CONTAMINATION OF VENICE LAGOON BY SEWAGE AND HEAVY METALS

Paul Johnston,
Ruth Swindlehurst,
Ruth Stringer,
School of Biological Sciences,
Queen Mary and Westfield College,
University of London, E1 4NS.
U.K.

INTRODUCTION

The lagoon of Venice has a surface area of some 549km^2 and is bordered by a littoral strip interrupted by three entrance channels: the ports of Lido, Malamocco and Chioggia. Through these ports, lagoon waters are exchanged with the sea. Freshwater inflows with associated contaminant burdens enter the lagoon body through more than 20 points distributed on the inner lagoon border. Industrial and sewage effluents discharge directly into the lagoon. Due to its enclosed nature the lagoon is a low energy area and it would be expected that contaminants discharged into it would remain there for some time in association with fine sediments. The mean lagoon depth is approximately 0.6m. It is evident that both wind and tidal waves can resuspend and transport the finest surface sediment (in: Raccanelli et al. 1989) and with it any associated contaminants. Dredging operations are carried out in order to keep the main waterways navigable and dredging spoils, with their contaminant load, are dumped in the Adriatic.

Venice itself is a highly populated city especially in the summer months. This population increase gives rise to increased amounts of sewage being released into the lagoon and has obvious health implications. In recent years eutrophication has become an increasing problem in the lagoon and populations of macroalgae have become very large. These algae may be responsible for the mobilisation of contaminants into the surface sediment when anoxic conditions occur (Pavoni et al. 1990).

There is little published information of practical studies of baseline levels of contaminants in the Venice lagoon area although Raccanelli et al. propose to develop a model that describes the diffusion of sediment-associated contamination. The present study investigates levels of heavy metals in the lagoon sediments in areas where dredging is likely to occur. Total and faecal coliform levels were determined as indices of sewage contamination in the lagoon.

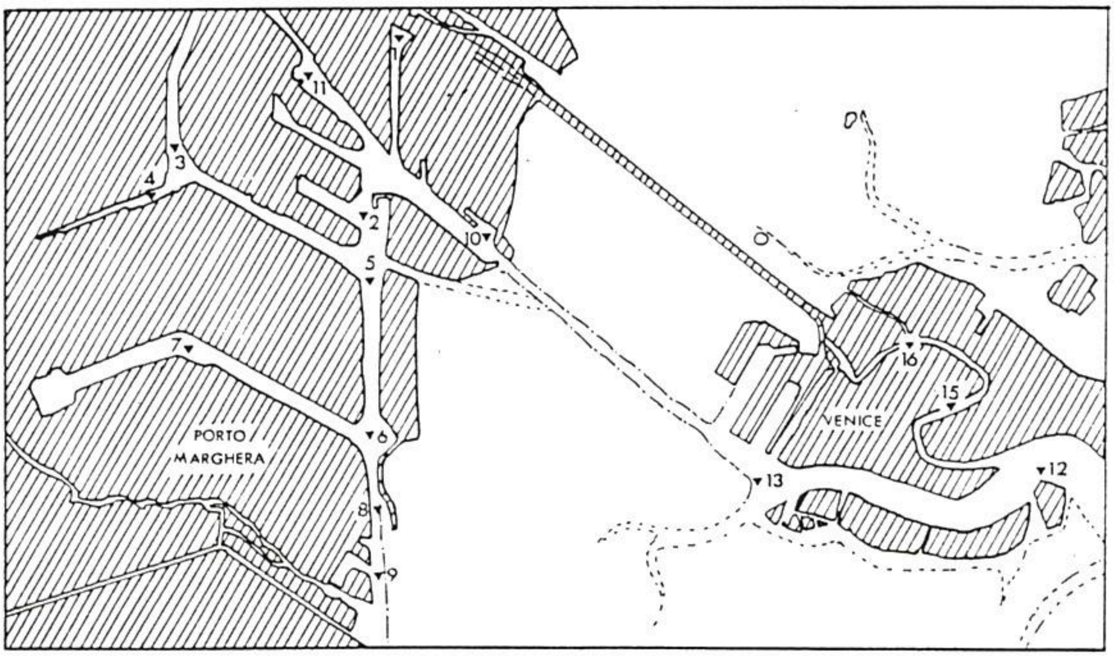

FIGURE 1: Section of Venice Lagoon showing sample sites.

