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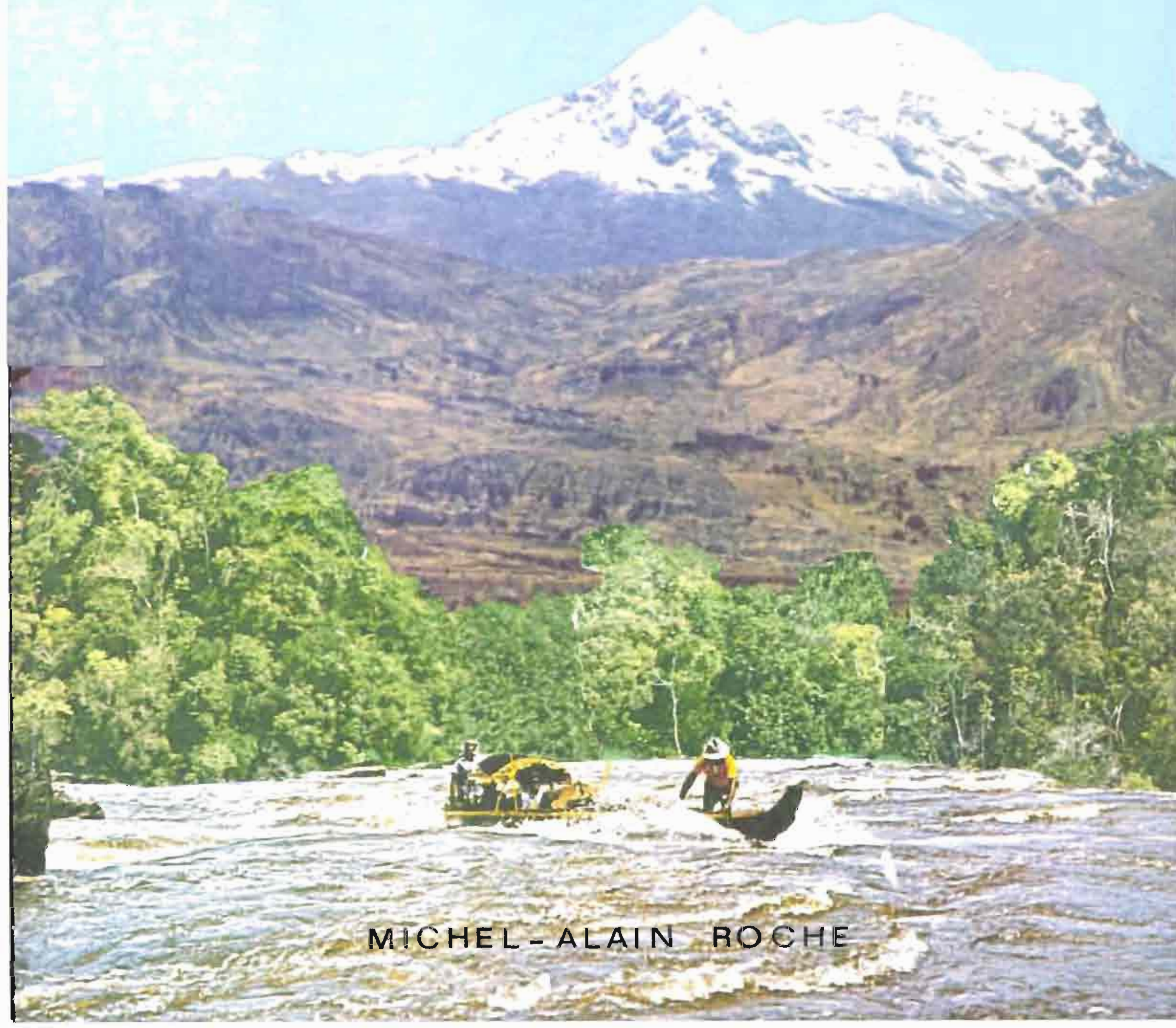
WATER QUALITY CONTROL IN THE HUMID TROPICS



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WATER QUALITY CONTROL IN THE HUMID TROPICS

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1. ROLE OF SCIENCE AND TECHNICS IN WATER QUALITY CONTROL

One of the essential chances of sustainable development is to minimize any adverse impacts on the quality of the atmosphere, water and terrestrial environment in general. The environmental unsound degradation of water resources has been aggravated by rapid international economic patterns, social and political changes which are causing an exploiting growing urban population. In most developing countries, in urban and also rural areas, water pollution control is still either lacking or grossly inadequate although preoccupying in many cases.

It is important to focus on the most important problems of water quality in the humid tropics, that hydrological sciences and technics, including chemistry, could contribute to solve. In return, it is also necessary to identify the greatest risks that water resources management may induce in water quality change of hydrosystems in that climatic zone.

Adequate strategies must be pointed out in order to promote a level of preparedness which could help many developing countries avoid a water quality crisis by the end of the century. Dealing with the problem of ensuring that humid tropics have a satisfactory, yet minimum in some cases, supply of water, mainly in quality than in quantity, is to face the needs of a population that does not often have the minimum required, or is seeking improved economic and social conditions.

There is an urgency to the question of whether the field of hydrochemistry, hydrology sciences and technology, and water resources management have the appropriate methods to meet the needed and rising demands in the humid tropics.

The most useful contribution scientists can offer, is to make available to the various parties involved (Agencies, Governments, social groups, etc...) the maximum amount of relevant information in a well-digested and constructed manner. So that, Authorities can make their choice knowingly, on scientific and technical basis and avoid the postponement of decision-making concerning mid and long-term planning and urgent solutions.

Gaps in information and methodology must be detected in order to define the present priority research needs, implement the existing scientific and technical knowledge (transfer, co-operation, related social and economical aspects), setup recommendations for actions in research, education and training, and institutional strengthening. Institutional topics, as well as human resources needs, must be analyzed as important basic issues.

These problems can be solved only by a multidisciplinary approach, including particularly Hydrobiologists, meanwhile emphasizing the hydrological and chemical aspects.

Water quality problems cannot be solved by an isolated mean, or for only a determinated sector or region. It is both, locally and regionally, a global problem that needs to look its causes, bearings and solutions from all points of view. This does not impede the broad prime variation of issues in their acuity from one country to another, besides some common and essential problems such as drinking water supply and sanitation , sewage, and treatment, that nevertheless show different aspects according to local conditions and the developing degree of each country. Therefore, at the begining of such an international analyses , the baselines of the most important topics must be presented extensively, in order to classify them by priority, and to propose strategies for the whole zone. In that same conception, this report deals with perhaps more specific hydrological and hydrochemical issues, such as hydrobiological issues, those benifit from being ubicated in a comprehensive context. It is shown in what aspects, humid tropics are really different from the temperate developed zones, where already exists a large and useful experience on water quality control for tropical countries; however this is not always applicable. From there also, can be examine according to the problems, if high and expensive technology must be applicable or if objectives would be more reached by "low" and appropriate technology, or both together.

2. WATER QUALITY PROBLEMS IN THE HUMID TROPICS

The worrying problems of water quality in the humid tropics are :

- Aquatic vectors and larvae responsible for water-borne endemics and epizooties, but also pesticides used in vector control programs and in agriculture.
- Organic urban (feacal) and industrial waste water, and sanitation systems.
- Drinking and recreational water supply in rural and urban areas.
- Industrial microtoxics (synthetic organic compounds such as pesticides, heavy metals).
- Change in salt and nutrient cycles and contents, and spreading of water-related diseases, due to land and water resources management, including new technics in agriculture (deforestation/forestation, new crop strains, fertilizers,

reservoir, irrigation, drainage).

- Other causes of water pollution that may occur locally, notably related to injections of hot water or specific compounds in the receiving medium

The consequences, that are already very serious in some sectors of rural and urban areas, will lead to a more acute water quality crisis during the next decades in many tropical countries, if no efficient and co-ordinated actions are seriously taken now.

3. NATIONAL AND INTERNATIONAL INSTITUTIONAL ASPECTS AND CO-OPERATION

Between the years of 1960-70, most of the tropical countries became aware of the pollution in their environment and the significance of water quality for a growing economy. As pointed out by A. Prost, a sustained development, the promotion of health, and the rational use of water resources are absolutely inseparable. In many of these countries, water quality control, as general water concerns, has been divided among the numerous existing national ministeries and services. Links seem difficult between national planning, co-ordination services, organisms responsible for investigation, applied or advanced technology, and the authorities. This pluralism may allow for more specialization. However, the lack of an efficient river basin authority, which is not represented by an adequate national institution and local and national committees (able to make use of a Water Law in which water quality is given priority), leads to incoherent actions, that are often supported by international organizations. Many national services, expecting a Water Law, are trying to adapt parts of this law that will concern their areas of water quality. Often, items of the law may interfere or even be opposite. This situation hinders rational decision-making, and is sometimes favoured by the fear of some services that measures against pollution may be against production and "low" public taxes.

Meanwhile, budgets of the different services are quite uneven, and the Department of Environment, when this exists, is generally given very little.

Often, national laboratories, in relation with the administration, do not have enough analysis capacity to make a systematic control of water quality. Nevertheless, this is an indispensable condition to any progress in the general problem (see special paragraph on laboratory).

Water quality control, in spite of numerous international

meetings, has traditionally been considered an internal problem. **Today**, however, population and industrial growth, as well as technological specifications, oblige us to a more comprehensive international outlook. Tropical countries may attempt to solve water quality problems by themselves, but this will result in useless, and unnecessary duplication of work and money for the most important issues.

The experience, gained in developed countries for more than 25 years, provides an important technological tool to solve most of the problems in the humid tropics. There is also a need for transfer of specific tropical scientific knowledge and technology between developing tropical countries, because the problems and the technical adaptations to the zone are similar. It would be important to record the technical adaptations for all types of water treatments with its conclusive results, in order to inform the technical services about all the actual possibilities.

Many hydrosystems cross or extend over various humid tropical countries, and are therefore affected by upstream, downstream, or common conditions dealing with water quality control. Those countries have generally understood their reciprocal responsibilities and rights, and organize multinational commissions to co-ordinate actions. However, the different aspects of managing water resources do not always include the problems of water quality. Few, or none of the multinational structures are able to study and control pollution efficiently. There are two main deficiencies : first, the need for international legislation and an inventory of present pollution, and second, homogeneous standards of maximum load and quality. For instance, the African Convention, established by AUO for Nature Conservation, could be the frame for such survey and legislation in the humid tropics of Africa, though various countries have not signed it yet.

For instance, themes such as eutrophication in warm waterbodies, groundwater pollution by nutrients or toxic materials could be carried out in the framework of international programs.

Some countries already have structures and laboratories that are able to conduct inventories and a water quality control monitoring network but many do not. International Programs can offer them a realistic way of participating as well as profiting from international networks of analyses and other technical possibilities. (Global Environmental Monitoring System GEMS/WATER, 1974 -IGBP, 1988, Geosphere-Biosphere).

Exchange of data base and interpretation softwares, and mathematical models acting on PC, are also one of the most important issues.

Interlaboratory calibration of the analyses is necessary to standardize the results and their utmost interpretations.

Education and training must rely on international co-operation. Developed countries, that have a great deal of experience in water quality control, can play a great role in this area.

4. LABORATORY ANALYSES

Many countries do not have analytic facilities to make isolated or routine analysis of water samples, including physical, chemical , bacteriological and biological standards. Sometimes, all these facilities exist in one country, but are dispersed, therefore making the co-ordination for an isolated analysis or a project study very difficult. It also occurs that high technological instruments are available in one laboratory, but are not used because of technical details, lack of a specialized operator or definition of research themes.

Therefore, for a rational organization dealing with water control, it seems imperative that every humid tropics country holds of at least one functional laboratory able to realize complete analysis, including all main water quality standards.

The basic appropriate needs are :
- infrastructure,
- equipment,
- specialized staff,
- financial means for salaries and functioning; part of the funds could come from the sale of the analysis.

Detailed lists of precise and optimal needs can be presented.

This kind of laboratory must :
- be regularly entitled to receive certificates of ability in analytic measurements. This means a national and international system of checking samples for interlaboratory calibration of methods and instruments.
- be recognized as an official entity of the water quality control system,
- be thoroughly connected with all the authorities in its field. It may be directly integrated in the service of a Ministry (of Health, for instance), or indirectly through municipal or departmental authorities responsible for local sanitation, or depend of the University.

