J. ENVIRONMENTAL SYSTEMS, Vol. 21(1) 85-99, 1991-92

GARBAGE PROBLEMS OF A WATER SETTLEMENT, KAMPONG AYER, BRUNEI DARUSSALAM*

K. C. GOH
Nanyang Technological University
Singapore

ABSTRACT

The concentration of population in the traditional water settlement of Kampong Ayer, Brunei Darussalam, brings about its own unique problem of waste and garbage production and disposal. The lack of waste disposal facilities has meant that all of the wastes are discharged into the surrounding waters of the Brunei River. This article examines the output of garbage by households based on a sample survey and the environmental implications for river water quality. Though the river quality has not deteriorated greatly over the years, action must be taken soon to dispose of the garbage of the whole settlement in a proper way.

Kampong Ayer with a population of 27,000 [1] is situated in the Brunei River of Brunei Darussalam (Figure 1) and is one of the largest water settlements in this part of the world. It was already a well-established, populous and vibrant entrepot [2] in the early 15th century. Its importance as a centre of government and economic activity continued up to the 17th century after which it saw a decline in importance. Today, Kampong Ayer occupies a significant place in Brunei only in so far as it reflects the traditional and cultural identity of the country. The central and dominant role it once played is no longer true today; it sits on the periphery of the fast developing Bandar Seri Begawan [2].

From purely fluvial considerations, Brunei River is unique in that though relatively short, the channel is very wide and is not commensurate with its mean discharge. Its wide channel which can accommodate a large number of wooden

*This study was made possible through a research grant provided by the Universiti Brunei Darussalam where the author was a staff member until December 1991, and the financial assistance given is gratefully acknowledged.

doi: 10.2190/KMHR-W9L7-PD7T-T1LX
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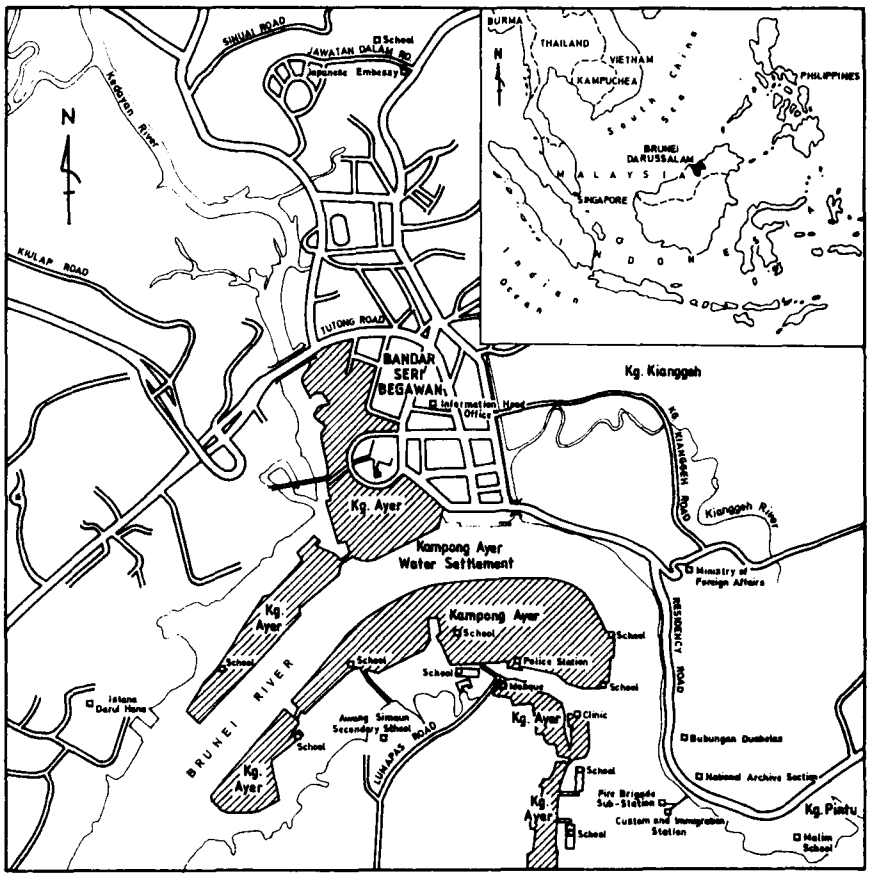

