Water and Wastewater Monitoring of Guia Submarine Outfall – an 11 year survey

Cristina Santos[i], Justina Catarino[ii], Zélia Figueiredo[iii], Sandra Calisto[iv], Eugénia Marques[v], Pedro Cunha[vi] e Margarida Antunes[vii]

Keywords**:** *monitoring program, urban wastewaters, receiving waters, submarine outfall*

ABSTRACT

SANEST is a public sanitation company that manages a wastewater treatment plant located at Guia, on the west coast of Lisbon, Portugal. This company collects and treats the sewage of four municipalities with an estimated 750 000 population equivalent, thus being one of the biggest sanitation companies in Portugal.

A Decision of the Commission 2001/720/CE conceded SANEST derogation, exempting it to apply less than secondary treatment to wastewaters discharged into the Atlantic Ocean from the four agglomerations. This decision was supported on a large monitoring program, presented to the EU, and set up by SANEST. It surveys the impact of the effluent disposal and includes measurements of physical, chemical, biological and microbiological properties in the effluent and in the receiving waters. This paper presents methods and results for the effluent chemical and microbiological quality as well as for the receiving waters and an ichthyofauna survey, and resumes an eleven year situation, with the preliminary wastewater treatment before effluent disposal. The WWTP results correspond to medium load urban effluents without treatment with temporal variability related to flood fluctuations. In the receiving waters almost legal values are respected and the plume of the outfall is only identifiable by faecal bacteria in the vicinity of the discharge.
The fish community, in particular benthic species, has revealed a slight degradation probably due to the fact that pollutants tend preferentially to accumulate on sediment.

The treatment plant is being upgraded to fulfil, by May 2009, an advanced primary treatment level that includes disinfection during the bathing season to fully observe the European Commission Decision 2001/720/EC.

[i] Cristina Santos (Mrs.) Biologist, Instituto Nacional de Engenharia, Tecnologia e Inovação. Estrada do Paço do Lumiar, nº 22, 1649-038 Lisboa, Portugal cristina.santos@ineti.pt

[ii] Justina Catarino (Mrs.), Environmental engineer Instituto Nacional de Engenharia, Tecnologia e Inovação. Estrada do Paço do Lumiar, nº 22, 1649-038 Lisboa, Portugal

[iii] Zélia Figueiredo (Mrs.), Chemical engineer, Instituto Nacional de Engenharia, Tecnologia e Inovação. Estrada do Paço do Lumiar, nº 22, 1649-038 Lisboa, Portugal

[iv] Sandra Calisto (Mrs.), Environmental engineer, Instituto Nacional de Engenharia, Tecnologia e Inovação. Estrada do Paço do Lumiar, nº 22, 1649-038 Lisboa, Portugal

[v] Eugénia Marques (Mrs.),Microbiologist, Instituto Nacional de Engenharia, Tecnologia e Inovação. Estrada do Paço do Lumiar, nº 22, 1649-038 Lisboa, Portugal

[vi] Pedro Cunha (Mr.), Biologist, Instituto Nacional de Engenharia, Tecnologia e Inovação. Estrada do Paço do Lumiar, nº 22, 1649-038 Lisboa, Portugal

[vii] Margarida Antunes (Mrs.) Biologist, Instituto Nacional de Engenharia, Tecnologia e Inovação. Estrada do Paço do Lumiar, nº 22, 1649-038 Lisboa, Portugal

1. INTRODUCTION

The hydrodynamic conditions of the western coast of Portugal, which result from tides, wind and coastal density currents associated to wind wave action, are among the most favourable of European coastal waters for dilution and dispersion of waste water. Classified as less sensitive area by INAG (Portuguese Water Institute), it is a convenient zone for the location of a submarine outfall.

SANEST is the operator company responsible for the management of a wastewater system that includes a 25 km long trunk sewer, an underground treatment plant and a 2.8 Km long submarine outfall discharging at 40 m depth. The outfall operates since 1994 and discharges in the Atlantic Ocean approximately 170000 m^3 per day of an urban effluent. The system supplies sanitation to about 720000 inhabitants equivalent (I.E.) of four municipalities on western Lisbon region, expecting to reach 920 000 inhabitants in 2020, thus being one of the biggest sanitation companies in Portugal.
The urban wastewater undergoes a preliminary treatment which includes a step-screen to remove solids (<3 mm) and a grit removal prior to the disposal.

This solution contributed to depollute the beaches of Estoril coast, on the west coast of Lisbon, Portugal, but didn't comply with the 91/271/CEE Directive on urban wastewater treatment. Nevertheless, in 2001 a Decision of the Commission 2001/720/CE conceded SANEST derogation, exempting it to apply less than secondary treatment to wastewaters discharged into the Atlantic. This decision was supported on a monitoring program presented to the EU, and is also linked to the fulfilment of certain requirements on the discharged water quality: an advanced primary treatment, followed by disinfection during bathing season (1st June – 30th September) which will be fully observed by May 2009.

To fulfil the requirements of the EU decision and of the Discharge Licence mandatory for all portuguese sanitation systems, SANEST undertook a very detailed Environmental Monitoring Program (Paulo-Martins *et al*, 2006). This paper resumes the results of an eleven year monitoring program, carried out by Instituto Nacional de Engenharia, Tecnologia e Inovação (INETI) a state independent institute and mention not only the quality of receiving waters that surround Guia submarine outfall but also the wastewater characterization and the ichthyofauna survey

Sampling and analytical work was carried out by the INETI team.

2. METHODOLOGY

2.1. Wastewater

From 1997 to 2007 wastewaters have been monthly monitored based on daily composite samples taken with a refrigerated automatic sampler (Fig.1). Table 1 shows physical, chemical and microbiological parameters reported in this paper and the correspondent analytical method. These analyses took place at INETI accredited laboratories according to NP EN ISO/IEC 17025:2005. Anionic surfactants, AOX, F-RNA bacteriophages, heavy metals and other elements, oils and greases, hydrocarbons, organochlorine pesticides, PAH, PCB, pH, total suspended and dissolved solids, total phosphorus and toxicity (Test Daphnia, Microtox and Lemna) were also analyzed in the wastewater.

