Contribution to Integrated Coastal Zone Management (ICZM) as a Solution to Coastal Environmental Problems of Fortaleza (NE-Brazil)

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ABSTRACT


The city of Fortaleza has suffered an intense occupation anthropic starting from the 19th century, causing environmental impacts as aquatic pollution and coastal erosion. The solutions presented were always punctual, without an integrated environmental vision. The aim of this paper is to analyze in an integrated way the environmental problems and to suggest solutions to contribute for the installation of a process of ICZM in Fortaleza The environmental problems have been identified and analyzed using images of the Ikonos satellite and using software Arc View 3.2. In the study area we checked the information obtained by satellite and we took samples of sediments to be analyzed in the laboratory. The area has been divided in 5 coherent units of environmental management. Their water have been polluted by domestic garbage, organic matter and fecal coliforms. They have presented embankment in the east coast and important erosive processes in the west coast. The solution for the aquatic pollution requests: public investments for pollution elimination in the rivers by dragging; cleaning of accumulated garbage; expansion of the basic sanitation; application of an environmental educational program. To obtain the balance between the embankment processes and coastal erosion it is necessary a solution that will integrate the elements of the coastal dynamics through: the adequate management of the sedimentary stocks of the Titanzinho beach; transport of those sediments for 4 reception cells located in the west coast; dredge of the harbor basin; construction of an artificial reef to dissipate the energy of the waves in the coast.

ADDITIONAL INDEX WORDS: Coastal dynamic, coastal erosion, pollution.

INTRODUCTION

The Brazilian politics for the management of the coastal zone has began in 1974 with the creation of the Interministerial Commission for Resources of the Sea - CIRM with the main objective of coordinating the National Policy for the Resources of the Sea - PNRM. The PNRM Act has been publishes in 1980 being so the legal support of the development of the coastal zone. The CIRM elaborated several plans for the coastal zone, among them the National Coastal Zone Management Plane - PNGC, transformed in Law in 1988 (Act 7661 of 16/05/1988). In 1997 objectives of this Plan have been reviewed, restructured and published with the title of PNGC II.

In Brazil, the federal management politics of the coastal zone have well advanced but the development of municipal actions for the management of the coastal zone was very little. According to REIS et al. (2002), “the implementation of the Brazilian Coastal Management Program is rather difficult although it is a consistent legal, political and institutional framework. Many problems observed along the Brazilian coast are caused by political, legal, human capacity and institutional reasons. These are: no policy of land use and land occupation; no integration between regional plans and policies; funding of impacting development projects; lack of enforcement; no social mobilization; conflict between government agencies; no Master Plan at municipal level; economic activities developed apart from local population traditions; lack of infrastructure (sanitation); and personnel involved with ICZM inadequately trained”.

The Municipal Master Plan does not foresee measures capable of reverting the serious existent environmental problems. Many of the actions accomplished in the coastal zone are unilateral decisions of the executive power, a lot of times not foreseen in that plan.

The main of this paper was to bring suggestions to solve the main coastal problems of Fortaleza, in order to contribute to start a ICZM process. We have analyzed problems in an integrated way to better understand the anthropic interventions, their interactions with the coastal dynamics and the associated impacts.

METHODOLOGY

We accomplished a vast bibliographical research regarding the several environmental problems of Fortaleza The analysis of the problem, the qualification of the coastal space, the definition of the coherent management units and the presented suggestions are in agreement with the Methodological Guide to ICZM (UNESCO, 1997). The main environmental aggressions were identified through the analysis of the images obtained by the satellite Ikonos in the year 2000. For the analysis of environmental impacts and to calculate the reached areas we used the software Arc View 3.2. In the study area we analyzed the areas submitted to the environmental impacts in order to check the information obtained in the bibliographical rising and supplied by the satellite images. We collected samples of sediments and we analyzed them in the laboratory according to the methods of FOLK and WARD (1957).

