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A COMPARATIVE STUDY OF INLAND WATER QUALITY — SÃO PAULO (BRAZIL), FRANCE AND ENGLAND

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ABSTRACT

Reports on inland water quality are often published in many countries. These reports present the results of monitoring networks and show the evolution of the water pollution control situation in these countries. The data in the reports published in France (Ministere du Environnement et Cadre de Vie, 1976) and England and Wales (Department of the Environment and the Welsh Office, 1975) were compared with similar data surveyed by CETESB (the Brazilian Environmental Protection Agency) in São Paulo State, Brazil. Some difficulties had to be overcome regarding adequate data processing to permit the comparison to be made. Moreover, it was necessary to deal with non-updated data. The main conclusion is that although some countries such as France and England traditionally have more resources and experience available than Brazil, they have not been able to solve pollution problems in a much more efficient way.

KEYWORDS

Water quality data; monitoring network; river pollution survey; river quality reports; water quality variables; water quality inventory.

INTRODUCTION

This paper compares the quality of inland waters in São Paulo State (Brazil) with those of France and England and Wales. This was done so as to determine the development of water pollution control and the results obtained, bearing in mind that since the 1960s water pollution control has received special attention from both the regional and national governments in Brazil.

The State of São Paulo began to control water pollution in 1968 after the formation of CETESB as a technological centre concerned with environmental protection, which was based on the State Plan for Water Pollution Control issued in 1969. The first corrective actions focused on the sugar cane industries, followed by other types of industry. The preventive actions were implemented in 1976 with the permit system for new potential sources of pollution. The results may be considered as very good in terms of industrial pollution reduction. Unfortunately, almost nothing has been achieved regarding the implementation of sewage treatment in urban areas because of the lack of resources and political support from the municipalities, which are responsible for the sewage collection and water supply services in most cities. Another problem was that PLANASA (the National Sanitation Plan of the National Housing Bank) had difficulty in achieving the centralization of the water industry in statewide companies; the mayors refused to let go of their political power

over this type of service. Thus, no financial resources have been available to industries and municipalities with the exception of statewide water companies.

In France, the water law of 16 December 1964, which rearranged and completed a great number of laws, modified the legal, administrative and economic approach with the establishment of the basin organizations. This policy is based on the participation and co-ordination of representatives of the users and of the various elected bodies.

In addition, effluent charges have been implemented as a method of creating a fund for investment in waterworks and treatment. The basin organizations are composed of Basin Committees and Basin Agencies as basically executive financial entities. After some discussion, six basin organizations were created and these have been operating since 1968.

The use of effluent charges was facilitated due to the fact that there was very little effluent treatment being undertaken in 1968. The pollution load was reduced by only 15%, with about 1,500 treatment plants. The number of treatment plants had increased to 8,000 nine years later. Since 1975, the pollution discharged into the rivers has stopped increasing, and 30% of the resources used for treatment works come from the Basin Agencies. Unlike in São Paulo, the increase in the number of sewage treatment plants in France was almost the same as that of industrial wastewater treatment plants, i.e., an increase of two to three times from 1970 to 1975.

In England and Wales, attention has been given to the treatment of sewage for a long time. Probably because of this, water supply and sewage collection (often undertaken by private entities) have survived on their own resources, practically without government grants. Despite this, the modern approach has also been implemented in this country, with the formation of 29 basin authorities in 1964, starting the nationalization of the water services. A further law in 1973 reduced this to 10 Basin Authorities and created the National Water Council. Thus, the British trend is to strengthen the structure of the Basin Authorities, which are involved in the planning, construction and operation of waterworks, with preference being given to the joint treatment of industrial and urban wastewater.

INVENTORY OF INLAND WATER QUALITY

The quality of the surface fresh waters must be monitored so as to evaluate trends and the results of the water pollution control activities. Two main aspects should be observed in designing the water quality sampling network throughout a basin, state, or nation: timing and spacial significance. The sampling frequency of CETESB's monitoring network is once a month, and 34 water quality variables are measured in the field or in laboratories. CETESB has published the results in a water quality bulletin every year since 1978.

In France, a national inventory of the quality of inland waters was undertaken for the first time in 1971, and repeated in 1976. The most recent inventory took place in 1984, however, the report was not available during the preparation of this paper, which is based on the 1976 data.

The French inventory has about 1,500 sampling points which are subjected to a series of standardized physical and chemical analyses. Analyses of hydrobiology, bacterial contamination or radioactivity may also be undertaken. There are also some 200 permanent sampling points which are monitored every month. It takes one year to complete the 5-yearly inventory, and 4 samples are collected to show seasonal variations at each sampling point.

