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OCEAN DISPOSAL AND LAND RECLAMATION PROBLEMS OF PENANG, MALAYSIA

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ABSTRACT

An account is given of the enviromental impact of solid wastes used for reclaiming land in coastal areas of Penang, and of the impact of a major sewage outfall on the Western Channel. Leaching of heavy metals was shown to be one of the main sources of contamination from solid wastes. Heavy metal accumulation by the Green-lipped mussel Perna viridis L. and juveniles of the Finfish, Liza subviridis L., used to monitor the effects of the Penang ocean outfall, indicated contamination by most metals in particular Pb and Zn.

The sewage outfall was also monitored for bacterial contamination and its role as a source of parasitic diseases evaluated. Recommendations for the treatment of both types of waste are discussed.

INTRODUCTION

In a rapidly growing community with increases in population density, the inevitable problem of household waste treatment occurs. Advanced countries have, to a certain degree, overcome the problems of handling and processing garbage. For example, there are large incineration plants which can lead ultimately to the generation of electricity, household winter heating systems and the supply of hot water at minimal cost to the community. Another approach is the use of composting plants such as that established in Heidelberg, West Germany. While the resulting compost is quite readily accepted by the farming community as an excellent organic fertiliser the problem of existent trace metals and unseparable glass fragments remains.

Until recently some countries have been employing garbage waste for land reclamation. It has, however, been found to be detrimental due to leaching of trace metals into the aquatic environment including underground drinking water. Nevertheless some developing countries are still employing this short-sighted method of disposal because of the initial economic gains. This seems to be the situation in Penang, where land reclamation in coastal areas is carried out haphazardously by dumping household garbage without the slightest consideration being given towards its environmental impact and public health.

Sewage treatment is quite a problem in most countries and at times fairly costly. The processing of such waste can be enhanced by the usage of chemicals to act as flocculents, [$FeCl_3$ $Fe_2(SO_4)_3$, $Al_2(SO_4)_3$, $Ca(OH_2)$], by mechanical processing leading to clarifiers etc., and by enhancing biological treatment. One such example of the last suited for the tropics is the oxygen ponding system. A present trend is to have fermenters for the processing of sewage sludge in order to obtain methane as a supplementary energy source.

The widespread practice of getting rid of household sewage to the sea assumes a tremendous self-purifying capacity of the oceans, with their reservoir of oxygen and powers of dilution. These assumptions show an unwillingness to consider the problems realistically. The belief that the sea can assimilate any amount of waste shows a total lack of understanding and callous insensitivity towards the marine ecosystem. Sewage outfall sites may not be "biological deserts" but the animal and plant communities near outfalls show obvious changes in structure, diversity, abundance, disease susceptibility and growth.[1]

The sea can degrade what is degradeable so long as its capacity is not overloaded. Even in a vast ocean, a continuous spot discharge may cause local overloading. A characteristic of sewage is that pollutants tend to be discharged in concentrated "slugs" since very little mixing occurs in a sewer[2]. Substances that cannot be degraded, a number of which occur even in domestic sewage, may persist, enter the food chain and reach man in a concentrated form.

Effluents discharged from submarine diffusers rise vertically towards the surface until their momentum and buoyancy forces are exhausted. Dilution is a mixing process requiring ambient energy generated through wind, wave, tidal and density forces which give rise to turbulence[3]. Even if these forces operate at the outfall and if they result in the calculated dilution, the concentrations achieved by dilution cannot be compared with the same concentrations obtained through treatment.

Proponents of ocean discharges fail to appreciate the value of the ocean as one of the most important food resources of mankind. Natural regulatory factors, beyond the influence of man, permanently act to preserve the biological balance of the marine environment. The intervention of man may modify this balance which is only resilient to a point. Those responsible for ocean outfalls are quick to point out that through dilution and natural purification processes the sea treats sewage and makes it virtually innocuous and thus, by implication, acceptable.

