

## **Evaluation of Sewage Outfalls by Using Tracer Techniques Combined with Oceanographics Measurements**

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### **Abstract**

Combined techniques have been successfully used in order to evaluate the Ipanema's sewage submarine outfalls dilution patterns. The oceanographic measurements were carried out during one full year. Sea current measurements were made by an acoustic doppler current profiler (ADCP) and vertical temperature profile time series by thermistor strings deployed near the diffusers. Field campaigns using fluorescent dyes were carried out for covering stratified and non-stratified oceanographic conditions.

The acoustic doppler current profiler and thermistor strings were home programmed based on the number of profiles, sampling time, and precision constraints.

Uranine and Amidorhodamine G were simultaneously injected in the outfall's pipeline during 6 to 8 hours by a continuous injecting device and detected at different depths in the receiving coastal water.

These combined studies for evaluating the dilution pattern of effluent in the sea water provided valuable data for calibrating and validating the hydrodynamic and water quality model.

## **1 Introduction**

Aiming one effective evaluation of dilution capacity of the Ipanema's sewage outfall, a complete and integrated monitoring program has been developed. Such study were carried out including the following points:

1. A careful program for adequate oceanographic data gathering.
2. Monitoring of physico-chemical parameters in the near field.
3. Monitoring of the real dilution conditions by using dye tracers in specific oceanographic conditions.

## **2 Oceanographic data measuring program**

The oceanographic measuring program included measurements of the vertical temperature profile and measurements of the sea current near the diffusers. For this study, one Acoustic Doppler Current Profiler (ADCP) and one thermistor string were used. The thermistor string is composed of 11 sensors equally distributed over the water column, at the depth of 28 m. The ADCP was home programmed in order to measure 9 layers over the water column. Both equipment were deployed for one full year, between December 1996 and November 1997, and setted up for gathering data every half an hour.

The analysis of the obtained data allowed to establish some important points, that lead to a better understanding of the submerged plume:

- The higher temperature differences between the surface and the seabed, occurred during the summer (December till March), reaching 10 °C in some situations. The lower differences were monitored in June, July and August, showing a water column practically non-stratified, with temperature gradients lower than 1 °C.
- Statistical analysis has shown a homogeneous water column, without considerable stratification due to thermal gradients in more than 80 % of the studied period of time. These results indicate that the use of bidimensional water quality models should be adequate.
- The current intensity, near to the diffusers, is lower than 20 cm/s in 78% of the time near the water surface and 80% near the bottom.

- The predominant current directions occurred with azimuths of  $60^\circ$  and  $240^\circ$ , parallel to the coast at the Ipanema's Beach. Figure 1 shows a summary of the data measured between December 1996 and November 1997.
- The spectral analysis shows that local circulation patterns are strongly affected by meteorological events, as cold fronts, mainly at the levels close to water surface. However, at the bottom the circulations patterns are governed by tide influence.

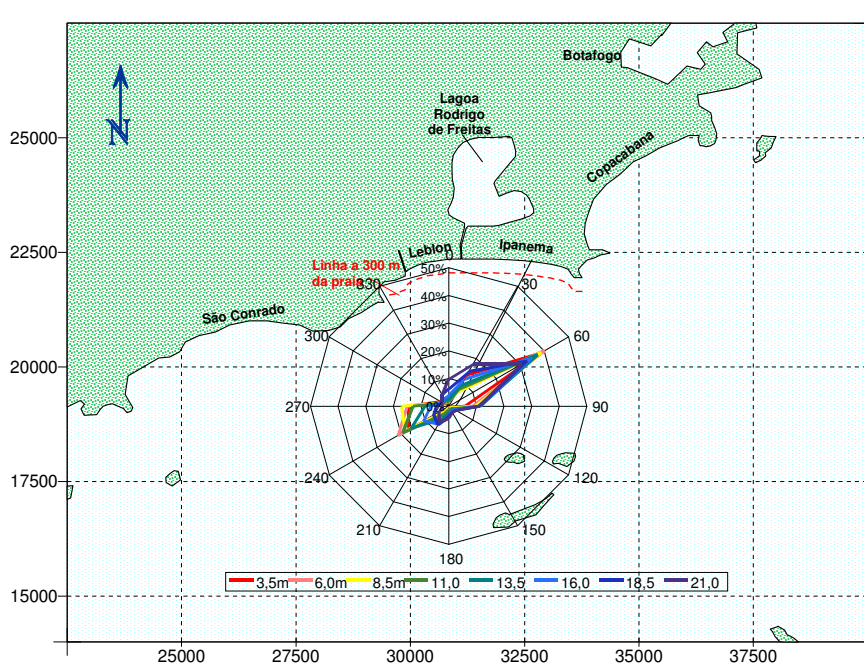


Figure 1: Dominance statistics for the current direction in different depths, from December till November 97.