There is an urge of interest in developing once again the role of the University Research Institutes that have analysis laboratories. These institutes generally have the adequate ability to rigorously put to use and adapt specific techniques and methodologies dealing with environment quality. They must not only make routine analysis, but also investigate specific environmental problems which occur from time to time, as well as on great national projects, or treatment technologies, for instance. It seems important that the analysis be realized within the proper Institutes or associated institutes that carry out the research study. Involvement of the University can provide the appropriate scale for the necessary global view of the problems, the multidisciplinary basic conception, and means. Moreover, a larger participation of this institution in water quality control would reflect directly on educational actions, which constitute an aspect of major importance in the fight against pollution.

Regional and international exchange of knowlegde and technology in the management of laboratories is one of the most urgent concerns about water quality control.

International organizations and other supporting bodies should give more assistance to humid tropical countries, on request and if appropriate by providing equipment, funds, training, manpower and expertise missions.

5. GENERALITY ABOUT STANDARDS

Water quality control must be based on standards for input and output water.

Threshold contents have been deduced from the knowledge about the effects of chemical constituents in animals or men, but also from empirical methods. The toxic effects of specific pollutants have not been studied much in the humid tropics, meanwhile their proliferation is increasing. Therefore, like in other areas, it is necessary to carry out such investigations in order to obtain precise and useful threshold standards. In the present state of knowledge, it is possible to think that carcinogenic or mutagenic substances and heavy metal components could take specific forms in that zone.

Local conditions must also be taken into account to modulate standards : higher temperature and solar radiations, lower oxygen contents, frequency of toxic discharges, type and amount of accumulation at various levels of the sediments and the tropical biotope, higher discharge, etc...

The most important standards for man, deal with drinking water and recreational water, taking into account that quality depends in the observance of the standards for waste water.

The standards for drinking water must guarantee a harmless consumption. WHO has published standards which are the base for drinking water quality control in many countries (EFP/82.39, EFP/83.58, Guide for drinking water quality -1986-), **although** others often have adapted their own standards.

Natural water, with its higher level of purity generally seems suitable, but is it favorable to health and not harmful in the tropics? On the other hand, general standards might eventually be ajusted in relation to the quantity of water absorbed, which is (a little) higher in the humid tropics than in the temperate zones.

It seems, that an eventual modification of standards would need particular and difficult studies. Meanwhile, an inventory of the standards used in all the countries of the humid tropics, and the justification of their values, could be of the highest interest.

The problem about the indicators of feacal contamination will be dealt with in the chapter about drinking water supply.

After Kilani (1989), from the point of view of the developing nations, the most significant shortcoming is the lack of flexibility of the standards. Many governments find themselves investing large sums of money in projects designed to attain high standards in communities where much lower quality standards may be required. Thus, unattainability of standards could be partially responsible for the failure of most water supply projects.

6. EDUCATION AND TRAINING

1. Education

Education, in the framework of an integrated water quality control, is one of the most important ways to develop in the humid tropics. Only the full awareness by the individual, from the earnest age, of one's own weight in the fight for a safe environment, can give satisfactory results at term.

Consequently, aquatic environment control should be prime concern in natural sciences educational programs in elementary and high schools, where it could easily replace some issues without damage. The education has to be completed by television (cartoons, vulgarization), newspapers (comic books), conferences, expositions, posters, stamps, contests/primes for children and adults.

Simultaneously informing the media as well as providing guidelines and facilities for the corresponding actions should be the responsability of the services of water quality control. Likewise, pedagogical and informative conferences would necessarily have to be given to professors.

In relation, it could also be the UNESCO's role to organize contests for aquatic medium protection, with prizes for pupils, investigators, laboratories, industrials, agricultors, and towns.

2. Training

Training would be the concern of universities, specialized schools and services. It would be necessary to make a census of the existing training structures in every country, not only in the humid tropics, and in particular those that could receive temporary foreigners. Also, each humid tropical country must establish a diagnosis and foresee the needs of scientifical, technical and administrative staff in order to insure essential education and training :

- Hydrologists, specialists in hydrodynamics, water quality, modelling, with complementary capacitation. Biologists and hydrobiologists. Statisticians.
- Engineers and technicians in water and waste water networks, treatment.
- Documentarists, reporters.

These issues have related impacts within each of the resource development areas and need to be adressed as such.

3. Information

Often national works and a fortiori foreign works are not available at the right time, or not known by who begins similar studies.

There is a need for most tropical countries to hold and to disseminate a national and international bibliographic index on ecology, hydroecology, hydrochemistry and water quality control, in order to facilitate an integrated approach in management design. This indispensible tool must be on microcomputer, with all investigation facilities .

Particularly, the circulation of information and reports concerning UNESCO / Conaphi about the works realized in the framework of the the new activities of the PHI, could concern the examples mentioned in the other chapters such as values of standards of operational models.

7. WATER QUALITY MODELLING AND HYDRODYNAMICS USEFUL FOR DECISION-MAKING

1. Development of modelling

The evolution of suspended and dissolved components in space and time depends mainly upon the evolution of the vector, i.e. the water dynamics. Water is an indispensable mineral to life, it irrigates ecosytems, and plays a role in the landscape similar to blood or sap in living organisms.

Many previous studies on water quality have not pondered sufficiently on the vector dynamics. Such a lack limits conclusions, notably prospectives and decision-making. However, nowadays, there has been such a prompt development of mathematical modelling of water quality that it is almost imperative to be acquainted with it in order to adapt to humid tropical conditions, if necessary.

In the last years, various symposiums and workshops have been held on this subject, and more are foreseen during the next two years, often sponsored by the UNESCO (Stuttgart, April 1989; Tunis, May 1990; Geesthacht, June 1990; The Hague, September 1990). Various books have recently been published on water quality modelling (James A., 1984; Orlot G.T., 1986; Trudgill S.T., 1986).

2. Structure of the models

Those models apply to unitary or complex hydrosystems, such as streams, lakes, lagoons, reservoirs, urban watersheds, ground-water and estuaries. They couple a chemical model to a hydrological model of transport. Physico-chemical phenomena can be taken into account in : (1) substance production functions (ex. the sediment production by erosion, nitrogen production in the root horizon), (2) physical or geochemical sedimentation (soil, streams, reservoirs), (3) physico-chemical, microbiological or biochemical trapping and transformation (interactions with the bottoms, flora, fauna), (4) concentration by evaporation, and dilution by rainfall. In some or all the pathways of the models, the transported components can also be considered with fixed contents, according to conservative chemical processes.

3. Role and limits of water quality models in decision making.

By the simulation of the process evolution in space and time, and with some purely hydrological results, it is possible to predict downstream from a disposal, that is : the dilution of a product, the self-purification capacities, the ability of sedimentation of dissolved and suspended substances, the risks of eutrophication or concentration (salinization, nutrients, pesticides, etc).

The adaptation of models to humid tropical conditions must be realized through the calibration of the different functions and the reliability of the results. Technology to evaluate the confidence levels of predictions must be developed in order to account for uncertainties in the decision-making. Various specific chemical and biochemical processes must be modelled to address the results in the best way.

The effects of irrigation and massive use of fertilizers constitute an area of application of the models, particularly for groundwater. Likewise, in urban and industrial media, they apply to (1) dimensioning and functioning of drainage networks of rain and waste water, according to the organic load (02, BOD, COD,...), notably for polluted urban flood storms, (2) evaluating the effects of purification systems, optimizing the funtioning of treatment stations or disposal control.

4. Some examples

Temperature is one of the parameters that differs the most between temperate and tropical zones. It has a direct influence on physical, chemical and biological properties of an aquatic medium. A water temperature model, in the framework of a water quality modelling in natural or made-up conditions (Morin et al., 1983-1985), has been coupled to the conceptual hydrological model CEQUEAU (Girard et al., 1972; Morin et al., 1981).

Girard (1988) presented a joint modelling of water and nitrogen in a groundwater system where the different yields of nitrogen are developed in a production module (rainfall, fertilizers, animal deposition); The author mentions that the main problem of the modelling is to determine the nitrogen flow from the non-saturated root zone to the aquifer. The model used agricultural parameters such as the type of crops, the spreaded dosis of the fertilizers, the chemistry of the products, so that it is possible to simulate preventive decision-making for the decrease of the pollutant, or curative measures based on the dilution of a contaminated aquifer by injection of clean water. Some biochemical processes and surface transport need to be included in the modelling, in order to improve the results. Likewise, the author insists on the need for better agricultural data (annual crop maps).

The Vollenweider-OECD model (Vollenwieder and Kerkes, 1982), has been used to predict the phosphorus concentration of lake from the inputs and the eutrophication risks.

In the PHICAB project, Benavidez (1988) applied a conceptual model (HYMO 10) to predict the effect of soil management on soil erosion and sediment transport in a watershed of the Andean Amazon of Bolivia.

The estuarine water quality modelling merits a special attention because of very marked hydrodynamics and changes of dissolved and suspended contents, that generally lead to interesting results (Symposium of Geetshacht, 1990).

Modelling of waste water sewage and disposal, urban storm floods, and/economical aspects of water quality control must also be examined (Servat, 1984).

5. Reflexions on actions

Those references should not be exhaustive, since it is an area of intense present activity specifically concerning water quality. In order to be able to use an efficient specific tool for water quality decision-making in the humid tropics, it would be extremely useful to dispose of a complete and detailed list of references of functioning models and books, and that all this information be communicated to the PHI National Committees. The most adequate models could be tested and adapted to local problems. Of course, specific modelling must also be developed for very specific cases.

The diversity of the areas of application, in order to hold a functionning "national whole model", would require studies of models for each type of sectors, hydrosystems or associated hydrosystems.

Modelling must associate telemetry technics for a better regionalization.

Collection of data related to the economy is very useful for the results given by the models.

6. Direct use of hydrodynamic data

To perform, water quality modelling needs or directly provides, partial results on water dynamics, that can be used for some evaluations or even be associated with the contents, for simple evaluations, such as transfer or residence times for instance. With or without complete modelling, it is then useful to carry out measurements to obtain the following evaluations :

- Rainfall : quantity, intensity.
- Trajectories and magnitudes of the horizontal, vertical and transversal movements, stratification, mixing, etc...
- Transit velocities, measured by natural tracing (dissolved constituents, salinity, isotopes), artificial tracing (radioelements, colorants, float-balls, chemicals, etc...) or by other appropiated hydrometrical methods. These data generally go along with the evaluation of discharges, volumes and transfer times.
- Turn-over and mean age of the water.

- **Infiltration**, resurgence, and evapotranspiration, that **represent** other terms of the water balance, established on an appropriate time step for the specific cases.

One should notice that research on water dynamics often uses physico-chemical characteristics, like qualitative or quantitative tracing. However, studies on hydrochemical processes benefit in return from the so-obtained knowledge on the vector.

8. INVENTORY AND DIAGNOSIS OF THE PRESENT NATIONAL STATUS OF WATER QUALITY, AND EVOLUTION OVER A MID-TERM PERIOD

1. It is a matter of urgency, for most countries in the humid tropics, and globally in that zone, to establish a scientific and technically detailed inventory and diagnosis of water quality, which would allow the availability of a national and general overview of the present situation, and to learn more about its evolution over a mid-term period, by a second study phase (five years later for instance).

2. Some synthetic works dealing with hydrosystems of regions which include humid tropics countries are available. Among these publications we can mention for example : the ecology and utilization of African inland water (Ed. Symoens J.J., 1981), draft review of the state of aquatic pollution of East African inland waters (Alabaster J.S., 1981); Tracage isotopique et salin des eaux du systeme hydrologique du Lac Tchad (Roche M.A.,1973,1980); La pollution des eaux continentales africaines (Dejoux C., 1988), etc...

3. In all countries, valuable studies on global environment, or water chemistry and quality of one or several hydrosystems, already exist (example : Bolivia, Chad). However, projects have generally not been exhaustive enough to draw a complete picture of the national aquatic environment (water, fauna, flora). Specially, the presented characteristics (often major ions only) were used to explain natural phenomena, without concluding on pollution aspects, because much contamination was not visible. Only the most serious problems have been taken into consideration.