It is a myth that dilution means fewer pathogens or less toxic substances - they are simply dispersed over a larger area. In view of the abundance of filter feeding organisms in marine environments (e.g. up to 500 cockles per m^2[2])and their efficient pumping systems (an average mussel can pump 3 l h^{-1} and filter all particles down to 0.0008mm) it may not be very wise to rely on dilution. While there is as yet no clear cut association between bathing in polluted seawater and enteric disease, the consumption of shellfish from polluted waters has been known to cause typhoid fever and hepatitis. Even if entirely harmless and non-cumulative, some of these wastes can do considerable damage by tainting commercially valuable species. The human palate is extremely efficient in noting the presence, for example, of oil and oil products.

In developed countries sewage outfalls into the ocean are subterranean, with built-in multi-port diffusers at depths of ca. 20-25m and at a distance offshore ranging from 5-8km in turbulent oceanographic environments. Under these conditions it is anticipated that the depletion of oxygen and pollutants such as trace metals, nutrients (P&N) and PCBs will not have an impact on the marine ecosystem.

Penang, with a population of about half a million people, has the sewage from approximately 60% of the households removed by sewer. The majority of this sewage is discharged untreated into the Western Channel via an 0.8km long overhead ocean outfall with a final single-port diffuser at a depth of ca. 18m. The South and North Channels between mainland Malaysia and the island itself are flushed primarily by diurnal tidal currents and so turbulence is likely to be only moderate. Based on this assumption, detailed characterisation of the sewage was planned, including the daily input of trace metals, microbial flora and pathogenic parasites (Fig.1). The concentrations of trace metals were also investigated in two organisms living in the vicinity of the outfall - the green-lipped mussel, Perna viridis L. and the finfish, Liza subviridis L.

METHODS

HEAVY METAL ANALYSIS OF SEAWATER IN VICINITY OF WASTE DISPOSAL SITE

As the dumping of garbage in Penang is confined mostly to coastal areas, an evaluation of the leaching of heavy metals was carried out. At low tide, when current and wave action are at their lowest, water samples were obtained at the boundary between the garbage heap and the seawater. These samples were extracted using the APDC-MIBK extraction method and analysed for the following metals: Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb and Zn. The chelating reagent of PAPDC was a composite misture of 0.5% APDC (Fisher Scientific Reagent A-182), 0.5% DEDC (Fisher Scientific Reagent S-287), and 0.06% oxine (Baker Chemical Company Reagent 2198). Five grams each of APDC and DEDC were added to a 500ml volumetric flask and diluted to volume with deionised water. The solution was thoroughly mixed, and filtered to remove any undissolved portions of the salts. The filtrate was purified by three successive

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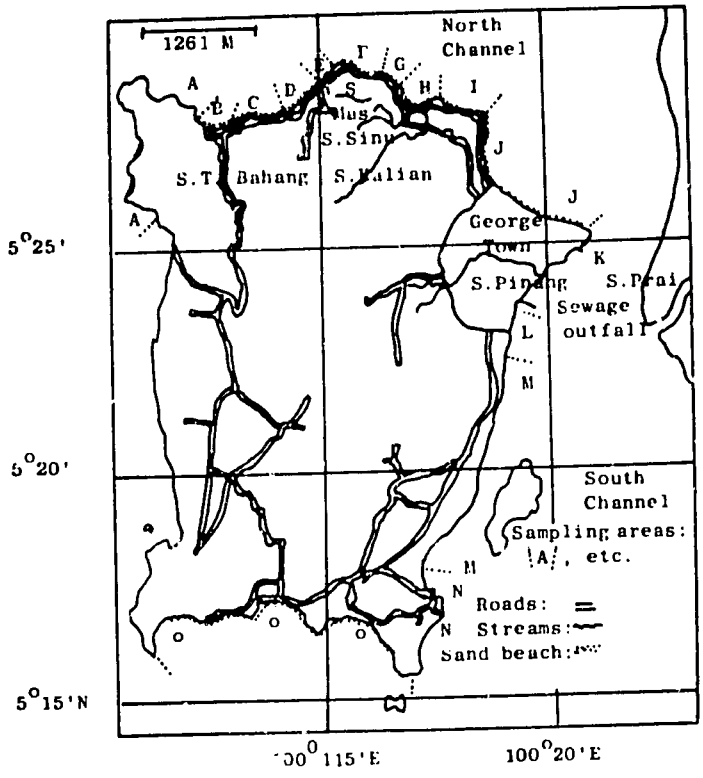

