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SUBMARINE OUTFALLS
A VIABLE ALTERNATIVE FOR SEWAGE DISCHARGE OF COASTAL CITIES IN LATIN AMERICA AND THE CARIBBEAN

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1. ABSTRACT

An overview of present sewage disposal practices in Latin America and the Caribbean is given. After reuse, the long submarine outfall alternative with pretreatment (milli-screens) or primary treatment is a more attractive disposal method relative to secondary treatment with near shore disposal in terms of reliability, efficiency, cost and low operational and maintenance requirements. However, sewage discharges near sensitive natural biological communities, such as coral reefs, should be avoided. Cost curves for submarine outfalls are presented. The availability of modern plastics and construction methods also make long submarine outfalls feasible for small communities and tourist centers.

Technical details of the present 104 outfalls in Latin America and the Caribbean are presented. Their distribution is as follows: Argentina (1), Bermuda (1), Brasil (12), Chile (18), Colombia (2), Costa Rica (1), Ecuador (1), Martinique (1), Mexico (9), Peru (2), Puerto Rico (15), Uruguay (1) and Venezuela (39). A brief performance summary of the submarine outfall at Ipanema servicing part of the city of Rio de Janeiro, Brazil is also presented.

2. INTRODUCTION

Since the dawn of man the oceans of the world, which cover 70% of the earth surface, have been utilized as a recipient for human wastes but nevertheless have, in general terms, changed very little as evidenced by the fact that the chemical composition of the sea has essentially remained the same for over a million years(1). Furthermore, when compared to the enormous quantities of organics and sediments carried to the oceans by rivers of the world, as a result of natural processes, man's contribution of wastes is comparatively small. An interesting observation concerning the general irrelevance of sewage organic material was made by Dr. John D. Isaacs who pointed out that the faecal discharge into Southern California coastal waters of the anchovy alone was equivalent in organic content (biochemical oxygen demand and suspended solids), to the sewage discharge of about 90 million persons and this is only one of hundreds of species of marine life(2). This would seem to refute a prominent point of view - advocated by some respected environmentalists and supported by certain policy decisions made in developed countries - that would eliminate all forms of ocean discharges.

Nevertheless, problems occur when man concentrates waste products in rather restricted areas instead of dispersing them over larger areas where natural purifying processes can better operate. A normal occurrence along sea coasts is the development of large population centers. In view of the vastness of oceans, it is only logical as well as economical, that the residual liquid wastes of coastal cities be discharged to adjacent ocean waters. A properly designed ocean outfall provides an efficient and secure mechanism for the elimination of these wastes. Initial immediate dilutions in the order of 100 to 1 can be consistently achieved during the first few minutes after discharge, thus reducing concentrations of organics and nutrients characteristic of domestic wastes, to levels which would have no adverse ecological effects in the open sea. Quite on the contrary, the introduction of such substances to a usually nutrient deficient ocean environment would probably be beneficial in many situations.

For pathogenic organisms, the orders-of-magnitude reductions required to meet established bathing beach criteria are achieved through physical dilution and mortality in the hostile ocean environment subsequent to discharge. As demonstrated by numerous investigators, properly designed ocean outfalls for the discharge of typical domestic wastes have not resulted in significantly adverse ecological impacts. For the discharge of toxic substances such as PCBs (polychlorinated biphenols), pesticides, mercury and others, a more in depth analysis is required with emphasis on source control.

Questions often arise concerning the most adequate final disposal: that is the use of conventional waste treatment versus ocean outfalls. Official policies often established for political instead of technical reasons in some developed countries that advocate secondary treatment should not be adopted by Latin America, a priori, unless there is a clear justification. Quite to the contrary, in an uncomplicated open-ocean situation, the approach of constructing ocean outfalls combined only with pretreatment for the removal of floatables and grease and oil or primary treatment offers many advantages over conventional solutions using secondary waste treatment with discharge closer to shore. For example, an initial dilution of 100 to 1 achieved by the application of ocean outfalls is far beyond the capabilities of conventional secondary treatment as far as organic and nutrient removal are concerned. Also, subsequent bacterial mortality can further reduce pathogens to levels comparable to or better than those achieved by chlorination of secondary effluents. An additional point favoring outfalls is the fact that biological treatment processes are often subject to upsets that could result in the direct on-shore or near-shore discharge of raw wastes. Discounting structural outfall failure, which is rarely encountered in modern designs, such discharges could not occur with the use of off-shore ocean outfalls. Also, ocean outfall systems can be designed to adequately handle large seasonal variations in sewage flow, due to typical transitory populations in tourist areas. Such flexibility would not be so feasible with biological secondary treatment systems.

Conventional secondary treatment also separates the effluent at great expense into two waste streams, treated effluent which is often chlorinated, and sludge - both of which usually find their way into the ocean environment via separate outfalls and, as such, may be considered as a superfluous accomplishment. Finally, in conventional plants, most toxic substances end up essentially untouched in the effluent streams.