4. It occurs that incomplete knowledge on the level of water quality, is sometimes due to the lack of national determination in the realization of a general inventory-diagnosis, besides the lack of necessary organization.

5. It is necessary to diagnose the present level of pollution in

all the different hydrosystems that are impacted by man activities, within each large basin, in order to know the magnitude of the actual problem, and therefore have a base of references that permits the detection of future evolution. A second state study would show the trends versus the origin state. Such a reconnaissance survey of water quality in the humid tropics is the basis of a water quality policy, by comparison of present and future characteristics. Water quality problems being classified, urgent national and international planning and decision-making could rapidly occur in case of emergency.

6. In some humid tropical countries, unpolluted or almost unimpacted hydrosystems can still be found. Their study is urgent, because they can bring reference criteria in numerous scientific areas (for instance chemical and biological processes, steady-states, etc...) about the original states of some types of aquatic ecosystems that will not exist within a few years. It is important to characterize representative hydrosystems to learn how natural systems function and to ensure them the highest level of protection, as baselines and reference areas over a long period (National Parks).

7. Lack of knowledge would be identified in space and time. Then, among the practical recommendations of such an inventory-diagnosis, the necessary complementary studies about water chemistry, water quality and other aspects dealing with water quality control as a whole could be defined.

8. A detailed inventory and diagnosis, in which multidisciplinary skills would have to be involved, could be the beginning (for the least advanced countries in this area) or an improvement (for the others) of a national functional organization and the necessary co-ordination of institutional structures.

   Moreover, for many countries, such a project study would be a useful experience in the creation of a water quality data bank, and the processing of standards and results at a national level.

9. Global knowledge about precise national situations in all the humid tropical countries would help detect common or similar concerns, that could then be properly addressed by international or bilateral co-operation actions.

10. To avoid the heterogeneity mentioned in previous publications, a working plan could be proposed as a guideline to lead project studies on inventories and diagnosis in a homogenous manner in each country, and realize a synthesis for the humid tropics. These studies would obviously take into account specific national conditions that might coerce to modify or end parts of them.

The studies would be made for large watersheds, a division that would correspond to local institutional structures.

Explanations would include charts of the numerous organizations, diagrams, plans and maps, including references to social, economic and manpower aspects.

a. Preliminaries

- Previous works and publications about water chemistry and water quality control.
- National and international divisions of watersheds and hydrosystems (water courses, aquifers, lakes, estuaries, etc...).
- Physical characteristics, biogeodynamics, geology, hydrodynamic characteristics of soil, ground and bottoms.
- Items of pollution tied to men activities : population (cities, villages,...), agriculture, industry, vectorial control.
- Climate, especially rainfall, radiation, temperature, and evaporation.
- General hydrology : water resources, water balance and regime, extreme values : (low waters, floods), physical aspects, existing models. Regime of sediment loads.
- Water dynamics (with or without mathematical models).
- General biological aspects (flora and fauna).

b. Institutional structures : concerned institutions, co-ordination laboratories. Available means (laws, equipments, co-operation).

c. Methodology used for the study.

- Recollection of information.
- Choice of standards versus classification of water uses (input, output), classification of water uses.
- Basic data banks. Softwares for data banks.
- Analyses methods and laboratories.
- Softwares for interpretation and water quality modelling.

d. Natural and modified characteristics of water quality in hydrosystems.

Present state of the hydrosystems and the entire basin, about abiotic and biotic characteristics. Present steady-states. Abiotic (sediments) and biotic (plants, animals) indicators of pollution. Effects, consequences of pollution. Water-associated diseases (bacteria, vectors,...).
Consequences of short- and long-term pollution on health, domestic and wild animals, cattle, and any form of life. Experiences with lethal effects. Accidents.

e. Available types of water quality, and respective resources, according to sectorial uses. Seasonal variability with discharges.

f. Needed types (and respective amounts)of water quality, according to sectorial uses. Adequation availability/needs. Existing and proposed water supply systems and treatments for drinking, agriculture (irrigation, drinking water for cattle), industry, navigation, etc... Perspectives (2000 ?).

g. Origin, situation, chemistry, flow of punctual or non-punctual pollution for any sector (including vectorial control). Systematic detection of secondary sources. Vast development projects having an impact on the hydrosphere (Program I.G.B.P.).

h. Present systems and technologies for treatment of pollution sources, by sector (waste water, industry, etc...). Recycling waste. In-plant control. Security systems. Control of treatment programs by pesticides. Needs, perspectives and propositions.

i. Specific concerns.

j. General classification of concerns and general perspectives. Proposal of solutions concerning :
  - Institutions : Structures, specialized man-power, laboratories, economic aspects, co-ordination, co-operation.
  - Complementary studies to complete the inventory-diagnosis.
  - Actions and means o eliminating or reducing existing pollution, avoiding predictable pollution and leading "catastrophe" operations, continuing long-term observations and control of all types of pollution.
  - Economic estimates : cost of preventive or curative measures/cost of damage.
  - Social implication.

k. Conclusions. Needs. Recommandations.

l. References : A national bibliographic reference list must be established by each country for projects dealing with water quality. Reference of studies on water dynamics, aquatic or associated fauna and flora, urbanization, industrialization, agronomy practices, and all matters related to water quality, would also be included. The most important results would be summarized in the national study.

9. WATER QUALITY MONITORING NETWORK

1. <u>Purposes of monitoring water quality</u>

Parallel to inventories or diagnosis, periodically carried out every five or ten years in order to gain a synoptic status of the situation, it seems indispensable to obtain daily to monthly data from a water quality network, in order to :

- Assure continuously that water quality is appropriate for the needed uses.
  Although a little different in design, a warning system is based also in monitoring, specifically in real time. More or less rapidly, both systems allow the identification of the nature and source of contaminants and immediate decision-making to face it, particularly to avoid an eventual accident or catastrophe before a spatial extension.
- Detect the long-term trends of water quality, from local to global levels, by acquisition and interpretation of long temporal series of analysis data, including extreme values and short-term shock loads of pollutants; improve the calculation of matter balances. Such a data base is essential for comparison purposes, and especially to investigate the potential impacts like the greenhouse effect or deplation of ozone, on water resources, including water quality.
- Improve mathematical water quality models, and their adjustement with longer series of measurements, which permit the identification of long-term trends in water quality. Feed prospective scenarii for the assessment and planning of the resources, long-range forecasts, and real time operational warning protocols. The obtained data are the background of a regional understanding.

2. International experiences for monitoring of water quality

Various long-term networks have been proposed or set up to monitor water quality locally.

- "The Global Environmental Monitoring System" (GEMS) has been organized by a group of international Organizations (UNESCO, WHO, WMO, UNEP) to create a world environment program, based on a world monitoring network, since 1974. The GEMS/WATER deals with the water quality monitoring system. The physico-chemical and biological analysis data are stored in a Reference Center where periodic interpretations are made. If desired, national participation can be limited to sampling and analysis. Calibration of methods and results of analysis can be helped by the reference laboratory, in particular by sending witness solutions. Not all countries participate in the GEMS/WATER, though contacts are being made for a broader international participation. Such a program will be meaningful only on a long-term period and with a sufficient density of stations. However, some countries can already see fluctuations.

- Among various world programmes including a water quality network, the recent "International Geosphere-Biosphere Programme (IGBP)" should be mentioned. Its goal is to develop a co-ordinated action to describe and understand the physical, chemical and biological processes which regulate the whole environmental conditions on Earth by their interferences; and to predict how human activities could disrupt this system.

- At a regional level, the following actions can be mentioned as examples, among many others (Dejoux, 1981):

* Commission of Lake Chad Basin (CBLT)
* Committee for Continental African Fisheries, 1972 (CPCA)
* East Environmental Pollution Research Committe (EEPRC)
* East African Federal Fisheries Organization (EAFFRO)

- In South America, the PHICAB Project (Climatological and Hydrological Project of Bolivia , ORSTOM - CONAPHI - IHH - SENAMHI), assures for some years the monitoring of water quantity and quality (salinity, major ions) in the Amazon Basin of Bolivia, and has carried out a reconnaissance of water quality in the entire Highlands of the Andes, in the lake Titicaca and Poopo Basins (Roche et al. 1986,1987; Guyot et al., 1987,1989).

3. National and international compliances with monitoring of water quality

To be realistic, the proper functioning of a long-term water quality network appears to be very difficult, especially in developing countries. Many factors, essentially the same ones that have been previously mentioned for a water quality inventory-diagnosis, are even more serious for the proper management of a monitoring network, because of the continuous specifications of the programs and the high needed means for instruments, installation, and maintenance. The economic crisis of these last years have weakened the quality and density of the networks, while the delays in the collection and processing of the data are getting longer and longer. National hydrological organizations are having more and more difficulty in performing properly the management of their networks.

Possibilities of rehabilitating the density and the efficient functioning of water quality networks must be explored urgently :

3 .1. Continuous and high funds. Both national and international compliances are necessary and need to be improved. Countries must search integration of their own actions with international programmes, in order to increase their possibilities. The ability of developing nations to support the funds of the monitoring of water quality and quantity networks as well as the ability and reasons of developed nations to share the cost, is an important issue. As a reference, one can mention the large participation of the French Institutite of the Scientific Research for the Development in Co-operation (ORSTOM) in the monitoring of national hydrometrical networks, often accompanied of hydrochemical studies, in West and Central Africa from the 1940's and in the 80's in the Bolivian and Brazilian Amazon. In past years, remote sensing hydrometric stations have been installed in West and Central Africa and Brazil. Recently, the EEC partly funded the telemetry equipment. Canada mentions also its co-operation in monitoring networks. The WMO and WHO support under specific hydrometric monitoring projects.

3.2. Definition of responsible institutions, in particular for water analysis laboratories.

3.3. National co-ordination and responsibility between and within institutions (for instance, the HYWA Organisation; paragraph 3.11).Circulation of information.

3.4. Specialization, trainings, staff increases for field work (measurements and sampling), laboratory and office.

3.5. Improvement of national laboratory, equipment and functioning.

3.6. Role and action of foreign specialized laboratories and center. Interlaboratory calibration and special analysis.

3.7. Role and action of United Nations Organizations and international co-operation in the organization, management, and maintenance of water quality networks. UNESCO can play an important role in some issues. In particular, there is a need to ensure circulation of information, such as protocols, softwares, results and publication of studies,...

3.8. Constitution of regional groups, committees or commissions to carry out actions in large basins or groups of similar small basins (Amazon, Congo, Nile..., small coastal tropical basins of Asia, etc...). Such organization for instance is indispensable for the telemetry system (HYWA Organisation).

3.9 Choice of suitable stations (minimum and satisfactory density and representativity), according to the results of the previous inventory-diagnosis study and previous experiences. Network design, of water quality monitoring sites must ensure the data being collected are adequate for the intended purpose and the establishment of the costs, benefits and economic aspects of water quality collection. In fact, the difficulty of monitoring water quality is due to the proliferation of man-made chemical compounds. Can observation networks and usual analisis control systems, truly detect the existence of all these harmfull substances in the hydrosystems ? It seems necessary to detect them at their potential industrial sources, and then to control them downstream, knowing that they find their way by complex patterns into water bodies, and are either removed partially by treatments or natural processes, or remain and accumulate. One example is the groundwater survey of a factory by a piezometer network, in order to control upstream risk of pollutant infiltration.

Due to maintenance, measurements and exploitation of the data, most of the water quality stations must be coupled with hydrometric stations.

3.10 Choice of constituents to be analyzed, number and frequency of analysis. It is necessary to decide, taking into account the new technologies of measurement and transmission, what pollutants need to be monitored, why and how. The specification of the objectives helps determine the precision and accuracy to be attained, considering the cost-effectiveness of the operation and the need to save money.

3.11. Use of new technologies. Water quality monitoring systems for continuous and long-term control in real time, and the prevention, have to be used along with remote sensing technics (telemetry by satellite, phone, radio, overall by satellite). Insulated large areas without observers in the humid tropics are the concerns particularly (Africa, Amazon, Borneo, ...).

Sensors responding to requested water quality standards must continue being designed, improved, tested, built, and widely disseminated. Those facilities seem to be the only near possibility to improve the lack of or false data of the 80's and the current evolutive attitude of the observers.