Regarding the water column temperature stratification, it is important to note that stratified and non-stratified conditions do not depend exclusively on seasonal conditions. Such conditions depend also on meteorological events. One such situation can be observed in the Figure 2. This figure represents the vertical temperature profile time series for April 1997, in a place near the diffusers.

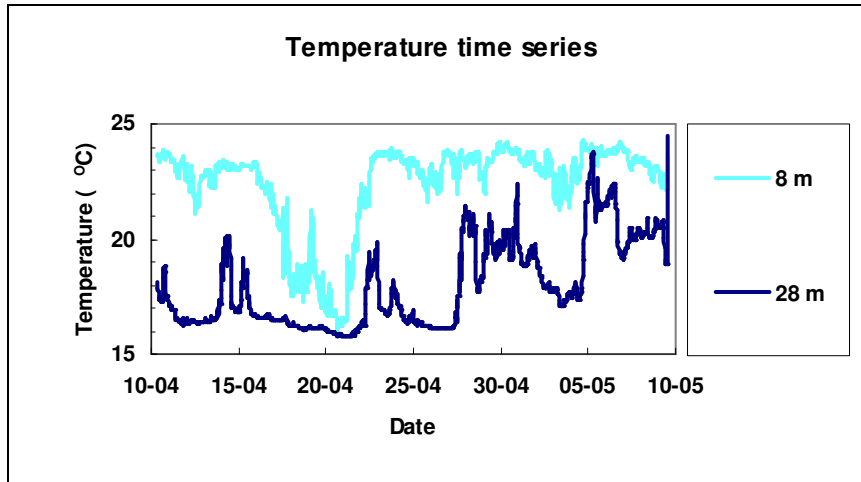


Figure 2: Time series for the upper and lower layer temperature during April 1997, showing stratified and non-stratified conditions.

### 3 Monitoring of physico-chemical parameters

During the dye tracers field campaigns, singular points were chosen in order to carry out vertical profiles for the parameters temperature, D.O., turbidity, conductivity, salinity and pH.

The measurement procedure includes also sample collecting activities in order to evaluate the tracer's vertical profile at the selected points.

The Figure 3 and 4 show the vertical profiles for both dye tracers, for temperature and for dissolved oxygen.

### 4 Monitoring of the dilution factor by using dye tracers

The field campaigns for evaluating the sewage outfall's dilution capacity, by using fluorescent dyes (Ref. 1) were carried out both in "typical summer conditions" (with stratified water column) and "typical winter conditions" (with homogeneous temperature over the water column and good mixing conditions).

In order to label an effluent which is continuously released into the sea, the tracer solution introduced in the pipeline should be continuously injected at a well known concentration and flow rate. The injection time was between 6 and 8 hours. A simple device that fulfills these needs uses a dilution barrel with an electro-mechanical stirrer and a peristaltic pump. The injection rate is around 1 liter/min and the tracer concentration lies between 5 and 10 %.

