Pesquisas em Geociências

http://seer.ufrgs.br/PesquisasemGeociencias

Approaches to Evaluation of Self-Purification in Estuarine Rivers of Souhteast of Amapá State - Brazil

Alan Cavalcanti da Cunha, Helenilza Ferreira Albuquerque da Cunha, Luis Roberto Takiyama, Marcio Sousa da Silva, Odete Fatima Silveira, Silvia Pantoja, Alan Silva Nazaré, Eduardo Queija de Siqueira

Pesquisas em Geociências, 28 (2): 487-496, maio/ago., 2002.

Pesquisas em Geociências, 28(2): 487-496, 2001
ISSN 1518-2398

Instituto de Geociências, UFRGS
Porto Alegre, RS - Brasil

Approaches to Evaluation of Self-Purification in Estuarine Rivers of Southeast of Amapá State – Brazil

ALAN CAVALCANTI DA CUNHA[1], HELENILZA FERREIRA ALBUQUERQUE DA CUNHA[1], LUIS ROBERTO TAKIYAMA[1], MARCIO SOUSA DA SILVA[1], ODETE FATIMA SILVEIRA[1], SILVIA PANTOJA[1], ALAN SILVA NAZARÉ[1] & EDUARDO QUEIJA DE SIQUEIRA[2]

[1]Scientific and Technological Research Institute of the State of Amapá, IEPA/GERCO - CNPq. Rodovia JK, Km 10, s/n, Fazendinha-AP, Brazil. Phone: ++(96)212.5350, CEP: 68902-280. E-mail: c_alancunha@hotmail.com, helenilz@uol.com.br

[2] Ph.D. Degree in progress - Guelph University, School of Engineering, Guelph, Ontario, N1G 2W1, Canada. Phone: ++ 519 824 41 20 ext. 6187. E-mail: eduqs@yahoo.com

(Recebido em 10/01. Aceito para publicação em 05/2)

Abstract -There are a number of reasons that make Amazon estuary an important natural water resource. First, it is biologically productive being the spawning and nursery ground for many important aquatic biota. Second, it serves as receiving waters for wastewater discharges and for navigation use. Third, it has been demonstrating its elevated dilution and self-purification capacity for constituents of the water, principally bacteria, toxic substances, organic material and nutrients. Many cities and small ports of the State of the Amapá located on estuaries and coastal zones are ready affecting their quality through runoff, domestic and industrial wastewater. So, the present research evaluated the water quality in four rivers located close to the periurban areas of Macapá and Santana and rural area of Mazagão municipality. The main objective is to diagnostic the spatial-temporal distribution of some variables and parameters of the water quality, considering important factors as atrophic, hydrologic and climatologic effects in streams sanitation.

Keywords - Estuarine River, Water Quality, Self-purification.

INTRODUCTION

Hydrologic Factors Combinations and Microbial Self-Purification in Streams

It is wise to recognize the many possible combinations that affect self-purification in each river, that is *unique*, and each must be subjected to intensive investigation and study. Velz (1984) affirms that although the character of water resources is dynamic, at a given time and place in natural setting an equilibrium stability in hydrologic environment is established through a complex interrelation of water, land, and vegetation cover, which is relative depending on the time period. In terms of geologic time changes have occurred, but whether a change is a downward pulsation in a otherwise upward trend of part of a well-defined cycle is difficult to establish. The referred author affirms that the history of the world in the past 2000 years does not lead us to expect sudden changes in nature's balance. Hence in the shorter historical view hydrologic stability may be accepted, and practical definitions of the water resources available can be determined by from statistical analysis of current records.

However, we do not always comprehend the consequences of man's impact on nature's balance of water, land, and vegetative cover, nor the potentialities for abuse, nor responsibility for intelligent use and management. Since physiography to a large extent determines the *unique water source characteristics* among drainage basins as well as within a given basin, its definition contributes to practical consideration in use and development. Relevant features to be considered are size and shape of the drainage area, the river system and tributary streams, physiographic regions and land forms, vegetative cover, and geology and groundwater formations. Groundwater is a primary source of water supply for small and moderate-size communities, industries, and in many instances is a major element in streamflow. In some of the studied cases, in the present investigation, we can mention the District of the Fazendinha, urban and periurban areas of Santana and Macapá cities (Cunha *et al.*, 2001; Cunha *et al.*, 2000; and Cunha, 2000).

The shape and size of the drainage basin and river systems are defined by topography. But in dealing with practical problems it is necessary to subdivide major systems into appropriate sub-basins. These vary in size, shape and arrangement of tributary

Em respeito ao meio ambiente, este número foi impresso em papel branqueado por processo parcialmente isento de cloro (ECF).

streams. The nature of the river system is radically influenced by the physiographic regions that cut the basin and the related land forms and vegetative cover. Although physiography in a given basin is reasonably stable, the climatologic factors – precipitation, temperature, wind velocity, vapor pressure, and solar radiation – are highly variable in time and place, and induce variation in stream runoff and in waste assimilation capacity (Velz, 1984).

Channel characteristics play a major role in self-purification of freshwater rivers and estuaries (Cunha 2000). There are so many variations in size, shape, topography, and physiography of the drainage basin, and stream cross-sectional shape, width, depth, bed slope, and hydraulic gradient, that channel characteristics along each watercourse require their own intensive investigations. Nevertheless, usually there are broad classifications of channel types encountered in the natural hydrologic setting and alterations induced by river developments (Cunha, 2000; Lung, 1993, and Velz, 1984).