The experience acquired by the Hydrological Watch Organisation (HYWA), with the participation of ORSTOM in West and Central Africa, under international co-ordination, permits data collection and dissemination from a selected number of Hydrological stations (Pouyaud et al., 1987). This is just the beginning of what must be done in various areas, for water quality control, pairing hydrometric and quality measurements (Bader J.C. et al., 1987; Gautier et al.,1987; Gioda A. et al., 1988; Le Barbe L. et al. 1987). Satellite telemetry is already widespread in the region as witnessed by the following :

* Linked with the ARGOS System : The WMO-Hydroniger Program on the Niger Basin is operating 65 stations. The WHO is operating nearly a 100 stations in the whole of West Africa for the purpose of Onchocerciasis Control Program (OCP). The Office de Mise en Valeur du Fleuve Senegal (OMVS), has installed 6 stations network and will have 10 stations in operation in 1989, in the Senegal River and its main tributaries. National hydrologic organizations are also using satellite telemetry facilities, such as Benin (10 stations) and Guinea (5 stations). On the other hand, 23 stations has been installed in Brazil (Amazon) by ORSTOM-DNAEE, independently of HYWA.

* Linked with the METEOSAT System : The Société Nationale d'Electricité du Cameroun (SONEL) is operating a 10 stations network on the Sanaga River. A Meteosat network (12 stations) will be installed in 1989 in the Zaire/Congo-Oubangui Basin, co-ordinated by ORSTOM.

The HYWA structure should be first a co-ordination organization to ensure proper collection, processing and dissemination of the data by electronic mailbox. This must be executed under international control to ensure effective data-share between several national organizations.

Softwares to process the data, in real time are part of the system. There is a need to develop more modelling to improve the benefit of these facilities.

3.12 Development and dissemination of PC softwares for data banks, process and interpretations, different from mathematical models, to elaborate regional synthesis.

There are serious gaps, like for instance in the establishment inventory-diagnosis. A lot of data is (more or less available and disseminated in many services, but it is not exploitable under its current heterogen form. So, most of the data does not go beyond the state of arrid tables accompanied by a few comments, in internal reports, that is to say with little or no use for anyone but a specialist. Cullens (1987) reports that considerable funds are spent in monitoring water quality, yet there appears to be a poor return for this investment. Stewart (1989) mentions justly that too little emphasis is placed in the ultimate use of data.

One of the first reasons, for this situation is the lack of the lack of data proccessing protocols and facilities, in front of the high number of data that constitute a specific difficulty in the water quality studies. The proliferation of data starts in the field and in the laboratory. Yet at this level, PC tools must help calculate and store the data, if possible directly from the analysis instrument to the computer.Then, other softwares must constitute a data bank, in which historical information in stations is very important. Specific process and interpretation softwares, directly connected to the data bank, must be developed or adapted, including statistics, relationships-extrapolation, drawing and mapping on ploter, expert systems, in order to produce a directly synthetic document that could be published. Of course, the linking of the hydrometry-quality data is indispensable.

3.13 Biological monitoring. There is a great interest in coupling both the chemical-physical monitoring with biological monitoring, of which design thecnics are to be developed. Impact on life is the main purpose of water quality studies. Biological changes induced by pollution seldom or never are directly indicated by chemical and physical measurements, such as once defined, sensitive biological communities may be the indicators of trends, more integrated to events than classical pollution measurements by themselves. Relationship and multivariate packages for chemical and biological data sets, by mean of microcomputers may be some of the techniques to be applied. This would mean some form of multidisciplinary staff, that barely was applied but that definitely needs to be developed.

In the last decades, taxonomy has lost importance in the biological sciences. However, pollution impact on aquatic biota is based on the identification of plants and animals, and their appropriate groups. It can only be shown with a precise knowledge of taxonomy, a speciality that must once again be valued.

10. AQUATIC TROPICAL DISEASE VECTORS, PARASITES AND PESTICIDES CONTROL IN HEALTH AND AGRICULTURE SECTORS

1. General aspects

1.1. Two types of pollution, interrelated,affect tropical inland waters, which create serious hazards for human health and the aquatic environment.

The big human or animal endemics and the epizooties rage heavily in the humid tropics : onchocerciasis, malaria, yellow fever, dengue, dracunculiasis, trypanosomiasis, leishmaniasis, bilharziazis, etc... The vectors or their larvae live in water, as well as the parasite itself sometimes (bilharziazis). This is a form of biological water pollution, whose extensive control by insecticides, molluscicides and herbicides leads to another type of contamination of the hydrosphere.

1.2. In other respects, in agriculture, disease and predation control treatments against various parasites or animal (micro-parasites, insects, birds, rodents, etc...) and land or water weeding are accomplished by insecticide, fungicide or herbicide spraying, in order to improve the yield of rice, cotton, sugar cane, citrus, palm, soya, etc... The same substances are often used in vector and agriculture control.

1.3. Thus, pesticides are one of the most preoccupying pollution in the humid tropics, now and in the future, because of the many attacks in wide areas of the hydrosystems.

1.4. Many articles and books on the toxicity of pesticides have been published in the world since the 1960's, but they have been scarce for the humid tropics. Among this abundant litterature, let us indicate that the WHO (1986) has published on spraying conditions, degradability in the environment, exposure type for man (air, water, food, contact), metabolism and effects on health. C. Dejoux (1985, 1988) made an exhaustive study about the impact of vectors and agriculture control programmes on the aquatic environment in Africa.

2. Chemistry, remanence and relative toxicity of pesticides

2.1. The products used are classified in different groups :
Organochlorides : the first synthetized, the most ubiquitous. Not very soluble in water, soluble in oil, accumulation in greases. Generally long remanence : benefit and danger. Main chemical species : DDT, Aldrine and Dieldrine, Chlordane, Hexachlorobenzene, heptachlore and heptachlore epoxyde, lindane, metoxychlore, 2, 4 - D. The HCH isomers (i.e. lindane) are among the most soluble in water.
Organophosphorus : less remanent. Ex. : Parathion, Malathion, TEPP, phosdrine.
Pyrethroids : Natural and synthetic. Average remanence in water.

Sticks quickly on organic matter. Generally, toxicity is very high. They would account for a high percentage in the world market. Pyrethre is a tropical chrysanteum and the use of pyrethroids is sometimes mentioned as biological control.
Organic or organo metallic compounds : are used as herbicides. Derived from urea, thioural, tiazenes, etc... Carbamates and dithio-carbamates are fungicides. Some are natural.
Mineral substances ; Ancient, but still in use. Compounds of mercury, copper (sulphates), tin, sulphur, etc... Mercury salts are used the most, despite a high residual toxicity.
Bacterial products : They are "biological insecticides", such as Bacillus thuringiensis israelensis. It is a bacterium whose spores produce a toxic cristallized protein. H14 serotype destroys the larvae of some insects (mosquitoes, simulies). It is not very toxic (Dejoux C.,1979).

2.2. The works of Pimentel (1971), Alabaster (1969), anon.SPVAG (1981), Dejoux (1988), establish a relative scale of toxicity for dozens of pesticides. Thus, some products may be mildly toxic for the environment (Temephos -Abate-, Bacillus t.i.), while other (Endrine, Dieldrine, Endosulfan, pyrethrinoides, etc...) can affect strongly the aquatic medium. The toxicity of a pesticide depends on its formulation; nevertheless, organo-chlorides are more toxic than organo-phosphorus. Herbicides are generally less toxic, at least towards fish. However, the proliferation of chemical formulations and the increase of the spreaded quantities are so fast (Smith and Lossey, 1981) that the consequences of many pesticides and their behaviour in the hydrosystems are not sufficiently known (biodegradability, residual products more or less toxic than the original substances, etc..).

2.3. It is known that some products, whose application is prohibited in industrialized countries, are still being used in developing countries, because of their large scope of action and their low prices (DDT, HCH, etc...). The chemical amounts and species of pesticides used are often not accounted for at a national level in the humid tropics (thousands of tons for the most advanced countries).

3. Behaviour and effects of pesticides in humid tropical hydro-systems

3.1. In the last decades, important control programmes for the eradication of vectors (breaking of the cycle) have been worked out, more often with the sponsorship of international organizations, sometimes within a twenty years period. In the same manner, treatments in agriculture are becoming more systematic. Public opinion (sometimes in the form of groups or organizations) have exerted pressure against the intensive use of pesticides, letting some governements face a dilemma : Protection of public health and production on one hand, environment degradation and backlash on public health on the other.

This is why big vectors eradication programmes or agricultural treatments, are considered with all the attention they deserve in every one of their phases. Nevertheless, the parallel scientific operations that are associated with them still are difficult.

3.2. The chemical substances used often have a very high toxicity which contaminates directly or indirectly the aquatic mediums. They lead to a high mortality of non-targeted organisms. They accumulate in sediments, weeds and all along the food chain at higher concentrations than in the water, sometimes in the order of 1000 times or more. The accumulation begins in microorganisms (Johnson and Kennedy, 1973), then phytoplancton, zooplancton, invertebrates, to end up in fish and man (Dejoux, 1975, 1985, 1988). These contaminations can irreversibly damage the ecological balance, in which human health or sources of proteins (fish stock). Besides accidents that happen in treatment operations, the effects of pesticides on inland hydrosystems are mostly mild. An indirect effect can be a diminution of plancton, and of the oxygen concentration, and a modification of pH and CO2. In humid tropical countries, these problems were examined long after the beginning of the treatments, and specific works are rare. Dejoux (1988) details the investigations realized in West Africa, especially as a part of the onchocerciasis control programmes. The impact on the environment has been studied, during the selection of insecticides (with different emerged gutters), according to the insecticides and organisms tested), as well as during routine treatments. The different links of the food chain were taken into account. Studies on the impact of other pesticides have also been carried out in other countries (Nile Victoria in Uganda, Sudan, etc...). There is availability then for some control programmes, of the main characteristics of the undertaken treatments, as well as a synthesis related with their impact on the non-targeted fauna. Generally, it appears that most of the products tested have a strong toxicity.

3.3. During many years, man was not concerned about0 the toxicity of the products he was using. Nowadays, various thousands of substances have been tested by the WHO and about one hundred of them have been the object of in situ studies. Nevertheless, while there is more concern about their ichtyotoxicity, the products without leading to a visible fish mortality can have a serious impact on some other groups of the aquatic fauna. Indeed, one seldom has access to a product that saves invertebrates. Consequently, fishes who feed on them, die or leave the area.

Emphasis has been put on the fact that the elimination of predators of the targeted group decreases considerably natural control. It increases the risk of proliferation of the targeted species after the end of the treatment. Man is now conscious that eradication of vector insect species is not feasible, but that it is feasible to eliminate the parasite. Concomitant destruction of other organisms, that would eventually contribute to impede the propagation of various diseases, is sometimes considered as a negative aspect of the treatment. Because of a reinfection of vectors from non treated zones, even far away, and a tendency of vectors to become more resistant to the applied pesticides, we can predict an intensification of vectorial control, that could lead to a continuous contamination of the hydrosystems by a set of pesticides with a range of various effects.

4. Factors of transfer of pesticides through the hydrosystems

Many factors are influent :

- The chemical characteristics of the pesticide are determinant : solubility, resistance to physical and biochemical degradation, qualities of the degradation sub-products, that can be more or less toxic and resistant than the precursor.
- The conditions of injection : Concentration of use, non-point or point injection, duration and frequencies.
- The general flow is determined by air and water dynamics : meteorological conditions during the treatment (wind, evaporation, humidity, etc...), height and intensity of rainfall, run-off and solid transport flows (Bader J.C. et al., 1987; Gioda A. et al.,1988; Le Barbe L. et al., 1987). In agriculture, the treatment steps at variable distances of water masses; toxicity may decrease when they are reached, meanwhile in vector control, running or stagnating waters are directly treated, therefore directly hit by the poison. Punctual accidents, sometimes serious, must also be taken into account.
- The characteristics of the medium and its interferences also have an influence : nature of the soil, mechanical action of the plants, chemistry of the waters, air temperature and humidity, etc... Interactions with the mineral and biological medium govern largely the gradual transformation of the precursors. For example, organochlorides are easily adsorbed on suspended matters and sediments, and then can progressively be washed-out or retaken by erosion. It is conceivable that an efficient use of mathematical models could be tricky, due to the large number of parameters that must be included in their algorithms, the selection of the values is therefore difficult.