Fig.1. Penang Island, Malaysia, showing positions of the sampling areas.

extractions with 100ml portions of MIBK. Oxine (0.6g) was added to the purified dithiocarbamates and the final combination was diluted to 1000ml with deionised water. Addition of oxine was done after the purification of the APDC and DEDC because oxine is extremely soluble in the organic phase. Hence, a significant portion of the oxine would be lost from the aqueous phase if it were included in the purification steps.

For the extraction of trace metals 500ml of the sample water were placed in 1L separatory funnels. To each was added 25ml of the combined chelating reagent and the mixture was dispersed by vibration. The pH was then raised to 8.2 with ammonium hydroxide and a second 25ml portion of the chelating reagent was added, dispersed, and allowed to stand for five minutes. To each separating funnel was added 25ml of MIBK, followed by vigorous vibration for 30 seconds. The emulsions were allowed to stand for five minutes followed by a repeated vibration. After a ten minutes separation interval, the aqueous phase was drained into an acid-cleaned nalgene bottle. The organic layer was transferred to 5ml glass test-tubes and set aside for atomic absorption analyses.

The aqueous portions were returned to their respective separating funnels and a final 25ml portion of mixed chelating reagent was added, dispersed, and extracted with MIBK as described above. Immediately following completion of the second extraction, both sets of solvent extractants were analysed for the nine trace metals.

MICROBIOLOGICAL STUDIES

1. Bacteria

For the determination of sewage samples (100ml) were taken at the final discharge diffuser-port of the ocean outfall and at three different times of the day: morning, evening, night. For transport of the samples, Cary and Blair's medium for enteric bacteria was employed.

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Total counts of aerobic and spore-formers were made as follows: 1ml aliquots of serial 10-fold dilutions of the samples were inocculated into duplicate Petri dishes and mixed well with 15-20ml of melted Standard Plate Count (SPC) Agar maintained at 50°C. For the enumeration of spore-formers 1ml aliquots of serial 10-fold dilutions were boiled for 10 minutes to kill off vegetative cells as well as to heat shock the spores, prior to proceeding with the above procedure.

Determination of coliforms and E. coli was carried out by the dilution tube method, using three tubes of lauryl sulphate broth for each dilution[6]. Positive tubes were examined for the presence of E. coli by testing cultures for the viability to grow in brilliant green bile salt medium at 44°C and to produce indole in tryptone water medium[7].

2. Parasites

Since sewage harbours many parasitic organisms, endeavours were made to determine and identify levels of contamination. Samples were obtained at the final discharge point at different times and processed immediately on reaching the laboratory. The samples were vibrated initially to produce a homogenous suspension and centrifuged at 2000rpm for 5 minutes in 10ml aliquots. The pellet was resuspended in 1ml 0.95% saline solution and examined for eggs of helminths and protozoans as counts in 0.04ml under a clean side cover (22x22mm).

RESULTS AND DISCUSSION

LEACHING OF HEAVY METALS FROM SOLID WASTE DISPOSAL

The results obtained indicate that the concentrations of Cd, Co, Cu, Fe, Mn, Ni and Pb were relatively high as compared with those of seawater samples from other parts of the island (Table 1). This reflects that leaching of heavy metals was occurring from the heap to the marine ecosystem at fairly large amounts at a rapid pace. This could be enhanced with incubation time and during the season of heavy monsoons. Hence some immediate action is needed to save this environment, especially for the fishing industry and public health.

EFFECTS OF POLLUTION IN THE VICINITY OF THE PENANG SEWAGE OCEAN OUTFALL

Investigations[5] on 15 shore-types (Fig.1) at varying hinterland features (Table 2) have indicated that the zone immediately adjacent to the Penang sewage ocean outfall had the highest coliform and E. coli counts (Tables 3 and 4). The next highest areas were those immediately adjacent on either side of the above, indicating the influence of tidal currents.