Figure 1. Location of Kampong Ayer water settlement, Brunei Darussalam.

houses, schools, mosques, clinics and police stations on stilts, attests to its out-of-place character, which was brought about more by past eustatic events of sea level rise rather than by the geomorphological processes of the river itself. Its uniqueness is further enhanced by the fact that it passes by the capital Bandar Seri Begawan which is located on one of its banks. The relatively low gradient of its long profile and the small size of its drainage basin account for the rather sluggish nature of its flow. This is further compounded by the strong tidal influence for most of its course.

One of the unavoidable and logical consequences associated with any concentration of population is the generation of wastes. Various kinds of wastes are generated and discharged by the Kampong Ayer settlement and the deleterious effects on the aquatic environment of Brunei River would seem to be unavoidable.

As a traditional and rather 'disorganized' settlement with an almost complete absence of waste disposal facilities of any kind, the problem of waste input into the river system has caused much concern to the authorities. Concern for human health in particular and the deterioration of the aquatic environment in general, has led the Ministry of Development to commission studies on waste disposal and the water quality of the Brunei River. Specifically, two studies conducted by private consulting firms on behalf of the government were Kampong Ayer Waste Management Study [3] and the Sungai Brunei Water Quality and Pollution Study [4]. Another smaller study on garbage output of Kampong Ayer was conducted by Muhammed (in Malay) [5] in fulfillment of an undergraduate degree requirement.

This present study seeks to complement previous investigations. Emphasis is placed on determining the amounts of garbage produced. However, the discharge of other kinds of wastes is not ignored and the environmental implications of such waste disposal as reflected in the water quality of the Brunei River are also examined.

METHOD

This survey contains three essential but interrelated elements. They are:

1. The weekly consumption pattern of households.
2. The weekly garbage production.
3. The present state of Brunei River water quality as a result of garbage and other waste disposals.

It is hypothesized here that the household consumption pattern is a good indicator of household garbage production and that the pattern of consumption is in some way related to household income. The water quality information provides an indication of the degree of pollution. However, it must be borne in mind that the pollution status is not wholly connected with Kampong Ayer *per se*; nor should it necessarily be a function of garbage disposal alone. The water quality in the river and the estuary is the result of the combined inputs of point and non-point sources which, among others, include the Pintu Malim Sewage Treatment Plant and five other smaller sewage works in the Brunei catchment, urban runoff from Bandar Seri Begawan and its fast developing surroundings and of course Kampong Ayer which can be regarded as a point pollution source.

Several techniques were employed in gathering the relevant data. For the first element of the study, a questionnaire survey was conducted and a total of 115 households were interviewed. Questions asked included household characteristics, income, and spending habits on items which have potential garbage and waste output. For the second aspect, a smaller sample of 50 households out of the original 115, were asked to cooperate in keeping the garbage produced during the day till the next morning so that weighing and analysis of its contents could be carried out. This was carried out daily for a period of one week. The one weekly

cycle was considered sufficient to indicate the average consumption pattern and garbage production of households. Plastic bags were supplied, marked with a label for each of the eight kinds of garbage produced, i.e., organic, paper, glass, plastics, rubber, metal and wood. Water quality data were obtained from the Sewage Work Unit of the Public Works Department which has been monitoring, on a routine basis, water quality at various points in the river. The relevant parameters are referred to and discussed below.

FINDINGS

The 115 households contain 232 families with a total population of 1267 people, giving an average family size of 5.46 and household size of 11.02. In general, 44.3 percent of households contain between five to nine members, 33 percent between ten to fourteen. There was one household with more than thirty members. The extended family tradition is generally kept with 62 percent of families living with one or more families under the same roof. The nuclear family household comprises 32 percent. Of these families, 30.3 percent or 384 are working adults; the majority (88.3%) works with the government. As far as income is concerned, only ninety-one respondents gave any useful and reasonably reliable information. The average household income per month for the ninety-one cases is relatively high in Southeast Asian terms with a value of B$2449.[1] About 65 percent of the households have combined incomes of between $1000-$3000 per month, 11 percent have incomes below $1000 while 12 percent above $4000.