5. Ways of fighting the agents of tropical diseases and pollution by pesticides : the integrated control

5.1. Only the search of a set of diverse complementary technics (integrated control) adapted to the humid tropics countries, will allow the control of vectors and parasites of human, animal or vegetal diseases. The treatment with pesticides must be considered only as one of them. Thus, if a set of technics allows a reduction in the expansion of pesticides, this should help in decreasing the contamination of the hydrosystems.

This means that integrated control is the solution for the future, with its methods that associate :

- Administrative and scientific structure
- Socio-medical education
- Minimum and rational treatment, with means scientifically controlled and oriented
- Contribution of one or more biological agents, predators or

competitives
- Management of the aquatic (mostly hydrological) and vegetal mediums.
- Contaminated water treatment
- Population and animal therapy.

The schitosomiazis control in the tropical zone illustrates, among other actions, the methodology for an integrated control. The World Bank sponsored more than thirty operations for the control of this disease (Lake Volta, Ghana, etc...) led by the WHO.

5.2. One of the most effective means in this set is the avalaibility of a national and international legislation, and to apply it according to strict rules that can be so strong as to prohibit the use of some products. Every country must count with one functional administrative and scientific organization to authorize products and supervise their use. In practice, this task is difficult, mustly in agriculture. The search for a consensus with the users seems necessary.

5.3. The intensification of individual and municipal education, particularly to eliminate direct feacal and urinary dumping in the aquatic medium (case of bilharziazis) and the domestic larval seats (mosquitoes and microorganisms), is a very effective mean. Yet, these efforts seem the least successful, because the educational actions do not seem to be well transmitted to the youngest part of the population (elementary and high schools).

5.4. Choice of pesticides, technologies and conditions of spreading are some fields where a lot still needs to be done.

We need to have better knowledge of the toxicity of many products, beyond absorption in rat or fish. The use of "mild" pesticides, as Bacillus t.i., is a method that must improve, even in the field of "natural" or synthetic chemistry. In the same way, investigations must continue to determine the minimal necessary amounts and the specifity of pesticides, in order to be more effective on the targets and save the most of the non-targeted environment. The degrees of remanence of the products, and the impact of their degradation products on the fauna and flora in tropical media must be better assessed. Treatment operations must be undertaken along with exhaustive studies of impact, during in situ tests for the products selection as well as during routine spreadings. Permanent evaluation of the results is necessary to be able to redirect the methodology of a treatment timely (amount, chemical nature, impact, etc...).

New treatment technics aimed to limit the propagation of pesticides in the environment, such as screen traps, must be investigated.

The know-how of spreading tends to limit technically useless propagation of pesticides.

5.5. Biological control is one of the possibilities that most needs to be developed . Predators (fishes, gasteropods, insects, etc..) and competitives (close species of insects, molluscs, radiosterilized males, etc...). Weakening the targeted species before and after treatment, allows a decrease in the amounts of the pesticides used . These methods have yet to be adapted and still very cautiously to the conditions of each humid tropical country. The general problem of the introduction of allochtonous species is particularly very tricky (example of rice-eating gasteropods).

5.6. The knowledge of climatological and hydrological regimes such as wind,temperature, hygrometry, rainfall, height of rivers, discharges, flooded areas and depths, etc..., is indispensable for integrated control. An inventory of the whole of the aquatic media is necessary to avoid reinfection of treated zones by non-treated ones. All these results must be acquired before and during the treatment programs. Prevision of the discharge by telemetry and modelling in real time, and of the dosis / diffusion ratio according to local morphology and hydrodynamic experiment, are direct contribution of hydrological technics in the determination of the quality of substances to spray for vector control. A lot of works has done in premodelling the effects of operations (Bader J.C. et al., 1987; Gioda A. et al. 1988; Le Barbe L. et al., 1987 ; Pouyaud B. et al. , 1987). Still, the dynamics of the substances, which are related to atmosphere and water dynamics, the chemical evolution that is controlled by factors of the medium, such as trappings and selective bioaccumulations, interactions, autopurification, etc..., make the application of theoretical exhaustive models difficult. Besides, their transfer to other sites than the one where they have been adapted is delicate.

5.7. The cleaning action of the aquatic medium by undertaking realization of public works is a basic method to take into account in plans of preventive or hydrological rehabilitation (curative). These mechanical instruments represent a fundamental contribution to sanitary battles.

- Deviation, sweeping, alternated drying of natural reactives or opened sewers, depending on the life span of targeted and non-targeted organisms.
- Improvement of drainage and water transit speeds , drying of damps, humid swamps, contact zones between savannah and forest.
- Removal of domestic seats.
- Building of vertical wall spillways. Removal of rocky thresholds, collapsed works, natural pits upstream and downstream the beds. Solidifying the basins of bridges, channels. Use of pipes for wells and road equipment.
- Improvement of withdrawal technics in order to avoid pollution of the rope and the bucket. Solidifying and draining the peripheries of the well; perimeter of protection. Setting of drill holes equiped with hand pumps.

- Withdrawal of over abundant plants. Etc...

5.8. The treatment of drinking waters can eliminate or diminish the contents of pesticides.

Flocculation, decantation and ultra-violets can be effective. One needs to know more about the use of solar radiation.

Activated carbon (powder or beads) can contribute to pollutant trapping ; but high doses are sometimes necessary. Nevertheless, even apparently used up carbon can still contribute to the elimination of pesticides.

A biologic treatment, realized under certain conditions, also eliminates a large part of the substances.

5.9. Therapies that consist in treating the whole affected population with specific drugs come along with the other methods. To conclude, integrated control of water quality, related to the fight against plagues (vectors, parasites, pesticides) appears as a wide field of multidisciplinary interventions, in which hydrology must take an important place in different aspects. The humid tropics countries must be more organized in that sense in order to have the availability of these specialized technics, a crucial question for their agriculture and population's health.

11. MICROBIOLOGICAL ASPECTS OF WATER QUALITY CONTROL IN THE HUMID TROPICS, CONCERNING DRINKING AND RECREATIONAL WATER

1. General aspects

Despite the momentum created by the International Drinking Water Supply and Sanitation Decade, progress can hardly match the increase in population size (Prost, 1989). Drinking water supply of acceptable quality and quantity for every man is far from being reached but must remain a high priority for the year 2000, as one of the most important factors of mankind's health.

In many countries of the humid tropics water kills, whereas it should be a source of life and health. The first objective of any program to manage water quality should therefore be to identify how many and overmore why people die due to water related problems (cf. paragraph 1) and seek the most effective approaches and researches (cf. paragraphs 2-5) to reduce the number of deaths (R.E. Manley).

Microbiological aspects that deal with water quality control are numerous. Bacteria, viruses, fungi, insects, larvae, worms, etc... are the causes of water-associated diseases which are very common in the humid tropics, more than chemical and micro-toxic pollution.

Vectorial diseases, whose parasitical cycles include an aquatic phase, are, together with feacal pollution, the main causes of man's poor health in the Humid Tropics. Hundreds of millions of people are contaminated. The aspects of vectorial diseases control, and its consequences on water pollution, are the object of a special chapter.

On the other hand, however, bacteriological methods provide the mean to detect these kinds of pollution, (analytic aspect), while bacteriological processes realize purification of water and waste water in the environment, and in treatment stations or lagoons, or of residues in digestors (treatment plants). In this chapter, hospital pollution could be added to feacal pollution.

2. Feacal bacterial contamination patterns in the humid tropics

The knowledge of the feacal bacterial contamination patterns is necessary for decision-making dealing with water quality control.

2.1. Feacal water-borne diseases : Cholera, dysentery, gastroenteritis, other diarrheas, typhoïd, infectious hepatitis, some vectorial diseases (bilharziasis).

2.2. In rural area, feacal pollution, though often localized, presents some serious aspects :

- Bad drainage and no protection around the wells and in the villages. Contaminated water stagnates with man (children) and animal's excrements. The string and bucket are contaminated by this polluted water at each withdrawal.
- Water and excrements remain in small ponds and puddles. There, organic matter favours the developent of germs (notably Escherichia coli).
- Lack of individual and community latrines. Excrements are dropped everywhere, particularly on river banks by men and animals, or directly into the water (life on boats), at the same place where water is used for drinking and personal washing. The remaining pollution is sweeped during the floods. During the dry season, low dilution increases the contents.
- Watering of vegetables with feacally (or chemically) contamined water brings diseases to the town where these products are sold.
- Agricultural re-use of municipal effluents may be a source of contamination. After Prost (1989), a WHO scientific group recommended to relax the bacterial guidelines for waste water use in agriculture (WHO,1989). It recommended, on the basis of epidemiological evidence and of available water treatment technologies, that water used for the irrigation of edible crops contains less than 10,000 feacal coliforms per liter,

and that irrigation of fodder crops, industrial crops, and trees be permitted after the retention of waste water for 10 days in stabilization ponds.

2.3. <u>In urban area</u>:

- Waste water open channels are used in the same way as the river banks in the country side, and moreover, are used as waste disposal which remain there between the big floods.
- Unsatisfactory waste water treatments lead the non-treated urban effluents to natural lagoons or streams where feacal contamination is high. It is one of the most important sources of pollution.
- Septic tanks are rare. Like draining well latrines, they are sometimes cleaned out by throwing residues without treatment to an aquatic medium. Locally, they can contaminate neighboring water wells. Even when toilets exist, hygienic paper is not usually thrown into the bowl.
- Clean water, coming from a waste water treatment station, can remain contaminated by pathogenic germs.
- Downstream sediments are contaminated locally and by urban effluents, and come back to the town with pathogenic germs, for use in construction, where they constitute a hazard for the building workers.

2. <u>Appropriate microbiological indicators of feacal and other pathogenic pollution, used for tests and alarm</u>

The difficulty of finding significant feacal indicators is a major problem

If feacal microorganisms appear in drinking water, normally alarm must be given, even though they can be not pathogenic. They are generally feacal coliforms and feacal streptococci; they may be enteroviruses. Other bacteria such as coliforms or sulfite-reductor Clostridium are ubiquitous, and are surely not indicators of feacal pollution. Moreover, other microorganisms, for instance fungi, actinomicetes, etc..., may be responsible for health troubles in man. Oxydant or reductor bacteria can be damaging for water supply and waste water networks.

Indicators are used for alarm, or as tests to estimate the efficiency of a treatment (for instance, the resistance of coliforms to desinfection is similar to that of Salmonella). Then they are basic tools to guarantee the public health of the people living in the tropics and their economic development.

However, the problem is not so simple, and is a much discussed topic. Research about suitable microbiological indicators of feacal and other pathogenic pollution, used as probes and alarm, is carried out in the most advanced humid tropics countries, but needs to be more expanded and submitted to reflexion on the base of the results obtained in the Zone as a whole.

Research concerns :

- Specific humid tropical species, according to local conditions: total coliforms, fecal coliforms, identification and isolation of Salmonella, identification of entoviruses, fungi, actinomecetes, etc...

The complexity of that issue appears with the research works of Fujioka (1981-1989) and Hazen (1981-1989).

Hazen (1989), mentioning Bonde's eight criteria of an ideal feacal-pathogen indicator (1977), examines various studies about bacteria (E. coli, feacal streptococci, Bifidobacterium spp., Clostridium perfringens), viruses, and bacteriophages as candidates to this purpose. He concludes that certainly the standard feacal indicator E. coli is unacceptable. Because few studies have reported the use of feacal indicators (other than E. coli) in tropical source water, objective evaluations of the efficacy of these alternate indicators is difficult. At present , obligate anaerobes, or their phages seem the best candidates for a better indicator for tropical source water, primarily due to their inability to survive extraenterrally. However, all of these indicators have the inherent difficulty that they or their host may survive under some conditions and that the media used for bacterial indicator enumeration may allow the growth of false-positive background flora. The viable but non-culturable phenomena reported for many pathogens in both temperate and tropical waters suggests that indicators may only rarely be corrrelated with disease risks in source waters (Colwell et al.,1985; Hazen et al.,1987; Baker et al., 1983). Thus the best indicator may be no indicator, i.e. direct enumeration of selected resistant pathogens. This would allow a more realistic estimation of health risk.