Table 1 – Parameters and methods for wastewater evaluation

Parameter	Method
BOD_5	ME 200_27 (manometric)
COD	NP 4329
Ammonium	NP 4319
Kjedhal nitrogen	NP EN 25 663
Nitrate	ME 200_24 (SFA)
Nitrite	ME 200_24 (SFA)
Total and faecal coliforms	ISO 9308-1:2000
Escherichia coli	ISO 9308-1:2000

NP – Norma Portuguesa (Portuguese Standard); **ME** – In-house method (INETI); **SFA** – Segmented Flow Analysis; **ISO** – International Standards Organization

Graphical analyses of data were performed and results were compared with typical composition of untreated domestic wastewater, according to Metcalf & Eddy (2003).

Figure 1- Guia WWTP External view and refrigerated automatic sampler

Flow rate data was furnish by technical personal from the WWTP.

2.2. Receiving Waters

From a large pack of sampling stations (Paulo-Martins *et al*, 2006), three were selected to cover the eleven years survey - stations 1, 8 and 14 (Fig. 2). The location of these points meets the terms of INAG guidelines, a portuguese baseline document, that rules monitoring submarine outfalls (INAG Guidelines, 1998) – one over the outfall (station 8) the others in a mile east (station 1) and west (station 14) from the outfall. Samples were taken with Niskin bottles and analysed in order to monitor percent saturation and chlorophyll *a* in summertime (July) and nitrate and transparency in wintertime (November). Faecal coliforms were evaluated in both seasons.

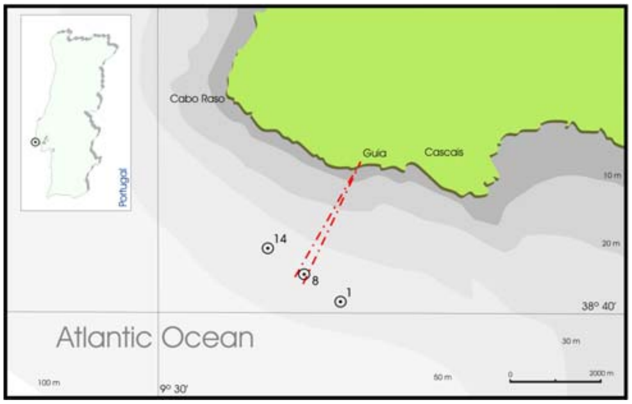

Figure 2 – Location of the 3 selected sampling stations.

The analysis processes took place at INETI accredited laboratories, according to NP EN ISO/IEC 17025:2005, Table 2 lists the parameters and the method for each one.

Table 2 - Parameters and methods studied in the receiving seawater

Parameter	Method
Transparency	Secchi disc
Dissolved Oxygen	NP 733
Nitrate	ME 200.24 (SFA)
Chlorophyll *a*	SMEWW 10200
Faecal coliforms	ISO 9308-1: 2000

SMEWW – Standard Methods for the Examination of Water and Wastewater; **NP** – Norma Portuguesa (Portuguese Standard); **ME** – In-house method (INETI); **SFA** segmented flow analysis; **ISO** – International Standards Organization.

Microbiological results were compared with referenced values (Guide and Mandatory) proposed by the 76/160/EEC Directive and chemical ones with INAG Guidelines for less sensitive receiving waters (Table 3). This document points out four parameters and their limits in summertime and wintertime with the objective to control eutrophication occurrence in coastal waters.

Table 3 – Reference values for surface waters, from Directive 76/160/EEC and INAG (1998)

Parameter	Bathing Waters Directive 76/160/EEC		INAG Guidelines
	Guide value	Mandatory Value	
Transparency	1	2	>2m, in wintertime
Dissolved Oxygen (Percent saturation)	80-120		>90%, in summertime
Dissolved Nitrate			<0.210 mg/L N, in wintertime
Chlorophyll *a*			<10 mg/m^3, in summertime
Faecal coliforms	100 CFU/100ml	2 000 CFU/100ml	

Guide value recommends not surpass the proposed value; **Mandatory value** obliges not surpass the proposed value

2.3. Ichthyofauna

Since 1997 samples have been carried out in Estoril coast, using an otter trawl, gill nets and more recently a beam trawl. A total of 105 species were caught. Results revealed the selectivity of the fishing gear as only 16 species were common to all types. The main factors influencing selectivity were fish size, depth and substratum. Gill nets were unable to capture small sized fish (v.g. Gobiidae). On the other hand, otter trawl and beam trawl showed very low captures of species with strong affinity to rocky substratum (v.g. Sparidae and Labridae). The present paper will also describe the local ichthyofauna giving an account of morphological anomalies found. All individuals were thoroughly inspected for external deformities namely head vertebral and fins. Since most pollutants tend to accumulate on sediment benthic species are commonly more contaminated than pelagic ones, specimens of *Arnoglossus laterna* a benthic species, were dissected for the detection of unobserved external deformities.

The relationship between fish deformities and/or pathology and pollution relies on a increasing amount of data (vg., Dethlefsen, 1984). Often the responsible agent of deformities is not found (Browder *et al*., 1992; Tutman *et al*., 2000). However a significative difference in deformities occurrence between polluted and non polluted areas, strongly suggest that the causative agent is related to pollutants. (Reash and Berra 1989; Tutman *et al*, 2000). Other causative agents can be parasites (Cunningham *et al*., 2005) or genetic structure (Afonso *et al*., 2000).

From 1997 to 2005 captures were made, at irregular intervals, with a commercial bottom trawl at a depth of approximately 90 m. Each trawl took approximately 20 minutes. Gill nets were used near shore also in three sampling stations as shown in Figure 3. Gill net samples were made during four consecutive days, being nets examined in the morning. From 2006 onwards instead of a bottom trawl a beam trawl was used enabling captures nearer the pretended studying zone and gill nets were abandoned.

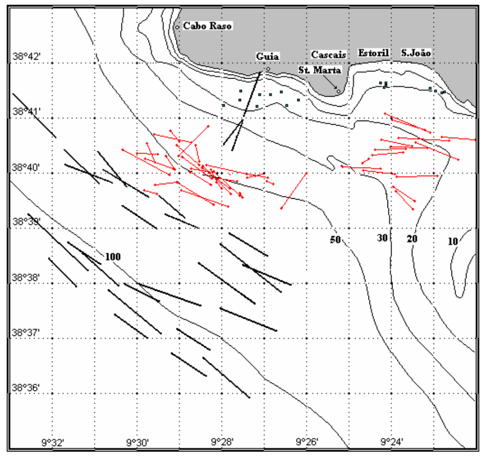

Figure 3 - Trawl samples in Estoril coast. Gill nets, small squares, otter trawl in black, beam trawl in red.