CHARACTERISTICS OF SEWAGE FROM THE OCEAN OUTFALL

In order to understand the various pollutants discharged via the Penang sewage ocean outfall, some key features were investigated. A large quantity of sewage is discharged, with fairly high BOD and COD loads (Table 5). The inputs of nitrate, NH_3 and total - P are also fairly high.

MICROBIAL POLLUTION BY THE SEWAGE OCEAN OUTFALL

The present study included estimates of the total aerobic and spore-formers, coliforms and E. coli.(Table 6). The justification for measuring spore-formers counts is that a variety of aerobic mesophilic bacteria which are not usually regarded as pathogens (e.g. Streptococci, Proteus, Pseudomonads) may be capable of causing enteric disorders when present in large numbers in water or food. High counts off mesophilic bacteria indicate the likelihood of gross contamination. The enumeration of mesophilic aerobic spore formers is also useful in assessing the bacteriological quality of water in that it helps to predict the survival of such organisms over extended periods.

For the purpose of water analysis, coliforms include all aerobic and faculatively anaerobic, Gram-negative, non-spore-forming rods that ferment lactose and produce gas within 48h at 35°C. They include Salmonella, Shigella and Escherichia coli. The common soil bacterium Aerobacter is also a coliform, so all coliforms are not of faecal origin.

Table 1. Comparison of trace metals in seawater seep-leachate near the garbage dumping site as compared to levels in seawater at certain coastal areas of Penang analysed for 1981

STATION	Metal concentration (ug g^{-1})								
	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	Zn
Garbage seep-leachate	0.21	0.93	0.07	0.11	1.16	0.25	2.33	0.69	0.04
Telok Duyong	0.084	0.25	0.212	0.065	0.555	0.096	0.356	0.30	0.51
Telok Aling	0.084	0.25	0.141	0.098	0.333	0.096	0.356	0.30	0.026
Telok Bahang	0.056	0.25	0.141	0.065	0.444	0.064	0.472	0.30	0.026
Morning Glory	0.084	0.125	0.141	0.065	0.222	0.096	0.472	0.40	0.051
Lovers Isle	0.084	0.375	0.212	0.098	0.333	0.096	0.297	0.40	0.038
Batu Ferringhi	0.084	0.50	0.141	0.098	0.222	0.096	0.472	0.40	0.051
Telok Nangka	0.112	0.063	0.071	0.065	0.444	0.096	0.415	0.50	0.102
Telok Tikus	0.084	0.125	0.141	0.065	0.444	0.096	0.297	0.30	0.077
Fort Cornwallis	0.056	0.125	0.141	0.13	0.333	0.064	0.472	0.50	0.051
Old Pier	0.084	0.188	0.212	0.098	0.222	0.096	0.297	0.30	0.061
Sungai Nibong	0.112	0.313	0.141	0.065	0.333	0.096	0.356	0.50	0.077
Permatang Damar Laut	0.084	0.25	0.141	0.098	0.222	0.096	0.296	0.30	0.051
Batu Maung	0.056	0.125	0.282	0.13	0.333	0.096	0.356	0.30	0.051
Telok Kumbar	0.084	0.125	0.141	0.13	0.444	0.096	0.178	0.40	0.051
Telok Asam	0.084	0.375	0.141	0.098	0.111	0.064	0.356	0.50	0.026
Pulau Betong	0.084	0.125	0.141	0.098	0.111	0.096	0.356	0.30	0.038

Table 2. Description of the sampling areas as designated in Fig.1.

