A DIFFUSING PATCH OF RHODAMIN ANALYSED BY DIGITIZED AERIAL PHOTOGRAPHY

J. Citeau and J. Noel
Office de la Recherche Scientifique et Technique Outre-Mer,
70, Route d'Aulnay, 93140 Bondy, France.

Abstract: In order to study the spreading of waste water near the shore a number of diffusion experiments were carried out by releasing a patch of Rhodamin B, at one kilometer off the coast, for a better knowledge of mixing coefficients in surface sea water at the South of Abidjan. A preliminary analysis of aerial photography of Rhodamin diffusion has shown that digitizing photography allows a check of different terms in diffusion equation; the evaluation of the transverse mixing coefficient is possible and simple and the decrease of the concentration peak can be observed. On the other hand, in the wind's eye the vertical stratified flow leaves the evaluation of the longitudinal mixing coefficient in its whole complexity.

1. INTRODUCTION

The evaluation of mixing coefficients, or diffusivity coefficients, has been and remains for oceanographers a critical exercise. To be convinced, it is enough to consider the existing models of diffusion that, in fact, cover the whole scale of turbulent processes in the ocean.

It is probably from that complexity that the need arose for experimental determinations of diffusion parameters by the release of dye tracers (Rhodamin B), the spreading of which could allow a more precise evaluation of mixing process. This is the case for the experiments reported here, which were undertaken at the request of the Ivory Government in connection with the selection of a site for the outfall into the sea for the main sewer of Abidjan.

In this kind of project the use of remote sensing techniques, instead of collecting data at the surface of the sea, possesses several advantages, without abandoning the principle of making quantitative measurements. It allows an evaluation of the extent of mixing, with more precise results and sometimes using simpler experiments.

2. METHOD

An instantaneous release of a conservative dye tracer (rhodamin B) is done at the surface of the sea which is assumed to be homogeneous in density and flow.

In order to describe analytically the process, we take the centre of the patch as the origin of coordinates which is assumed to move with the speed of the upper homogeneous layer horizontal velocity. In the Lagrangian axes that are defined (with the abscissa Ox parallel to the horizontal velocity), the diffusion equation reduces to a simple form which allows integration. With the usual notation, C indicating concentration and M the whole mass of dye, the solution is

$$C\,(x,\,y,\,z,\,t) = \frac{2M}{\sqrt{(4\,\pi\,t)^3\,.\,K_x\,K_y\,K_z}}\;\exp\left(-\frac{1}{4t}\left(\frac{x^2}{K_x}+\frac{y^2}{K_y}+\frac{z^2}{K_z}\right)\right). \qquad (1)$$

K_x, K_y, K_z are the diffusivity coefficients along different axes and are assumed to be constant locally (Fickian model).

The computation process for the transverse mixing coefficient K_y (Quentin, 1976) is as follows. The advance of the rhodamin front is followed along the Oy axis and this front is assumed to have the same concentration in the early stages of the

With aerial photography, the width (2y) of the rhodamin patch can be measured; in order to take into account the vertical integration of dye by the eye or by the sensing film, the final and more accurate relation involving t_1 and t_2 is

$$K_y = \frac{y_1^2/t_1 - y_2^2/t_2}{4 \log t_2/t_1} \quad . \qquad (2)$$

In theory, it would be possible to make the analogous computation for K_x.

Without going into more details here about the computation of mixing coefficients, we note that it was shown (Schott et al., 1978), with similar experiments and quite isotropic conditions in the upper mixed layer, that a statistical evaluation of the equivalent mean radius of the patch leads to a similar formula.

3. RESULTS

Six experiments were carried out, south of Abidjan, in shallow waters (bottom depth at 50 m), under different weather conditions.

Each time an experiment was done, a glass container of 30 l of rhodamin, with density adjusted to sea-surface density, was broken at sea, to leeward of our ship, with the engine stopped. Aerial photographs were taken over the dye patch during a two-hour period and crossings of the patch were done at the end of the experiment for sampling water. The aircraft must be kept horizontal during photography and the flight altitude must be selected so to cover the whole patch in a single photograph.