METHODS

Sampling points were selected to include channels which are regularly dredged and channels in the highly populated centre of Venice. Sub-surface water samples were collected in sterile containers and held on ice until processing. 1ml and 10ml volumes were filtered through Gelman 0.45um filters and these then incubated on pads soaked in lauryl sulphate broth for 16 hours. Duplicate plates were run at 37C and 44C using a PAQUALAB portable unit to determine total and faecal coliforms respectively. At the end of the incubation period, colonies having a persistent colouration on cooling were counted.

Sediment samples were obtained using a 10x10x20cm Ekman grab operated from a small vessel. Samples were stored in nalgene bottles and transported chilled to the analysing laboratory. The procedure for mercury analysis is different from that used for the other heavy metals: 4 grams of material were cold, wet-digested for twelve hours in concentrated analytical grade nitric acid and subsequently brought to boiling for one hour. Analysis for mercury was by cold vapour generation using stannuos sulphate reduction according to the method of Hatch and Ott (1968), using a Thermoelectron 151 AAS. The samples were also analysed for the metals Cd, Pb, Cu, Ag, Zn and Cr. Here the samples were digested in a mixture of nitric and hydrochloric acid using the method of Harper (1989). Analysis was by Thermoelectron IL157 AAS calibrated against known standards and background corrected.

RESULTS AND DISCUSSION

TABLE 1. BACTERIAL COUNTS-VENICE LAGOON. MAY 1990

Sample (SITE)	Total Coliforms /100ml	Faecal Coliforms /100ml
1(1)	3200	n/a
2(2)	700	100
3(3)	6400	930
4(4)	8300	180
5(5)	2500	220
6(6)	-	-
7(8)	1000	180
8(12)	70	10
9(15)	12300	10400
10(16)	5800	5700
EEC guideline*	500	100
EEC mandatory*	10000	2000

* Council directive 76/160/EEC December 1975
(Sampling sites are shown diagrammatically in FIGURE 1)

From the results it can be seen that Venice lagoon is highly contaminated with both sewage bacteria and heavy metals. The coliform levels (table 1) are with one exception equal to or in excess of EEC guidelines for bathing water. Although actual bathing is infrequent in the lagoon many people using the varied forms of boat traffic come into direct contact with the water. The sample taken at site 12 is also above EEC mandatory levels for both total and faecal coliforms. Coliform bacteria are an accepted indicator of sewage pollution and are invariably associated with other pathogenic bacteria and viruses, for example salmonella, hepatitis A and poliovirus. Hurst (1989) has suggested that the HIV virus may have an environmental stability comparable to that of the enteric viruses which are known to persist in seawater for considerable periods of time. Antibiotic resistance has been demonstrated in Salmonella and coliform bacteria isolated from sewage polluted waters (Al-Ghazali 1988, Umaran 1989 & Morinigo 1990). Aerosols of seawater have been demonstrated to contain enriched levels of bacteria, viruses and toxins (Blanchard 1989) and may constitute a health hazard for those living near the water. Human pathogenic bacteria and viruses have been shown to accumulate in shellfish (Nicholson et al. 1989). EEC guidelines for shellfish waters (council directive 79/923/EEC) state a limit of 300 faecal coliforms per 100ml of flesh and intervalvular liquid. It is likely that this level is exceeded in shellfish from Venice lagoon. This must cause concern as Venice lagoon supports a substantial shellfishery. Not only are the pathogens a direct health problem but it is possible that heavy metals will exceed a number of advisories. This may be particularly true of mercury.