Area	Type of shore	Description of hinterland	Number of locations sampled
A	Sandy bays with rocky headlands	Coconut palms and natural forest.	20
B	Sand/mud bay	Coconut palms and natural forest at western end; busy trawler harbour at centre; urban area of Telok Bahang at centre and east. River Telok Bahang is polluted with household wastes.	6
C	Sandy bays with rocky headlands	Coconut palms and natural grassland with a few houses at western end; hillside with natural vegetation and a few houses at centre and east.	13
D	Sand beach	Hillside with natural vegetation and a few houses at western end, beach-side hotels and low density housing at centre and east.	10
E	Sand beach	Beach side hotels. Low density housing inland. River Mas is polluted with partially treated sewage.	7
F	Sandy bays with rocky headlands	Hillside with natural vegetation and a few houses.	9
G	Sandy bays with rocky headlands	Hillside with natural vegetation and a few houses.	7
H	Sand/mud	Urban area with waterfront restaurants; fishing harbour at western end; streams are polluted with household wastes.	5
I	Sandy bays with rocky headlands	Low to medium density urban.	3
J	Mud/sand/rocks	Medium and high density urban area of Georgetown; many polluted drains.	17
K	Mud	Very high density urban, industrial and harbour area of Georgetown. River Penang is grossly polluted and untreated sewage is also discharged into sea in this area.	3
L	Sand	Medium density urban with fishing villages	2
M	Mud	Medium and low density urban interspersed with grassland and coconut plantations.	3
N	Mud/sand	Medium to low density urban; includes Batu Maung trawler harbour.	2
O	Sandy bays with rocky headlands	Low density urban; fishing villages	5

Table 3. Pollutant levels of coliform bacterial counts in coastal waters of Penang Island, malaysia (From areas A to O).

Area*	Sampling Period+	Total no. of samples	Number of samples containing $\log_{10}$ concentrations of coliform bacteria per 100 ml with index number as follows: 1	1	2	3	4	5	6	7	Log mean coliform concentration /100 ml
A	ii	39	10	17	7	1	0	0	0	0	31
B	i	6	0	0	6	0	0	0	0	0	1350
	ii	10	0	0	3	5	2	0	0	0	
C	i	3	0	2	0	1	0	0	0	0	493
	ii	30	0	7	12	10	0	1	0	0	
D	i	3	0	0	2	0	1	0	0	0	921
	ii	19	0	2	7	8	2	0	0	0	
E	i	4	0	0	0	2	1	1	0	0	3936
	ii	13	0	0	2	9	1	1	0	0	
F	i	2	0	0	0	2	0	0	0	0	632
	ii	18	0	2	12	2	2	0	0	0	
G	i	2	0	1	1	0	0	0	0	0	574
	ii	21	0	2	10	9	0	0	0	0	
H	i	1	0	0	0	0	1	0	0	0	29020
	ii	8	0	0	0	3	2	3	0	0	
I	i	1	0	0	1	0	0	0	0	0	3634
	ii	6	0	0	0	4	2	0	0	0	
J	i	7	0	0	0	0	4	2	1	0	62130
	ii	40	0	0	0	8	14	11	6	1	
K	i	2	0	0	0	0	0	0	2	0	712000
	ii	6	0	0	0	0	1	3	1	1	
L	i	2	0	0	0	1	1	0	0	0	159600
	ii	5	0	0	0	0	0	3	1	1	
M	i	5	0	0	0	2	2	1	0	0	20450
	ii	2	0	0	0	0	2	0	0	0	
N	i	4	0	0	0	1	3	0	0	0	9539
	ii	8	0	0	1	3	4	0	0	0	
O	i	8	0	0	1	4	2	1	0	0	2956
	ii	12	0	0	5	4	3	0	0	0	
All		283	10	33	70	79	50	27	11	3	

* See Table 1 Fig. 1 for descriptions and locations of sampling areas.

\+ Period i. from 9 April, 1975 to 26 June, 1975
Period ii. from 27 October, 1975 to 8 November, 1975.