HISTORICAL ANTECEDENTS AND ACTUAL PROBLEMS

The city of Fortaleza possesses 336 km² of surface and 2,100,000 inhabitants with demographic density of 5,600 inhab./Km² (IBGE, 2001). The population has been multiplied by 5 in the last 50 years, occupying the urban soil in a disordered way, provoking environmental aggressions through the embankment of lakes, deforestation and occupation of the margins of rivers, construction on the field of dunes, release of sewers and garbage in the courses of water (VASCONCELOS, 1998).

The rivers of the city are composed by courses of water of small flow, being the main ones constituent the rivers Cocó, Maceió, Pajeú, Jacarecanga and Ceará. These rivers suffer
current impacts of the accelerated urbanization process, they present different degrees from embankment, presence of accumulated garbage and high pollution index for organic matter and fecal coliformes. The quality of the water is considered, in a lot of times, inappropriate for bathing because the presence of fecal coliforms is superior to 1000 NMP/100 ml. Besides polluting the water of the rivers, the fecal coliforms also contaminate the water of great part of the beaches of Fortaleza (Figure 1, point 1) (SEMACE, 2003).

The Trade winds determine a train of waves of predominant direction of south and of southeast that, associated to the inclination of the coast, determinate a coastal stream that transports sediments from east to west.

In the coastal zone the population has occupied the sea shore zone of the beaches and the field of dunes. There were accomplished more than 20 important constructions in the 32 km of the coast. These constructions contribute to modify the existent equilibrium of the coastal dynamic.

The first great coastal construction was the port of Mucuripe, built between 1939 and 1945. The dyke of protection of the port provoked a change in the coastal dynamics by diffraction of the incident waves, in consequence, the sediments transported by the coastal stream started accumulating in the basin port embanking the channel of the port and forming a sandy bank in the internal part of the dyke called Mansa beach (Figure 1, point 3). Since the 1950's the retention of the sediments in the port basin have been causing an erosive process on the beaches to the west of the port. Iracema beach was the first one to be eroded (Figure 1, point 4).

To decrease the embankment of the port basin, in 1966, a perpendicular groyne was built on Titaninzo beach that started to retain the sediments to the east of the port. The retention of sediments worsened the erosive processes of the beaches placed to the west of the port. The surplus of accumulated sediments is impelled by the wind, invading the properties located at the sea side, provoking material damages and problems to the health of the local population. (Figure 1, point 2).

Starting from 1960 many constructions were accomplished to contain the coastal erosion to the west of the port. 12 groynes were built and more than 1.800 m of rocks. These constructions extend themselves from the Iracema beach to the mouth of the river Ceará (Figure 1, point 5). These constructions protected the coast from the erosive process but they have as main negative impact to transfer the erosive process to the beaches placed to the west. (Figure 1, point 6).

In the year 2000 an attempt of regeneration of Iracema beach was accomplished. They built a new groyne perpendicular to this beach to the east of the first groyne built in 1969. Between the two groynes an embankment was accomplished with sediments dredged in the continental platform in a depth average of 8 m. The embankment was not shown very stable, suffering a fort erosive process during the winter storms that happened in the beginning of 2001 (VASCONCELOS et al., 2003). The works of dredging and embankment were repeated in the end of 2001 to recompose the volume of sediments lost during these storms. (Figure 1, point 4).

UNIT OF MANAGEMENT AND PROPOSITION OF SOLUTIONS

The environmental problems of the coastal zone of Fortaleza city are associated to: the nonexistence of basic sanitation; the lack of environmental education of the population; the permissiveness of the public power in the occupation of the water margins by the population or yet for the construction of coastal works. Until the present the actions executed were always punctual, in the attempt of solving each problem specifically, a lot of times without considering the complexity and the interaction among the environmental coastal factors. Some actions accomplished to minimize deleterious effects had more serious impacts than the problems that they were destined to solve.

The solutions here presented, if they happen to be executed, will represent a first stage of a process that seeks to revert an important environmental degradation of Fortaleza's coastal zone. It also represents a first step heading to a ICZM plan. The second stage consists on inviting the several actors that have interests in the coastal zone (inhabitants, fishermen, managers etc.) so that together with the representatives of the legislative, judiciary and executive powers they can discuss the use and the occupation of the coastal zone assisting PNCG IF's guidelines. That is necessary for the management of opposite interests and for the taking of decision on the public and private investments that should be accomplished in the coastal zone.

