10

Remote sensing techniques complementary to chemical and microbiological determinations in coastal water studies*

by

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Abstract

In the ambit of the Coastal Water Quality Control programme, in order to determine the behaviour of currents which affect the fate of plumes of discharges into the sea along the coast, chosen as monitoring area by the Istituto Superiore di Sanità, and near it, a series of surveys have been carried out. For this purpose, remote sensing apparatus has been used:

— a thermal scanner operating in the field 2,5 - 5,6 micron, equipped with cameras for black and white and colour photographs;

— a set of Hasselblad cameras for simultaneous shootings with the thermal scanner, both in the visible and in the "near infra-red" (photographic).

Together with these shootings from helicopters, a series of ground checks, both with dyes and the above-mentioned apparatus, have been performed to compare the methods.

The results archieved show the validity of the remote sensing techniques especially as regards the immediacy of results, both in the case of discharges into the sea and in the case of fortuitous but not rare oil spills.

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The Istituto Superiore di Sanità has chosen as sampling area for the research to be carried out for the MED VII programme the stretch of sea facing the beach known as "public beach of Castelporziano". This sandy beach — donated some years ago to the Comune of Rome — was fitted out with eight buildings (2 visible in figure 1) with changing rooms, public conveniences and showers, besides a supply of drinking water for drinking fountains and booths selling food and drinks, etc.

The sandy beach — between the coast and the sea — stretches for about 2 km and is bounded at either end by two drainage canals, one of which flows through some inland urban settlements before flowing into the sea, while the other originates from the presidential estate of Castelporziano. Figures 2 and 3 show the two canals, respectively that to the north and that to the south, called "Fosso del Tellinaro".

The researchers carrying out the chemical and bacteriological analyses of the water samples collected along the coast, with the aim of correlating better the results obtained with the environmental conditions, have realised the necessity of studying the area affected by the above drainage system by means of the observation of the behaviour of the "plumes" of the above outflows as they are formed by the various sea currents. This study is usually carried out with the help of dyes, and by following the course of the coloured wave (1), or more recently, by survey techniques carried out at a distance, i.e. with a thermal scanner.

With this brief report it is hoped to illustrate the use of this latter method in the case of the stretch of coast under examination, to demonstrate its validity also in relation to results previously obtained, to perceive its limitations, and to compare it with the method of visualization by means of dyes. It is also necessary to point out that the research has not been limited just to the above-mentioned stretch of public

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Pour des raisons techniques, les illustrations de cette communication n'ont pu être publiées.

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beach, but has been extended to nearby beaches which are also crossed by drainage canals and also much frequented in the summer season.

Before outlining the results obtained, a brief description of the apparatus used is given :

— A thermal scanner AGA THV (Camera Unit) sensitive in the range of wavelength 2 - 5,5 micron, which collects the infra-red radiation emitted by an object and focuses it on a detector (Indium Antimonide cooled by liquid nitrogen) which transforms it into an electric signal.

— A display unit with a function similar to that of a television, which receives these signals and visualizes on its screen in continuous grey-tone (from black to saturated white), the thermal image taken by the camera unit. This is in "real time" as the apparatus is capable of 16 exposures a second.

— A colour slave monitor which produces the same pattern quantized, both in "mono" (quantized grey-tone) and in colour (2). The quantization consists of the subdivision of the pattern into different levels of temperature (ten) marked by the same number of colours recorded on a reference scale at the bottom of the thermal picture (as in the case of grey-tone). This representation is particularly useful in the case of "plumes" which are crearly recognizable, more so, in this case, than the pattern in black and white which is often less sharp and which also deteriorates in the subsequent printing process (For this reason, using previous experience, often only the colour photo of the infra-red image is reproduced). Each of the two monitors is equipped with a motor-driven camera with a 250-exposure magazine, able to take up to four photos a second.

— A group of four cameras, Hasselblad EL/M 500, remote-controlled and equipped with 500-exposure magazines ; films used have been TRI X Kodak 400 ASA, Kodak Vericolour II 100 ASA and Kodak Aerochrome Infra-red 2443 (estar base) with filters Wratten 12 or 15 according to the developing process (3).

The use of the films in the visible spectrum is justified by the necessity of having to identify immediately the relevant area and then having to reconstruct it with the photos of the infra-red images. The Aerochrome Infra-red film was used because it is sensitive within the range of wavelength which goes from the visible up to about one micron (almost contiguous to the thermovision range) and can sometimes provide information supplementary to what is recoverable in the thermal infra-red. Prevailing in the so-called photographic infra-red is the radiation reflected from the body under examination which depends on the presence of a striking radiation (solar light, special lights, etc.). In the thermal infra-red however, what prevails is the radiation emitted directly by the body being examined and which depends on the temperature and on the emittance of the body itself. The latter quantity is expressed by a number < 1 and it tells us by how much the behaviour of a body deviates from that of the black body, this being a body capable of giving out all the radiation which it absorbs (and it has therefore an emittance of 1) (4).

The best operating conditions for the thermovision would therefore be in darkness, that is in the absence of reflected radiation, but for obvious practical reasons one works with diffuse lighting : dawn, sunset or cloudy conditions.

Some examples will now be given of infra-red teleimages as realized on previous occasions.

These photos were taken from aboard the Europa 2 Blimp of Goodyear, the first three at night and the fourth by day. One sees how it is possible to follow the "plume" until it merges completely with the sea, which absorbs it. This is particularly clear in Fig. 7 which, on the basis of the scales of grey-tone and of the colours at the bottom of the thermal picture, tells us also that this inflow (originating from the nearby hills) is distinctly colder than the sea-water.

