

Implementation of the Forced Tangential Aeration Technique for the Recovery of the Guanabara Bay-Rio de Janeiro (Brazil): Preliminary Overview of the TAGUBAR Project

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ABSTRACT

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The TAGUBAR (TAngential GUanabara Bay Aeration and Recovery) project has been proposed as an interdisciplinary cooperation project between Italy and Brazil, in order to test the forced tangential aeration technique for the recovery of the Guanabara Bay with minimum environmental impact. The Bay of Guanabara, one of the most important aquatic environments in Brazil, is located in the surroundings of Rio de Janeiro. Unfortunately, this Bay is, nowadays, under great environmental pressure and has a high level of pollution (organic and inorganic) especially due to urban and industrial discharges (heavy metals, pesticides, hydrocarbons, etc.) related to the fast development of the city of Rio during the last decades. The aim of the project is a) to test the effects of forced tangential aeration on the bottom sediments and the water column above in a 4 km² study area in the Guanabara Bay and b) to provide local authorities in charge of the Guanabara Bay management with the instrumentation and methodology for the environmental recovery of the Bay and other polluted coastal areas in Brazil. Two general survey campaigns and four tangential aeration campaigns are planned for the three-year project during which geological, sedimentological, biological and chemical investigations will be carried out in order to determine the ecological conditions of the experimental area before and after the aeration activities. Forced aeration will be provided by an *ad hoc* constructed technical unit (MODUS), based on a non turbulent laminar aeration by jet-venturi aerators, tangentially directed to the bottom and maintained at a constant distance from the bottom sediments of the Bay.

ADDITIONAL INDEX WORDS: *Water pollution, heavy metals, coastal areas, sediments.*

INTRODUCTION

Nowadays coastal areas globally are under a great pressure due to intense anthropologic activities that have caused extreme pollution levels and overexploitation of resources. Since coastal areas are very fragile ecosystems any activity carried out in these areas should be carefully planned in order to avoid ecological damages, that most of the times are irreparable or have very long term consequences. Coastal areas are very attractive for urban and industrial development, because of their convenient location, availability of resources, facilities, space, etc, this has caused many of these areas to reach critical environmental conditions.

The Guanabara Bay is a typical example of a polluted coastal area affected by urban and industrial discharges of a big city such as Rio de Janeiro. These discharges (solid and liquid) have been deposited for many years directly into the Bay without any previous depurative treatment. Currently the Guanabara Bay has a very high level of pollution both organic and inorganic, which has caused the reduction of more than 90% of its fishing productivity and the absence of almost all living organisms except for anaerobic bacteria (WAGENER *et al.*, 1992).

Presence of heavy metals, especially high concentrations of zinc, lead, and copper as well as high quantities of polynuclear hydrocarbons have been found in the Bay. Heavy metals and other dumping materials discharged (past and present) into the Bay have accumulated on the bottom of the Bay and therefore have increased its pollution level especially with regard to organic substances (PERIN *et al.*, 1993). Surficial bay sediments are currently in a complete anoxic state and therefore in relative stable condition (reductive environment), which does not favor any living organism, specially benthos.

Several studies carried out by Brazilian and Italian

researchers (Universidade do Rio de Janeiro (UERJ)-Rio de Janeiro, Brazil; the Ca'Foscari University of Venice and the Institute of Marine Sciences (CNR)-Venice, Italy) have put into evidence the extreme pollution of the Bay's bottom sediments (PERIN *et al.*, 1997). In consideration of the critical environmental state of the Bay, the TAGUBAR project was proposed. The TAGUBAR is an interdisciplinary cooperation project between Italy and Brazil, created in order to provide local authorities with the necessary methodology and technology for the environmental recovery of Guanabara Bay, using tangential forced aeration.

The recovery of the Guanabara Bay by means of forced aeration must take into consideration several precautions on the way it will be applied, specially related to the release of heavy metals and other pollutants contained and buried in the bottom sediments once aeration takes place. Release of pollutants without an efficient control will bring serious damages to the Bay's ecosystem, therefore and in order to minimize the environmental impact, the construction (Italian design) of an *ad hoc* technical unit (MODUS) has been planned for the efficient application of forced aeration in the test area of the Bay.