In the quantitative evaluation of stream self-purification three relevant channel parameters are the *occupied channel volume*, *surface area*, and the *effective depth*, reach by reach. From these are derived two additional vital factors – *time of the passage* and *mean velocity*, reach by reach. All five factors are related to stream runoff and at any specific runoff regime are determined from channel cross-section soundings and these data are usually not available. Time of passage, defined as occupied channel volume divided for flow rate of the stream, from reach to reach along the watercourse, is an essential parameter in all stream self-purification computation involving degradable wastes such as microbial, organic, radioactive, heat and so on (Lung, 1993; Velz, 1984).

The one remaining parameter that is required in reaeration computation, for example, is not directly measured in the stream but is strongly related to effective-depth, and thus is tied to stream channel characteristics. For practical application, the velocity factor is dealt with by dividing streams into three broad classes: (a) those of moderate depth and velocity – may be taken as representative of the large majority of streams of moderate depth and velocity; (b) tidal estuaries subject to ebb and flood translation – is applicable to tidal estuaries in which tidal currents and reversals of ebb and flood translation tend to shorten the mix-interval for a given effective-depth; and (c) streams of shallow depth and relatively high velocity – may be taken as a first approximation for shallow, relatively high-velocity streams, but verification should be made by comparison of the computed and observed dissolved oxygen profiles through the shallow reaches.

Lung (1993) affirms that there are two aspects to the time and space scale determination: (1) the temporal and spatial extent of the water quality problem and variable; (2) the temporal and spatial interval of the computation, i.e., the time step and spatial grid dimensions of the computational scheme. Both are important for any type of analysis. For example, the time scale of dissolved oxygen problems is in the order of days, which is understandable since the controlling reactions rates typically range from 0,05 to 1,0 d^{-1} (base *e*). Similarly, the spatial scale for dissolved oxygen is in the order of tens of kilometers. This way, the computational time step may vary from minutes to days and spatial grid may vary from hundreds of meters to kilometers for dissolved oxygen. In addition, the relevant spatial scale may also involve determination of the necessity to include vertical calculations in addition to horizontal calculations.

Self-Purification in Estuaries and Approach to Its Evaluation

A fundamental component of the wastewater disposal is the associated environmental impact and the two aspects mentioned above: the time and space scale determination. Metcalf & Eddy (1991), affirm that the numerous environmental regulations, criteria, policies, and reviews now ensure that the environmental impacts of treated wastewater discharges to ambient water are acceptable. This regulatory framework affects not only the selection of discharge locations and outfall structures but also the level of treatment required. Treatment and disposal are thus linked and cannot be considered independently. In this context, the emphasis of environmental impact evaluations of water pollution used in this text to be on microbiologic, i.e., coliform bacteria.

Coliform bacteria are used as indicator of other pathogenic organisms of fecal origin and as such provide a measure of the safety of the water for recreational and other uses. This way, all types of wastes reaching the watercourse are of public health significance. Consequently, there is special public health concern with the disposal and ultimate fate *microbiological* wastes contained in municipal sewage, principally those intestinal origin that cause waterborne diseases. These are specially bacteria and viruses, and the cysts and ova of parasitic worms. Our three major contacts with water are drinking and domestic uses, consumption of shellfish, and bathing and other water recreational activities.

The number of pathogenic microorganisms contained in municipal sewage is dependent on the prevalence of the diseases in the population. Therefore, are possible remains potential hazards from carriers or isolate cases, and the water polluted by raw or inadequately treated sewage are always suspect. The number of organisms contributed per day by a single infected person is so great that reliance on dilution and self-purification cannot be depend on to extent that pertains in dealing with other types of wastes.

Success in control of waterborne diseases is built on the principle of *multiple barriers*; the principal lines of defense are treatment of sewage before return of wastewater to the rivers or watercourses and treatment of the domestic water supply again before distribution for use. However, as with all treatment systems, there remains a residual that must be handled by the *waste assimilation capacity of the streams*, and hence microbial self-purification is a vital factor.

On another hand, beyond the results of bacteriological examination of water samples in the laboratory, the interpretation of the water quality destined for human use and contact depends to a great extent on detailed sanitary field surveys and surveillance of the area tributary to the watercourse. It can be affirmed that in absence of more extensive data the daily per capita discharge of nonpathogenic bacteria in municipal sewage is extremely high (Street, 1928 *apud* Velz, 1984), approximately 200 billion coliform organisms.

Velz (1984) classifies the self-purification in the stream environment, which depend of various factors, named Modifying Factors, such as (1) temperature, (2) pH, (3) nutrients, (4) sedimentation and adsorption, (5) contact opportunity and biological extraction, (6) competitive life, and (7) seawater salinity.