Ludwig(3) conducted economic analyses which demonstrate that for typical urban waste flows, the life time cost differential between conventional secondary treatment on the one hand and conventional primary treatment with long ocean outfalls on the other clearly favors the latter. This conclusion is based on the fact that properly designed long ocean outfalls (3 to 5 km) discharging into waters of depths greater than 20 meters will almost always meet both total and faecal coliform standards for bathing beaches. Limiting treatment to only the removal of floatables and grease and oil would make the comparison even more favorable for the ocean outfall alternative, although such discharges should be scrutinized for possible sediment buildup and subsequent onshore movement due to bottom currents. Also, the recent use of more economical plastics in the construction of outfalls further demonstrates the viability of this alternative for waste disposal especially for small to intermediate communities.

The ocean outfall alternative must also be evaluated in terms of local area needs. For example, in the arid coastal areas such as Peru, reuse of treated sewage can be a viable alternative. Finally, socioeconomic priorities may come more into play in some developing countries where the allocation of scarce resources must be made in the face of shortages in hospitals, schools, safe water supplies or even the food necessary for survival.

The discharge location of outfalls near environmentally sensitive areas such as coral reefs, shelling fishing beds, etc. must be avoided.

3. METHODS OF WASTE DISPOSAL IN LATIN AMERICA AND THE CARIBBEAN

The demographic explosion occuring in Latin America and the Caribbean is being primarily absorbed by the larger cities with urbanization proceeding at an average annual rate in excess of 3.8% while the total population (441 million in 1990) is growing at only 1.7%(4). Presently (reference year 1995) there are 433 cities in the Region having more than 100,000 inhabitants, distributed statistically as shown in Table 1 and geographically as depicted in Figure 1, in which 45% of the Region's population lives(4). Of these cities, 103 (see Table 1) are located in coastal or estuarine areas with a total population of 70.4 million inhabitants in 1990. As such, more than one quarter of cities having more than 100,000 inhabitans and more than one third of the total urban population of this category of city can potentially be serviced by submarine outfall systems for the final disposal of sewage wastes. This number of cities increases four to five fold when urban centers of 20,000 to 100,000 are also considered. The total urban population in 1990 was 314 millions(4) or 71% of the total.

Common practice in the coastal cities is to discharge untreated wastewaters to the nearest or most convenient water body and usually minimal considerations are given to the ensuing environmental consequences primarily due to the lack of economic resources. Indeed, raw sewage discharges have often occured on or very near bathing beaches as happened in the case of the world famous Ipanema Beach of Rio de Janeiro and as currently happens at or near the beaches of most other coastal cities of the Region. Geometric average levels of total coliforms in excess of 100,000 MPN/100 ml have frequently been observed on public bathing beaches with individual measurements at times approaching levels of raw sewage. The problems associated with near shore discharge of untreated sewage are aesthetic, can cause potential health and ecologial hazards and often bring economic consequences due to curtailed tourism.

Figure 1
Latin American and Caribbean cities with population greater than 100,000 inhabitants

Table 1

Distribution of Urban Centers in Latin America and the Caribbean in 1990

	Regional Total		Coastal or Estuarine Areas	
Population Greater than	**Number**	**Total Population (millions)**	**Number**	**Total Population (millions)**
100,000	433	195'858,508	115	71'017,264
500,000	78	125'779,666	36	55'138,273
1'000,000	36	98'040,482	17	43'073,117
3'000,000	7	53'920,328	3	22'343,515

(Based on data from reference 5).

Based on a survey originally conducted by CEPIS in 1983 and updated, to the extent possible, the situation in the Region in 2000 with regard to submarine outfalls of lengths of 500 meters or greater is as follows:

- Constructed	99
- Design completed and construction planned*	05
Total	104

Some of the most pertinent details of these outfalls are presented in Table 2. It is noted that in order to meet commonly applied recreational beach coliform standards, modern design procedures require an appropriate combination of outfall length, discharge depth and ambient current structure. The minimum outfall length of 500 meters used as a criteria for Table 2 is simply applied here as reference point and outfalls longer than 500 meters would usually be required for major sewage discharges to comply with coliform standards.

Puerto Rico, with a total population of about 3,53 million inhabitants(4) in 1990, counts with fifteen constructed outfalls in 2000. In comparison to the rest of the Region, Puerto Rico has the highest per capita use of this means of final sewage disposal. The Puerto Rico Aqueduct and Sewer Authority is responsible for design and construction of outfall systems and, at least, primary treatment is utilized. Final discharge permits are granted by the Environmental Quality Board which conducts extensive

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* Since the list could not be totally updated, it is possible that these outfalls have already been constructed.