Table 4. Pollutant levels of Escherichia coli bacterial counts in coastal waters of Penang Island, Malaysia

Area*	Sampling Period+	Total No. of samples	Number of samples containing $\log_{10}$ concentrations of *E. coli* bacteria per 100 ml with index numbers as follows: <1	1	2	3	4	5	6	Log mean *E. coli* bacteria per 100 ml
A	ii	36	28	8	0	0	0	0	0	<7++
B	i	3	0	0	3	0	0	0	0	758
	ii	10	0	0	6	4	0	0	0	
C	i	3	2	1	0	0	0	0	0	72
	ii	26	3	13	8	2	0	0	0	
D	i	3	0	2	0	0	1	0	0	130
	ii	18	2	6	8	2	0	0	0	
E	i	4	0	1	2	0	1	0	0	721
	ii	13	0	3	4	4	1	1	0	
F	i	2	0	0	0	2	0	0	0	155
	ii	16	0	10	5	1	0	0	0	
G	i	3	0	3	0	0	0	0	0	165
	ii	18	0	7	7	4	0	0	0	
H	i	2	0	0	1	1	0	0	0	7920
	ii	8	0	0	1	2	4	1	0	
I	i	1	0	0	1	0	0	0	0	1995
	ii	5	0	0	1	3	1	0	0	
J	i	7	0	0	1	2	2	2	0	21200
	ii	37	0	0	4	10	10	8	5	
K	i	2	0	0	0	0	0	2	0	234700
	ii	6	0	0	0	1	1	3	1	
L	i	2	0	0	1	0	1	0	0	41560
	ii	5	0	0	0	1	4	0	0	
M	i	5	0	0	0	4	1	0	0	12330
	ii	2	0	0	0	0	2	0	0	
N	i	2	0	0	0	1	1	0	0	2251
	ii	7	0	0	4	2	1	0	0	
O	i	8	0	1	4	1	1	1	0	991
	ii	11	0	1	8	2	0	0	0	
All		265	35	56	69	49	32	18	6	

* See Table 1 and Fig. 1 for descriptions and locations of sampling areas.

\+ Period i. from 9th April, 1975 to 26 June, 1975
Period ii. from 27th October, 1975 to 8th November 1975

+Includes 17 samples with less than 4/100 ml.

+

Table 5. Some basic characteristics of the Penang sewage ocean outfall.

Parameters	
Moisture	99.95%
Org. Matter	0.04%
In. Org. Matter	0.01%
pH	7.05
Daily Total Discharge	16.75×10^6 gal.
Daily BOD Load	6.3×10^9 ppm
Daily COD Load	1.1×10^{12} ppm
Nitrate	12.39 ppm
NH_3	8.01 ppm
Total - P	2.32 ppm

Table 6. Levels of microbial flora in the Penang sewage ocean outfall.

Microbial Type	Count/100 ml
Coliform	4.9×10^7
E. coli	1.6×10^7
Total aerobic count	1.3×10^8
Total spore formers	2.3×10^3

The idea of evaluating Escherichia coli as a faecal indicator of waters is that it is a prominent member of the microbial community in the human intestine; large numbers are found in human faeces. For this reason, the detection of E. coli in natural waters is used as an indication of faecal contamination. This does not confirm the presence of pathogenic micro-organisms but suggests the possibility of their presence.

Table 6 shows the results of the above investigations. It is noticeable that the coliform and E. coli counts (average of three sampling times) were 4.9×10^7 and 1.6×10^7/100ml, respectively. Owens [5] reported a count of 7.1×10^5 coliforms and 2.3×10^5 coli/100ml at some distance from the outfall. Taking into account the dilution factors involved, our results compare well with those obtained by Owens[5] and also with Jenkins[8].

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It is relevant to state here the standards used in the USA with respect to microbial contamination. The coliform density permitted is dependent on the purpose for which the water is to be used, and the population density it serves. The permissible coliform count/100ml for drinking water being 1, recreational water 1000, water used for shellfishing 70 and levels in oysters for raw consumption <230/100g. The US Public Health Service Standards prohibits shellfish collection in areas where coliforms exceed 23,000/100ml, because shellfish provide a reservoir for infective hepatitis. Nevertheless, removal of shellfish is approved on a restricted basis if it can be demonstrated that the high count is not of faecal origin e.g. from agricultural wastes. Hence, determination of contamination with human faeces is of prime importance in shellfish beds. Our data and those of Owens[5] justify the prohibition of shellfish farming or fishing in the vicinity of the sewage ocean outfall.

