathing waters so that pollution phenomena occurring along the beaches can be related to the causes that produced them. This also allows to take measures on the pollution source in order to try and eliminate it.

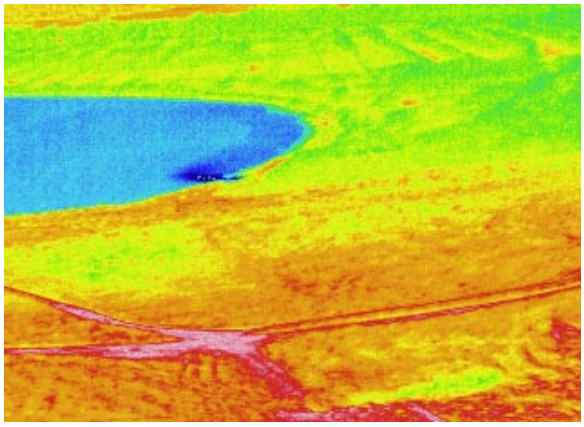


Picture 4. The thermography shows a plume flowing nearby a water treatment plant. It is not the emission of the plant but a submarine spring, unknown to the tecnicians tasked with the management of coastal waters. It is possible to see how the high tide pushes the plume towards the shore and the NE wind deviates it towards NW



Picture 5. Example of the cromatic scale which is present in each thermography. It allows to assess the different temperatures present in the relative thermal image. The more the colour at the bottom the lower the temperature

Picture 6. The arrow shows the drainage canal of a protected area. The thermography in picture 7 has been taken from a position opposite to the one from which this photograph was taken



Picture 7. This thermography reveals how this plume unexpectedly has a direction opposite to that of the other emissions, even if the wind and tidal conditions are the same

The detection of submarine freshwater springs in a bathing area is of great importance in the fight against the pollution of the beaches. In fact if there is the habit of inserting treated water in water tables as it happens in this area, if the water table is polluted, the whole beach where it comes out as a spring will be polluted. In the area under investigation there should be many of these springs because it is known that the Merchant Navy of the Republic of Venice drew potable water from such sources during their long voyages towards the East.

4. Conclusions

The analysis of the microbiological parameters which take tens of hours to be available even though it is very reliable is not the right system to grant a quick and immediate action in case of

pollution or contamination of the water, therefore there is the need to pass from an “a posteriori” management to a preventive one.

The new Directive proposed will grant at least the same actual level of protection for the environment and human health, but it intends to introduce innovative systems of investigation, in order to know the condition of the territory and to actually face pollution sources such as waste waters and farming waste.

The few thermal images taken from low altitude which are shown as examples confirm the big possibilities offered by the use of such investigation technique for the detection of water discharges of different origin and to check their impact on bathing areas.

It is hoped that the presence of many unknown submarine springs along the Apulia coast will stimulate the execution of a census, in order to take immediate action if the water table is polluted, considering the big anthropic pressure near the coast.

The introduction of the data in a Territorial Information System (TIS) will allow a more cautious management of bathing areas, thus permitting to forecast the situation that may occur in case of accidents or malfunctioning of plants and equipment.

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