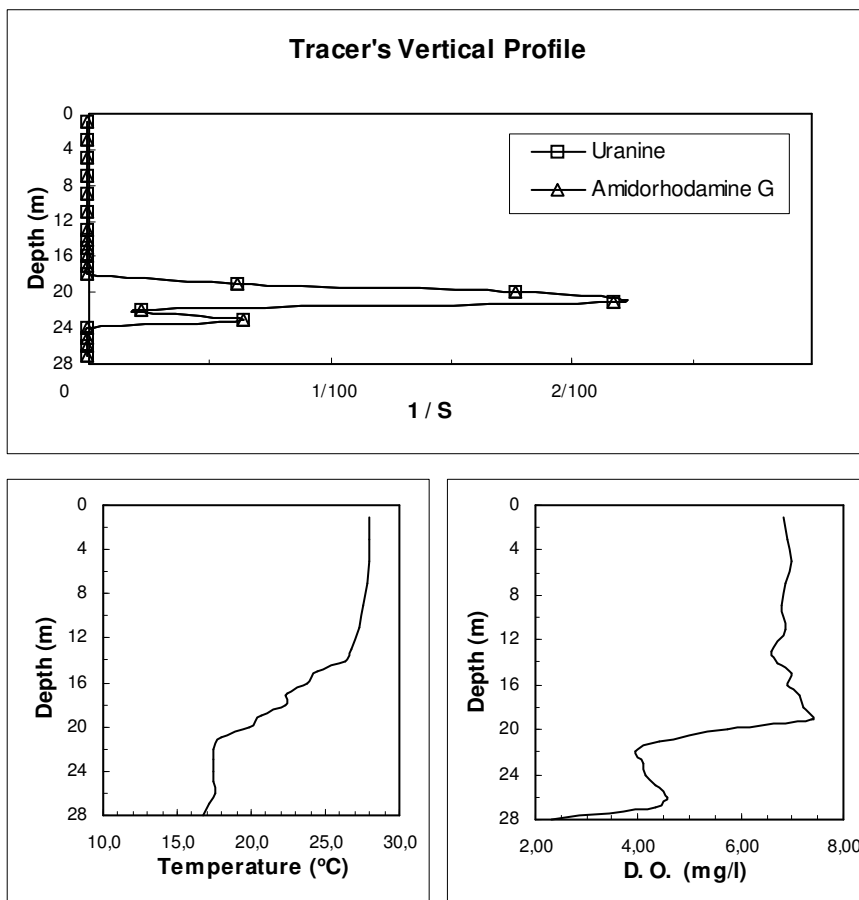


Figure 3: Vertical profile for dye tracers, temperature and dissolved oxygen during the stratified condition field campaign.

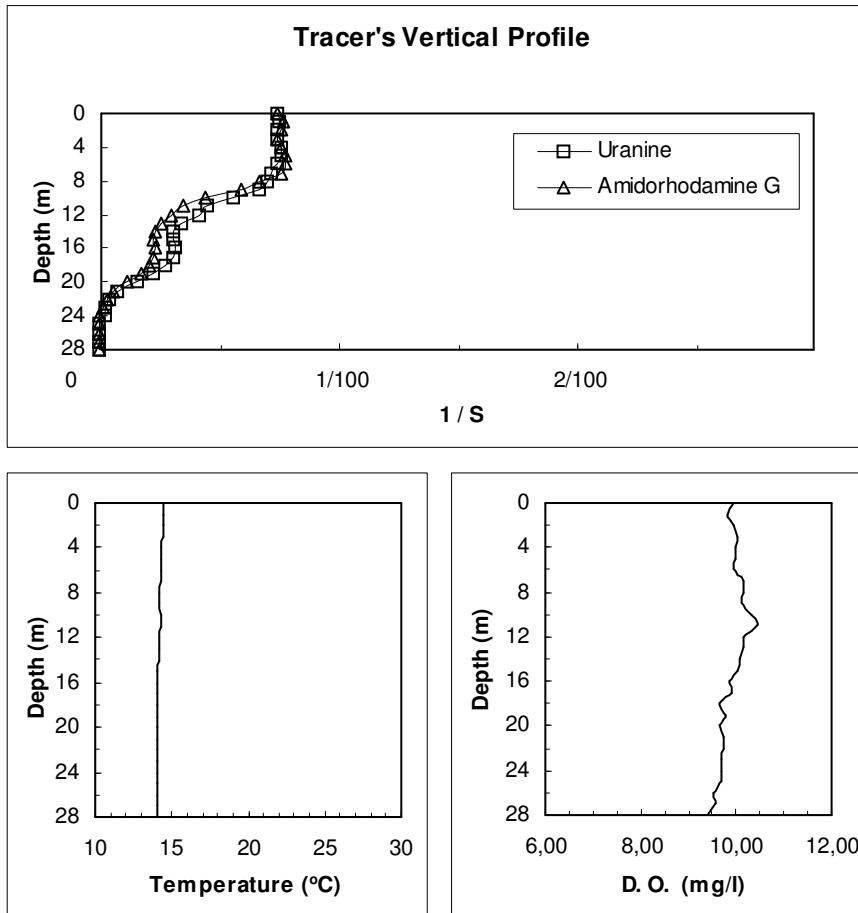


Figure 4: Vertical profile for dye tracers, temperature and dissolved oxygen during the non-stratified condition field campaign.

The mean tracer concentration of the labeled effluent was obtained when a proper sampling program is established at a point sufficiently away from the tracer injection site.