The English methodology for surveying river quality is quite different. The 'River Pollution Survey of England and Wales, updated 1975', published by the Department of the Environment and the Welsh Office, presents the results in terms of length of rivers and canals allocated to four classes, from class 1 (unpolluted) to class 4 (grossly polluted). In addition, the report presents the situation regarding discharges into rivers and canals as satisfactory or unsatisfactory in number and in wastewater volume.

COMPARING THE DATA FOR SÃO PAULO AND FRANCE

To compare the data of São Paulo with that of France, the water quality data from São Paulo State's rivers surveyed in 1978 have been processed in the same way as France's water quality inventory report for 1976. Although it was possible to obtain data for 1976 for São Paulo State's water quality, the data for 1978 were more easily available since they were the first to be published (CETESB, 1978). Another important reason for choosing the 1978 data was that rainfalls for São Paulo in 1978 and France in 1976 were similar. Tables 1 to 9 present data from France and São Paulo for some water quality variables including chloride, BOD_5, COD, phosphorus, Kjeldahl nitrogen, faecal coliforms, phenols, and some heavy metals. The number of sampling points (and the percentages) falling into certain ranges makes some comparison possible. However, it is clear that with different sampling criteria and sets of points such a comparison is rather subjective, and thus it is not possible to draw precise conclusions.

Table 1 Number of Sampling Points Falling Within Various Ranges of Average Chloride Concentrations

Country or State	Chlorides, mg/l			Total number of sampling points (%)
	< 20	20 to 50	> 50	
France (1976)	582 (46)*	441 (35)	232 (19)	1255 (100)
São Paulo (1978)	59 (80)	12 (16)	3 (4)	74 (100)

*No. of sampling points falling within chloride range, percentage in brackets

Table 2 Number of Sampling Points Falling Within Various Ranges of Average BOD_5 Concentrations

Country or State	BOD_5, mg/l				Total number of sampling points (%)
	< 5	5 to 10	10 to 25	> 25	
France (1976)	781 (62)*	325 (26)	107 (8)	42 (4)	1255 (100)
São Paulo (1978)	51 (68)	9 (12)	7 (10)	7 (10)	74 (100)

*No. of sampling points falling within BOD_5 range, percentage in brackets

Table 3 Number of Sampling Points Falling Within Various Ranges of Average COD Concentrations

Country or State	COD, mg/l				Total number of sampling points (%)
	< 25	25 to 40	40 to 80	> 80	
France (1976)	895 (72)*	200 (16)	90 (8)	58 (4)	1243 (100)
São Paulo (1978)	50 (68)	11 (15)	7 (9)	6 (8)	74 (100)

*No. of sampling points falling within COD range, percentage in brackets

Table 4 Number of Sampling Points Falling Within Various Ranges of Average Total Phosphorus Concentrations

Country or State	Total phosphorus, mg P/l				Total number of sampling points
	< 0.065	0.065-0.326	0.326-1.630	> 1.630	
France (1976)	335 (27)*	603 (49)	256 (21)	46 (3)	1240 (100)
São Paulo (1978)	31 (42)	30 (40)	8 (11)	5 (7)	74 (100)

*No. of sampling points falling within total P range, percentage in brackets

Table 5 Number of Sampling Points Falling Within Various Ranges of Average Kjeldahl Nitrogen Concentrations

Country or State	Kjeldahl nitrogen, mg N/l				Total number of sampling points
	< 1.00	1.00-3.00	3.00-5.00	> 5.00	
France (1976)	332 (27)*	536 (44)	189 (15)	176 (14)	1233 (100)
São Paulo (1978)	42 (57)	14 (19)	6 (8)	12 (16)	74 (100)

*No. of sampling points falling within KN range, percentage in brackets

Table 6 Number of Sampling Points Falling Within Various Ranges of Average Faecal Coliform Concentrations

Country or State	Faecal coliforms (MPN/100 ml)*					Total number of sampling points (%)
	< 20	20 to 2000	2000 to 20000	20000 to 200000	> 200000	
France (1976)	7 (1)**	88 (16)	203 (36)	189 (34)	77 (13)	564 (100)
São Paulo (1978)	3 (4)	24 (32)	19 (26)	11 (15)	17 (23)	74 (100)

*MPN = most probable number
**No. of sampling points falling within faecal coliform range, % in brackets

Table 7 Number of Sampling Points at which Two or More of the Phenol Measurements were > 0.1 mg/l, > 0.001 mg/l, and the Remaining Points (<0.001 mg/l)