3. RESULTS AND DISCUSSION

3.1. Wastewater

Results from Guia wastewater treatment plant (WWTP) concerning flow rate, BOD_5 and COD, nitrogen and microbial load, from 1997 to 2007, are presented.

Guia WWTP effluent flow rate ranged from 99 926 m^3/day in 1998 to 186 490 m^3/day in 2003, with an average flow of 142 222 m^3/day (Fig. 4).

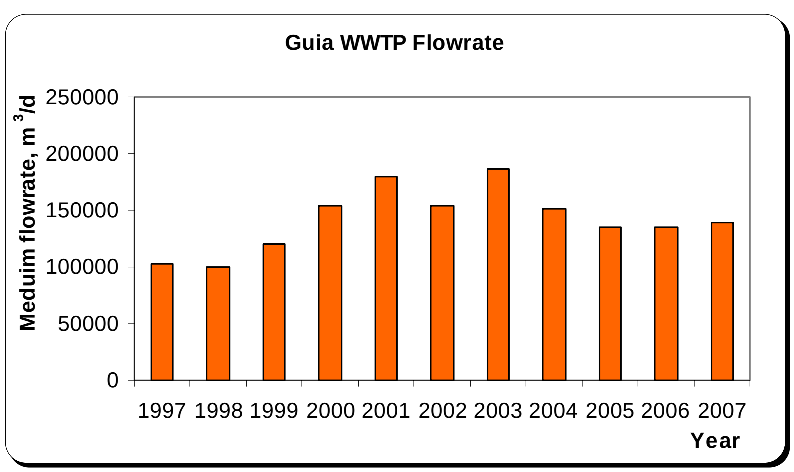

Figure 4 – Medium flow rate at Guia wastewater plant from 1997 to 2007.

In what concerns organic load, BOD_5 ranged from 210 mg/L in 2003 to 381 mg/L in 2007, with an average value of 261 mg/L, while COD ranged from 480 mg/L in 2004 to 687 mg/L in 2006, with an average value of 589 mg/L (Fig. 5).

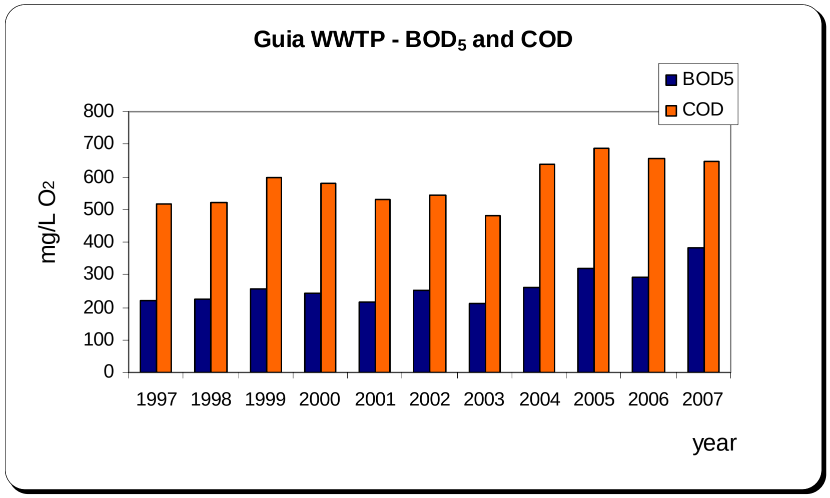

Figure 5 – BOD_5 and COD concentration in the effluent from 1997 to 2007.

Guia sewage composition is largely domestic wastewater and the nitrogen load is mainly organic nitrogen as can be observed by Kjeldahl nitrogen that ranged from 44.2 mg/L N in 1997 to 63.2 in 2007 mg/L N and by N-ammonium ranging from 27.2 mg/L N in 1997 to 42.6 mg/L N in 2007, with average values equal 53.5 mg/L N and 35.8 mg/L N, respectively. The inorganic fraction is low. N-nitrate ranged from 0.2 mg/L N in 2004 to 6.2 mg/L N in 2002 and N-nitrite from 0.01 in 1997, 1998 and 1999 to 0.56 mg/L in 2001, with average values of 1.7 mg/L N and 0.1 mg/L N, respectively (Fig. 6).

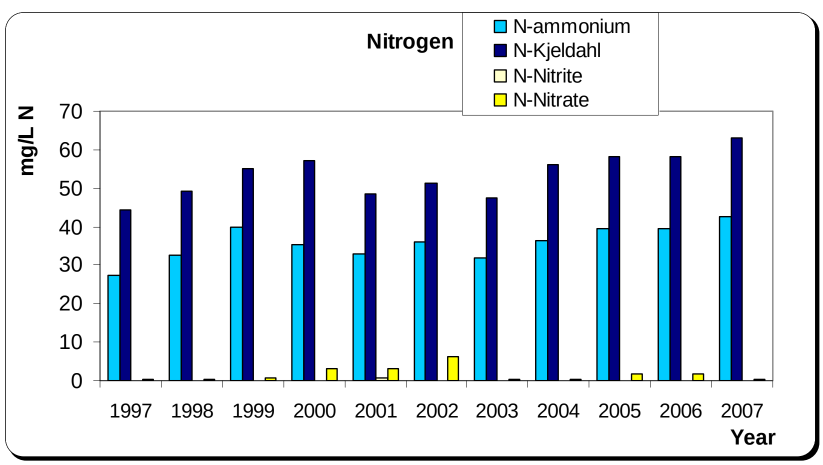

Figure 6 – Nitrogen concentration in the effluent from 1997 to 2007.

Through the eleven years monitoring of Guia wastewater the microbiological concentration of the three studied parameters showed a quite steady evolution. Total coliforms showed a geometric mean of 2.1×10^7 CFU/100ml, faecal coliforms present a geometric mean of 1.0×10^7 CFU/100ml. *Escherichia coli*, studied only since 2001, showed a geometric mean of 4.8×10^6 CFU/100ml (Fig. 7).