METHODS

The recovery of the Guanabara Bay will be based on the restoration of optimum oxygenation conditions of the deep-water layer (TRAVERSO *et al.*, 1994). Decontamination of bottom sediments must take place without allowing pollutants and specially heavy metals to become available for marine animals (fish, benthos organisms, etc) and the water column above them. Therefore, it is extremely necessary that the methodology applied for the recovery of the Bay (test area) should be carefully tested, so that the same or similar

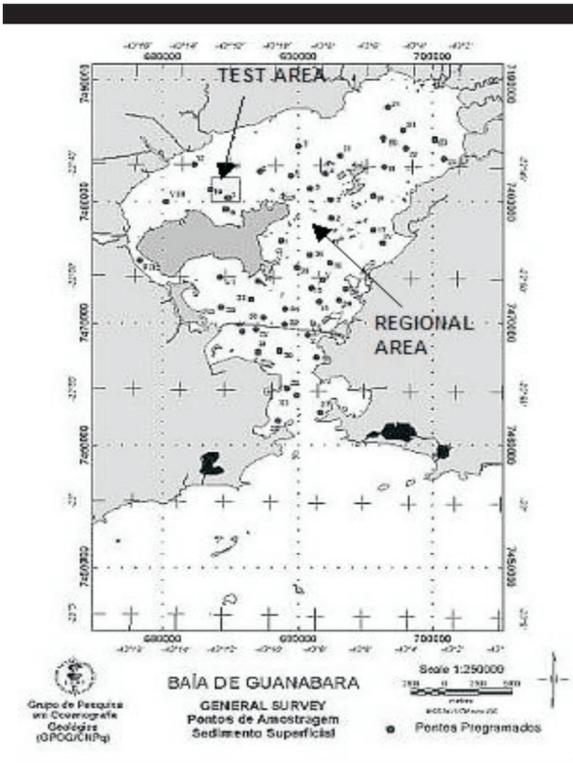


Figure 1. Location of Guanabara Bay, test area and sampling points planned for the first general survey campaign.

methodology could be applied to the whole Bay and other polluted coastal areas in Brazil.

The TAGUBAR project has a multidisciplinary approach; several activities and studies will take place simultaneously to field campaigns, so to have the most complete comprehension of all the processes taking place in the Bay.

A test area of 4 km² (where tangential forced aeration will be applied) in the Guanabara Bay (Figure 1) was selected based on its critical pollution conditions. The planned methodology to be applied for the ecological recovery of the test area by means of forced aeration consists of two general survey (GS) campaigns (before and after the aeration) and four tangential aeration campaigns in the test area where the technical unit MODUS will be used. Collection of superficial and sub-superficial sediment samples from the test area and from the rest of the bay will take place during these campaigns for biological, geological, sedimentological, geochemical, micropaleontological and chemical analyses.

The two GS campaigns will provide useful information about the ecological conditions of the Bay before aeration and after aeration. The first GS campaign took place during July 2003 in Rio de Janeiro and more than 700 samples were collected by the Italian and Brazilian research teams. These samples consisted of: a) 88 surficial bottom sediments from the Guanabara Bay (regional area) and from the test area collected by a Van-Veen grabber; b) 45 cores (approximately 55 cm in length) of the bottom sediments of the test area collected by a diver; and c) net sampling of the bottom surface for biological purposes.

The 45 core sampling points were evenly distributed throughout the 4-km² test area (Figure 2), including 4 control points (A, B, C, D) close to the test area. The sediment cores were collected with a plastic (PVC) corer by the diver (Figure 3) and each sampling took less than 5 minutes, which resulted in being the most efficient way to collect these samples considering the approximate average water depth of 5 m in the test area.

In order to avoid any mixing of the sediments inside the corer, the corers were always carefully kept upright and later frozen for future slicing and sub-sampling. Surface bottom sediments in each site, were collected in triplicates, then well