After Hazen (1989), immunofluorescent staining can detect densities of pathogenic bacteria as low as 10 cell per ml, a density which may give no cultural counts (Flierman et al., 1981; Colwell et al., 1985). The use of monoclonal antibodies makes this technique specific even at the straigh levels of some organisms. However, as a result of cross-reactivity when using immunofluorescence (even with monoclonal antibodies) the most specific and sensitive methods for detecting pathoghens may be the nucleic acid probes (DNA or RNA). DNA probes have already been developed and tested for enterotoxigenic E. coli (Bialkowska-Habrzanska,1987; Hill et al.,1983; Moseley et al,1982) and Salmonella spp. (Fitts et al.,1983). Thus direct detection of pathogens is current . Common enteric pathogens which could be enumerated are poliovirus and Salmonella typhimurium. Detection of either one of these in tropical source water would indicate risk of human disease. Instead of enumeration, maximum contaminant levels could be base on detection only. One potential problem with this approach is that the presence or absence of one pathogen may have little bearing on other pathogens. A multi-species test for two or more of the more resistant and common pathoghens found in tropical waters may be necessary.

After Fujioka (1981-1987), many of the national regulations such as the use of bacterial indicators to assess water quality are not applicable to Hawaii because the bacterial indicators selected are naturally present in the environment of these islands. On the contrary, aquatic organisms selected for toxicity assessment by USEPA are not present in Hawaii. On the other hand, sunlight, a natural environmental agent which is more predominant in the tropics that in the temperate zones of the world, is the primary factor in the inactivating indicator bacteria in the environmental waters of Hawaii.

- Relative statistical distribution of germs, feacal indicators/ non significative germs ratio, feacal indicators/pathogenic germs ratio, etc..., which vary with local and periodical conditions.
- Tests for detection of mutagenic substances, used with Salmonella typhimurium, enzymatic activator, extraction XAD resine, liquid extraction, extraction of solid and lixiving residues, etc... (Salmonella/Mammalian Microsome Mutagenicity Assay-AMES Assay).
- Selective analyses methods : filtering membranes, multiple tubes, gelose (incorporation, spreading); cultural medium and reactives; isolation and identification of Salmonella (Moore technic); determination of entoviruses in water; analytical quality tests; signification and interpretation of bacterial analyses, etc...

4. Appropriate microbiological water quality standards and legislation for drinking water and recreational water in the humid tropics

WHO (1972; EFP/82.39 ; EFP/83.58 ; guide for drinking water quality, 1986) proposes standards that are often used as grounds for national references, eventually adapted by each country under specific conditions. The United States Public Health Service, 1977, France, The European Communities Council, 1975, 1976, have adopted their own standards (tables are available). Many humid tropical countries have done the same or need to do so.

Most countries have no law that deal with the bacteriological quality of input water to treatment stations for drinking water. In this case, standards are only guidelines.Other microorganisms can be responsible for complaints (for instance, cutaneous diseases in recreational water), without inevitably being of feacal origin. Therefore the use of feacal indicators does not constitute an universal test for any hazard alarm. Only "classical" detections are made, but other water-associated diseases whose microorganisms are not sistematically detected (may be unknown), should also prohibit the input of water with a strong feacal pollution to supply treatment stations.

The law usually determines standards with maximum threshold values of total coliforms and feacal coliforms per volume in swimming water (for instance, 5000 total coliforms per 100 ml, 2000 fecal coliforms per 100 ml, neither Salmonella nor virus). In temperate countries, water is generally acceptable for drinking only if it does not contains neither feacal nor pathogenic germs and only a very small number of cultivable germs (37 degrees, nutritive medium). For instance, the adoption of general law text by the EEC countries has recently strenghtened the standards for drinking water. Those are considerations given for example, but the studies of Fujioka and Hazen have emphatisized that such standards have no significance in the tropical waters. In a general manner, Fujioka (1989) mentions that conditions in tropical countries will never be fully understood and tropical countries will continue to be forced to operate under assumptions which often are not applicable to their own conditions. Anyhow, these obvious standards are not often respected in rural areas, where treatment stations do not exist. There, drinking water is taken from the common well or, more often, from the stream or the lake, at the same place that is reserved for personal washing, swimming or animal watering. It becomes increasingly difficult to attain WHO standards specially in respect to feacal coliforms. Even in big cities, the performance of the existing stations is sometimes unsatisfactory, because of technical or human faults.

After Kilani (1989), there is a need for relaxation of the existing Water Quality Standards in Kenya. Experience has shown that the use of FC (indicator organisms) as an indication of feacal contamination and therefore presence of pathogens is a luxury that may no longer be afforded in rural water supply. It is to be hoped that research work starts in this area.

A serious problem is the unavaibility of published data to characterize the quality of waters in the tropical zone. As well as for standards in general, it would be very useful to make an exhaustive review and comparison of bacterial standards or guide-lines determined in each humid tropical country for both supply and waste water of treatment stations.

As background of standards and law, research should identify more the bacterial flora of water sources and distribution systems in these countries.

It is a need to develop better technics to detect and enumerate various pathogens and indicators in water without the bias of guidelines established for temperate countries. Only with such backgrounds, microbiological monitoring of water quality will have significance.

Epidemiological works are needed on health hazards from various standards of water, including the relationship between cyanobacteria (and phytoplancton) in water storages and the effects on human health. Epidemiological statistics, "in real time", could be also considered as efficient indicators for awareness.

In relation to this, the identification of environmental conditions that lead to unusual occurrences of health significant or nuisance organisms must be carried out, according to the scheme exposed for feacal contamination (paragraph 2).

5. Role of microorganisms in the biodegradability of organic matter, chemical substances and industrial waste

This aspect of microbiology grows higher in the humid tropics because temperatures are a favourable factor for biodegradability, in spite of the decrease in the dissolved oxygen content. Biodegradability in an anaerobic medium is also a research theme of great interest, able to provide power alternatives.

Particularities in the acting of unique or common aerobic species in diverse humid and hot local conditions, such as activated sludges, ponds, aerated media, disgestors, according to the types of waste, can be useful knowledge for these purification technics. Numerous studies to be carried out should correspond to the diverse operational technics which exploit very different mediums.

The main items to consider in the microbiological and biochemical area are : microbiology of degradation in humid tropics water and soil; aerobic and anaerobic processes, metanogenic and non metanogenic bacteria, methods of analysis and tests, peculiar kinetic processes, reaction velocity, characteristics, kinetic and control of parameters, mixture regime, operational problems such as starting up and routine, cases of herbicides, detergents, hydrocarbons, etc...

6. Ways of bacterial water pollution control in the humid tropics

Ways of bacterial water pollution control in the humid tropics are quite diverse and complementary. Some are cheap, some are expensive , but they must be applied together at each corresponding level. The cheapest ways are capable to efficiently alleviate the most urgent problems in most of the areas, but would nevertheless need education and grants from the governements and international organizations. For example, mentioning Prost (1989), cyclops, vector of the Guinea Worm, are relatively large animals which can be removed through filters made of cotton, nylon, or polyester cloth.

The following issues can be interpretated as scientific, technical or an economic research study, or training to be developed in most countries.

6.1. General means against bacterial pollution

- Individual education, in order to obtain personal participation after hazard comprehension.
- Organization of control at individual, municipal, departmental levels (urban, rural zones), with alarm systems for particular cases.
- Identification and characterization of those microbiological drinking and natural water problems that may, directly or indirectly, adversely affect the local public health.
- Identification of those microbiological organisms for which local adequate control methods are not available, and then research and development of the needed control methodologies.
- Identification of parameters of water quality improvement.
- Identification, characterization and development of methods for removal and/or destruction of biological (and chemical) pollutants of hazardous nature.
- Research and technology on treatment systems for specific control of water pollution by carcinogenic, teratogenic and mutagenic substances.
- System engineering approach to the solutions of water quality problems.
- Development of data base for drinking water quality control, and assessment for domestic and recreational purposes.
- Quantify uncertainty in risk assessment for water quality control.
- Develop mathematical models for water quality control.

6.2. Means against bacterial contamination of waste water

- Construction of sewage disposal systems through the stages of the collection and conveyance networks as well as treatment and disposal of domestic waste water. However, until a satisfactory removal of feacal pollution is reached, treatment of collected effluents remains difficult, and the outpout water contributes to the pollution of hydrosystems. In this case, a discharge into the sea is preferable, because most of the bacteria can not survive in salted water.
- Downstream desinfection of effluents of waste water treatment stations with oxidants.
- Controled "lagoonage" is a solution to be considered as often as possible. Strong solar radiation favours the destruction of germs . Research on biodegradability must be developed in the humid tropics : microbiology and applied technology.
- Reduction of feacal pollution by the construction of small and cheap individual or municipal systems (unsewered sanitation), based consumption (see : Colcanap et Dufour, 1982). In rural area, communal facilities can be planned (such as compost systems), but often present social difficulties.

6.3. Means against bacterial contamination of drinking water and recreational water

Protection of water resources used for drinking water and recrational water, overall upper watersheds and ground water : geological, hydrological, hydrogeological, social studies.

Generally there can exist pressure to open up water supply catchments for recreation or other uses: there are threats to poison water supply.

- Analysis to quantify the main contamination problems and locating the places where they are most severe.
- Protection of water in contact during work or recreation, or used for cloth or personal washing. Policy for impeding the use or contact of contamined water by unaware people.
- Water treatment of individual and community swimming pools : test controls, operational technics for treatment (floculation, filtration, disinfection); quality control; legislation.
- Bacteriological standards do not guarantee against viruses such as thyphoid and infectious hepatitis. Sand filters and chlorination would not eliminate hepatitis viruses (Smith, 1969). Classic analyses cannot detect some toxics or viruses, in the same way as classic treatments cannot remove them. The proliferation of toxic substances in agriculture and vectorial control represents an actual risk in the humid tropics. Therefore, appropriate standards for the use of toxics and waste water disposal, constitute also priority measures in the protection of drinking water, since the generalization of domestic water supply will not be achieved by year 2000. The lack of such standards, and the difficulty in detecting all types of hazards, must lead to avoid the use of too much polluted water in supplying treatment stations.

- Increase of the number and quality of municipal and domestic treatment stations and other supply systems :
  a) Sedimentation, flocculation, filtration.
  b) Chlorination, cleaning and desinfection of water tanks
     * oxidants (chlorination, ozonization, etc...), oligodynamization, other new desinfection, Physico-chemisal characteristics and quality of reactives. Reactions with microorganisms (and organic and inorganic components)
     * technics : local production of oxidant, place and time of injection, equipment, continuous and emergency desinfection, super chlorination, contact time
     * control technics : security, residual contents, dechlorination, quality of reactives, applied microbiology to operational control
     * standards and legislation.
  c) Piped and tap water supply in the household itself, better than public standpost.
  d) Simple and inexpensive domestic water supply systems, granted by the governments and international organizations :
     * pipes and tanks for rain water collection and storage from roof run-off : potential and availability of rain water supply, reliability during each month, roof area; household demand; optimum tank size; types of concrete (with bamboo), metal, plastic tanks; use of mathematical models for such studies. The withdrawal system from these tanks and the desinfection processes are also important issues. Prost (1989) justly points out that small amounts of water are drawn all day long from the main jar, using

small cups deposited nearby. It is obvious that each collection contaminates the reserve. The multiplication of bacteria after a certain period of time is sufficient to create significant risk. So, periodic desinfection of water tanks (ground cistern, roof cistern) is likely the main aspect of these systems.

* Technics of construction and (once again) maintenance of small flocculation tanks and sand / carbon filters for villages.
* Use and local production of kitchen gravity filters made of porous ceramic. This is a main issue because, in many areas, piped and tap water is not supplied or, if it is, its quality is generally dubious. The quality needs an ultimate treatment just before consumption. Only some litres of water are drunk per family per day, which can be safely provided by such simple filters. For instance, in Bolivia, price of a porous cell, imported from Brazil is 3 US$. The complete system (2 superposed tanks of 4 litres), is more expensive but could be cheaply manufactured locally, with large publicity and distribution.
* Hydrological studies and technics for the building, setting up and maintenance of hand-pumps/small bore-holes with "crepine" to avoid pollution of the wells from the surface or the use of surface water. This technics should be developed everywhere sandy phreatic aquifers exits.