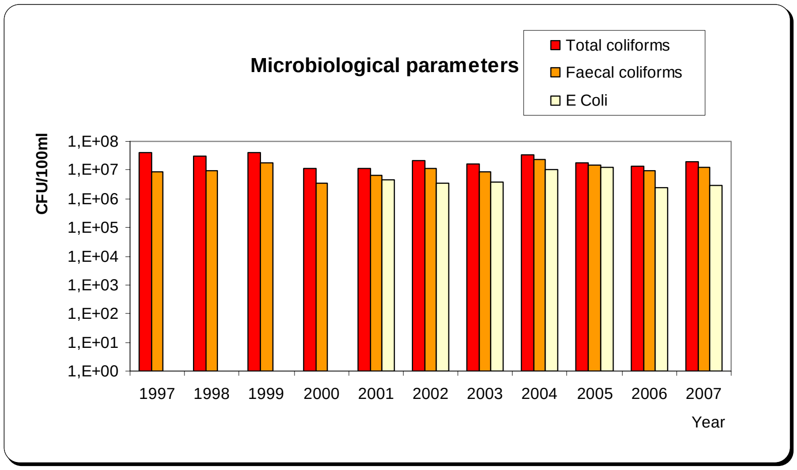

Figure 7 – Microbiological parameters concentration in the effluent from 1997 to 2007.

3.2. Receiving waters

Table 4 resumes the average, standard deviation and variance for the parameters pointed out in the INAG document: percent saturation and chlorophyll *a* in summertime and transparency and nitrate in wintertime over the eleven year period of monitoring (1997-2007). The values in shade can also be compared between seasons. Results concern only surface waters.

Table 4 – Average, standard deviation and variance of the four parameters in summertime and wintertime

	WINTERTIME				SUMMERTIME			
	%Saturation	Chlorophyll a (mg/m3)	Transparency (m)	Nitrate mg/L N	%Saturation	Chlorophyll a (mg/m3)	Transparency (m)	Nitrate mg/L N
Average	99	0.9	6.4	0.086	107	1.9	6.3	0.046
St.deviation	4.72	0.38	2.72	0.069	14.18	1.02	1.53	0.042
Variance	22.85	0.14	7.39	0.005	201.1	1.05	2.34	0.002
INAG Guideline	>90%	<10	>2	<0.210	>90%	<10	>2	<0.210

From 1997 to 2007, the INAG guideline for water transparency (2m) was always surpassed, in wintertime (Fig. 8). Summertime values were quite similar with minor variation.

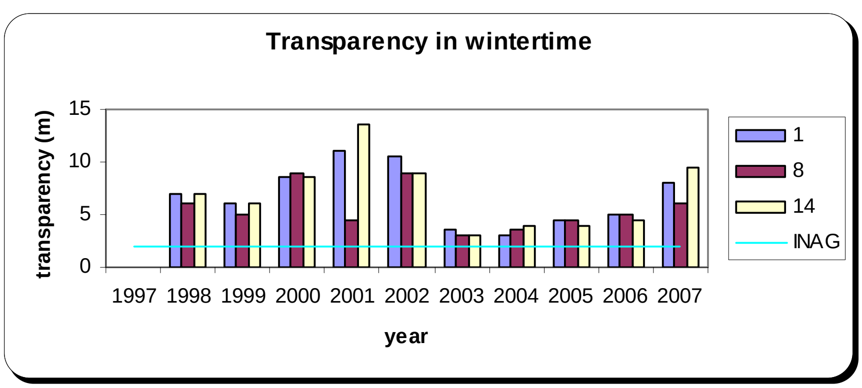

Figure 8 – Transparency in wintertime, from 1997 to 2007 --- INAG guideline.

Along the eleven years of monitoring, N-nitrate mean concentration in surface waters was of 0.086mg/L N (SD=0.069), and never exceeded INAG guidelines (Fig. 9). In summertime nitrate concentration was about half the wintertime values.
In surface waters N-nitrate showed significant differences in the course of the ten years (d.f. =9; p<0.05) but not among sampling stations.
In these coastal waters nitrate don't seem to create any problems in what concerns eutrophication, nor even phosphate (Paulo-Martins *et al*, 2006).

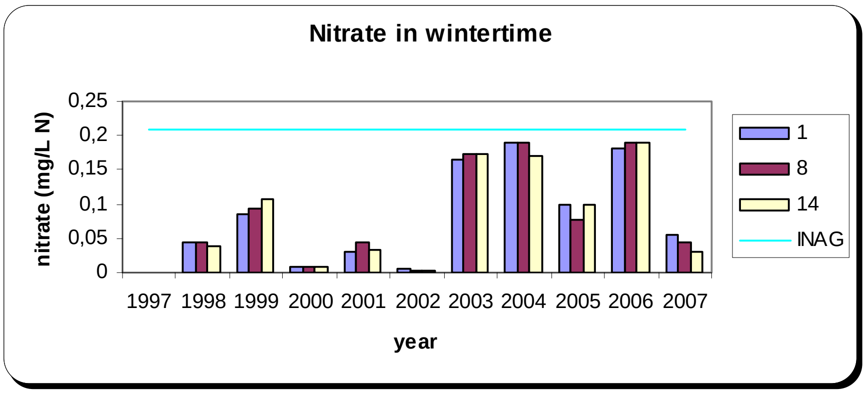

Figure 9 – Nitrate in wintertime, from 1997 to 2007 --- INAG guideline.

In surface waters, dissolved oxygen, presented here as percent saturation, ought to be superior to 90%, in 90% of the cases. Along the eleven years only 88% of the samples comply with INAG guidelines (Fig.10), even though the terms of the Directive 76/160/EEC were met (Table 3).

Nevertheless the results show that these coastal waters are well oxygenated. Analysis of variance (ANOVA) show significant differences among the eleven years for % saturation (d.f.=10; p<0.05) but again no significant differences were found among sites.
In wintertime, % saturation was lower with a shorter variance (Table 4).

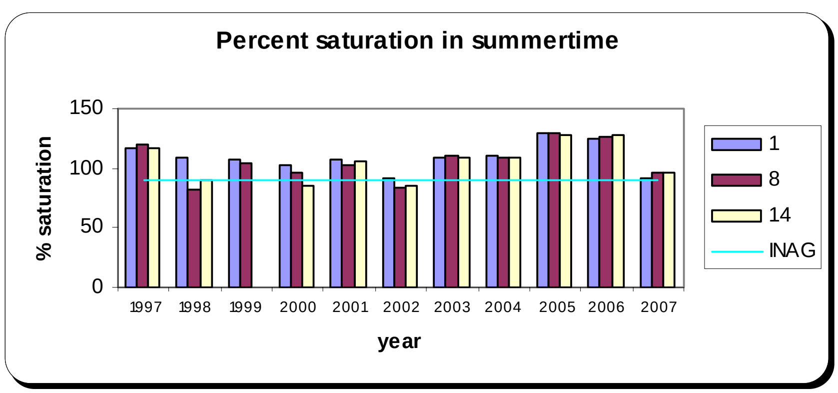

Figure 10 – Oxygen saturation in summertime, from 1997 to 2007 --- INAG guideline.