The *temperature*, within the usual natural ranges, stimulates biological activity, and in the otherwise more overshadowing, unfavorable environment, an increasing in temperature may show some increase in death rate. But is very difficult to distinguish only between broad temperature ranges. The pH effect is a factor very important because the acidity and alkalinity increase the bacterial death rate in laboratory tests. But under stream conditions the specific contribution of pH is not definable except when there is pronounced deviation from neutrality. The effect of *nutrient* (pollution) in the streams seldom presents the character and magnitude as to stimulate sufficient growth for a net change in death rate to be detectable. *Sedimentation* and *adsorption* undoubtedly increase the death rate. However, turbid conditions associated with high stream runoff usually show a net increase in bacterial concentrated by virtue of contamination flushed by surface wash from the drainage area. Sedimentation with adsorption may induce a decrease in bacterial concentration to a point below that expected for a time of passage in the death rate. *Contact opportunity* and biological extraction are very important factors. Shallow and small streams afford greater biological contact opportunity for bacterial extraction than large, deep rivers, and they usually show higher death rate. The effect of the *competitive life* is likely one of the most potent factors beyond the element time of the passage in the death rate of coliform bacteria in the stream environment, because the natural biological life rivers is much too rugged for the survival of organism whose normal habitat is the shelter of the intestinal tract of man and other warm-blooded animals. The effect *salinity of the seawater* on the death rate of coliform are based on laboratory results, as it is difficult to measure reliably the time of the exposure in the open ocean. However, in the river environment the interest is the brackish formed by the large freshwater rivers discharging into the ocean or estuary. A further complicating factor is the ebb and flood translation induced by tides.

Metcalf & Eddy (1991), affirm that the rate of disappearance of pathogenic bacteria and viruses due to die-off approximately follows first-order kinetics: $r_B = - K_B C_B$, where r_B = rate of bacteria die-off per unit time per unit volume of water, K_B = die-off constant, and C_B = bacteria concentration. The die-off constant K_B, depends on the bacteria and viruses and on the salinity, temperature, and light intensity. For freshwater, decay rates of 0.12 to 0.26 d^{-1} with a median of 1.0 d^{-1} where measured for coliform in 30 separate in-situ studies. In seawater, bacterial decay is more rapid (Bowie *et al.*, 1985 *apud* Metcalf & Eddy, 1991). Lung (1993) classifies a number of the water quality problems that have been observed in estuaries. The well-known examples of estuarine water quality management using water quality models are showed in Table-1.

Table 1 - Estuarine water quality problems, based in Lung (1993).

Salinity (dissolved solids)	Alteration of local salinity regime through dilution
Suspended solids	Altering the habitat of benthic organism and serving as a carrier of contaminants
Bacteria and viruses	In runoff from farms and feedlots Effluents form municipal and industrial wastewater discharges Pathogens may be transported to shellfish habitat
Dissolved Oxygen	Requirement for most aquatic organism Seasonal or diurnal depletion of OD disrupts or displaces estuarine communities Best conventional indicator of water quality problems
Nutrients	Excessive nutrients loading can stimulate overproduction of some species of algae Periodic phytoplankton blooms can cause widely fluctuation DO and DO depletion in benthic and downstream areas
Toxic substances	High concentration of ammonia, metals, and many organic chemical can disable or kill aquatic organism; Acute toxicity is caused by high exposure to pollution for short periods of time

Velz (1984) affirms the complexity of estuaries has led to several approaches to evaluation of self-purification, roughly grouped into five schools: (a) tidal prism, (b) mathematical model, (c) experimental model, (d) statistical and (e) rational.

The *tidal prism approach* is centered on the effect that water of the tidal are completely available for dilution and that wastes are flushed to the sea on each ebb tide, not be returned on the following flood.

With the advent of the computers, a great deal of effort is being devoted to solutions through elaborated *mathematical models* that apply to tidal phenomena hydrodynamic theory developed for atmospheric diffusion. A great many independent variables are involved but only a few of which are measurable, and in the end, a number of the quite arbitrary assumptions must be made in application of the mathematical models to a specific estuary. The limitation of these hydraulic models is the difficulty of incorporating the features of specific prototype so as to test simultaneously the complexities associated with tides, the hydrodynamic diffusion, and the fate unstable wastes, such as are associated with bacterial survival, deoxygenation, and reaeration.

Limitations of the mathematical and experimental model approaches have given rise to *statistical school* of though. In this approach no attempt is made to define and formulate the fundamental relationships involved and reliance is placed on statistical analyses of observed water quality and results from a give waste loading, correlating with recorded variables, such as landwater runoff, seasonal water temperature, and tide. The statistical approach is helpful in interpolation within the frame of observed results, but since it is not based on self-purification fundamentals, it cannot be employed with any sense of security in analyses of other conditions, such as interpretation of waste loads for treatment regime as channel changes, storage of upland runoff, or low flow augmentation.

The *rational approach* breaking down the complex problem into rational parts and applying to each its primary relevant factors. The fundamental principles of self-purification developed for application to inland rivers will apply to estuaries. It is necessary only to consider modifications associated with tidal translation and seawater intrusion. In this approach seawater intrusion is critical factor; estuaries are classified by this factor.

The last two cited methodologies are being used in the present study due to the shortage of data and information. The present study has as one crucial objective to obtain such information necessary for only hereafter to apply the rational and statistical models or even the hydrodynamics of quality of the water.

METHODOLOGY

In this study the extent to which pollution is affecting streams, such as the Matapi, Fortaleza, Vila Nova and Paxicu Rivers, is reported, mainly measuring fecal coliform in 15 sampling stations along these rivers and some physio-chemical parameters such as pH, dissolved oxygen, turbidity, conductivity, total dissolved solids and temperature.