All houses visited are provided with basic amenities such as water and electricity but not all enjoy the benefits of a telephone and garbage disposal system. 44 percent of the houses have telephones while 16.5 percent have some kinds of garbage disposal, particularly those close to land and some in the villages in which a pilot garbage collection system has already been introduced. One hundred percent of all human wastes and wastewater goes into the river direct.

The amount of wastewater produced was not gauged but is reflected in the way water is used daily within the household. Washing of clothes is done mainly by hand and 90 percent of households wash once or twice daily. Washing of dishes is generally done twice or three times daily. Personal bathing habits indicate that all have at least two to three showers per day. More than half (62%) have two showers daily. If the results of a study on domestic water consumption in Penang, Malaysia [6] are anything to go by, per capita per day consumption of water varies from 202 litres for village and low income households to 515 for high income urban households. In the Kampong Ayer Waste Water Management Study [3], selective surveys of the settlement yielded an average per capita water

[1] US$1.00 is approximately B$1.8.

consumption of 205 litres/day. However, for households with more than ten members, the average per capita consumption was 168 l/d while the corresponding figure for households with less than that number was 248 l/d. The average household consumption was about 2475 l/d with a range of 1480 to 4890 1/d. The figures for Kampong Ayer may appear to be underestimated when compared with the results of the study in Penang. Nevertheless, if this average figure is multiplied by the number of households for the whole of Kampong Air (about 3000), the total daily water consumption is 7,425,000 litres. Because of the uniqueness of Kampong Ayer, in that none of the water is lost through infiltration into the soil, almost 100 percent of this water used will find its way back into the Brunei River in various forms (toilet wastes and sullage).

There is a wide variation in total household monthly income ranging from $400 to $6600, and the average income, as mentioned above, is about $2500. The expenditure pattern of any household is not necessarily confined to items which are waste or garbage producing. Purchases of essential goods such as electrical appliances and furniture are made infrequently. Of more significance to this study is the expenditure pattern on items which directly or indirectly generate waste output. These items include foodstuffs, newspapers, detergents and soap powder.

It must be stressed that no matter how high the income, the capacity for food consumption has a lower and an upper limit per person or per household (of course the larger the household the greater will be the overall expenditure). This means that any attempt at seeking a statistical relationship between income and weekly household food consumption based on regression and correlation analyses is rather tenuous. Nevertheless, within a certain range of validity, some statistical analyses can still be carried out to show this relationship.

For the whole sample population, monthly food expenditure constitutes an average of 36 percent of monthly income. Unsurprisingly, the range is wide, from 12 percent to 100 percent. In fact there are a few cases where the monthly food and other household expenditure exceeds the household income. A regression analysis between monthly income and weekly expenditure on food does not reveal a clear relationship. Table 1 shows the pattern of food and other weekly household expenditure in Brunei dollars. As the price of rice is subsidized, the amount spent does not necessarily reflect the quantity consumed. As far as other foodstuffs are concerned, there is a much higher consumption of fish relative to meat. In a number of cases, households did not buy meat at all for the week of study.

Human body wastes discharged in the Brunei River are estimated in Table 2, which shows per capita sewage waste in terms of gram BOD_5/capita/day for some urban areas of South East Asia. Based on the assumption that the average total BOD_5 contribution comprises 35 gm/d from toilet wastes and 25 gm/d from sullage, for the Kampong Ayer population of 27,500 the total sewage pollutant load produced would be of the order of 1.65 tonnes BOD_5 per day [3].

Containers for canned and bottled food, drinks, and cooking oil, and plastic bags and wrappers, and any food leftovers are habitually thrown into the water.