To analyze the problems and to suggest appropriate solutions we divided the study area in 5 coherent units of management of the coastal zone (Figure 2, units 1 to 5). The choice of these units follows geomorphologic parameters. The units were defined in order to facilitate the environmental management.

The unit of management 1 corresponds to the hydrographic basin of Cocó river. This river coppers 80% of the surface of Fortaleza (Figure 2, unit 1) and it presents the following degradations and environmental impacts: a) embankment of inundation areas located in its margins, that work as areas of fluvial expansion during the flood; b) deforestation of the margins; c) embankment of the river; d) decrease of the river flow; e) decrease of the penetration of the sea water in the estuary; f) decrease of the purifying power of the river; g) release of domestic sewers; h) pollution by organic matter; i) eutrofisation of the water; j) contamination of the water by pollutants originated from the sanitary wastes of Fortaleza.

We suggested as solutions to the problems of Cocó river: a) dredging of the 24 km of the river's bed; b) retreat of the garbage accumulated on its margins; c) sanitation of the sanitary wastes. After the dredging, the river flow would increase, expelling the pollutants quicker. It would facilitate the renewal of the waters by the penetration of the tide (maximum width of 3,4 m), increasing the purifying power of the estuary and increasing the area of expansion of the river in the flood periods. (Figure 2, letter A).

This solution will bring immediate benefits to the environmental quality of the Cocó river, however it will have a limited duration if two other measures do not happen to be taken: the expansion of basic sanitation and the accomplishment of a program of environmental education. These actions are of long period and they need important public investments.

The unit of management 2 corresponds to Futuro beach from the mouth of the Cocó river to the groyne of the Titaninzo beach (Figure 2, unit 2). This beach presents a profile from stable to progressive, receiving sediments by the coastal stream and by the fluvial contribution. It has great importance to the economic development of Fortaleza's tourist activity for possessing an important infrastructure of bars and restaurants on its sea side.

The pluvial galleries of this beach present pollutants originate from clandestine release of domestic sewers. These pollutants are transported to the west by the coastal stream (Figure 2, letter B).

The groyne of Titaninzo beach accumulates part of the sediments transported by Futuro beach's coastal stream. The volume of accumulated sediments is in order of 800.000 m³ a year, with a stock esteemed in 26.400.000 m³ (PITOMBHEIRA, 1995). This beach changed from the condition of stable to progressive, increasing its surface in 493.000 m² in 37 years. The progression of the beach also increases the deflation surface in the intertidal zone, increasing the power of transportation of sediments by the wind in direction to the continent. The sediments invade the houses placed at sea side, causing damages to the proprietors and to the heath of the inhabitants of this beach. The sediments trapped at this beach accelerate the erosion to the west of the port.

To improve the environmental quality of the water it is necessary to stop with the release of domestic sewers in the pluvial galleries.

The solution to the main problems related to the changes in
the local coastal dynamics is the correct management of the stock of the beaches’ sediments (Figure 2, letter C).

The report accomplished by the Laboratoire Dauphinois d’Hydraulique - SOGREAH (Vincent, 1957) suggests as a solution to the erosive processes the transport of sediments from east to the west of Mucuripe’s point by hydraulic bombing. This report warns that if these measures happen not to be taken it would worsen the erosive processes to the west of the port. This solution wasn’t viable due to the high cost of installation and maintenance. We retook this idea here because the transport of the surplus of sediments from Titanzinho beach to the beaches placed to west is the best solution to contain the coastal erosion. The most economic ways would be the transport by trucks or by ships.

Samples collected on the sea shore of this beach indicate that starting from 30 cm of depth we can find sand with medium granulometry superior to 0.25 mm. These sediments can be used in the recharging of beaches.

To minimize the problems caused by the embankment in Titanzinho beach and to feed the beaches to the west, we suggested to take away sediments from this beach in an initial volume of 600,000 m³ to be transported to the 4 reception cells located to the west of the port. This solution wasn’t viable due to the high cost of installation and maintenance. We retook this idea here because the transport of the surplus of sediments from Titanzinho beach to the beaches placed to west is the best solution to contain the coastal erosion. The most economic ways would be the transport by trucks or by ships.