The river stretches for the monitoring of water quality were chosen considering factors such as land use, tributary influence by polluted water bodies and shantytown areas and other potential pollution sources (Cunha *et al.*, 2000, Cunha *et al.*, 2001). The period of research comprised since September of 1999 to July of 2001 and the four rivers investigated are tributaries of the Amazon River (Fig.1).

In the studies and analyses of the measured parameters, until the present moment, still limited for the conditions of operation of the laboratory of SEMA/IEPA, it was evaluated mainly some located points in Rio Matapi. This way, the points and the monthly frequencies of collections were selected especially located potentially in the area affected for the Industrial District, from the denominated point Porto do Céu, until the mouth of the river. These were chosen with base in the field works and visits previous *in situ*.

First, in Rio Matapi's studies were chosen five points considered strategic for we consider to be enough for to present investigation, considering the space-temporary variability of the physical-chemical and bacteriological parameters already studied (Cunha *et al.*, 2001a,b). As it was already commented, during the execution of the previous works, it was also evaluated a second body of water, Igarapé da Fortaleza, belonging to the Curiaú Watershed, that divides in a certain space of its course the Districts of

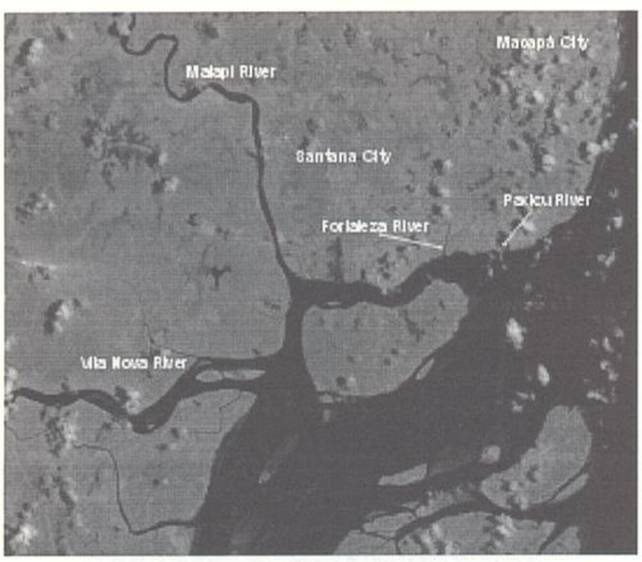

Figure 1 - satellite image of area studied - southeast of Amapá State-Brazil and Amazon River. Arrows, respectively indicate Vila Nova River (Mazagão) and Matapi River (Santana). In northeastern of Matapi River lie Fortaleza and Paxicu Rivers, near Macapá. Paxicu River is smaller than Fortaleza River and is not shown in the map. It is illustrated some anthrophic impacts of the Macapá and Santana cities. Source: Cunha *et al.* (2000).

Fazendinha and Santana Municipality. In this river, the interest resulted of the observation of an intense urban occupation, deforestation of the ciliate forest, in a rhythm considered preoccupying, and sensitive decrease of the quality of the water, easily observed during the previous visits initialized in September of 1999. Besides, Igarapé da Fortaleza, in the ambit of the close micro basins, seems to be with the quality of the water being altered in a faster velocity than the other bodies of water studied, as it will be seen further on. Igarapé da Fortaleza became also important for the analysis because it is also a close tributary of Amazon River, but with a connection to the Lagoa dos Índios, which is a conservation area (tourist point - State Law 455/99).

Igarapé da Fortaleza served and it is still a good referential for Rio Matapi's specific studies, because it presents hydraulic characteristics, physical-chemistries and bacteriological useful for future comparisons, mainly in the elaboration of reduced models of the hydrodynamic behavior and Rational Method application for the river Matapi. In the Igarapé da Fortaleza were initially chosen 10 points. Later they were only six, located strategically along your course, from an area already influenced by urban antrophic action, until its mouth (political division of Fazendinha and Santana), where there is also urban growth and an intense trade movement, and traffic of boats that discharge and carry goods of everywhere of the State and out of this. (Fig. 1,2).

Third, is included more four sampling points: two in Vila Nova River (problems with cyanide and Arsenic) and Igarapé do Paxicu, bacteriological and organic contamination intense of a municipal slaughterhouse and of the own urban occupation of the area. In the figure 2 *a, b, c, d* some are shown sampling points of the four studied rivers and important places of the study area.

In the total are being appraised 15 points of collection of the quality of the water, until the present moment, being observed the capacity always limit of the laboratory of chemical analyses of SEMA/IEPA. And it can be observed, among the limit of 15 stations imposed by the operational capacity of the laboratory, some points were included and others were excluded in the optimization process and definitive choice, during at least one year. In other words, these 15 current points will stay until the end of the experiment the end of September of 2002, when three years of analyses would be completed.

New parameters as DO (Dissolve Oxygen) and COD (Chemical Oxygen Demand) were already initially introduced in some analyses. In the end of the second semester of 2001 will be made analyses of BOD (Biochemical Oxygen Demand) and already in September of the current it will be made use of ADCP of 600 MHz, type RDI, for the water flow measures, velocity and hydraulic parameters. Actually, these measurements already began. However, the results of these operations will only be parts of the analyses, once the obtained results are insufficient for deeper analyses. The bacteriological analyses are being accomplished through the technique of multiple tubes. The pH-metric is of the mark Hanna instruments, HI8314. The oximetric equipment is of the mark OD-Orion, IP-CE 66. Used turbidimetric is of the mark Hach – 2100P. Condutivimetric (also Solids Dissolved Total) used it is of the mark TDS Hach, SEM Ion 5.