12. DOMESTIC AND INDUSTRIAL POLLUTION CONTROL : ORGANIC MATTER, NITROGEN AND PHOSPHATUS; EUTROPHICATION. SANITATION, SEWAGE AND WATER DISPOSAL

1. Types of urban and industrial pollution

In the humid tropics, the exploding growth of the cities and the accompanying development of industries, which is oriented to the exploitation and transformation of biological resources (vegetal and animal), often in the same place, determine a dominating pollution by organic load and suspended matter. A high rate of fecal contamination, which is sometimes accompanied also by inorganic toxics, exists. Pollution by hydrocarbons constitutes a special form of organic contamination.

According to the countries, the cause of major pollution in urban area is domestic waste water and solid water, or on the contrary, industrial waste water.

2. Causes and aspects of organic pollution

2.1. Waste evacuation, and, in particular, waste water disposal if they exist, are rapidly unsuited for a disproportionate domestic production.

The biodegradable organic pollution proceeding from the industry originates in slaughterhouses, dairy industries, canneries, pulp and cellulose mills, wood transformation, breweries, fruit juice factories (citrics, pineapple,...), oil mills and soap factories, sugar cane, coffee, rubber, cocoa, rice transformation, extraction zones of hydrocarbons, refineries, garages, etc...

2.2. Tropical storms generate urban floods which sweep all of waste and waste water. Rain water and waste water networks are generally not separated, which increases the difficulty of treatment and the pollution of the receiving media. Flood or pollution basins do not exist on drainage networks.

2.3. Eutrophication and landscape deterioation appear over more or less large areas, with the pollution by domestic or industrial organic waste water, because of oxygen depletion and the high production of nitrogen and phosphorus. Phosphorus (phosphate and phosphoric acid) and nitrogen, which are very much used in the agro-alimentary industry for instance, contribute as point sources to eutrophication. This phenomenum can be stronger where toxic contamination is low. Self-purification of the water is not sufficient, particularly where the turn-over is slow. Eutrophication injures biocenoses : growth of primary production and weeds is observed and contributes by decomposing the increase of nutrients and BOD, rarefaction of animal species and proliferation of some species of fishes, development of vectors, etc... Sitting and smelling gases correspond to the anaerobic deposition of organic and suspended matter and sand.

2.4. Pollution by hydrocarbons in the humid tropics (Andren, 1976; Orokoya, 1978; Dejoux, 1988) is limited to the extraction zones and refineries. Accidents in transportion eventually create local problems. The many individual disposals of waste oil, wherever, and sometimes directly in the aquatic medium, are often the source of the most important form of water pollution by hydrocarbons. Lagoons with a low turn-over are affected the most by this type of pollution.

Hydrocarbons form an asphyxiating film over the water and limit oxygen exchanges through the surface. Some of them evaporate. Compact residues remain, the soluble phases enrich in aromatic compounds, both with toxic potentials. Degradability by bacteria, more active under a high temperature, can produce substances that are more toxic than crude oil, especially when they are dissolved in the upper part of the water. Refined products are generally more toxic than crude oil, and, moreover, can have an anti-bacterial action (kerosene), that inhibits biodegradation.

Little is known about the consequences of hydrocarbon pollution in continental waters, besides the effects of catastrophic accidents : black tide in the sea. However, it is certain that the use of detergents to make hydrocarbons disappear is worst for aquatic life than the hydrocarbons themselves.

2.5.Pollution by detergents is increasing in the humid tropics.

Then, the status of urban and industrial environment healthiness is generally very deficient. This is particularly true for aquatic media, such as lagoons, groundwater, drinking water sources, estuaries with little stream input, which may receive untreated waste water. Domestic pollution in small towns, without industry, is also preoccupying.

3. Waste and waste water disposal

The problem of waste and waste water collection, disposal and treatment by appropriate processes for cities, towns or villages, seems one of the most important for man's health and dignity in the humid tropics (see chap. about feacal pollution).

The studies made on the city of Abidjan by Broche and Pejchet (1983), Chantraine and Dufour (1983), and summarized by Dejoux (1988), are examples of research about the evacuation and treatment of the waters of a great urban centre in a tropical lagoon zone. They lead to the modelling (in terms of BOD) of the pollution deriving from various urban and industrial sectors, and transported through different systems (sewers, surface drainage, run-off) to the outlet lagoon.

Softwares dealing with waste water networks have been elaborated by several specialized services. They allow, partly or totally, various estimates of run-off on urban watersheds and through waste water networks, with the determination of the piezometric line, according to actual or fictitious rainfalls. Other estimates about spillways, siphons, succints are facilitated. Visualization of hyetograms and hydrograms, and longitudinal profiles are available. The direct discharge in the natural medium is evaluated through the hydraulic monitoring of the existing networks, and the simulation of the functioning spillways and storm basins.

Urban drainage is often difficult because of the extension of the town all along the coast or the bank, almost at the level of the sea or the lagoon.

4. Ways of organic, nitrogen and phosphatus pollution control

The means of organic pollution control in villages and cities include those already mentioned about bacterial contamination control. Many studies must be undertaken to adapt and complete the knowledge on specific conditions of the humid tropics :

4.1. Individual or community waste collection and waste water treatment systems. These remain the best methods to avoid organic pollution of the hydrosphere, with high contents of nitrogen and phosporus. However, design and managment of such systems require an adequate understanding of many phenomena.

- The biochemical phenomena which determine the functioning of the treatment systems, according to the type of organic pollution. The processes which remove nitrogen and phosphorus in these systems, need complementary research for determining design parameters used in particular for modelling.
- The study of the flock, activated sludge, deposition and decomposition of the sludge in humid tropics.
- The conditions of the biodegradability of specific substances.
- The metabolisation of hydrocarbons and phenolic products.
- The adapted technology for water treatment, bacteria, physico-chemistry and biochemistry of :
  . Activated sludge spread over different types of soil, with infiltration and drainage
  . Areal lagoon and no-areal lagoon, artificial or natural wetlands
  . bacterial bed
  . Individual sanitation : septic tank.
- The Tertiary treatments :
  . bactericides
  . nitrogen elimination (by anaerobic bacteria). Technics for the reduction of nitrogen contamination
  . waste incineration with retention of soot and dust; without transference of water pollution into air pollution.
- Creation of technical attendance for the functioning of purification stations, training of specialized engineers in the public services for community stations and individual systems.
- The study of the mixing of polluted water (urban + industry) for optimal degradability. Selection of microflora. Effects of the addition of nitrogen and phosphorus (elimination of phenols).
- The problems of the treatment, elimination and valorization of waste and sludge :
  * anaerobic digestor: power source, functioning problems, harmful effects
  * desiccation, transport
  * valorization : knowledge of the product. Minimum treatment. Periodic analyses control (toxics, heavy metals, microbiology). Desiccation.
    Use in agriculture. Pasty or liquid spreading. Comparative tests for crops, forest, soil condition and climate. Promotion with farmers. Risk of the reuse of untreated waste water, waste or sludge in agriculture, in the expansion of enteric diseases.
  * Improvement of sewer networks (open or piped). Separation of pluvial and waste water networks.

4.2. <u>Study of the causes and effects of local urban and industrial pollution : eutrophication</u>.

4.3. Chemical and biological pathways

In order to predict eutrophication and to assess management strategies, biochemical and physical chemical processes occuring in natural or artificial media must be better known in their main pathways.

- Study of microbiological populations, including pathogenic, protozoa, rotiferes, nematode threadworms, algae, fungi, that intervene in the self-purification of the environment, lagoonage, activated sludges, bacterial beds, septic tanks, anaerobic digestors. Role of microorganisms in the biochemical processes concerning nutrients in hydrosystems.
- Study of local pollution effects, as suspended matters, color, transparency, temperature, radioactivity, pH, Eh-rh, salinity, chlorides, nitrogene, phosphorus, sulphur, carbon, iron, manganese, etc...
- Dissolved oxygen balance in aquatic media :
  - Estimation of the balance terms.
  - Role of photosynthesis in self-purification :
    - . radiation, temperature, Influence Oof thermic pollution and natural high temperature.
    - . biological sample and measuring such as algal biomass, including in situ chlorophyll measurement and investigation of photosynthetic pigments (potential indicators of nuisance).
  - Diurnal variation
  - Longitudinal profile of dissolved oxygen concentration downstream a pollution. Sag curve.
  - Hypolimnion aeration and destratification.
- Local processes of the nitrogen and phosphorus cycles, in polluted aquatic media and treatment systems (wetlands, ponds, flooded plains: varzoes, pantanales, yaeres) :
  - Nitrification and denitrification. Tertiary treatment to reduce nitrogen.
  - Interaction (removal/release) between phosphorus and suspension or bottom sediment.
  - Nitrogen and phosphorus control plant production.
  - N/P ratio and limiting role of each nutrient.
  - Transport of particulate phosphorus maintaining an an eutrophic system over following years.
  - Sediment oxydation with nitrates, sediment sealing, flocculation.
- Local processes of carbon and sulphur cycles, in polluted aquatic medium and treatment systems.
- Chemistry and role of iron and manganese (and other metals) in the exchange of pollutants between water and sediments in natural and contaminated media. Role as a factor limiting algal biomass.
- Methods of estimating the polluting load of industrial or urban waste water.
- Organic matter / oxygen / nutrient pollution modelling (O2, BOD, nitrogen, phosphorus) , in town and industry; transport, treatment, and eutrophication.

The effectiveness of the Volleinweider-OECD model must Obe checked in the humid tropics. Cullens (1987) mentions three major problems that must be resolved :

* The validity of the nutrients / chlorophyll /groups of phytoplancton/biomass relationships for turbid and non clear waters,

* The sensitivity of the model to its assumption of constant sedimentation in turbid and variable systems,

* Better estimates of inflows of phosphorus from non point sources on a stochastic basis rather than the approach of using annual means,

* Role of external loads.

* Equipment needs for successful mechanical control of macrophytes infestation.

4.4. Health aspects of organic substances, nitrates and phosphates, in water.

4.5. Types of preliminary studies to choose technical options of treatment systems. Management of waste water treatment (cost, Ofinancial help, etc...).

4.6. Institutional problems and specialized staff for sanitation, waste water disposal and treatment (technical attendance and consulting).

13. INDUSTRIAL MICROTOXICS AND CHEMICALS CONTROL

1. General causes of pollution

Microtoxics and chemical pollution comes mainly from the industry, but in some cases, can also originate from natural alteration and erosion. The sources of the toxics, specially those of natural origin, are not always identified. In Kenya for instance (Kilani, 1989), high fluoride contents in drinking water, closely related to the characteristics of the aquifer of each area, are one of the major water quality problems. Industrial pollution in the humid tropics, as in the rest of the world, is characterized by the diversity of the effluents and the toxicity, as well as the variability of the waste quantity. Each type of industry has its own technical processes that lead to typical waste water and solid wastes, related to its production and subproducts. The degree of contamination varies with the degree of development, the type of primery material resources and the exploitation technology. The race for development in the humid tropics is not always favourable for the installation and control of adapted purification technics for waste water. Foreign competition does not weight prices for the sale of factories by sophisticated purification systems. Therefore, waste water treatments, when available, are often inadequate. Moreover, the desire of setting up factories with the most economic yield comes along with a flexible application of waste water standards, when they are determined by law.

2. Chemical characteristics

2.1. Heavy metals such as mercury, lead, zinc, arsenic, manganese, copper, tin, nickel, cobalt, iron, uranium (radioactive), and other constituents as cyanide, fluorine, acid, soda, chloride compounds, etc...,are very toxic. Thus priority must be given to to them in water quality control. They originate in mining activities, metallurgy, tanneries, surface treatments, pulp mills, cellulose, wood transformation, etc.... Heavy metals pollution is known only in some places in the humid tropics, often near mines.

2.2. Waste oils, by their often uncontrolled spreading, also contributes to raise heavy metals levels.

2.3. Pesticides (organo-halogens, organo-phosphorated), used in cellulose, wood transformation and construction, are often considered as inorganic toxics because of their weak degradability and behaviour patterns in the aquatic environment. To those point originated from the industry, are added those proceeding in a diffuse pattern from the vectorial and agriculture spreadings.