Interpretation of the photography has been done by obtaining the true scale of each pass and by measuring the width of the patch in the best possible conditions of contrast and light.

The numerical determination of the transverse mixing coefficient, which was explained previously, was done. The results were poor (lack of precision, negative value ...).

It is necessary to mention that the formula in equation (2), in this model, is valid if the relative growth of the patch is less than the relative growth of the square root of time.

Unsuccessful attempts were made at smoothing the data of patch width versus time and these unreliable results led us to check the different terms in the equation of diffusion by digitizing photography.

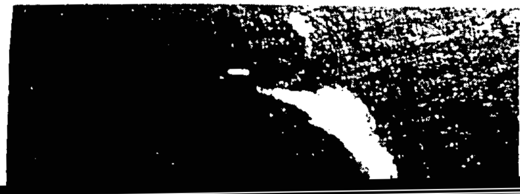
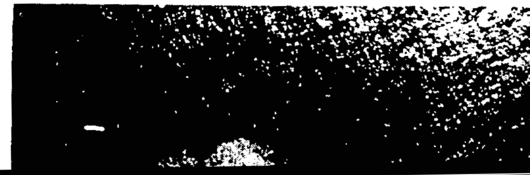
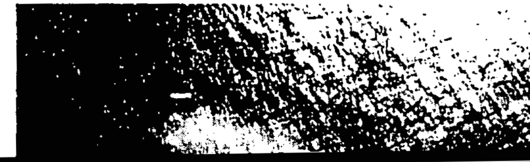
4. REMOTE SENSING TECHNIQUE APPLIED TO A PHOTOGRAPHY ANALYSIS

The processing of selected photographs is done by a densitomer with a resolution of 25 µm, scanning line by line the relevant proportion of the photograph. Optical densities are eight-bit coded (0-255) and stored on tape with a format similar to those of satellite data tapes.

By processing on a colour screen (a PERICOLOR screen which allows the representation of a matrix of 256 x 256 pixels), it is quite easy to distinguish "sea-class" and "rhodamin-class". In order to calibrate and compare successive photographs, it was necessary to know the mean value of the optical density of the rhodamin-free area. That value corresponds to the low values of grey on the negative film and the PERICOLOR device has been developed in such a manner that integration of zones, the value of a pixel, histograms or smoothing are really easy to obtain; "ground noise" is also corrected.

In the rhodamin class area, a linear classification was done. After that for each class a color was defined. The results show a uniform blue color for sea and selected colors for homogeneous rhodamin concentration (Figure 1).

Coming back to our numerical determination of mixing coefficients, measurements were done either on the Benson graphic output or using a spot marker device on the PERICOLOR screen, and the true scale was obtained by the photography on each scene of a long floating and linear device of known length (ten meters). Preliminary

results of the numerical determination of the transverse mixing coefficient seem to be a good application of this particular diffusion equation, controlling computation hypothesis. The small amount of data does not allow us to obtain a satisfactory result; nevertheless, referring to similar work (Schott <u>et al</u>., 1978), precise and reproducible values of the mixing coefficient K_y can be expected from a whole data series. On the other hand, numerical integration of the diffusion equation is necessary to obtain K_x, along the eye wind, due to vertical velocity stratification.

5. DECAY OF THE PEAK OF RHODAMIN CONCENTRATION

Calibration can be undertaken between optical densities and the true values of the concentration. Observation of the decay of peak concentration can be followed on processed photographs. The formal way, consisting of sampling the water, introduces turbulence due to ship propellers and is too long for gaining a real synoptic view.

The experiment was designed to investigate what would become, at sea, of an outfall of sewage water under dilution and bio-degradation processes. These two effects can be analyzed separately (Citeau and Pages, 1979) and the observation of