RESULTS AND DISCUSSION

The survey showed that the main sources of pollutants causing usage impairments of estuarine rivers are mainly crude sewage and urban runoff. Besides, so much separately as combined, the effects of the tides and of the rains are important for the dilution, dispersion and self-purification. This way, the principal picks of concentration of fecal coliforms were found in the period of beginnings of the rains and during low water.

As display the Table-2, the use of the waters in these rivers already implicates in some use restrictions, such as: fishes, bath, feeding, hygiene and other. The areas that present some alteration in the quality of the water are naturally not used, even if the population is not real aware that this can be in inadequate conditions. For instance: the people don't like to fish in the Igarapé da Fortaleza. They prefer go fish in Matapi River because there the environment is more favorable and the fishes have a better quality and abundance. In Paxicu, for the characteristics already observed, with its bad constant smell, to obligate the population doesn't use it for drinking water, because some houses are already served by the public net. However, the risks of contamination are great because children and adults bathing in these waters (cultural characteristic behavior). The Table-3 display the result of this

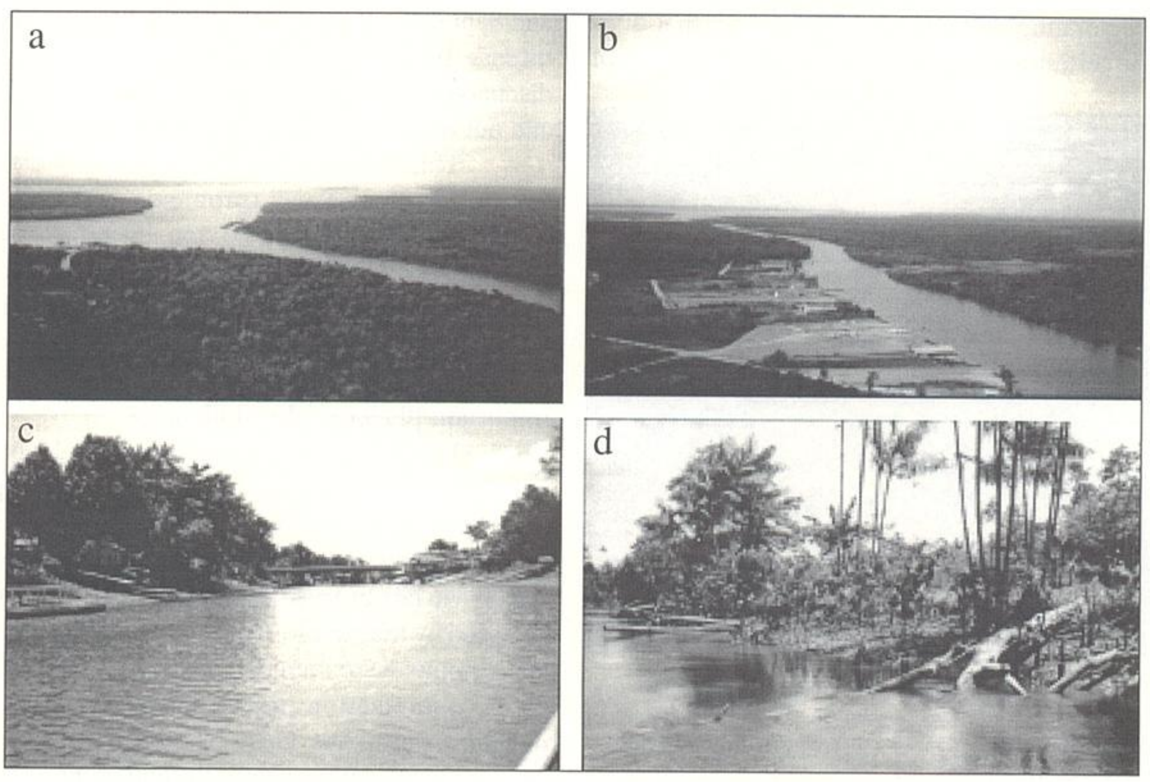

Figure 2 - Pictures of some sampling points: a) Mouth of the Matapi River. Above it is located the mouth Vila Nova River. b) Matapi River close of Santana's Industrial District. c) Bridge above the Fortaleza River. d) Deforestation of the ciliate forest of Fortaleza River.

Table 2 - Water use in the four rivers studied (September 1999-February 2001). Source: Cunha *et al.* (2001b).

Water use in the river	% Matapi	% Fortaleza	% Paxicu	% Vila Nova
	20 interviewed people	26 interviewed people	50 interviewed people	19 interviewed people
Bath/Swimming	89	39	17	100
Garbage disposition	89	10	4	25
Feeding	85	8	-	80
Hygiene and consumption of animals	50	13	-	50
Fishing	89	25	13	95
Navigation	73	5	8	95
Irrigation	12	-	-	10

behavior, that has implications on the problems of Public Health.

The registrations on municipal health service show a large number of patients with gastric-intestinal diseases possibly transmitted for water resources. For example in Igarapé da Fortaleza, children with age in the range from 0 to 5 years, seem to be the most affected such as display the Table-3.