2.4. Carbon dioxide, chloride fluoride hydrocarbons and ozone in the atmosphere, acid rainfall, are serious topics to take into consideration by governments, organizations, and the industry. Although these themes have some speculative aspects with some uncertain conclusions, they have been predicted to have considerable world-wide effects. From the use of chloride fluoride hydrocarbons (CFC) arises the problem of the loss of atmospheric ozone, with indirect impacts on water quality. The increase in the radiation and temperature will rebound on the plancton, and weed growth, temperature and pH of the water. Likewise, the high disposal of CO2, methane and nitrogen oxides in the atmosphere by the industry (fossile combustibles), the constant increase of ozone in the troposphere, and the cutting of the humid tropical forest, would increase temperatures by the greenhouse effect. Among many serious bearings, the rising of the ocean level would modify in hydrosystems, hydrodynamics and water quality of inland waters associated with sea water, such as estuaries, lagoons, coastal and island groundwaters.

The acid smoke and rainfall (N, CO2, ozone, ...) from the industry are changing many ecosystems and water quality, at least in the temperate zone.

3. Behaviour in the aquatic environment

Even in small degrees, above toxicity threshold standards in effluents and water, microtoxic and chemical contamination is harmful : heavy metals (like pesticides), accumulate in sediments, flora and fauna, leading to hardly reversible situations. The effects on the aquatic environment and health are not well known, besides the consequences of accidents and laboratory experiences.

Toxic for microorganisms, these micro-pollutants can be cumbersome in a classical purification.

Kinetics of the accumulation depend on the dissolved or particular form of the constituents, and the characteristics of the aquatic environment, notably those of the sediment, physico-chemistry (pH, temperature, salinity) and flow. Reactions, inter-actions, absorption, adsorption (chelate with organic matter, humic acids, detergents), control the patterns of sedimentation or dissolution of the constituents between the water and the suspended load or sediment. Salinity and pH variations favour the Kinetic evolution of the components : precipitation of hydroxydes, carburates, sulfites with alcaline pH; dissolution with acid pH or low dissolved oxygen contents due to phosphatus and nitrogen yields (redox potential). These phenomena of precipitation-dissolution, due to the variations of the physico-chemistry, are important in estuaries and also for waste water with high salinity and extreme pH, which will evolve strongly in the environment.

The behaviour of toxic components is little known and must be studied in specific cases.

4. Standards, analysis and assays

The substances to be controlled are numerous. The following incomplete list is given as an indication and must be fitted to local pollution sources : aldrine, dieldrine, endrine, isodrine, endosulfan, chloronitrobenzene, trichlorobenzene, hexachlorobenzene, chlorosaniline, parathion, benzene, 1.1.1.-trichloroetane, 1.2.- dichloride, chloroforme, PCB, phosphatus, ammonium, adsorbable organohalogen compounds.

Accumulation in tropical organisms is not sufficiently known, as well as toxicity. Detection must be developed by toxicity assays on aquatic mussels (briophytes) and algae, bacteria, zooplancton (daphnies), fish, sometimes on man, and tests of inhibition of the cholinesterase and mutagenic assays.

A general standard is often useful to estimate toxicity budgets and calculate tax coefficients. Let us mention the standard "Equitox".

5. Ways of controlling industrial microtoxic and chemical pollution : In-plant control, waste water treatment, self-control, specialized treatment and security system.

The difficulty in eliminating harmful micro-toxic pollution in the hydrosystems makes comprehensible the need to avoid it as much as possible at the source. Prevention is better than cure. Therefore, integration of efficient anti-pollution systems in the conception and building of production systems is of great necessity.

5.1. In-plant control

New fabrication processes are being sought after in order to modify in a positive way the quantity and quality (nature and composition) of the wastes, and the characteristics and intensity of contamination (for instance : new-technics for pulp whiting). Technics of "in-plant control" are still being developed, opening the way to a "clean technology", according to local conditions. It is better to avoid leakages than to treat them, for treatments are expensive, while recuperation helps saving raw materials. These technics separate water to a maximum, according to the phases of manufacture, and use the minimal amounts (eventual recycling) in order to facilitate subsequent treatments. The dry processes must be researched. Valorization of the waste and sub-products is one of the large ways for the future.

5.2. Waste water treatment

Infrastructures for waste water treatments must also be developed : physical, chemical, biological processes, activated sludge, activated carbon, solvent extraction, oxydation, etc... Recovery of wastes and elimination of leakage in the main product by improving the yield, represent a profit that contributes in the long-term to pay for the cost of the specific technology.

The methodology of dimensioning and setting up infrastructures of treatments (pre-treatment, primary and secundary treatments) is an important aspect. In the case of ponds and stabilization basins, it can be directly integrated to the hydrosystems. Among all the avaible systems for improving effluents quality, purification of waste seems to remain the most important. In many cases, the treatments can be performed in the urban station.

The problem of the future of the sludge is something serious, as in the case of mining exploitations (spreading, stocking, areas and dams).

5.3. Self-control

The times of the "ashamed polluter, cautious polluter" are gone. It is natural to produce, then it is natural to depollute. The manufacturer is the one who knows better what he is throwing out, notably the peaks and fluctuations. It is necessary to promote the notion of self-control of disposal and anti-pollution infrastrutures. These may count with discharges-spillways, instantaneous and integrated counting, and continuous quality of waste, on the site and in the receiving medium (automatic stations on the river). Instantaneous transmission of data, allow the modulation of the rejections or to give the alarm. This implies the responsibility of the factory and transparency, with technical attendance for a correct set-up and routine functionning, as well as grants, but also taxes. The principle of "the polluter must pay" must be applied at every level, as a persuasive basis to the beginning of water quality control. The bases of the calculation must be higher for toxicity than for the other parameters. Administrative pressure is a

necessary mean. In order to function, the self-control system must be the subject of visits from the responsible services of the environment, and the object of a contract between the industry and the administration. Training of specialists (industrial and administrative) must be promoted in this field, as well as education of the workers. An inventory of the main sources of pollution is necessary for micro-pollutants.
Self- control operations, that are most efficient towards hydrosystems, must be privileged.

5.4. Special treatment and security system

In the humid tropics, few measures are actually adopted, to:
- Reduce toxic waste water effluents, by completing individual treatments with specific processes when it is necessary to destroy harmful wastes.
- Set-up treatment centers for special wastes (oily emulsions, neutralization of acids, solidification of liquid waste, treament of sludge, etc...).
- Avoid uncontrolled dumping of harmful aqueous or solid wastes that are notably damaging to groundwater (discharge of class I, toxic products).
- Prevent accidental toxic leakage. An accident, always possible, can annihilat in a moment all the efforts, yet realized with much application and money. Efforts must be set on the reliability of works that suffer from the lack of preventive maintenance, spare parts, specialists in this field. Security systems can be complex, but an organization must be planned : detection of leakages, observation basins, retention areas, drainage areas and basins for solid waste, belt of pumping wells around the factory to prevent the risks of propagation in the water table, upstream control and alarm wells, watertight gutters, waterproof areas, separative sewers...

Other types of pollution are due to mining activities, such as the long-term reaction of sulphur (pyrite, marcassite) in the cuttings, leading to an acidification of the runoff water.

The diphenyl polychlorinated compounds used in the manufacture of plastic materials can also be dangerous after their degradation or incineration, because polychloropiphenyls accumulate in the food chain. An agreement of the Economic Cooperation and Development Organization (1973) attempts to limit their production.

Finally, each industry must adapt or find the appropriate technics, economically bearable, to control its own wastes. Systems against pollution must be conceived and built at the same time than production systems.

In the humid tropics, the different cases of microtoxic pollution, all the works to improve it and the advances, with special attention to the consequences for the hydrosystems, could be classified according to the types of industry .

5.5. Control of specific toxics with global bearings

Assessment of diverse predictable impacts of the loss of atmospheric ozone, greenhouse effect, and acid rainfalls, on water quality, must be carried out in order to anticipate general and local concerns. International policy measures must continue to be taken urgently concerning spreading and disposal of the incriminated products.

6. Ways of natural chemical substances control in drinking water

The problem of high fluoride content is an example. Mentioned by Kilani (1989) as a major issue of water quality in the Rift Valley, and Kenya in particular, because of some adverse effects in human health, investigation is currently under way in this country to develop a technically feasible, cheap and simple method to reduce fluoride levels in drinking water : use of clay pots, activated alumina, bone charcoal and alumflocculation. Activated alumina shows the highest fluoride removal capacity. The WHO standard of fluoride content, not more than 1 mg.1-1, has been found to be too difficult to attain in rural water supply.

14. INDUSTRIAL THERMIC POLLUTION

Thermic and atmospheric pollution is largely due to the industry. Thermic sources are generally power generation, industrial cooling, and geothermal power plant. The increase of temperature in the receiving medium is generally of little extension in the humid tropics, but research on the use of hot water (aquaculture, greenhouses, for instance) must be developed for specific projects.

15. WATER QUALITY CONTROL RELATED TO LAND MANAGEMENT

Deforestation/ land management on large areas or riverbanks and mining exploitation, increase erosion and, the turbidity and sedimentation in streams and lakes. Organic effluents can act in the same manner. Thus, the weaker penetration of light disminishes photosynthesis of weeds and phytoplancton. Sedimentation of the suspended load modifies the physico-chemistry of the bottoms, disturbs gas exchanges with plants and animals (fish), limits growth and reproduction at different levels of the food chain. Suspended matters absorb microtoxics whose effects can be more harmful, depending on the mineralogy of the particules (clays). These phenomena should be investigated deeply.

Deforestation/land management modify salts and nutrients cycles and balances, from rainfall to stream. This important aspect should be studied in the framework of an eperimental watershed management for exploitation of humid tropical mediums. The same is true for the management of irrigated perimeters, where natural salts and nutrients cycles are very much modified, with the risk of salinization.

Reuse of waste water in agriculture is of major importance. Standards and control are the crucial issues to be investigated in specific cases (WHO, 1989).

16. WATER QUALITY CONTROL RELATED TO WATER MANAGEMENT

Various kinds of water management have been previously mentioned as means of pollution control. Water quality is also generally changed by other water managements such as reservoirs, irrigated areas, channels for transport or drainage, intensive pumping, exploitation of quarries.

The strongest physical, chemical and biological impacts appear with the creation of man-made lakes, and the drainage of flatlands, in the area itself and downstream. So as to minimize destruction of aquatic ecosystems and degradation of water quality, multidisciplinary studies are required, at the design stage, and at each step of the projects, over the tens of years that are often necessary to reach new steady-states.

The effects of progressive river regulation (filling or drying), and the new regime of the hydrochemistry, related to levels and discharges, in the area and downstream, have to be progammed according to diverse issues :

- Biodegradation of the previous vegetation : high BOD, liberation of nitrogen compounds and toxic substances
- Biocenotic changes, including :
  * development of vectorial endemics (insects, gasteropods, larvea), favoured by man migration, and accumulation of organic matter. It is necessary to establish ecological guidelines for the disease vectors, building, and hydraulic works for the design of water storage and drainage, in order to minimize the danger (see chap. 10).
  * Abnormal development of macrophytes, plancton and toxic algae. Water management modifies the ecology of plancton and macrophytes. It may favour the occurrence of nuisance species such as toxic algae (cyanobacteria Microcystis and Anabaena). Factors with regards to succession and growth at both cellular and ecosystem levels (N/P ratio, iron, climate...), must be assessed in the framework of the study of various groups. Toxins should be detected and methods developed to remove or inactivate them. The role of riparian vegetation and buffer strips in stream, lake and flatland, in protecting surface water quality should be investigated more, as well as the organic vegetal matter cycle.
- New dynamics and chemical kinetics. Reduction of the flushing effect of minor flood events. Evolution of the stratification :

O_2, temperature; anoxy of the hypolimnic water, occurrence of toxic substances such as hydrogen sulphide, euphotic surface lying, dynamic changes related to yields and meteorological conditions.

- Central or downstream modification of the leaching by the floods of soils, ponds, riverbanks, wetlands.
- Increasing pollution (bacteria, toxics, eutrophication) due to concentration of population and new activities, allowed in the area by water resources management.

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