Country or State	Phenols, mg/l			Total number of sampling points (%)
	< 0.001	0.001-0.1	> 0.1	
France (1976)	242 (60)*	144 (36)	14 (4)	400 (100)
São Paulo (1978)	27 (47)	24 (41)	7 (12)	58 (100)

*No. of sampling points falling within phenol range, percentage in brackets

Table 8 Number of Sampling Points at which Two or More of the Heavy Metal Measurements were Greater than the CEE Standards

Country or State	Cr, 0.05 mg/l	Pb, 0.05 mg/l	Cu, 0.05 mg/l	Zn, 3 mg/l	Cd, 0.005 mg/l	Hg, 0.001 mg/l	Total no. of sampling points (%)
France (1976)	45 (11)*	29 (7)	37 (9)	5 (1)	73 (18)	25 (6)	399 (100)
São Paulo (1978)	12 (20)	22 (38)	10 (17)	1 (2)	0 (0)	2 (3)	58 (100)

*No. of sampling points falling within heavy metal range, % in brackets

Table 9 Number of Sampling Points Falling Within Various Ranges of Water Quality Indexes

Country or State	Biotic Index (Biological Quality, Scale 0 to 10)					Total No. of sampling points
	> 8 Biological quality normal	8 to 6 Biological quality sub-normal	6 to 4 Noticeable pollution	4 to 2 Bad pollution	< 2 Very bad pollution	
France (1976)	171 (34)*	167 (33)	131 (26)	32 (6)	8 (1)	509 (100)

Country or State	WQI Average Based on 9 Water Variables (Scale 0-100)					Total Number of sampling points
	100 to 80 Excellent	80 to 52 Good	52 to 37 Acceptable	37 to 20 Bad	20 to 0 Very Bad	
São Paulo (1978)	12 (16)	41 (55)	10 (14)	6 (8)	5 (7)	74 (100)

*No. of sampling points falling within index range, percentage in brackets

The following comments may be made on the figures presented in the tables above as regards the water quality variables.

Chloride

Water in São Paulo contains less chloride than water in France. In São Paulo, the water is only affected by chloride in sewage, whereas in France there are also other sources of this pollutant.

Organic Matter

The organic matter present in the water is measured by the biochemical oxygen demand (BOD_5) and chemical oxygen demand (COD), and the figures for these variables are shown in Tables 2 and 3. It can be seen that the situations in São Paulo and France are not very different, since the percentages of sampling points with good quality of water are similar (68% and 62% respectively with BOD_5 < 5 mg/l and 68% and 72% respectively with COD < 25 mg/l. São Paulo has a greater percentage of sampling points which are grossly polluted (BOD_5 > 25 mg/l and COD > 80 mg/l).

Nutrients

The levels of the nutrients phosphorus and nitrogen appear to be lower in São Paulo compared to France.

Coliforms

Regarding the levels of faecal coliforms, it can be seen that France has fewer sampling points which are grossly contaminated, i.e., MPN/100 ml > 200,000 at 13% of sampling points in France compared to 23% in São Paulo. This reflects the better situation in France regarding sewage treatment.

Phenolic Compounds

The figures in Table 7 regarding phenols confirm the differences in sewage treatment between São Paulo and France.

Heavy Metals

Regarding heavy metals, the waters of São Paulo have greater concentrations of Cr, Pb and Cu than those of France. However, the opposite is the case with Cd and Hg, with France having the higher concentrations.

Water Quality Indexes

The comprehensive evaluations using water quality indexes (Table 9) show a greater percentage of samplings points with very bad water quality in São Paulo, compatible with the above statements.

COMPARING THE DATA FOR SÃO PAULO AND ENGLAND AND WALES

To make this comparison, it was necessary to use a rather subjective method, particularly when assigning stretches of rivers to each class as was done in São Paulo. Thus, the results for São Paulo are not so precise as for England and Wales. Indeed, the data for São Paulo represent only a part of the situation, whereas the data for England and Wales give the total length of rivers in each class, including the distribution by range of river flow.

England and Wales use a chemical classification, as given below:

Class 1: Unpolluted rivers and those reclaimed from pollution.

1. All lengths of rivers, whatever their composition, which are known to have received no significant pollution discharges.
2. All rivers which, though receiving some pollution, have a BOD less than 3 mg/l, are well oxygenated, are known to have received no significant discharges of toxic materials or of suspended matter which affects the condition of the river bed.
3. All rivers which are generally biologically indistinguishable from those in the area known to be quite unpolluted, even though the BOD may be somewhat greater than 3 mg/l.

Class 2: Rivers of doubtful quality and needing improvement.