Analysis of Fecal Coliforms

Natural water bodies contaminated by pathogens can lead to serious public health problems (Laws, 1993). Thus, it is observed that the more urban are Fortaleza e Paxicu rivers, because their uses are restrict. It is noticed by the Table-2 that is easy to evaluate this statement comparing the lines of the Vila Nova River (more distant of the urban area) with Paxicu (closer of the urban area). Intermeddle are Matapi River and Fortaleza River. In this present evaluation resulted in the logic. But, in case of the Amazon Area, this logic not always it is obtained. Therefore it is prudent to be always attentive for it is not reached conclusions that, at the beginning, they seem obvious. In this sense it is important to maintain the monitoring to discover if the behavioral tendency of the water quality is maintained.

On another hand, the results of these studies, in the specific approaching of interest of that project, should not be extrapolated for other areas but used for a first local evaluation, as a pilot experiment. In other words, until the present moment, this analysis has its foundation in results more based on a statistical evaluation than in a direct relationship of cause-effect

Table 3 - Map of morbidity of the basic unit of health of Fortaleza River - Municipal City Hall of Santana (Pediatric Data). August 1999 until June 2000. Source: Cunha *et al.* (2001b).

More Common Diagnoses	Aver Max Min	N°. of cases Frequency (0-5 years)	N°. of cases Frequency (5-15 years)	Total Cases	% Cases 0 – 5 years	Period with larger incidence of cases of diseases
Intestinal Parasites	Aver	25	56	81	31	December/February
	Max	62	194	256	24	
	Min	8	14	22	36	
Diarrhea	Aver	10	11	21	48	December/February
	Max	20	27	47	42	
	Min	3	3	6	50	
Vermin	Aver	21	40	61	35	December/May
	Max	47	82	129	36	
	Min	1	1	2	50	

with the dynamics of the aquatic ecosystem, influences of impacts antrophic truly measurable or even with the decisive climatologycal factors. Therefore, these are the critical reasons for they are not made extrapolations for other areas. It is a limitation, however it doesn't minimize its importance for the area and it support for initial information, implementation and sequence for ultimate studies.

The investigation showed that the main sources of pollutant that cause impediment of use of estuarine rivers are mainly crude sewer and urban and rural runoff. Besides, so much separately as combined, the effects of tides and of the rains they are important for the phenomenon of the dispersion, self-purification and dilution. This way, occurrence probability that the concentrations of fecal coliforms don't surpass a certain value for instance Y is showed in the figure 3.

The present result shows the apparent tendency of the deterioration of the quality of the water in terms of concentration of fecal coliforms in the studied basins. The figure 4 display an apparent irregular cyclical behavior of the medium concentration. However, this demonstrates and reinforces the hypothesis that the phenomena occurs in the rain period, when is waited the largest picks. The principal pick of concentration of fecal coliform was found at the beginning in the period of the rains and during the low tides.

Analysis of Electrical Conductivity

In any landwater stream discharging into an ocean, seawater intrudes upstream counter to the landwater flow to form a brackish reach that extends well beyond the flood tide translation. The extension of the intrusion depends primarily on the characteristics of the local tide, the configuration of the channel, and tributary landwater runoff. Figures 5,6 show the influence of the saline intrusion in the estuary.

The present result shows the apparent tendency of the quality of the water in terms of the conductivity in the studied basins suffer significant influence of the sea and of the tides. The figure 5 shows the probability of occurrence of the conductivity in not surpassing a certain value for instance Y. This way, exists 50% of chance that the concentration average of the 15 analyzed points is smaller or equal to 40 uS/cm. The traced curve if it adjusts well to a normal distribution, in that the coefficient of Pearson (R^2 = 0,8989) it is relatively close to 1.

CONCLUSION

Two elements favor the improvement or worsening of the quality of the water in the ambit of the

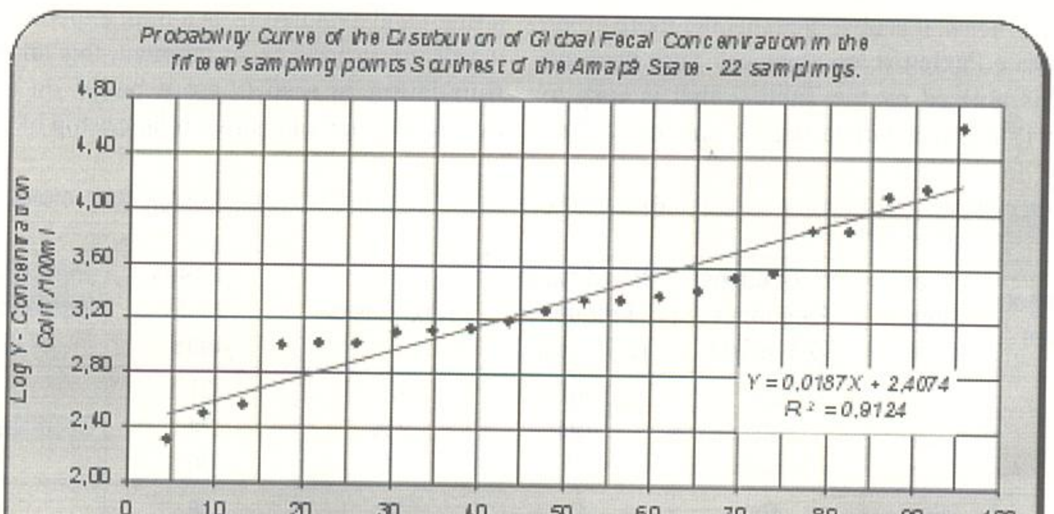

Figure 3 - Occurrence probability that the concentrations of fecal coliforms don't surpass a certain value for instance Y, There exists 50% of chance that the concentration average among the 15 analyzed points is smaller or equal to 5147,4/100ml. The traced curve it well adjusted to a normal distribution, in that the coefficient of Pearson (R^2 = 0,9124) it is close to 1.