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The cell C1 is located in the portion more to the east of Meireles beach, right after the blooming of beach rocks. The sediments deposited on this beach would be transported to the west by the coastal stream guaranteeing the stabilization of this beach. The cell C2 is located at Iracema beach. The discharge of sediments should be done in the area of artificial embankment, guaranteeing its maintenance. The cell C3 is located at Pirambu beach, after the installation of the naval shipyard of Fortaleza. The sediments thrown on this point would guarantee the feeding from the west coast to the mouth of Ceará river. The cell C4 is located at Dois Coqueiros beach. Its feeding has a crucial importance to combat the erosive process to the west of the mouth of Ceará river.

After this first phase, it should be done 3 ditches of reception of sediments in Titanzinho beach. They are to each other parallel trenches and lightly inclined following the same orientation of the waves that arrive at the beach. They should have depth of 1.5 m, width of 5 m and length of 100 m. The first ditch should be located in the superior part of the sea shore and close to the groyne. The other two should be distant in 50 m one of the other (Figure 2, letter C). They will have the function of reception of sediments moved by the wind, protecting the properties located to the sea side. Another function of them is to stock the sediments that will be regularly transported to the 4 reception cells. The periodicity of the transport should be determined in function of the time of the sediments' accumulation.

The works of management of this stock of sediments should be assured by the municipal public power and should be part of an ICZM plan. Other sections interested in the recovery and maintenance of the coast line should be involved, among them the Mucuripe port and the tourist trade.

The unit of management 3 corresponds to the area between Mucuripe port and the naval shipyard including the hydrographic basins of the rivers Maceió and Pajeú (Figure 2, unit 3).

This unit is the zone of larger economic interest of the coastal area, where there are located, besides the port, wheat mills,
refinery and stocking of derived from petroleum, fishing port and an important tourist infrastructure. The properties located to the sea side are the most valuably of the city. The use and occupation conflicts in this unit are constant.

The main problems with this unit are: a) pollution of the rivers Maceió and Pajeú by domestic garbage; b) release of domestic sewers in these rivers; c) release of domestic sewers in the pluvial galleries; d) frequent presence of fecal coliformes in the water of the beaches (SEMACE, 2003); e) embankment of the port basin f) accumulation of sediments in the internal part of the port's dyke, forming a sandy bank with a current surface of 133,000 m²; f) coastal erosion starting from the beach of Iracema, extending itself to the west direction; g) presence of rocks to the coast protection.

The solution to these problems requests a lot of actions. The first one is to continue with the periodic works of dredging of the port basin (Figure 2, letter D). In spite of the negative impacts, dredging is still the most economic solution for the maintenance of the necessary depths to the sailing in the port basin. These sediments should not be used to feed the adjacent beaches that find themselves in erosion process. These sediments are, in the most part, fine and they present high concentration of oils and greases (VASCONCELOS and MELO, 1996).

We recommend the dredging of the beds and cleaning of the margins of the rivers Maceió and Pajeú. It is also necessary the amplification of basic sanitation and the impediment of releases of clandestine sewers. It is also necessary to apply a vast program of environmental education to avoid that the population makes use of this natural resource badly.

The solution to the problems related to the alteration of the coastal dynamics is tied up, partly, with the management of the sedimentary stock of Titanzinho beach. The receiving cells C1 and C2 would receive the sediments from captivation cell C. The feeding in sediments in cell C1 would guarantee the maintenance of Meireles beach, area relatively well protected from the waves by the point of Mucuripe. For its time, the cell C2 is located in the Iracema beach that receives the waves directly from open sea, therefore it subjects to an intense coastal stream. This beach has received strong investments in tourist infrastructure, among them, the execution by the municipal public power of an artificial embankment. The beach was embarked with 1,500,000 m³ of sediments in an extension of 1,100 m. The profiles accomplished at the beach indicate that it is constantly losing sediments. Even with the artificial embankment this beach is being eroded because the erosive processes have been acting for more than 60 years, since the construction of the port of Mucuripe.