1. Rivers not in Class 1 on BOD grounds and which have a substantially reduced oxygen content at normal dry summer flows or at any other regular times.
2. Rivers, irrespective of BOD, which are known to have received significant toxic discharges which cannot be proved either to affect fish or to have been removed by natural processes.
3. Rivers which have received turbid discharges which have had an appreciable effect on the composition of the water or character of the bed but have had no great effect on the biology of the water.
4. Rivers which have been the subject of complaints which are not regarded as frivolous but which have not been substantiated.

Class 3: Rivers of poor quality requiring improvement as a matter of some urgency.

1. Rivers not in Class 4 on BOD grounds but which have a dissolved oxygen saturation below 50% for considerable periods.
2. Rivers containing substances which are suspected of being actively toxic at times.
3. Rivers which have been changed in character by discharge of solids in suspension but which do not justify being placed in Class 4.

4. Rivers which have been the subject of serious complaint accepted as well-founded.

Class 4: Grossly polluted rivers.

1. All rivers having a BOD of 12 mg/l or more under average conditions.

2. All rivers known to be incapable of supporting fish life.

3. All rivers which are completely deoxygenated at any time, apart from times of exceptional drought.

4. All rivers which are the source of offensive smells.

5. All rivers which have an offensive appearance, neglecting for these purposes any rivers which would be included in this class solely because of the presence of detergent foam.

For the evaluation of the water quality of São Paulo, a water quality index was used, based on 9 parameters: temperature, pH, dissolved oxygen, BOD_5, faecal coliforms, total nitrogen, total phosphorus, total solids, and turbidity. This index was developed at Michigan University, USA, and it indicates water quality on a scale of 0 to 100. Table 10 shows the lengths of rivers in the various quality classes for England and Wales (using the UK classification) and São Paulo (using the Michigan University index).

Table 10 Lengths of Rivers in Various Quality Classes

	England and Wales Classification				
Country or State	Class 1 Unpolluted	Class 2 Doubtful	Class 3 Poor	Class 4 Grossly polluted	Total*
England and Wales (1975)	28037 (77.6)**	5458 (15.1)	1449 (4.0)	1178 (3.3)	36123 (100)

	University of Michigan Water Quality Index					
Country or State	100 to 80 Excellent	80 to 52 Good	52 to 37 Acceptable	37 to 20 Bad	20 to 0 Very bad	Total
São Paulo (1978)	1300 (15.2)	4800 (56.5)	1400 (16.5)	800 (9.4)	200 (2.4)	8500 (100)

*Due to rounding, totals may not exactly agree
**Length of rivers in class in km, percentage in brackets

The evaluation of the river lengths in São Paulo covers only a part of the water bodies and considered the range of flows greater than 3 to 4 m^3/s. Despite this, it is thought that these river lengths are representative of the overall situation. Table 11 shows the lengths of rivers in England and Wales in the various classes divided into flow categories.

Table 11 Lengths of Non-Tidal Rivers in the Various Quality Classes and Flow Categories in England and Wales for 1975

	Quality classes								Total*	
	1		2		3		4			
Flow category	km	(%)	km	(%)	km	(%)	km	(%)	km	(%)
I = 0 to < 0.62 m^3/s	16332	(45.2)	3311	(9.1)	860	(2.4)	543	(1.5)	21046	(58.2)
II = 0.62 to < 5.0 m^3/s	8034	(22.2)	1425	(3.9)	373	(1.0)	376	(1.0)	10208	(28.1)
III = 5.0 to < 20.0 m^3/s	2620	(7.2)	520	(1.4)	169	(0.5)	199	(0.6)	3508	(9.7)
IV = 20.0 to < 40.0 m^3/s	543	(1.5)	108	(0.3)	13	(**)	56	(0.2)	720	(2.0)
V = > 40.0 m^3/s	508	(1.4)	94	(0.3)	33	(0.1)	4	(**)	640	(1.8)
Total	28037	(77.6)	5458	(15.1)	1448	(4.0)	1181	(3.3)	36123	(100)

*Due to rounding, totals may not exactly agree; **less than 0.1

CONCLUSION

São Paulo and France have some similarity in terms of methodology of water quality monitoring. Both have a set of permanent sampling points being sampled once a month. Unlike São Paulo, however, the French national inventory of water quality is done every five years, surveying 1,500 sampling points. A higher percentage of polluted sampling points were seen in São Paulo compared to France.

The British methodology for evaluating water quality is quite different. This type of methodology is more subjective when assessing the quality of stretches of rivers. On the other hand, it is more precise when evaluating the length of rivers allocated in one of four classes. The percentage of polluted rivers was apparently the same in São Paulo and England and Wales ten years ago.

Finally, in conclusion it may be said that pollution is a challenge to be faced now and always.

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