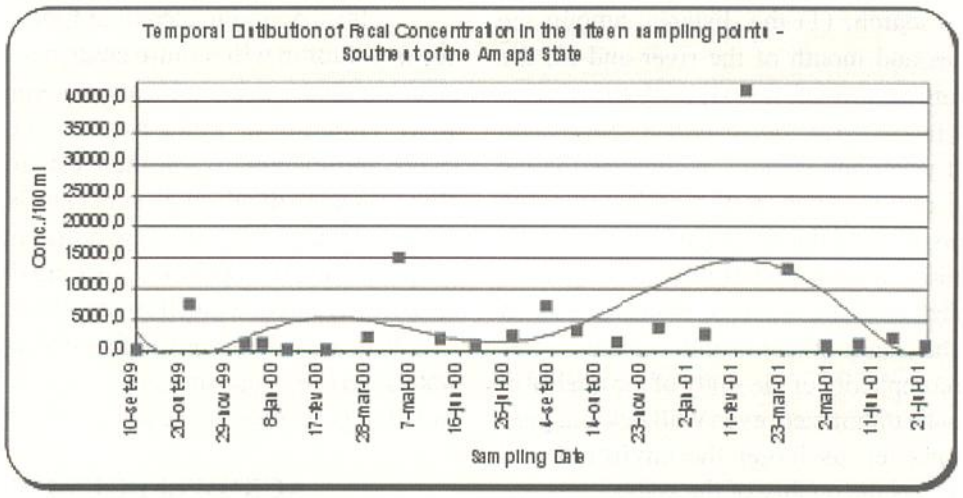

Figure 4 - curve of variably of the distribution of fecal coliforms in the four estuarine rivers. Each point represents the average of 15 samplings in the date. Apparent tendency of the deterioration of the quality of the water in terms of concentration of fecal coliforms in the studied basins.

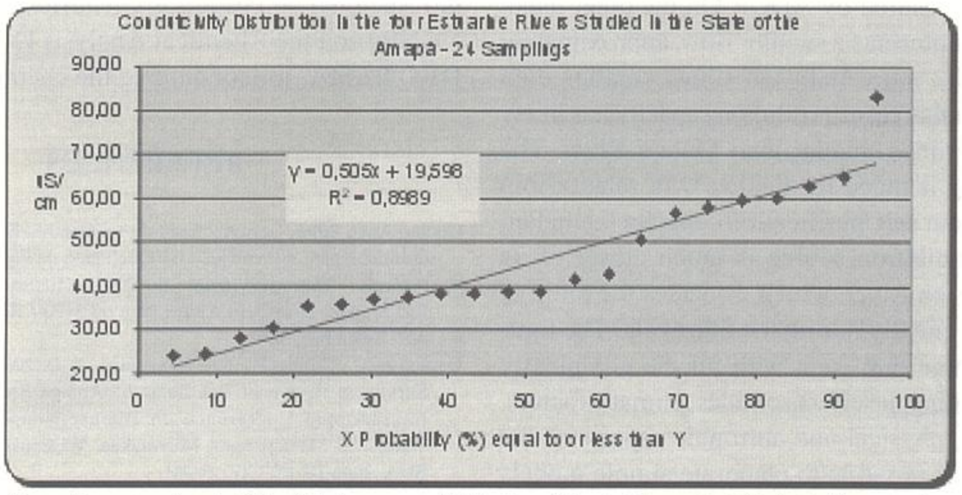

Figure 5 - curves of probability of the temporary distribution of the electric conductivity in the four estuarine rivers. Each point is the average among 15 collections.