Table 1. Types of Food Items Bought Per Week by Households

Items	Cost ($)B	Quantity
Rice	15.45	12.36 kg
Fish	57.82	10.40 kg
Vegetables	13.26	5.50 kg
Meat	18.58	1.60 kg
Fruits	12.05	3.56 kg
Canned food	5.48	5-7 cans
Canned/bottled drinks	14.32	12-24 cans/bottles
Cooking oil	6.13	3-5 bottles
Newspapers	5.17	
Soap/detergents	15.36	
Total	163.62	

Table 2. Waste Output in Gram BOD_5/Capita/Day for Some Selected Cities

Location	Waste Discharge gm BOD_5/capita/day
Butterworth, Malaysia (measured)	37
Seremban, Malaysia (design basis)	45-50
Kuala Lumpur, Malaysia, Wardieburn STW (measured)	45
Kuala Lumpur, Malaysia, Pantai STW (measured)	49
Kuala Lumpur, Malaysia (future planning)	55-60
Surabaya, Indonesia (design basis)	40

Average household spending on newspapers and magazines is low (some 3.2 percent of the weekly household expenditure). Expenditure on soap, soap powder, detergents and washing liquids accounts for some 9.4 percent of weekly household expenditure. The pollution imports of the use of these items was not investigated.

Garbage Components

Sorting and weighing of the garbage in plastic bags was carried out daily in 50 households for one week. Results are shown in Table 3. Total weekly garbage production per household averages 24.23 kg, of which 71.3 percent is organic

garbage. This figure is comparable to those found by Muhammad for Kampong Ayer and by Maniatis et al. [7] for Jakarta (see Figure 2).

A simple linear regression analysis between organic waste output and weekly expenditure shows some relationship with a coefficient $r = 0.546$ while weekly expenditure when regressed with total garbage output produces a value of $r = 0.625$. In the latter relationship, weekly expenditure as a variable accounts for

Table 3. Mean Garbage Production (by Components) Per Household Per Week

Types	Weight (%) (kg)
1. Organic	17.28 (71.3)
2. Cloth	2.80 (11.5)
3. Metal	0.46 (1.9)
4. Paper	0.69 (2.8)
5. Plastics	0.23 (1.0)
6. Wood	0.31 (1.3)
7. Rubber	0.59 (2.4)
8. Glass	1.87 (7.7)
Total	24.23 (100.0)

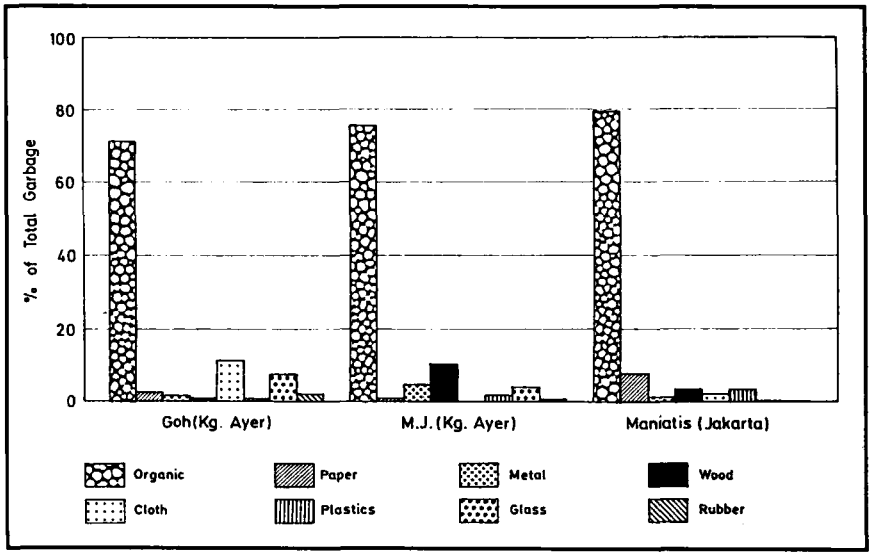

Figure 2. Garbage components as percentages of total weight.

some 39 percent of the variation in the total garbage values. However, organic garbage is not significantly related to expenditure on food.