Table 2

Characteristics of outfalls of lengths of 500 meters or greater in Latin America and the Caribbean in 1983

No.	Location	Year Construc. Completed	Treatment Level	Pipe Size and Materials	Approx. Length (m)	Approx. Discharge Depth (m)	Diffusor Length (m)	No. of Ports	Diameter of Ports (cms)	Receiving Water	Ref.
1	Aguadilla, Puerto Rico	1983	Primary	48" (122 cm) Cast Ductile Iron	863[a]	15	46, ∅=30" 45, ∅=24" 25, ∅=18" (2 diffusors tapered)	10 6,6 7	10.1 11.4, 12.0 12.7	Open Coast Ocean	6
2	Arecibo, Puerto Rico	1983	Primary	36" (90 cm) Reinforced Concrete	1,000	26	250 (∅=750mm)	56	10.5	Open Coast Ocean	7
3	Barceloneta, Puerto Rico	1979	Secondary Industry	48" (122 cm) Prestressed Concrete	850	30	100 (2 diffusers, Y) (∅=36")	39/ diffuser	20 of 7.6 18 of 10.1 1 of 30.5	Open Coast Ocean	8
4	Camuy-Hatillo, Puerto Rico	1982	Secondary	24" (61 cm) Reinforced Concrete	600	15.5	69.7	20	10	Open Coast Ocean	9
5	Bayaman-Pto.Nuevo Puerto Rico	1982	Primary	120" (305 cm) Reinforced Concrete	2,561[a]	41	316 (2 diffusers, Y) (∅=84")	103/ diffuser	82 of 15 20 of 18 1 of 25	Open Coast Ocean	10
6	Mayaguez, Puerto Rico	1982	Primary	60" (152 cm)	1,816[a]	11	97 (2 diffusers, Y) (∅=36")	16/ diffuser	15 of 15 1 of 25	Open Coast Ocean	11
7	Ponce, Puerto Rico	1972	Primary	72" (183 cm) Reinforced Concrete	1,524	15	230	64	7.6	Ocean Embayment	10
8	Santa Isabel, Puerto Rico	1983	Secondary	20" (51 cm) Ductile Iron	1,993	9	6.1	3	2 of 10.2	Open Coast Ocean	12
9	Carolina, Puerto Rico	?	Primary	72" (183 cm) Reinforced concrete	1,972	27.44	203.16	34	20 of 19.1 13 of 22.2 1 of 38.1	Open Coast Ocean	13

a. Includes diffuser length.

No.	Location	Year Construc. Completed	Treatment Level	Pipe Size and Materials	Approx. Length (m)	Approx. Discharge Depth (m)	Diffuser Length (m)	No. of Ports	Diameter of Ports (cms)	Receiving Water	Ref.
10	Guayana, Puerto Rico	?	Primary	1.2m (3.9 ft) Reinforced Concrete	1,095[a]	12.14	245.0	100	8	Open Coast Ocean	14
11	Huamacao, Puerto Rico	?	Primary							Open Coast Ocean	10
12*	Guayanilla, Puerto Rico	?	Primary							Ocean Embayment	10
13*	Fajardo, Puerto Rico	?	Primary							Open Coast Ocean	10
14	Sun Oil Co., Yabucoa, Puerto Rico	?	Industry.	15" (38.1 cm) Coated Steel	816.6[a]	6.7	108.8	22	5.7	Embayment	15
15	Ipanema, Río de Janeiro, Brazil	1975	No treatment	2.4 (7.87 ft) Prestressed Concrete	4,325	27	450	180	17	Open Coast Ocean	16,17
16	Manaus, Amazonas, Brazil	1976[b]	No treatment	1.0m (3.28 ft) High Density Polyethilene	3,600[c]	58	(∅=800 mm)		10	River	18,17
17	Santos, Sao Paulo, Brazil	1978	Rota screens and chlorination	1.75[d] m (5.74 ft) Coated Steel	4,000	10	200	40	30	Santos Bay	16,20
18	Fortaleza, Ceará, Brazil	1975	No treatment	1.5 m (4.92 ft) Reinforced concrete, internal epoxy coat	3,205	12	600	120	11	Open Coast Ocean	16,20
19	Salvador Bahía, Brazil	1975	No treatment	1.75[d] m (5.74 ft)	2,350[a]	27	350	70	15	Open Coast Ocean	21,20

a. Includes diffuser length.
b. It is not in operation (1985).
c. Distance to the shore is 300 m.
d. ϕ internal
*. Never constructed. Substituted by regional systems.