In summertime, chlorophyll *a* mean concentration was 1.86 mg/m^3 (SD=1.03) and never reached the maximum value stated by INAG guidelines through the monitoring period (Fig.11). Nevertheless, ANOVA showed significant differences amongst the eleven years (d.f.=10; $p<0.05$) but not among sites. In wintertime concentration were reduced to half (Table 4).

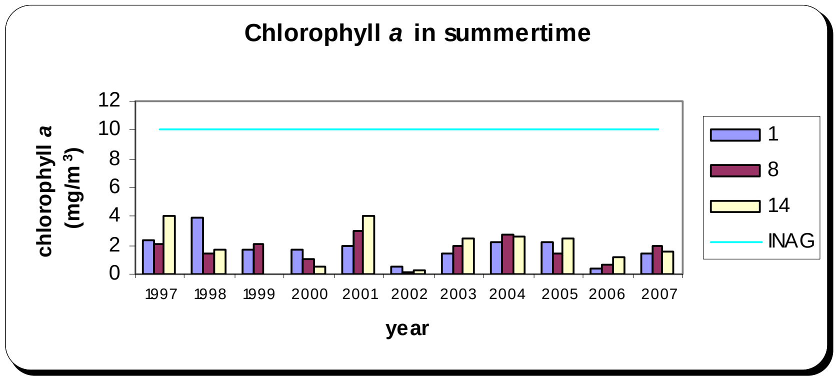

Figure 11 – Chlorophyll *a* in summertime from 1997 to 2007. --- INAG guideline.

The WWTP, located at Guia, discharges continually an urban effluent with a high faecal concentration (10^7FCU/100ml), with origin in human and other warm blood animals, through Guia submarine outfall, at 40 meters depth. In the water column, the highest concentration of this faecal population occurred in middle waters, followed by bottom waters and by surface waters that presented the lowest concentration.

Unlike chemical parameters, microbes, in particular faecal coliforms (FC), behave in a similarly way in both summertime and wintertime therefore analyses of variance showed no significant differences among the eleven year study in both seasons (d.f.=10; $p>0.05$). Among sampling sites ANOVA showed significant differences for mid and bottom waters, probably due to stratification that traps the outfall plume about 20m depth, contrasting with surface ones where no significant differences among sites were found.

Faecal coliforms tend to concentrate in the station 8, which is the nearest to the outfall mouth. In surface waters, the outfall plume is carried out northwest following the residual velocity surface currents while in middle and bottom waters the trend is to a more diffuse dispersion (Neves, 1998).

In both seasons, in surface waters, FC concentration decays until it reaches mandatory value (2000 CFU/100 ml) within approximately 1km. In the middle waters that distance is higher attaining approximately 1.5 to 2.5 km to reach the mandatory value and approximately one more kilometre until reaching the guide value. In what concerns bottom waters mandatory value is attained within a few meters while guide value was only reached within approximately 1.5 km.

3.3. Ichthyofauna

Table V lists all species caught by type of fishing gear during the studying period.

Table V - Species caught by fishing gear. **GN** - gill nets; **OT** - otter trawl; **BT** - beam trawl.