Given the high rate of decomposition in the humid tropical climate of Brunei Darussalam, the organic wastes are quite easily broken down. The impact of non-biodegradable items such as glass, metals and plastics is more significant than the average quantities might suggest; for example, almost all glass is whole bottles tossed into the water. These results are reasonably consistent with [5], which found garbage production per household per week (40 households) to average 26.197 kg, with organic garbage contributing 19.812 kg per household. It should be borne in mind that in a study of this nature, care must be taken in choosing a representative week so that it does not coincide with a festive season such as the Ramadan or with the periods just prior to sending relatives off on the Haj pilgrimage (or after they have just returned from such a trip). Additionally, while housewives were very willing to cooperate in throwing the different types of rubbish in the several plastic bags provided, the habit of throwing items straight into the river below dies hard; this could result in some under-estimation of the results. To some extent, this problem was encountered in this study. Assuming that Kampong Ayer has a total of 3000 houses, the total yearly garbage production would be 3.77 million kg using the present figures (compared to 4.09 million kg using the results in [5]).

Different types of garbage produce different kinds of effects on the Kampong Ayer environment and the Brunei River. The biodegradable varieties tend to decompose easily and revert to food for aquatic life of different types. It is well known that the Brunei River is not a dead river and fish and prawns and other life-forms abound although the species may be limited. The more obvious and visible forms of garbage are the non-biodegradable items which can be further subdivided into the floatables and non-floatables. Floatables include plastic bags and bottles, paper and cardboard boxes, styrofoam (usually used in the packaging of electronic goods) and the occasional corked glass bottles. Wood and planks also result from house repairs and boat construction. This debris moves with the tides, helped by waves formed by fast boats and water taxis. Significant movement occurs during spring tides and rather insignificant movement during neap tides. Judging from Currie [8], effluent discharged from Bandar Seri Begawan takes two to three days to be flushed from the estuary. However, the nature of the Brunei River channels and the flow limitations imposed by the dense stilts of houses impede such movement and trap significant amounts of floatable garbage in certain areas. Accumulation of garbage in rather stagnant water under homes in some villages is especially thick and unsightly. So are the large volumes of garbage stranded on the convex banks of the river at certain localities. Plastics are frequently seen caught in branches of the swamp vegetation during high tides but suspended as 'buntings' during low tides.

The volume of non-floatable garbage which sinks to the river bed is difficult to ascertain. Like sediments after heavy rainfall, it will sink to the river bed and, in

time, help reduce the channel depth. In the Bandar Seri Begawan side of the Brunei River, especially in the market and sundry shop localities, large accumulations of garbage of all sorts are common and they have to be frequently cleared.

Perception of Garbage Problem

Garbage is a common feature of the environment of Kampong Ayer. The villagers interviewed recognized this fact as having been the case ever since they could remember. There is a sense of resignation in the opinion expressed by the respondents that very little can be done to change the situation apart from a concerted government effort at providing a proper waste disposal system for the entire water settlement. Some attempts have been made by the villagers themselves in an effort to clear the rubbish, particularly that trapped underneath their houses, but this is always a very short term measure. Efforts are also made by those whose houses are close to the banks and where rubbish could be deposited on land and burnt. In villages situated within the channel proper, such attempts are of little consequence. A pilot study of centralized garbage collection is being tested in a few villages, the exercise has yet to be implemented on an operational basis for the entire community.

While waste and garbage problems are recognized by the respondents as needing attention, an open-ended question soliciting responses regarding the most pressing problems faced by them did not necessarily indicate that garbage problems top the list. Out of the seventy-five respondents who provided one or more answers, issues related to garbage and the environment such as an unsightly scene, smell, vermin and health hazards account for only 33 percent of the total responses (Table 4). Only 23 percent mentioned garbage specifically. Car parking is seen as an important problem in 27.7 percent of the responses (the lack of space by the bank of the Brunei River greatly restricts parking). Overcrowding and fire

Table 4. Perception of Problems

Types	Frequency (%)
Car parking	63 (27.7)
Telephone	4 (1.8)
Garbage and waste disposal	52 (22.9)
Transportation in times of emergency	12 (5.3)
Smell	7 (3.1)
Overcrowding	35 (15.4)
Fire hazard	20 (8.8)
Drowning	18 (7.9)
Health Hazard (vermin, poor environment, etc.)	16 (7.0)

hazards also are cited; major fires have razed substantial numbers of dwellings and caused many injuries.