No.	Location	Year Construc. Completed	Treatment Level	Pipe Size and Materials	Approx. Length (m)	Approx. Discharge Depth (m)	Diffuser Length (m)	No. of Ports	Diameter of Ports (cms)	Receiving Water	Ref.
20	Sao Sebastiao Sao Paulo Brazil	1982	No treatment	15 cm (5.9") Polyester / Fiber glass	1,000[a]	11	3.5	7	5	Open Coast	22
21	Boa Vista[e] Brazil	?	No treatment	35 cm (14") High Density Polyethilene	1,250					River	18, 17
22	Aracruz Celulose S.A., Aracruz, Espírito Santo, Brazil	1978	Industry	1.0 m (3.28 ft) Polypropylene	1,100[f] (2 out- falls)	17	284	70 (by outfall)	10	Open Coast Ocean	18, 24
23	Nitrofértil, Aracajú, Sergipe, Brazil	1982	Industry	8" (20.3 cm) Coated steel AP.I 5L, gr B	4,400	10	12	5	5.1	Open Coast Ocean	25
24	Salgema, Maceió, Alagoas, Brazil	1980	Industry	20" (50.8 cm) FRP (Plastic reinforced with fiber)	3,000	18	300	48	8	Open Coast Ocean	26
25	Titanio do Brazil TIBRAS Salvador, Brazil (2 outfalls)	1980 1980	Industry Industry	26 cm (10.2") High Density Polyethilene 40 cm (10.2") High Density Polyethilene	4,000 4,000	16 16		Open end Open end	26 40	Open Coast Ocean Open Coast	17
26	Dept. Nac. de Obras de Saneamento (DNOS) (1979) Manaus Ind. District Manaus, Brazil	1979	Industry	56 cm (22") High Polyethilene	3,600	5		Open end	56	River	17
27	Veracruz, Ver. México	1970	No treatment	94 cm (37") Steel	1,500	15				Open Coast Mexican Gulf	27, 28
28	Nuevo Vallarta, Nayarit, México	1976	Primary	(24") 61 cm Steel	2,600	15	70	15	10	Embayment Pacific Ocean	27, 30

a. Includes diffuser length

e. Broken, never functioned.

f. Total length 2,500 m, 1,100 m under water.

No.	Location	Year Construc. Completed	Treatment Level	Pipe Size and Materials	Approx. Length (m)	Approx. Discharge Depth (m)	Diffuser Length (m)	No. of Ports	Diameter of Ports (cms.)	Receiving Water	Ref.
29	Productos y pigmentos químicos de México (P.P.Q.), Altamira, Tamaulipas México	1978	No treatment Industry	38 cm (15") Steel	1,500	16				Open Coast Mexican Gulf	27, 28
30	Acapulco Guerrero, México	In project	Primary							Open Coast Pacific Ocean	27, 28
31	Lázaro Cárdenas Michoacán, México	In project	Primary							Open Coast Pacific Ocean	27, 28
32	FERTIMEX, Industrial Port of Lázaro Cárdenas Michoacán, Mexico	1985	Secondary Industry	36" (91.4 cm) Polypropilene (two lines)	1,250	26	3[g]	3 per line	35.6	Open Coast Pacific Ocean	28, 30, 31
33	Altamira Tamaulipas México	In project								Open Coast	27
34	Petróleos Mexi-canos (PEMEX) - Salina Cruz, Oaxaca, Mexico	1979	Secondary Industry	36" (91.4 cm) Protected steel	2,680	15	38.5	28	17.5	Open Coast Pacific Ocean	29
35	Mazatlán, Sinaloa, México	1985	Primary	36" (91.4 cm) Coated Steel	715[a]	18-22.5	80 con ∅ 91.4 cm 40 con ∅ 76.2 cm 60 con ∅ 61.0 cm	20 10 15	10	Open Coast Pacific Ocean	27, 32
36	Nueva Buenos Aires Barcelona Edo. Anzoátegui Venezuela	1983 Project Phase		168 cm (66.1") Concrete	4,373	13.13	7.0	4	45	Open Coast Caribbean Sea	33
37	Zona Intercomunal Barcelona, Edo. Anzoátegui, Venezuela	1982		90 cm (35.4") Steel	4,063	11	6.60	4	30	Open Coast Caribbean Sea	34, 33
38	Higuerote, Estado Miranda Venezuela	1977		60 cm (24") Protected steel	4,100	11	56	12	20	Open Coast Ocean	34, 33

a. Includes diffuser length.

g. Diffuser has three tubes of ∅ 24" with a reduction to 14" at the end. The number given is the distance between the two extreme diffusers.

No.	Location	Year Construc. Completed	Treatment Level	Pipe Size and Materials	Approx. Length (m)	Approx. Discharge Depth (m)	Diffuser Length (m)	No. of Ports	Diameter of Ports (cms.)	Receiving Water	Ref.
39	Carúpano Edo. Sucre,Venezuela	?		70 cm (27.6") Steel	1,400					Open Coast Ocean	33, 36
40	Buen Maestro, Zulia, Venezuela	1949		107 cm (42") Concrete	1,850	9				Maracaibo Lake	34, 33
41	Güira Edo. Sucre Venezuela	1977		40 cm (15.9") Steel	1,653	3.5	9.0	4	10	Open Coast Caribbean Sea	34
42	Puerto Perico Cumaná, Edo. Sucre, Venezuela	1982 Project phase		75 cm (22.5") Concrete	1,600	18.00	9.0	8	15	Open Coast Caribbean Sea	33
43	Carúpano Edo. Sucre Venezuela	1980 Project phase		50 cm (19.7") Steel	1,387	10.00	21.00	8	15	Open Coast Caribbean Sea	33
44	La Rosa, Zulia, Venezuela	1970		107 cm (42") Cast Iron	1,340	4				Maracaibo Lake	34, 33
45	La Silva, Zulia, Venezuela	1971		108 cm (42") Steel	1,220	6.5				Maracaibo Lake	34, 33
46	Plaza Rodo Zulia, Venezuela	1949		137 cm (54") Concrete	1,210					Maracaibo Lake	33
47	San Luis Camaná, Edo. Sucre, Venezuela	Project phase		90 cm (35.7") Concrete	1,100	39.4				Open Coast Caribbean Sea	33
48	Punta de Piedras Isla de Margarita Edo. Nva. Esparta, Venezuela	1979		30 cm (11.8") Steel	1,076	8	3.00	2	15	Open Coast Caribbean Sea	33
49	Altagracia, Zulia, Venezuela	1968		30 cm (12") Reinforced Concrete	1,020	4.2					34, 33
50	Punta Santa Zulia Venezuela	1969		91 cm (36") Cast Iron	1,010					Maracaibo Lake	33