In the Western Channel of Penang, not far from the sewage ocean outfall, a number of grouper (Ephinephelus salmoides) aquaculture farms do exist and there are already indications of the prevalence of "red boil disease"[9] due to faecal microbial contamination.

POLLUTION BY PARASITIC ORGANISMS IN THE SEWAGE OCEAN OUTFALL

All samples examined carried Ascaris lumbricoides, Trichurus trichura and hookworm eggs (Table 7). One of the samples also carried Toxocara eggs.

Table 7. The various prevalent parasites and intensity of eggs in sewage from the Penang ocean outfall

Specimen	Volume examine	Ascaris lumbricoides (eggs/250ml)	Trichurus trichura (eggs/250ml)	Hookworms (eggs/250ml)	Toxocora canis (eggs/250ml)
1	250	3125	625	125	150
2	250	2750	250	175	nil
3	250	1250	50	25	nil

Parasitic infections due to Ascaris lumbricoides, Trichurus trichura, hookworm and others are very common among the rural population in Malaysia[10,11,12]. The severity of the disease varies according to individuals, their genetic backgrounds, ethnicity and physiological conditions. Some infections like Trichurus and hookworm depend on the intensity of the infection, while for Ascaris even a single infection can be very dangerous. Toxocara, found in one of the examined samples is known to cause visceral larval migrans and is a clear indication of contamination via infected dog faeces. The foregoing indicates vividly that the sewage ocean outfall transports soil transmitted helminths and protozoa.

It is at present uncertain whether the eggs detected in a viable state at the final point of discharge of the sewage will survive marine conditions. A point in urgent need of further research.

HEAVY METAL POLLUTION NEAR THE SEWAGE OCEAN OUTFALL

A number of investigations on the levels of heavy metals in sewage ocean outfalls and their possible adverse effects on marine biota have appeared recently[13,14,15,16,17].

Table 8 demonstrates the daily input of the heavy metals: Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb and Zn, to the Western Channel. It is evident that the input of all these metals is very high. As the Western, North and South Channels are flushed only by diurnal currents then these metals are presumably being deposited in the sediments and so potentially assimilated within the marine food web. The gravity of this problem is verified by the facts obtained. These pollutants may be expected to have adverse effects on the juveniles of both shellfish and finfish and in the long-term the breeding grounds will be eliminated.

Table 8. Daily input of trace metals into the marine ecosystem by the Penang sewage ocean outfall.

Trace Metal	Kg/day
Cd	14.32
Co	3.15×10^2
Cr	2.01×10^2
Cu	3.44×10^2
Fe	3.41×10^4
Mn	7.45×10^2
Ni	6.01×10^2
Pb	1.29×10^4
Zn	2.46×10^3

To illustrate the impact of trace metal pollutants on biota in the vicinity of the outfall, concentrations in the green-lipped mussel Perna viridis and the finfish Liza subviridis were investigated and compared with samples of mussel from other areas and data for finfish reported by Lee and Low[18].

Table 9 shows the results for Perna viridis. All the metals are very high except for Cd and Zn. The magnitude in difference from the lowest to the highest values of the shellfish in other areas are as follows: Co, 1.4-2.4; Cr, 1.8-11.9; Cu, 12.38-12.38; Fe, 3.3-7.9; Ni, 2.9-8.1; Pb, 1.2-3.0. As mussels are sedentary and efficient filter feeders the results indicate that this area is extremely polluted and mussels should not be consumed.

Table 10 shows the concentrations of heavy metals in the juveniles of the finfish, Liza subviridis, caught near the ocean outfall as compared to other finfish reported by Lee and Low [18]. The levels are comparatively high as those detected for Perna viridis, i.e. Cu ranging between 14.89 - 1720 times for the lowest and highest values reported for other finfish by Lee and Low[18]; Fe, 67.34-1239.2; Pb, 27.04-1771.17; and Zn, 9.61-65.34. The values of Cd, Co, Cr, Mn and Ni are relatively high but comparative data is not available to illustrate their range.

This study shows that there is a large daily input of heavy metals from the ocean outfall and these tend to be accumulated by organisms in the vicinity.