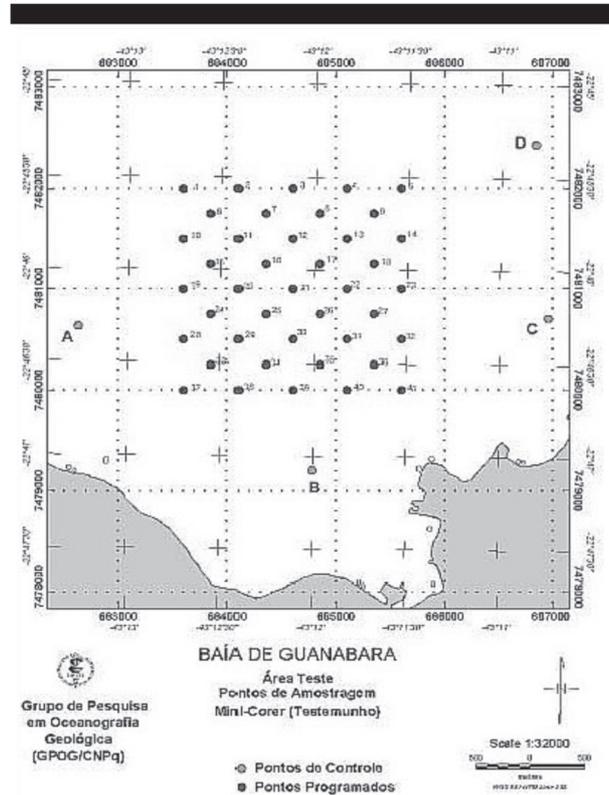


Figure 2. Location of coring sampling points in the test area.

mixed to obtain an homogenous sample that was stored in two different containers: a) a plastic one for sedimentological analyses and b) a glass one for chemical analyses.

Geology lab work consisted of sub sampling (slicing), labeling and storage of the 45 cores for future geochemistry, mineralogical and XRD, grain size and chemical analysis. Visual description of the cores was performed once they were extracted from the plastic corers, in order to have a general reference of their original appearance previous to slicing and analysis (Figure 4). No distinct lithostratigraphic textures were observed in the sediment cores that appeared, very uniform, without traces of stratigraphy; this could be taken as an indicator of how many organic and inorganic materials have accumulated over many years.

All samples collected (core and surface sediments) consisted of black mud characterized by a very strong sewage-like smell.

Biological analysis will include microbenthos and microfauna analysis of the bottom sediments of the Bay collected during the first GS campaign by net sampling.

Also as part of the project activities a detailed bathymetric survey of the study area was performed during the first GS campaign in order to provide the hydrodynamic mathematical model with specific data and the MODUS with the accurate measures to maintain the forced aeration apparatus at a constant distance from the bottom. Collection of useful information as wind direction, tides, depth, currents, etc is also planned as required for the development of the hydrodynamic model. The use of satellite images (radar and multispectral) for the observation of past, present and possible future scenarios of the study area and surroundings, as well as monitoring of polluting plumes, morphological changes, urban development, water condition, etc are also part of the project's activities. A graphical representation (GIS) of various parameters as: hydrodynamic, sedimentological, environmental characteristics, etc is also an objective to have a general idea and correlation of all these parameters.

Tangential Forced Aeration Technique and Technical Operational Unit: MODUS

The MODUS (MOdulo di Disinquinamento Unitario di Sedimento) represents the technical unit that will provide



Figure 3. Bottom sediment core collected by diver.

tangential aeration (Figure 5) in the test area. It will be designed and constructed in Italy, first on laboratory scale and finally on full scale to be used at the Guanabara Bay. A series of tests, calibrations and validations as well as determination of operational parameters will be necessary before constructing the full-scale version of MODUS and transferring it to Brazil. The preliminary operational tests of the MODUS unit (actual dimension) will be developed in the Lagoon of Venice in Italy.

The MODUS will in principle pump surface water (taken at 0.5 m depth), mix it with atmospheric air and then tangentially distribute it to the bottom of the Bay. The strategy to be applied for the environmental recovery of the test area in the Guanabara Bay consists in the formation of a 10-20 cm layer (bio-ox-capping), highly oxidized, where the oxygenizing conditions ($>3\text{g.m}^{-3}$) will be applied. All organic substances deposited on the bottom of the Bay by sedimentation will find in this way an oxygenated environment and a layer of sediments in aerobic conditions that will allow the re-colonization of microorganisms and benthos animals on the bottom.

To avoid bottom sediment mixing, the system (MODUS) will apply non-turbulent laminar aeration by jet-venturi aerators, tangentially directed to the bottom of the Bay. The aerators will be kept at a constant distance from Bay bottom sediments and they will keep the flow of water aerated tangentially directed to the bottom the most laminar as possible.

Continuous control and monitoring of the effects caused by the application of tangential forced aeration in the test area will take place during each field campaign. Analytical validation and in-situ bioassay of diffusion of pollutants and suspended solids are part of these monitoring mechanisms.