	% number			% biomass			frequency		
Species	GN	OT	BT	GN	OT	BT	GN	OT	BT
Scyliorhinus canicula	0,07	1,67	0,03	0,21	10,95	0,81	0,032	0,854	0,014
Mustelus mustelus	0,05			0,56			0,020		
Torpedo marmorata	0,01			0,11			0,003		
Raja brachyura		0,01	0,05		0,03	0,78		0,021	0,019
R. clavata		0,84	0,10		5,54	1,69		0,479	0,039
R. undulata	0,42	0,01		5,85	0,11		0,141	0,021	
Myliobatis aquila	0,01			0,02			0,005		
Alosa alosa	0,02			0,05			0,015		
A. fallax	0,25			1,14			0,094		
Sardina pilchardus	30,54	0,02	0,07	12,87	0,02	0,01	0,558	0,063	0,037
Engraulis encrasicolus	1,30	0,02		0,22	0,01		0,056	0,042	
Maurolicus muelleri		0,02			0,001			0,042	
Glossanodon leioglossus		0,01			0,002			0,021	
Conger conger	0,04	0,49	0,15	0,02	1,19	0,93	0,017	0,500	0,111
Belone belone	0,01			0,04			0,003		
Macroramphosus scolopax		0,06			0,01			0,083	
Hippocampus hippocampus			0,10			0,02			0,065
Nerophis ophidion	0,07			0,00			0,018		
Merluccius merluccius	3,42	25,17	1,40	5,09	34,09	2,82	0,283	0,958	0,351
Gadiculus argenteus		2,04			0,11			0,063	
Gaidropsarus vulgaris	0,02			0,06			0,010		
Micromesistius poutassou	0,54	13,58		0,14	9,01		0,045	0,396	
Phycis phycis	0,70			1,99			0,178		
Pollachius pollachius	0,08			0,23			0,026		
Trisopterus luscus	10,62	5,54	6,76	9,68	8,68	4,54	0,744	0,896	0,516
Zeus faber	0,02	0,12		0,02	0,33		0,008	0,208	
Capros aper		4,77			1,62			0,354	
Serranus cabrilla	0,20			0,16			0,079		
S. hepatus		0,11	0,56		0,07	0,82		0,104	0,176
Dicentrarchus labrax	0,35			1,15			0,092		
Cepola rubescens		0,33	0,06		0,37	0,08		0,313	0,030
Trachurus picturatus	0,02			0,01			0,003		
T. trachurus	18,96	9,21	0,38	6,75	4,23	0,25	0,430	0,646	0,084
Argyrosomus regius	1,26			7,60			0,126		
Mullus surmuletus	0,77	0,04		1,55	0,08		0,145	0,104	
Boops boops	1,71	0,08		1,52	0,15		0,233	0,146	
Diplodus annularis	0,02			0,01			0,008		
D. bellottii	0,11		0,20	0,07		0,36	0,042		0,084
D. cervinus	0,02			0,04			0,008		
D. sargus	1,22			2,37			0,151		
D. vulgaris	4,56	0,41	0,03	6,87	1,66	0,06	0,569	0,208	0,028
Lithognathus mormyrus	0,01			0,02			0,003		
Pagellus acarne	0,99	0,03	0,26	1,14	0,08	0,03	0,181	0,063	0,019
P. bogaraveo	0,59	0,06		0,19	0,24		0,084	0,042	
P. erythrinus	0,15			0,20			0,041		
Pagrus pagrus	0,48	0,01		0,70	0,02		0,138	0,021	
Sparus aurata	0,15			0,40			0,034		
Spondyliosoma cantharus	0,62	0,11		0,88	0,36		0,283	0,125	
Sarpa salpa	0,02			0,08			0,008		
Centrolabrus exoletus	0,01			0,00			0,003		
Labrus bergylta	0,12			0,38			0,048		
Symphodus bailloni	0,94			1,16			0,246		
Echiichthys vipera			0,03			0,02			0,019
Trachinus draco	0,02		0,05	0,02		0,31	0,011		0,019
Euthynnus alletteratus	0,01			0,04			0,003		
Scomber japonicus	3,40			3,17	0,03		0,307	0,021	
S. scombrus	5,93	0,01		10,23	0,07		0,547	0,042	
Aphia minuta		0,01	0,17		0,000	0,01		0,042	0,056
Deltentosteus quadrimaculatus		0,01	0,08			0,01			0,037
Gobius gasteveni			0,18		0,000	0,03		0,021	0,051
G. niger		0,01	0,03			0,01			0,019
Lesueurigobius friesi		0,02			0,000			0,042	
L. sanzoi		3,75	1,24		0,71	0,09		0,792	0,143
Pomatoschistus lozanoi		0,04	1,51		0,00	0,12		0,083	0,139
P. minutus			0,64			0,06			0,111
Callionymus lyra	0,41	2,04	20,75	0,21	2,44	37,44	0,137	0,646	0,822
C. maculatus		0,20	6,36		0,01	1,27		0,229	0,349
C. reticulatus			0,71			0,10			0,121
C. risso			0,20			0,02			0,09
Blennius ocellaris		0,05	0,07		0,03	0,01		0,125	0,019
Chelon labrosus	0,15			0,93			0,064		
Liza aurata	0,19			0,62			0,045		
L. ramada	0,20			0,88			0,073		
L. saliens	0,01			0,03			0,006		
Mugil cephalus	0,02			0,10			0,008		
Scorpaena notata			0,20		1,55	0,65	0,133	0,604	0,076
S. porcus	0,31	1,21		0,15			0,003		
Aspitrigla obscura	0,01		0,25	0,01	0,02	0,34	0,006	0,042	0,065
Eutrigla gurnardus	0,01	0,01	0,04	0,01	0,00	0,08		0,021	0,028
Lepidotrigla cavillone		0,01	0,03			0,00			0,014
L. dieuzeidei		0,01	0,20		0,01	0,05		0,042	0,033
Trigloporus lastoviza		0,03	0,04		0,05	0,02		0,083	0,028
Trigla lucerna	1,36	1,17	0,48	1,98	2,97	3,54	0,450	0,729	0,271
Citharus linguatula		5,18	1,56		4,93	1,85		0,958	0,330
Lepidorhombus boscii		0,01			0,03			0,021	
Psetta maxima	0,06			0,36			0,026		
Scophthalmus rhombus	0,14			0,57			0,052		
Zeugopterus punctatus	0,02			0,01			0,008		
Arnoglossus imperialis	0,14	0,06	0,20	0,04	0,03	0,19	0,05	0,042	0,056
A. laterna	0,04	19,68	39,71	0,00	4,67	20,60	0,016	0,958	0,917
A. thori		0,04	0,28		0,01	0,06		0,063	0,111
Bothus podas		0,01			0,01			0,021	
Platichthys flesus	0,02			0,03			0,008		
Buglossidium luteum	0,01	0,10	9,52	0,00	0,03	3,36	0,003	0,104	0,694
Dicologoglossa cuneata	0,67	0,75	4,72	0,43	1,06	12,46	0,191	0,104	0,544
D. hexophthalma		0,01			0,01			0,042	
Microchirus azevia			0,29			1,41			0,139
M. variegatus		0,03	0,04		0,02	0,06		0,042	0,028
Solea lascaris	2,40		0,03	2,27		0,28	0,308		0,014
S. senegalensis	2,05	0,03		4,01	0,08		0,424	0,063	
S. vulgaris	0,81	0,76		1,22	2,25		0,217	0,563	
Balistes carolinensis	0,17			0,97			0,067		
Mola mola	0,01			0,14			0,003		
Halobatrachus didactylus			0,19			1,35			0,065
Lophius piscatorius		0,01	0,05		0,02	1,01		0,021	0,019

The most common were some commercial species namely, *M. merluccius*, *Sardina pilchardus* and *Trisopterus luscus*. As expected, differences were evident between results from each fishing gear as well as within stations sampled with the same fishing gear. Gill nets captured mainly pelagic species but whilst *Trachurus trachurus, Scomber scombrus* and *S. japonicus* were more abundant in Guia, *Sardina pilchardus* prevailed in Estoril. Some species with affinity for rocky substratum were also caught, *Diplodus vulgaris*, *D. sargus* and *Symphodus bailloni*. Benthic species more common in Gill nets samples were *Solea senegalensis* (Guia) and *S. lascaris* (Estoril). Beam trawl captured mostly, small sized benthic species, *Arnoglossus laterna*, *Buglossidium luteum* and *Dicologoglossa cuneata*. This fishing gear revealed the presence of four Callionymidae species, *C. lyra*, *C. maculatus*, *C. reticulatus* and *C. risso*. The first was by far the most common in Estoril, decreasing numbers with increasing depth. Very small individuals of commercial important species (*T. luscus* and *S. pilchardus*) were also observed in sheltered places (Estoril). Otter trawl samples were dominated by *M. merluccius* juveniles and *A. laterna*. Other common but less abundant species were *Scyliorhinus canicula*, *Trachurus trachurus*, *Lesueurigobius sanzoi*, *Citharus linguatula* and *Solea vulgaris*. Captures of some rare species were clearly related with increased depth (over 100m), *Maurolicus muelleri* and *Gadiculus argenteus*.
All species were examined for external deformities namely head, vertebral as well as deformed fins. Head deformities occur most frequently as an altered dorsal profile nevertheless missing one of the eyes and mouth deformities have also been found. Fin deformities occur more frequently in caudal fin and consist of a variable number of deformed rays (Fig. 12).