The solution for coastal erosion suggested by the embankment projects of this beach was the construction of a break-sea with stone blocks that would impede the arrival of the waves to the coast. This work would solve the problem of the erosion on Iracema beach but it would block the coastal stream completely, worsening the erosive processes of the beaches placed to the west. These beaches were stabilized by the contention works of the coast line. If this break-sea happen to be built this equilibrium will be broken, and the erosive processes could come back.

To decrease the erosive processes in this unit of management it is necessary to decrease the energy of the waves that arrive in
the coast line, without however blocking totally the coastal stream because that would worsen the erosion to the west. The solution consists on combining the feeding of the system with more sediments and to decrease the energy of the waves, without impeding totally the displacement of the sand trough the coastal stream. That would be possible through the installation of a submerged artificial reef built with old automobiles' tires, installed at -1m below the water line, in the quota of -8m of depth and an extension of 3 km (Figure 2, letter E).

Besides its function of waves dissipater the artificial reef would still have the following functions: a) to create a favorable zone to the development of several marine species; b) to create an area of handmade and sporting fishing; c) sanitary function because it would eliminate many tires that serve as accumulative recipient of water, favorable atmosphere to the development of the mosquito *Aedes aegypti* transmitter of the dengue. Another positive factor of this artificial reef is its low installation cost if compared to the construction of a break-sea with granite blocks.

The unit of management 4 corresponds to the beaches from Pirambu to Goiaibeiras in the mouth of Ceará river, including the hydrographic basin of Jacarecanga river (Figure 2, unit 4).

The river Jacarecanga crosses an industrial neighborhood and several slums. The environmental aggressions to this river are the garbage release and the pouring out of dejection of industrial and domestic origin. The pollutants thrown commit the quality of the river water and the beaches water of that unit of management.

In the coastal zone were installed 11 groynes, 820 m of rocks and the submarine's emissary of Fortaleza's basic sanitation. The groynes and the rocks have as purpose to contain the recoil of the coast line by the erosive process. These works were shown efficient but they have as negative impact to transfer the erosive process to the beaches placed to the west.

The adequate management of this unit demands measures of environmental recovery of great magnitude in the hydrographic basin of Jacarecanga river. There will be necessary sanitation works, dredging, cleaning and environmental education. It will also be necessary to move the population that lives in the slums installed on the river's margins. (Figure 2, unit 4).

The beaches of this area were stabilized through the groynes and the rocks. This stability can be maintained through the feeding in sediments in cell C3 and by the decrease of the wave's energy through the artificial reef.

The unit 5 is formed by the hydrographic basin of the Ceará river and by the beaches placed to the west of the mouth of this river (Figure 2, unit 5).

The river Ceará receives pouring out of domestic and industrial sewers, besides garbage thrown by the population of the slums located in its margins. Another serious problem is the retreat of sand from the bed of the river for use in the civil construction, decreasing the volume of sediments transported to the coast and contributing to the worsening of the erosive processes.

Starting from 1980 these beaches have suffered an erosive process that is consequence of the installation of groynes to protect Fortaleza's coast. The erosion already consumed a strip of beach superior to 100 m.

We suggest the cleaning of the bed and of the margins of Ceará river for retreat of the accumulated garbage. This river is the only one that doesn't need dredging. It is necessary public investments in sanitation and in environmental education.

The feeding of cell C4 with sediments would decrease the intense process of coastal erosion. The coastal stream would transport the sediment to the beaches to the west.

CONCLUSIONS

The presented suggestions follow the logic of Fortaleza's coastal dynamics, where the processes of displacement of water and sediments happen from east to west. To decrease the water pollution it's necessary public investments to: a) dredging and cleaning of garbage accumulated on the rivers' margins; b) expand basic sanitation; c) apply a program of environmental education. To decrease the coastal erosion it's necessary to consider the integration of the several elements of the coastal dynamics and better manage the sedimentary stocks. We suggest: a) to remove the surplus of sediments retained to the west of the port, that are embanking that area; b) to transport those sediments to the 4 reception cells to the west of the port; c) to continue the dredging of the port basin; d) to build an artificial reef with the purpose of decreasing the energy of the waves on the coast west of Fortaleza.

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LITERATURE CITED