ENVIRONMENTAL QUALITY

The quality of the environment in Kampong Ayer generally and of the Brunei River in particular is the product of many factors. Brunei River receives organic and non-organic inputs of sediments from Bandar Seri Begawan and the surrounding areas, urban runoff, effluents from sewage works, and wastes from Kampong Ayer. Water quality depends on the assimilative abilities of the aquatic ecosystem and the efficiency of mixing in the water body.

The possible deterioration of water quality of Brunei River due to garbage and other waste disposal has been recognized as having potential adverse effects on aquatic life and human health. As Kampong Ayer is part of the capital city, the beauty of the urban environment is an important priority in urban landscape management. It was due to this concern that a study of the water quality of the Brunei River was carried out in 1987 [4]. The data were derived from samples taken and analyzed over a period of a few months in 1984, which provide baseline water quality data against which to gauge subsequent changes. Routine monitoring of water quality at designated points has since been undertaken by the Public Works Department; this data is assessed here.

Samples have been taken at sixteen points along the river (Figure 3). *In situ* parameters measured included depth, temperature, conductivity, oxidation-reduction potential, dissolved oxygen and secchi-disc depth. Laboratory analyses of parameters included ammoniacal, nitrite, nitrate and organic nitrogen, total phosphorus, chlorophyll "a", suspended solids and bacteriological analysis (total plate count, total coliform and *Escherichia coli*).

It was found that the estuary appeared to be almost fully mixed vertically in terms of salinity and temperature. Salinity stratification occurred over the top 2 to 5 m, particularly at the upstream sampling points. For the whole length of the stream under study, the mean salinity gradient was of 0.24 percent; the gradient steepens on the flooding tide and flattens on the ebbing tide. Acidity is slightly higher in the upper end of the estuary due to extra anoxic runoff from mangrove areas in the upper part of the catchment and along the Kedayan River. The mean pH value in these localities was 6.9 while at the lower reaches the value was higher 7.5.

Of direct relevance to organic inputs into the Brunei River are the dissolved oxygen results. The mean longitudinal profile of DO showed a mean gradient of 2.4 percent saturation per km length with mean upstream level being 49 percent and the downstream mean level of 84 percent. There was a dip in the percent saturation in the vicinity of the confluences of the Kedayan River and Kianggeh River and Kampong Ayer, a significant cause of high organic pollution loading entering the Brunei River at this point. Effluents from Pintu Malim Sewage