The definition of “dilution factor” is given by:

$$S = \frac{\text{mean tracer concentration in the effluent}}{\text{tracer concentration in the sea}}$$

The comparison between the tracer concentration in the pipeline and the tracer concentration for every sampling point allows the construction of a affected area map, in terms of the dilution factor (Ref. 1).

Such maps allowed to estimate the contaminated area for the 3 lower dilution factor ranges. The affected area values for the winter campaign are showed in the table below.

Table 1 : Affected area as a function of dilution factor range for the non-stratified conditions campaign with dye tracers.

Sea current direction	Depth (m)	Dilution Factor Range		
		30 a 50	51 a 100	101 a 200
West → East	4	zero	zero	0,107 km <sup>2</sup>
	7	zero	zero	0,021 km <sup>2</sup>
	10	zero	zero	0,001 km <sup>2</sup>
East → West	2	zero	zero	0,215 km <sup>2</sup>
	4,5	zero	zero	0,103 km <sup>2</sup>
	6,5	zero	zero	0,030 km <sup>2</sup>

During the study, four field campaigns using dye tracers were carried out. Two campaigns in typical summer conditions (stratified water column) and two campaigns in typical winter conditions (non-stratified water column). For each one of these campaigns, water samples were taken simultaneously in 3 different depths.

The Figure 6 shows the plume obtained from the tracers campaign for west-east sea current conditions, with a homogeneous water column, in “typical winter conditions”.

Figure 6 shows that dye tracer flows in direction parallel to the coast, governed by the currents at the low levels of the water column. As mentioned before, the circulation patterns close to water surface, strongly influenced by local winds, do not interfere on the circulation close to the bottom, as shown in Figure 5.