The following photos refer to the object of this report and were taken during the period March 1978 to April 1980 from aboard a militar helicopter AB 204, from a height of 180 metres in the early hours of the morning. As can be seen from Fig. 8, utilising the structure supporting the auxiliary fuel tanks, on the outside of the helicopter, a container of inox steel was fixed, devised to contain the cameras and to support the thermovision camera. The sturdiness and weight of the container, plus its position in the barycentre zone of the helicopter, almost totally counteracted the vibrations which could disturb the photo-taking.

Fig. Nos. 9 and 10 reproduce in the visible spectrum, in black and white and colour the canal called "Fosso del Pantanello" which bounds to the north the public beach under examination. The simultaneous photo of the image in infra-red (Fig. 11) shows how the canal (red) flows into the sea (blue, green) in a thin layer above the sand (golden yellow) which accumulated at the outlet during a previous high tide. In this case the plume is almost non-existent as the sand at the outlet slows down the flow of the inflow which, as one can see (coloured red), is distributed along the beach above and below the actual

outlet. The scale of colours clearly shows the progress of the temperatures which vary from the lowest (blue-light green) of the sea-water to the highest (white) of the dry sand.

Photo No. 12, in black and white, shows the canal called Fosso del Tellinaro, which bounds to the south the stretch of public beach. It shows how, when the shot was taken, the course of the canal was almost invisible, so that the simultaneous infra-red shot was meaningless.

Figures Nos. 13, 14 and 15, simultaneous shots, show the canal "Fosso di Pratica". From the colour photo of the image in infra-red (No. 15) one can see clearly the plume of the drainage canal (both in red) which diffuses into the colder sea-water (light green), and, owing to the current, is distributed mostly towards the north, and only a little to the south. These types of canals which flow into the sea across sandy tracts often modify the form of their outlet according to the sea currents which touch it, in such a way as to make its own current, usually not strong, flow in the same direction as that of the sea. This is illustrated in the preceding three photos, and even more clearly confirmed in the next three photos nos. 16, 17 and 18 of the "Fosso Grande". In the colour photo of the infra-red (No. 18) the golden yellow and full-red stains near the outlet in the sea represent the area of wet sand which one can see clearly in the photos in visible black and white and colour. Their temperature is in fact intermediate between that of the dry sand (white) and that of the plume (lighter red) whose behaviour, distribution and merging with the sea-water (green-light blue) is clearly described by the lighter red colour and its various hues. As regards the reference scale at the bottom of the thermal picture it must be pointed out that its value increases from right to left. This is due to the fact that the photo must be reversed in the printing process in order to correct the inversion due to the mirror placed between the thermovision camera (horizontal) and the image to be photographed (on the vertical).

For a comparison between the data obtained with the thermovision and those obtainable by means of the previously mentioned method of dyes, in the "Fosso di Pratica" and the "Fosso Grande" some tests were carried out using Rodamina B, the dye utilized most in these cases. The substance was added to the two canals, a little above the beach, about thirty minutes prior to the passing of the helicopter (photos A, B, and C). As one can see also from photos D and E, taken at ground level, the dye is dispersed along the whole beach by the movement of the waves, mainly following the direction of the sea current.

With the lapse of time, this diffusion moves offshore and not only in that direction, affecting the whole zone in front of the outlet, carried alos against the current probably by the movement of the waves and complex factors of diffusion. It is clear that at this point one cannot deduce the final course (the fate of the plume) taken by the plume of drainage.

Besides the advantages of not having to wait the necessary time for diffusion, of giving an immediate result (as has been pointed out the image appears on the screen in real time and can also be photographed with a polaroid), of not requiring personnel on land, of reducing considerably the flight time, thermovision has the particular characteristic of being able to "see" the plume owing to certain physical properties — temperature and emittance — and be able to follow its course until these properties, progressively diminishing, equalize those of the recipient body (the system at room temperature, is able to reveal differences of 0.1° C.

The dye, however, is visible in the water as long as its concentration is greater than the perceptable minimum. Not being able however to define the necessary quantity, one tends in general to exceed the amount to ensure easy detection.

Even thermovision has its limitations, such as the difficulty of use in case of rain, alteration of results in case of heavy insolation or of phototaking from too high an altitude. It was also seen that after a period of rain sufficient to minimize the difference in temperature between the inflow and the recipient water mass, or when there is for various reasons an equal turbidity in the two, the use of thermovision is almost useless or superfluous. In these circumstances, mud and debris, carried along by the water which flows into the sea or a lake, are the best indicators of the course of the plume. This is illustrated in Figures 24, 25 and 26, photographed, after heavy rain, on Lake Bolsena from 500 m altitude, with normal films in black and white and colour for the first two, and with Kodak Aerochrome Infra-red film 2443 (false colour) for the third, which in fact adulterates the colours of the objects.

With the aid of thermovision, it was possible to identify on the surface of the sea, stains formed by hydrocarbons. Figs. 27 and 28 represent respectively the photographs of a vast oil slick (discharged by the tanker Vera Berlingieri, sunk off Civitavecchia) located at 24 miles/280° (centre of geographic co-ordinates is Pratica di Mare heliport) photographed from aboard a helicopter AB 205 of the Carabinieri, and the photograph of the oil that is flowing out of a tanker during unloading.

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