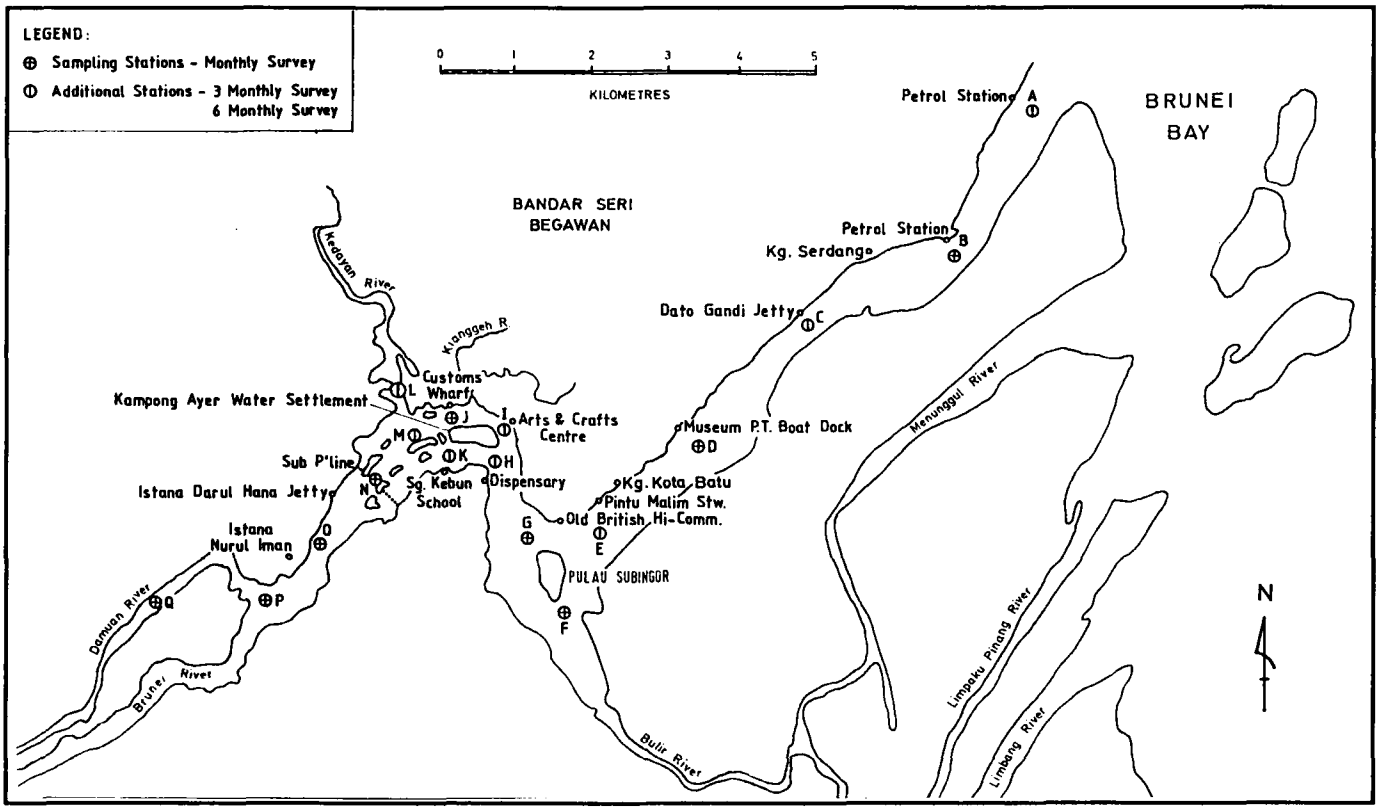

Figure 3. Brunei River pollution monitoring stations.

Treatment Works did not have such an effect. Vertical profiles showed DO to be relatively constant with depth. Secchi disc depths of 1.0 to 1.2 m were generally recorded at the downstream locations whilst depths of 0.5 to 1.5 m were recorded in the central section of the estuary. The inflow of water from Kedayan and Kianggeh Rivers with high turbidities and sediment loads accounted for this. Ammoniacal nitrogen, organic nitrogen, nitrite and nitrate, and phosphorus levels were very low. Suspended solids were high, as expected, bearing in mind the background turbidity and sediment load. Bacteriological water quality analysis showed that the average levels were higher than international bathing water quality standards. Heavy metals and synthetic detergent levels in the waters were low and in most cases non-detectable.

It was concluded that in spite of the continued discharge of wastes into the Brunei River estuary, there has been no drastic deleterious effects on the aquatic environment. The marine biological surveys, however, showed a reduction in diversity and an increase of biomass of some animals at specific locations (Pintu Malim STW, Kampong Ayer). The fish and prawn population has not declined over the years; in fact, fish had become a more commercially important component catch in the estuary. In short, in spite of the garbage and other waste discharges, the Brunei River and its estuary has been able to maintain its environmental quality.

Selected water quality parameters of Brunei River for 1989 and 1984 are shown in Table 5.

Mean salinity values were slightly lower in 1989 than in 1984. Dissolved oxygen values changed little with lower values at points M and N, locations in the vicinity of Kampong Ayer. The lower values suggest a higher oxygen demand from bacteria breaking down organic wastes. However, pH values seem to be slightly lower at all locations. Of greater significance from the health standpoint is the *E. coli* counts, which no doubt reflect the presence of feacal bacteria. Near Kampong Ayer the values were high in both 1984 and 1989. Whether this will pose health problems from fish and prawn caught in the area and eaten by the residents is not known. Certainly the amount of *E. coli* is well above World Health Organization swimming water limits. In Kampong Ayer children frequently swim in the water. However, no studies have been made to determine whether swimming in such contaminated water has led to high incidences of skin or other diseases. The problem of organic pollution, surprisingly, has not brought about a drastic decline in the water quality. One reason for this relatively healthy state of the Brunei River is the relative efficiency of mixing of the water due to the interactions of runoff, tides, currents and the churning effects of water by the water taxis and other boats. However, the curtailment of disposal of wastes into the river by providing the residents alternative disposal systems would ensure a definite improvement in the water quality.