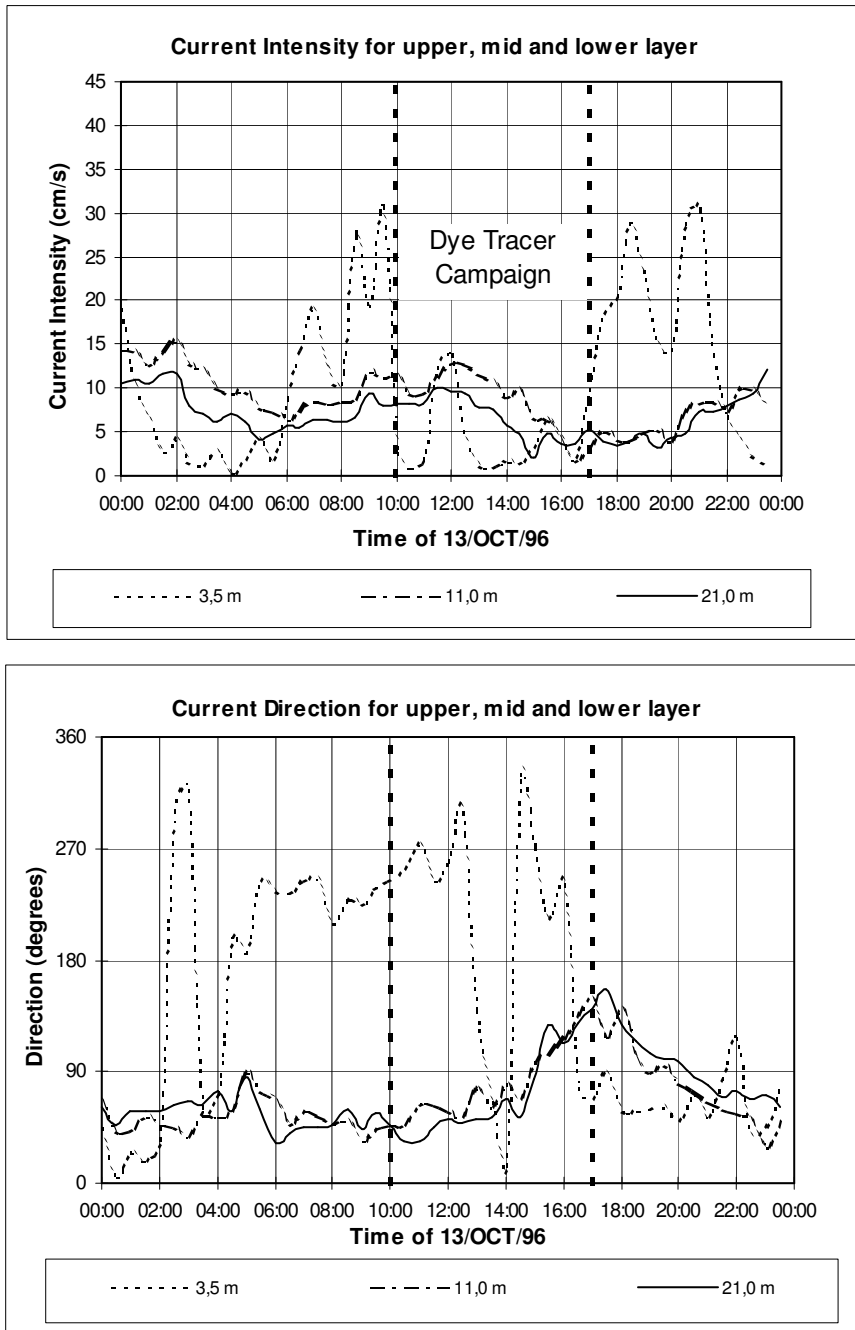


Figure 5: Current intensity and direction in the near field during the dye tracer field campaign, showing current from SE-NE.

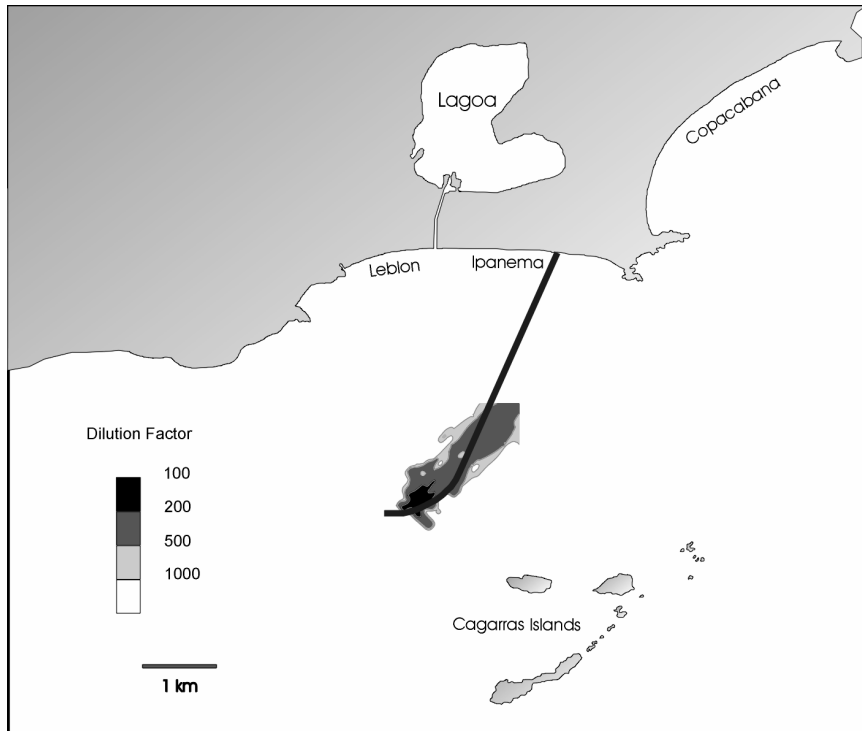


Figure 6: Contamination plume as measured with dye tracers at depth of 4 m, with *SE-NE* sea currents and non-stratified water column.

## 5 Conclusions

- The oceanographic program carried out between December 1996 and November 1997 showed that the predominant sea currents are parallel to the shore at Ipanema's Beach. The higher intensities are associated to meteorological events showing coherence with cold fronts.
- Sea currents in the beach direction are uncommon, with low intensity and short duration.
- Water quality models that consider the effluent mixed in a wide range of the water column (weak stratification or completely homogeneous), are adequate to simulate the effluent transport and dilution, as the field measurements has shown a water column nearly homogeneous during 80 % of studied year.

- As expected, the preferential effluent transport direction, as measured with fluorescent dyes, has perfect agreement with the sea current direction.
- The tracer vertical profile showed good agreement with the temperature and dissolved oxygen vertical profiles, presenting the same tendency. During a stratified condition, and so poor mixing conditions, the plume trapping level could be inferred from the temperature profile.
- During the winter conditions campaigns, the minimum dilution factor for the 3 monitoring depths presented approximately the same value, in agreement with the good mixing conditions expected for a homogeneous water column.

## References

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