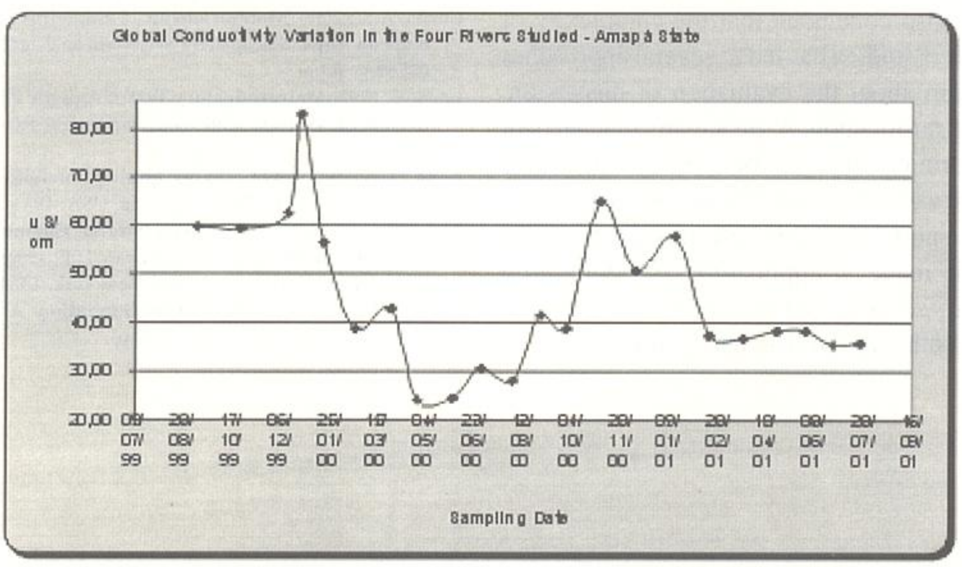

Figure 6 - Variation of the electric conductivity for all the 15 collection points along the time. It is observed that during the months of rain (mainly April) there is a fall of the concentration of salts. In the summer it was happened the opposite, when there are an increase of the salinity and larger influence of the saline intrusion in the estuary.

accomplished research: (1) the distance among the pollutant sources and mouth of the river and (2) the increase or diminution of the size of the rivers. Considering the favorable factors to the self-purification of the bodies of water and streams, commented in the bibliographical review, such as the hydrologic and physiographic aspects of the drainage basin, climatic aspects of the rainy stations and of drought, vegetable covering, parameters of the drainage channels, uses of the watershed, the results obtained of the collected data display that the complexity of the study of the quality of the water can yet be minimized, even with few analyzed parameters. However, as larger the environmental degradation worse is the quality of the water.

The Vila Nova and Matapi rivers present high flows, respectively, 1500 m^3/s and $1000 m^3/s$ in the summer day, measured by ADCP. On the other hand, Fortaleza River presents a smaller flow, approximately $70 m^3/s$. That is, more than ten times smaller than Matapi. And, in this case, its dilution capacity it is likely more than ten times smaller than Matapi River. The same reasoning is made for Paxicu with relationship to Fortaleza. Your self-purification capacity is smaller. However, its pollution source is much closer of its mouth or Amazon River, which disperses the plum of contamination quickly during the tide cycle. The figures 3 and 5 show that even with all the complexity involved, including the effects of tides, climatic factors, hydrodynamic, physical and antrophic aspects of the watershed it was possible to elaborate simple models that approach all the variability of the dynamics of the estuarine in simple manner.

But we also concluded that the complexity of the estuarine rivers studied has led to several approaches and interpretation about the evaluation of dispersion, dilution and self-purification. A great many independent variables are normally involved but, on the other hand, only a few of the variables necessary are yet measurable, and in the end, a number of quite arbitrary assumptions must always be made in application of models to a specific estuary. Then, urgent need for attention particularly on collection of data and information.

It is becoming clear that limiting estuarine and ocean pollution will require control of events that take place on land – even in locations remote form coastal areas. Pollution of watersheds has visible effects on rivers and eventually on their estuaries. With these obvious fact in mind, environmental cleanup programs, with objective of reducing pollutant inputs, have adopted a holistic approach, recognizing the bays and estuaries as part of a much larger interacting ecosystem. Events in areas far removed from the coast – in remote watershed sites – can influence the well being of human and living organism in the lower reaches of the system.

ACKOWLEDGEMENTS

We would like to thank support of the Conselho Nacional de Pesquisas Científicas e Tecnológicas – CNPq and the Chemical Analysis Laboratory of the DAQ/SEMA, for conducting the chemical analysis.

REFERENCES

Cunha, A. C. 2001. Levantamento de Parâmetros Físico-químicos e Hidráulicos para a Avaliação da Qualidade da Água em escoamentos naturais – Desenvolvimento do Distrito Industrial/AP na Bacia do Rio Matapi. **Relatório Anual** para o CNPq / IEPA/Gerco. Macapá-AP. Setembro, 58 p.

Cunha, A. C.; Cunha, H. F. A. & Siqueira, E. Q. 2001. Diffuse Pollution Survey in Rivers of Southeast of Amapá State – Brazil. In: 5th International Conference on Diffuse/Nonpoint Pollution and Watershed Management, Milwaukee, Wisconsin. In: **Proceedings**, EUA. June 10-15. CD - ROM.

Cunha, A. C.; Cunha, H. F. A. & Siqueira, E. Q. 2000. Water Pollution Survey in Rivers of the State of Amapá–Brazil. In: WORKSHOP ECOLAB, 5., 2000, Macapá. **Anais...** Macapá, p. 315-323.

Cunha, A. C. 2000. **Monitoramento, Parâmetros e Modelos de Qualidade da Água**. Macapá/AP: Secretaria de Estado do Meio Ambiente (SEMA). 83 p.

Laws, E. 1993. **An Introductory Text of Aquatic Pollution: Pathogens in Natural Waters**. John Wiley & Sons Ed. EUA. Cap. VII, p. 157-178.

Lung, Seng-Wu. 1993. **Water quality modeling: Application to Estuaries**. Vol. III. CRC Press, Inc. USA. 194 p.

Metcalf & Eddy, Inc. 1991. **Wastewater Engineering: Treatment, Disposal and Reuse**. 3ª ed. McGraw-Hill, series in water resources and environmental engineering, New York. 1334 p.

Velz, C. J. 1984. **Applied Stream Sanitation**. A Wiley-Interscience Publication. Second Edition. 799 p.