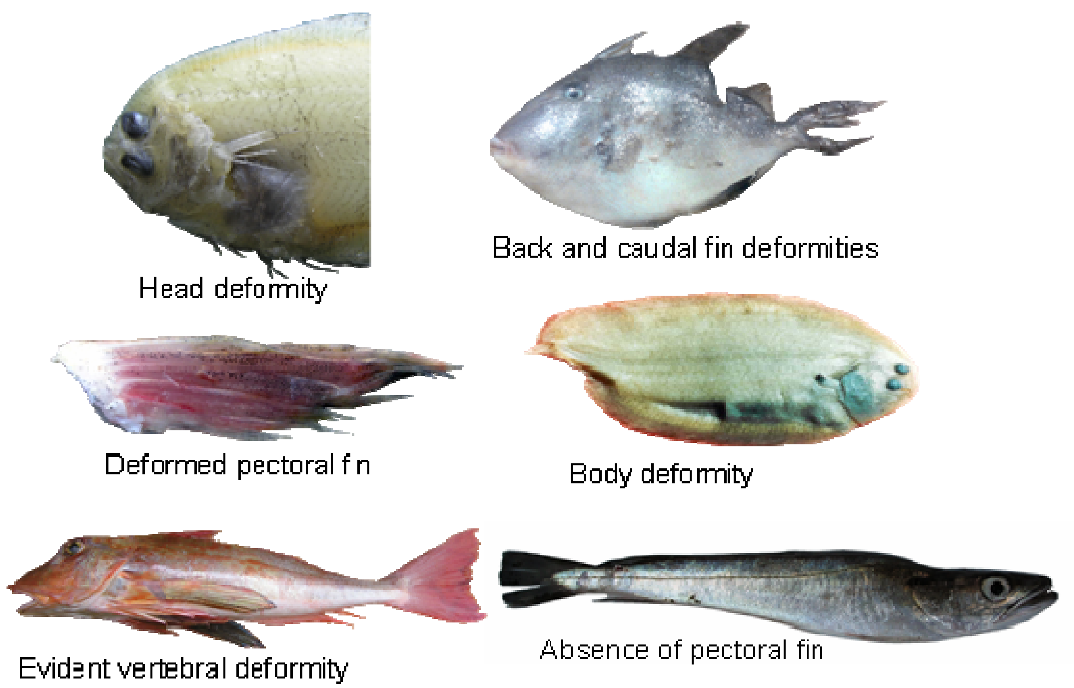

Figure 12 - Examples of fish deformities.

Since most pollutants tend to accumulate on sediments. Benthic species, being those, that are almost permanently in contact with the substratum tend to be contaminated.
Benthic species deformities were not particularly high in gill net samples most probably due to the low number of fishes examined (Fig. 13).

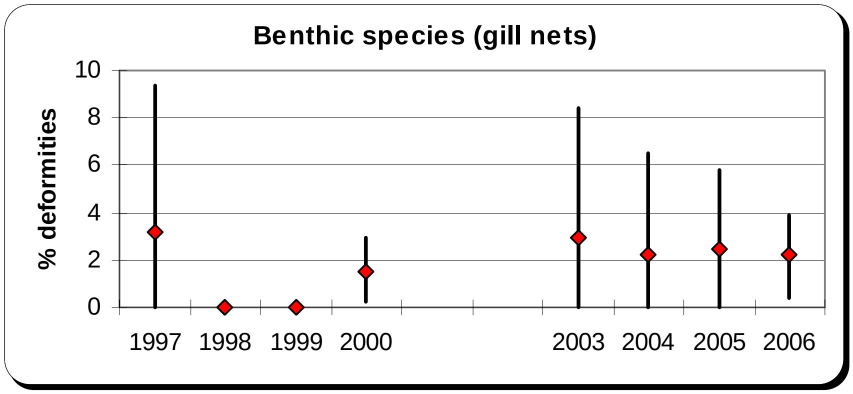

Figure 13 - Benthic species deformities in gill nets samples. Vertical bars are 95% confidence intervals.

Deformed benthic fish in trawl samples were more common, averaging over 4%, except in 2006 when it reached just over 2% (Fig. 14).

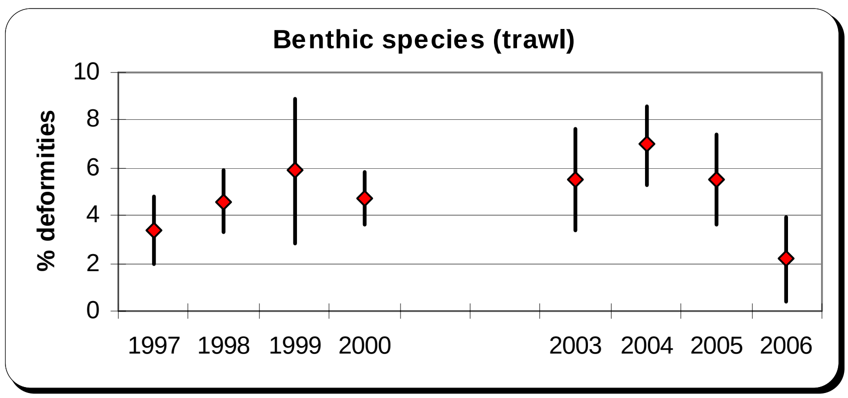

Figure 14 - Benthic species deformities in trawl samples. Data of 2006 is from beam trawl. Vertical bars are 95% confidence intervals.

Excepting the two last years when evident deformities reached 4% bentho-pelagic species caught in gill nets had the lowest evident deformity levels, less than or just over 2%. In trawl samples bentho-pelagic species showed the lowest level of deformities, usually less than 1%. This might most probably be related with the capture of high numbers of juvenile hake which seemed not to be prone to deformities.

4. Conclusions

Concerning WWTP effluent and according to Metcalf & Eddy (2003), BOD_5 and COD values are typical of medium concentration untreated urban wastewater. These parameters are flow rate dependent once the wastewater system is not completely separated and also collects some storm water along with residential, commercial and industrial wastewaters, contributing to effluent dilution in the months where the precipitation is higher. Also, nutrient and microbiological descriptors showed a typical concentration of untreated domestic wastewater with a medium-high load.

Nutrient enrichment in surface waters was not found since the effluent itself is poor in these elements. Discrete enhancement can be associated to runoff episodes during rainy periods and to the upwelling phenomenon that, according to Fiúza *et al*. (1998), is typical of the western coast of Portugal, in summertime.