As far as heavy metals are concerned, a comparison of 1984 and 1990 data (for stations D and P) indicates that there has been a slight increase in the values of

Table 5. Water Quality of Brunei River in 1984 and in 1989 for Selected Parameters

1984	Salinity	DO	pH	Org-N	NO2	S.S.	*E. coli*	
A	24.1	82	7.5	0.10	36.6	53	300	
D	22.7	73	7.3	0.03	59.0	78	800	
G	21.3	68	7.2	0.06	61.4	93	1200	
J	20.2	62	7.0	0.04	74.2	67	800	
M	20.5	61	7.1	0.09	80.9	86	1200	
N	20.7	58	7.0	0.08	82.0	58	1800	
P	20.6	49	6.9	0.07	85.0	77	700	
1989							H[a]	L[b]
A	20.7	81	7.2	—	—	—	—	—
D	19.4	70	6.7	0.15	44.6	138	1.08k	10k
G	18.7	67	6.5	0.14	54.3	130	5.38k	1.20
J	17.3	64	6.4	0.12	50.4	138	1k	2.25
M	18.1	57	6.6	—	—	—	—	—
N	16.8	62	6.4	0.12	62.5	128	0.0	1.62
P	15.8	55	6.3	0.13	64.8	132	0.08k	3.75

[a]H = high tide
[b]L = low tide

Copper, Manganese, Zinc and particularly Lead (Table 6). Nevertheless these values are still low. The river water is not used for drinking or animal husbandry.

Bandar Seri Begawan and the Brunei River catchment are fortunate in that factories which produce heavy metal discharges are almost absent. Nevertheless, in Kampong Ayer, a few household factories that work with paints and welding materials may be sources of lead and zinc. Regulation of such activities may be necessary.

CONCLUSION

The broad channel of the Brunei River has seen human occupation over a long timespan, accompanied by the discharge of wastes. Yet despite the length of occupation and the amounts of waste discharged, the Brunei River has been able to maintain itself in a relatively healthy state. Its ability to maintain itself in such a state perhaps attests to the resilience and the dynamic nature of the river ecosystem. However, this is no reason for complacency. Waste discharges from the Kampong Ayer settlement must be disposed of through proper sewage and

Table 6. Heavy Metals Content of Brunei River, 1984 and 1989 (ppm)

Heavy Metals (1984 survey)				
Stations	Copper	Lead	Manganese	Zinc
A	0.002	0.008	0.005	0.007
D	0.002	0.010	LT 0.002	0.008
M	0.002	LT 0.001	LT 0.002	0.008
P	0.002	LT 0.001	LT 0.002	0.004
10th September 1990 (Low Tide)				
B	0.086	0.0246	0.106	0.048
D	0.084	0.255	0.104	0.048
G	0.094	0.249	0.122	0.050
J	0.088	0.139	0.126	0.050
N	0.087	0.113	0.133	0.063
P	0.085	0.148	0.130	0.057
Q	0.088	0.093	0.134	0.062
18 September 1990 (High Tide)				
B	0.101	0.261	0.115	0.060
D	0.097	0.309	0.110	0.063
G	0.101	0.250	0.126	0.076
J	0.098	0.344	0.112	0.068
N	0.106	0.339	0.112	0.060
P	0.105	0.230	0.140	0.071
Q	0.098	0.372	0.159	0.077

garbage disposal systems. Initial steps have been taken by the government to identify design concepts and undertake pilot studies of waste disposal systems. Garbage disposal systems employing a central collection point should be implemented on a routine basis for the whole Kampong Ayer. At the same time, greater efforts should be made to encourage residents to be relocated on land, so reducing waste discharge into the river. Over and above these considerations, the management of Brunei River must be seen in the light of its total catchment. In the years to come, the Brunei River Catchment will be the most developed catchment in the state. The future direction and pace of development, in terms of population and urban growth, industrialization, infrastructural development and other land uses will inevitably have far reaching repercussions on the quality of the Brunei River.

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Direct reprint requests to:

Professor K. C. Goh
Division of Geography
Nanyang Technological University
NIE, 469 Bukit Timah Road
Singapore 1025