CONCLUSIONS

1. The disposal of household garbage and sewage to the sea in Penang leads to the following conclusions. The shellfish and finfish industry will be affected by microbial contamination and such aquaculture practices should be discouraged in the vicinity of the outfall.

2. The aesthetic and recreational aspects of the waters are way below current norms. Hence, this will in the long run affect the tourist industry.

3. The possibility of transmitting parasitic diseases by the sewage discharge is also supported by this study.

4. There is a high heavy metal and nutrient input from the outfall and an obvious accumulation of these metals in shellfish and finfish.

Table 9. Levels of biodeposited trace metals in *Perna viridis* harvested at the Penang ocean outfall as compared to those from other areas (*BDL; <0.01 μg g^{-1}).

STATION	Metal concentration (μg g^{-1})								
	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	Zn
Ocean outfall at Penang	3.23	25.98	11.91	12.38	2166.33	75.15	81.21	21.04	162.36
Telok Aling	5.27	17.69	BDL*	BDL	271.05	12.05	22.39	9.40	144.54
Batu Ferringhi	5.26	17.65	BDL	BDL	458.61	24.04	27.98	9.38	216.35
Port Weld	4.85	10.83	BDL	BDL	365.28	27.67	10.31	8.65	133.02
Marine Depot	3.97	8.85	BDL	BDL	314.35	22.62	16.85	7.07	126.87
Permatang Damar Laut	5.31	11.86	BDL	BDL	652.10	36.35	28.28	9.48	145.77
Gertak Sanggul	5.60	11.48	6.52	BDL	489.11	23.50	21.85	18.34	117.51
Telok Asam	8.36	18.66	BDL	BDL	563.08	38.22	17.76	14.91	152.78

Table 10. Comparison of heavy metals (μg g^{-1}) in juveniles (< 2.5cm) of the finfish, Liza subviridis at the Penang sewage ocean outfall with those of other local finfish. (*ND: not determined. Data of other finfish other than Liza subviridis was obtained from Lee and Low[18].).

Fish	Metal concentration (μg g^{-1})								
	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	Zn
Liza subviridis L.	2.6	56.0	18.9	34.4	2713.9	38.8	118.5	106.3	269.2
Stromateus cinereus (Black pomfret)	ND*	ND	ND	0.7	10.8	ND	ND	1.4	12.0
Stromateus cinereus (White pomfret)	ND	ND	ND	0.4	10.3	ND	ND	1.1	6.7
Stolephorus commersonii	ND	ND	ND	0.6	11.8	ND	ND	2.5	28.0
Megalaspis cordyla	ND	ND	ND	2.3	34.4	ND	ND	1.0	22.0
Rastrelliger kanagurta	ND	ND	ND	1.4	17.9	ND	ND	1.2	19.3
Polynemus spp.	ND	ND	ND	0.7	5.4	ND	ND	1.2	4.1
Dasyatidae spp.	ND	ND	ND	0.3	3.9	ND	ND	0.5	7.5
Soleidae spp. (sole)	ND	ND	ND	1.2	40.3	ND	ND	0.6	8.0
Selaroides leptolepis	ND	ND	ND	1.3	13.7	ND	ND	1.3	19.5
Polynemus tetradactylus	ND	ND	ND	0.9	10.5	ND	ND	4.0	15.4
Soleidae spp. (flatfish)	ND	ND	ND	0.4	6.5	ND	ND	0.8	7.6
Scomberomorus spp.	ND	ND	ND	0.0	2.2	ND	ND	0.7	7.3
Chirocentrus dorab	ND	ND	ND	0.3	24.1	ND	ND	0.1	8.1
Osphromenus trichopterus	ND	ND	ND	0.3	5.6	ND	ND	0.9	14.9

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5. It is suggested that a total ban be imposed on fishing in the vicinity of the outfall to protect public health.

6. It is advisable to resort to other means of treatment of household sewage or to find a different site for the outfall which has better oceanographic factors at least 8km from the shore.

7. The current practice of dumping garbage near the coastline for land reclamation should be stopped and alternative processing methods should be developed, i.e. incineration or composting.

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