No.	Location	Year Construc. Completed	Treatment Level	Pipe Size and Materials	Approx. Length (m)	Approx. Dischage Depth (m)	Diffuser Length (m)	No. of Ports	Diameter of Ports (cms.)	Receiving Water	Ref.
51	El Tirano, Isla de Margarita Edo. Nva. Esparta, Venezuela	1978 Project phase		40 cm (15.7") Steel	1,000	9.30		4	20	Open Coast Caribbean Sea	33
52	Juan Griego Isla de Margarita Edo. Nva. Esparta Ven.	1979		40 cm (15.7") Steel	1,000	6.9	8.00	2	20	Open Coast Caribbean Sea	33
53	Puerto Píritu Edo. Anzoátegui Venezuela	1980 Project phase		40 cm (15.7") Steel	962.52	9.58	8.00	5	10	Open Coast Caribbean Sea	33
54	Porlamar[*] Isla de Margarita	1980		45 cm (17.7") Cast iron	920	4.5		4	20	Open Coast Caribbean Sea	33 35
55	Los Cocos Pto. La Cruz Edo. Anzoátegui Venezuela	1956		90 cm (35.4") Cast iron	720	7.0	6.40	6	45	Open Coast Caribbean Sea	33
56	Cumaná II Edo. Sucre Venezuela	?		60 cm (23.6") Steel	720					Open Coast Caribbean Sea	33
57	Pampatar, Isla de [*] Margarita, Edo. Nueva Esparta, Ven.	1973		40 cm (15.7") PVC	718	13		1	15	Open Coast Caribbean Sea	33, 34 35
58	El Guapo Camaná Edo. Sucre, Ven.	1973 Project phase		50 cm (19.7")	700	23		8	25	Open Coast Caribbean Sea	33
59	Marïitar Edo. Sucre Venezuela	1977		25 cm (9.8") Steel	690	50.00	6.00	3	15	Open Coast Caribbean Sea	33
60	Papelón, Pto. La Cruz Edo. Anzoátegui, Venezuela	1968		30 cm (11.8 [*]) Cast iron	600	9.0	5.95	4	20	Open Coast Caribbean Sea	33

[*] According memorandum PWR/VEN/0682/91, submarine outfalls No. 55 and 58 were cancelled and have been replaced by Treatment Plant "Los Cerritos" recently constructed, see reference 35

No.	Location	Yeat Construc. Completed	Treatment Level	Pipe Size and Materials	Approx. Length (m)	Approx. Discharge Depth (m)	Diffuser Length (m)	No. of Ports	Diameter of Ports (cms.)	Receiving Water	Ref.
61	Lavela de Coro Edo. Falcón Venezuela	1961		10" (25.4 cm) Cast iron	544		0.8 - 4			Open Coast Caribbean Sea	33
62	Irapa Edo. Sucre, Ven.	1976		25 cm (9.8") Steel	510	3.0		1	15	Open Coast Caribbean Sea	33
63	Los Angeles, D.F., Venezuela	?	No treatment	38 cm (15")	996					Open Coast Ocean	33, 37
64	Tanaguarena D.F., Venezuela	1977		20" (50 cm)	900	24.9				Open Coast	33
65	Higuerote, D.F., Venezuela	?			800					Open Coast Ocean	33
66	Macuto, D.F., Venezuela	1963	No treatment	61 cm (24") Steel	800	60				Open Coast Ocean	33, 37
67	Naiguatá, D.F., Venezuela	1983	No treatment	76 cm (30")	700	38	40	9	35.5	Open Coast Ocean	33, 37
68	Tacagua, D.F., Venezuela	1972	No treatment	76 cm (30") Steel	700	35				Open Coast Ocean	33, 37
69	La Zorra, D.F., Venezuela	1970	No treatment	35 cm (14") Steel	635	15.6				Open Coast Ocean	35, 37
70	Escuela Naval (Mamo) D.F., Venezuela	1976	No treatment	30 cm (12")	600	26				Open Coast Ocean	33, 37
71	Carabelleda, D.F., Venezuela	?	No treatment	15 cm (6")	550					Open Coast Ocean	33, 37
72	Carmen Uria D.F., Venezuela	1975		8" (20 cm) Steel	500	15				Open Coast Ocean	33
73	Cerro Grande (Uria) D.F., Venezuela	?	No treatment	20 cm (8")	500					Open Coast Ocean	33, 37