Throughout the eleven years monitoring (1997-2007) the four physical chemical parameters analyzed in the receiving waters almost observe the established reference values (INAG Guidelines) in summertime and in wintertime.

The result of the analysis of variance, applied to the same chemical parameters of surface waters, in function of the sampling station and year revealed that this factor was the more significantly affected, which means that time is still the large cause of the system variability throughout the eleven years monitoring.

Unlike chemical parameters, faecal coliforms in surface waters presented significant differences among site, but not among the years which means that the adverse conditions of the receiving waters – salt water (effect of chlorine), solar radiation, predation, high dilution processes – do not allow long time survival for coliforms.

The outfall plume was essentially detected at the medium level of the water column. In a distance of 1.5 to 2.5 km, the population of faecal coliforms approximately reaches the Mandatory value (2000CFU/100ml) and the Guide value (100CFU/100ml) one more kilometre ahead, which reveals a high level of dilution due to local hydrodynamics.

Ichthyofauna samples were quite rich and diverse; however, some signs of environmental degradation were noticed. The presence of deformed fish is probably related with pollutants even though no direct cause-effect relationship could be established. Benthic species were the most affected by evident deformities, over 2%. This pattern could be expected if pollutants were the cause, as those tend to accumulate in the sediment. Comparisons between urbanized and pristine zones could, probably, clarify this situation, mainly by revealing a "natural" deformities incidence.

Guia surrounding waters are strongly influenced by the contaminants coming not only from the effluent but also from the Tagus estuary. However, the hydrodynamic conditions of Portugal western coast lead to a high dilution and dispersion (Santos *et al.,* 2005) as well as to high biologic deceasing processes. Neves *et al.*, (2002), refer that the wave climate and the local circulation, which induces resuspension, are the main causes of the reduced impact of the discharge in this coastal ecosystem. Further, the strong currents induced by the tides, density, wind and also the wave climate, promote initial dilutions up to 1/1000.

…..

Since 1994, the environmental monitoring of Guia submarine outfall maintains its goals, with a huge effort of all the team involved. The development of deep and long term knowledge on coastal systems is very important because it provides the explanation of the processes responsible for the obtained results, which in turn, allows prevention and management actions. With this information we are supporting decision making, thus enabling the sustainability of this coastal area.

5. REFERENCES

Afonso, J.M.; D. Montero, L. Robaina, N. Astorga, M.S. Izquierdo and R. Ginés*et* , (2000). Association of a lordosis-scoliosis-kyphosis deformity in gilthead seabream (*Sparus aurata*) with family structure. *Fish Phtysiology and Biochemistry*, **22** (2): 159-163.

Browder, J. A., David B. McClellan, Douglas E. Harper, Michael G. Kandrashoff & Walter Kandrashoff (1992). A major development defect observed in several Biscayne Bay, Florida, fish species. *Environmental Biology of Fishes,* **37**: 181-188.

Commission Decision 2001/720/EC, of 8 October 2001, granting Portugal a derogation regarding urban waste water treatment for the agglomeration of the Estoril coast. *Official Journal* L 269, 10.10.2001, pp. 14–16.

Council Directive 76/160/EEC, of 8 December 1975, concerning the quality of bathing water, *Official Journal* L 31, 5.2.1976, pp. 1–7.

Council Directive 91/271/EEC, of 21 May 1991 concerning urban waste-water treatment. Official Journal L 135, 30.5.1991, pp. 40–52.

Cunningham, M. E., D. F. Markle, V. G. Watral, M. L. Kent and L. R. Curtis (2005). Patterns of fish deformities and their association with trematode cysts in the Willamette River, Oregon. *Environ. biol. fishes*, **73** (1): 9-19.

Dethlefsen, V., (1984). Diseases in North Sea fishes. *Helgo. Wiss. Meeresunters*. **37**, 353–374.

Fiúza, A., Hamann, M., Ambar,I., Diaz del Rio,G., Gonzalez, N. & Cabanas, J.M. (1998) - "Water masses and their circulation off western Iberia during May 1993". *Deep Sea Research* I 45: 1127-1160. 1998.

INAG Guidelines (1998) – "Linhas de Orientação Metodológica para a Elaboração dos Estudos Técnicos necessários para cumprir o art.7º, do DL 152/97 – Descargas em zonas menos sensíveis". INAG – Ministério do Ambiente. Lisboa.

Metcalf & Eddy, inc. (2003) - *Wastewater Engineering Treatment, Disposal, Reuse*. McGraw-Hill, Inc. New York.

Neves, R. (1998) - "Programa de monitorização do emissário submarino da guia: modelação matemática. Instituto Superior Técnico", Universidade Técnica de Lisboa. 99p.

Neves,R., Marecos do Monte,H., Santos,C., Quintino,V., Matos,J. & Zenha,H. (2002) - "Integrated Wastewater Management in Coastal Areas: Wastewater Treatment, Environmental Monitoring and Performance Optimisation of Costa do Estoril System". *2nd International Conference "Marine Waste Water Discharges".* Istanbul, Turkey, September 16-20.

NP EN ISO/IEC 17025:2005 General requirements for the competence of testing and calibration laboratories. June 2005, 40p.

Paulo-Martins, C.; Santos, C.; Catarino, J.; Trancoso, A.; Ralheta, C.; Calisto, S.; Cabrita, M. & Neves,R. (2006) "Guia Submarine Outfall – Water Quality Monitoring" *4th International Conference "Marine Waste Water Discharges".* Antalya, Turkey, November 16-20.

Reash and Berra, (1989). Incidence of fin erosion and anomalous fishes in a polluted stream and a nearby clean stream. *Water, Air & Soil Pollution*, **47** (1-2): 47-63.

Santos, C., Paulo-Martins, C., Marques, E., Barreiros, A., Ralheta,C., Caldeira,Z. Figueiredo, Z., Trancoso,A., Marecos, H. & Neves, R. – "Quality assessment of the water around a submarine outfall". *10th EuCheMS-DCE International Conference on Chemistry and Environment* Rimini, Itália. 4-7 September 2005

Tutman, P., B. Glamuzina, B. Skaramuca, V. Kož ul, N. Glavić and D. Luč ić Tutman, 2000Incidence of spinal deformities in natural populations of sandsmelt, *Atherina boyeri* (Risso, 1810) in the Neretva river estuary, middle Adriatic. *Fisheries Research*, **45** (1): 61-64.