EXPECTED RESULTS

The most important aim of the TAGUBAR project is to prove the feasibility of applying tangential forced aeration by means of technical unit, MODUS, to improve the environmental conditions on the selected test area in the Guanabara Bay. According to results obtained after the aeration campaigns on the test area, this technology will be supplied to local authorities in charge of the management of the Bay, so it could be applied to the entire Guanabara Bay and other polluted coastal areas. The application of tangential forced aeration to the entire Bay should significantly improve its present environmental conditions and therefore important changes could be expected from the ecological and economical point of view.

From the ecological point of view the following results are expected:

- Re-equilibrium of the Bay's system
- Recovery of oxygenated conditions at the bottom
- Return of living organisms especially traditional benthos fauna
- Return of primary productivity also on the middle layers



Figure 4. Frozen sediment core ready to be sliced.

of the water column

- Increase of primary and pelagic productivity

From the economical point of view the following results are expected:

- Increase of ichthyological production, benefiting coastal population
- Re-qualification of fish in terms of commercial value
- Re-qualification of hygienic-sanitary conditions
- Possible use of water of the Bay for sports and recreational activities
- Possible extension of mollusk farming in the Bay
- Recovery of tourism activities in the Bay

As mentioned before, a series of geological, geochemical, chemical and biological analyses will be performed in all campaigns of the TAGUBAR project. Also ecological, socio-economical, and technological research will be developed as part of the project, in order to have a complete view of the whole situation and scenario. Analysis and research will be done in Brazil and in Italy, and all results obtained by each team will be collected and stored on a database for their complete and detailed interpretation. This will be the basis for the creation of a Decision Support System (DSS), based on ecological balance criteria. The DSS will consist of an operative and management system, composed of a series of procedures, regulations and scientific-technological methodologies, as well as interrelationship of standards between a variety of institutions, users and social groups related with the Bay itself. The DSS allows community involvement at different levels, promoting cooperation and joint activities between the research organism and academic institutions.

The DSS will also include a MASTERPLAN for the decontamination of the Guanabara Bay that should be immediately applicable by the local authorities of Rio de Janeiro.

CONCLUSIONS

The development of the TAGUBAR project is very important for facilitating cooperation and technology transfer between Italy and Brazil based on environmental purposes. The environmental recovery of the test area on the Guanabara Bay should just be the beginning of an expected successful application of the tangential forced aeration technique to recover the whole Bay of Guanabara and later on of other polluted coastal areas in Brazil.

To supply local authorities of Rio de Janeiro in charge of the management of the Bay with a Decision Support System (DSS) for the economical-financial estimation of applying the MODUS technology is also one important concern of this project. Collection of information referred to the current polluted and anoxic state of bottom sediments in Guanabara Bay, will be possible during the sampling and aeration campaigns of the TAGUBAR project. This information and future geochemical, chemical, sedimentological and biological

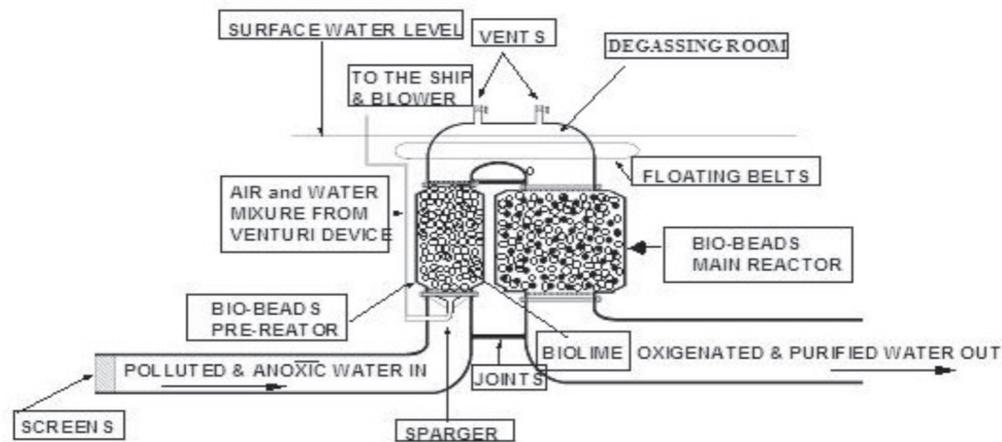


Figure 5. Preliminary design of patented MODUS to be applied for the tangential forced aeration at the test area-Guanabara Bay.

analysis, plus other planned activities during the development of the project will facilitate the creation and definition of a MASTERPLAN to be followed by local authorities in order to perform the ecological recovery of the Guanabara Bay.

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