No.	Location	Year Construc. Completed	Treatment Level	Pipe Size and Materials	Approx. Length (m)	Approx. Discharge Depth (m)	Diffuser Length (m)	No. of Ports	Diameter of Ports (cms.)	Receiving Water	Ref.
74	Las Caracas, D.F., Venezuela	1977	No treatment	25 cm (10")	500	10.5				Open Coast Ocean	33, 37
75	Cartagena, Chile	?	No treatment	50 cm (20") Steel	500	14				Open Coast Ocean	38
76	Arica, Chile	1987	Primary Screens and tritulators	831 mm (32.7") Polyethilene Flow=950 l/s	2,214	18	100 (Y)	24 + 24	7.5	Open Coast Ocean	39, 40
77	Serena, Chile	1988	Primary Screens and tritulators grid chamber clorifier	900 mm (35.4") High Density Polyethilene Flow=713 l/s	1,750	18	40 (Y)	20 + 20	14.0	Open Coast Ocean	39, 40
78	Coronel, Chile	1990	Primary	517 mm (20.3") High Density Polyethilene Flow=296 l/s	600	12	26 (Y)	1 + 1	25.0	Open Coast Ocean	39, 40
79	Playa Brava Iquique, Chile	In construction	Primary	831 mm (32.7") Polyethilene	1,500	50	48 (Y)	5 + 5	13.0	Open Coast Ocean	40
80	Playa Negra Iquique, Chile	In construction	Primary	738 mm (29.1") Polyethilene	1,340	30	42 (Y)	4 + 4	13.0	Open Coast Ocean	40
81	Tomé, Chile	In construction	Primary	525 mm (20.7") High Density Polyethilene	1,200	19	25	4	20.0	Open Coast Ocean	40
82	Penco-Lirquen, Chile	In construction	Primary	591 mm (23.3") High Density Polyethilene	1,300	15	25	4	20.0	Open Coast Ocean	40
83	Montevideo Uruguay	1990	No treatment		2,250					Estuary	41
84	Fort-de-France Martinica		No treatment	60.9 cm (24") Reinforced polyester with fiberglass	1,000					Open Coast Ocean	42

detailed reviews of final designs applying procedures, models and criteria of the U.S. Environmental Protection Agency. Thus, the most modern criteria are generally applied and postoperative water quality studies are carried out to ascertain performance and compliance. In 1998, the Ponce's project of the new outfall was able to obtain an exemption for primary treatment instead of secondary treatment.

Three of the five most populated coastal cities of Brazil (Rio de Janeiro, Salvador and Fortaleza) are, at least, partially served by a major outfall structure. Generally, no waste treatment is applied. Following the example of Ipanema Outfall, the most modern criteria have usually been applied in diffuser design to assure maximum dilution. Brazil counts with twelve constructed outfalls (five for industrial discharges). It is noted that the plastic Boa Vista outfall failed after its construction and was never put into operation.

Mexico has nine constructed outfalls (two for industrial discharges). Modern design criteria generally have been applied in their design. Primary waste treatment is usually applied.

Of the 104 outfalls presented in Table 2, 39 or more than a third, belong to Venezuela and two of them were constructed in 1949, being the oldest in the Region. Only 17 of these 39 outfalls of Venezuela have lengths of 1000 m or greater. Twelve outfalls of less than 1000 m long service small towns and recreational facilities in the Federal District. The public beaches in this District can be frequented by as many as two million persons during national holiday weekends. Based on bacteriological surveys conducted in 1971, 75% of these public beaches were found to have acceptable coliform levels(44). Poor water quality conditions were usually limited to the vicinity of raw discharges on or near shore and of tributary discharges heavily contaminated by animal wastes. Beaches in areas serviced by outfalls were generally classified as acceptable. Therefore, in spite of their relatively short lengths (less then 1,000 m), those outfalls apparently performed well during the studies, as a result of favorable east-west currents and stratified environmental conditions. However, structural deterioration has been reported in recent years with leaks throughout the lengths of some of these outfalls and water quality has probably been degraded.

Chile counts with 18 operating outfalls using modern plastics in 17 of these. There are numerous other outfalls of lesser length but are generally mere extensions of the sewer systems. Primary treatment is applied to waste waters.

After many years of technical discussion, the outfall in Montevideo, Uruguay was constructed in 1990.

Fort-de-France, Martinique and Bermuda in the Caribbean Sea, each one of them, count with one outfall built.

The outfalls from Cartagena, Colombia; Panama, Panama; Costa Rica; and two in Lima, Peru, are designed and financed for their construction.

In addition to estuarine and coastal areas, outfalls may also be used for the discharge of sewage into large fresh water lakes or rivers. Such is the case in Manaus, Brazil (see Table 2, outfall 16) where sewage is discharged into the Black River, a tributary of the Amazon River, through a one meter diameter outfall of 3600 m in length. Since most of the outfall is constructed parallel to the coast line, actual discharge occurs only 300 meters from shore. This additional potential inland use of subaquatic outfalls, increases the potential population that could be served by this mechanism of wastewater disposal above the 70 million cited in Table 1 and thus further emphasizes the importance of this technology.

Although there are a total of 104 existing and planned outfalls in the Region, the present population served or to be served is comparatively small. Only 22 (including Manaus) of these outfalls, service cities of populations greater than 100,000 and in most cases these cities are only partially serviced. Therefore, the greater part of the wastes generated by the estuarine and coastal population continues to be discharged on or near shore without treatment of any kind, often resulting in the aesthetic, public health, ecological and economic problems previosly mentioned.

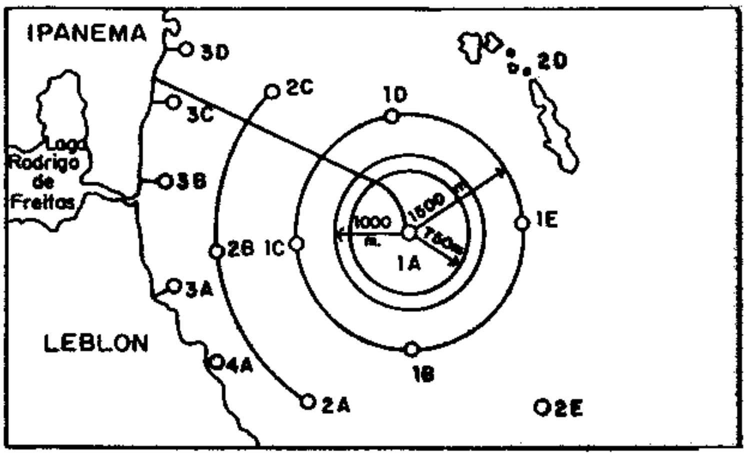
The potential improvements in water quality that can be achieved through the use of properly designed submarine outfalls may be best exemplified by the water quality conditions attained on the beaches of Ipanema and Leblon in Rio de Janeiro. The Ipanema Outfall was inaugurated in September of 1975 and services the southern zone of Rio de Janeiro with a design flow of 12 m^3/s. Its physical characteristics are presented in Table 2 (outfall No. 15). Continuous water quality monitoring conducted by the local water and sewage authority, "Companhia Estadual de Aguas e Esgotos" demonstrates significantly improved conditions as can be seen in Figure 2(45). Furthermore, except for course screening to protect pumps, no other waste water treatment or chlorination is practiced for the Ipanema Outfall effluent. Nevertheless, due to its construction on piles, an unusual practice for submarine outfalls, a segment near shore collapsed in 1990, but has subsequently been repaired.

4. SUBMARINE OUTFALL COSTS

Figure 3 shows the cost of submarine outfalls in situ developed by Wallis(46) and updated by Ludwig(3) and the author. This figure also includes costs developed by Reiff(47) of small diameter submarine outfalls of high density polyethylene applicable to small communities. Unfortunately, the final costs for most of the outfalls in Table 2 were not available and therefore are not reflected in Figure 3.

5. CONCLUSIONS

In summary, submarine outfalls provide an efficient, secure and relatively economic technology forthe final disposal of liquid wastes which, when properly designed, can achieve water quality objectives and minimize adverse environmental/ecological and public health impacts. If the present urban growth rate of 3.8% continues, the coastal and estuarine population potentially serviced by submarine outfall will increase from 71 million to almost 124 million by the year 2010 with a consequent waste water flow of about 210m^3/s (5,646 cfs). The proper disposal of these wastes is critical to future development and environmental well-being of the Region.



LOCATION OF SAMPLING STATIONS

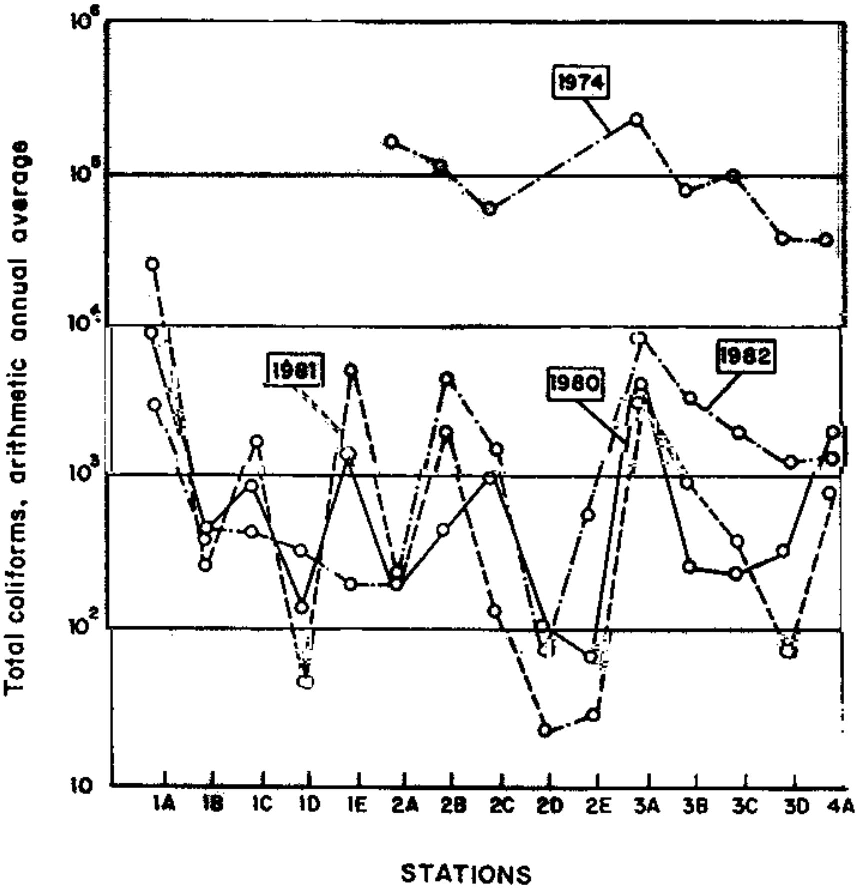


Figure 2
Total coliforms prior and after construction of the
Ipanema Submarine Outfall

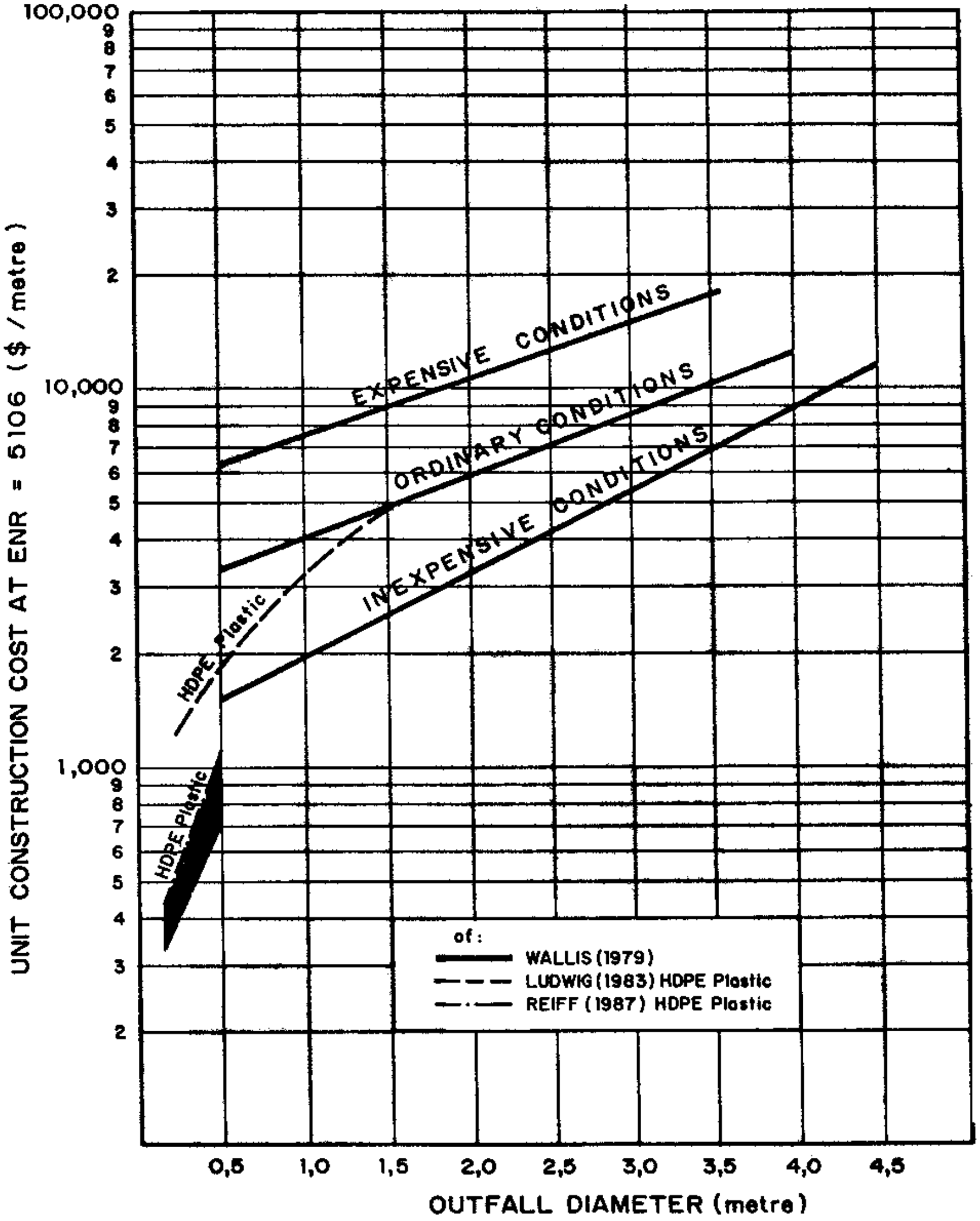


Figure 3
Submarine Outfall Cost

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