Heavy metal levels in Venice lagoon (table 2) exceed that of dredged material from Rotterdam and Hamburg harbours (see table 3). Particularly, sites 1 and 11 from Marghera canals are highly contaminated and probably compare with Rotterdam's Class 4 dredgings. The majority of Rotterdam dredgings are considered to be too polluted to dump in the sea or to spread on agricultural land and are therefore treated as toxic waste by the Netherlands authorities (Nijssen 1988). The dredgings are grouped into four classes according to contaminant levels (this is easily done geographically because of an east-west decrease in the degree of contamination). Class 1 material is dumped at sea, being the least polluted because it is from the western part of the system contains a high proportion of marine sediment. Classes 2 and 3 are disposed of on land in a large-scale site and Class 4 waste is disposed of in a specially designed and lined site. The long term policy for these dredgings is to reduce pollutant loading of the sediments from source so that Class 4 waste is no longer produced. Hamburg dredgings are disposed of in upland sites.

TABLE 2: HEAVY METALS-VENICE LAGOON. MAY 1990

Sample	Cd	Pb	Cu	Ag	Zn	Cr	Hg	%H2O
				[ppm dry weight]				
1	11.87	206.37	276.39	1.22	1441.36	51.18	2.91	55.43
2	5.70	76.37	76.81	n/d	443.35	41.26	2.29	59.31
3	5.65	173.66	230.70	2.05	652.53	113.55	15.90	64.86
4	2.18	84.62	136.48	n/d	278.42	79.70	4.10	68.74
5	5.52	99.93	78.34	2.01	497.17	48.21	2.29	63.12
6	4.25	69.11	60.60	2.12	345.57	48.91	1.54	64.37
7	6.53	91.47	64.03	2.17	444.32	57.06	1.48	58.71
8	2.54	46.88	49.93	n/d	229.31	40.25	1.29	62.40
9	1.93	45.17	46.71	n/d	212.35	29.34	1.29	52.90
10	4.88	58.60	63.11	n/d	349.40	38.32	1.69	54.57
11	30.43	362.03	188.36	1.57	2161.72	72.40	16.07	63.06
13	1.92	28.13	29.09	n/d	140.65	23.65	0.98	41.41
14	2.46	44.63	57.32	n/d	212.90	37.25	1.70	55.59
15	3.46	619.00	125.19	1.04	387.32	29.74	2.55	48.91
16	4.53	95.05	153.51	1.51	482.78	34.32	2.55	47.60
D.L.	0.4	0.8	0.4	0.4	0.2	0.5	0.4	
EEC(1)	1-3	50-300	50-140	-	150-300	-	1-1.5	
EEC(2)	20-40	750-1200	100-1750	-	2500-4000	-	16-25	
Italy	10	500	600	-	2500	-	-	
EPA	2.5	500	125	-	250	-	-	

D.L. = detection limits
EEC(1) = limit values for concentrations of heavy metals in soil. Annex IA, council directive 86/278/EEC, 1986.
EEC(2) = limit values for heavy-metal concentrations in sludge for use in agriculture. Annex IB, council directive 86/278/EEC, 1986.
Italy = limit values of compost applied to soil (Petruzzelli 1989)
EPA = United States Environmental Protection Agency, maximum recommended application of municipal sludge-applied metals to medium-textured cropland soils to prevent phytotoxicity.

TABLE 3. HEAVY METALS FROM OTHER HARBOURS

	Rotterdam# [mg/kg]	Hamburg$* [mg/kg]	Background* [mg/kg]
As	13-38	122	13
Pb	80-240	268	30
Cd	3-13	9	0.3
Cr	97-187	90	73
Cu	39-142	237	20
Ni	24-63	45	26
Hg	0.8-3.8	8.7	0.2
Zn	256-1079	1238	76

#figures for 1984 dredged material in: Nijssen (1988)
$concentration in dredged material disposal site
*in: Driel & Nijssen (1988)

There is no EEC legislation which deals directly with the pollutant loads of dredging spoil. However it has been agreed that industrial wastes should no longer be dumped in the sea. The failure of the EEC to categorise dredging spoils which contain high levels of industrially-generated pollutants as industrial waste is a major oversight. Many industries discharge directly into harbours and estuaries only for their waste to be dumped at sea adsorbed onto the fine sediment in dredging spoils. This gives industry a back door route to cheap and easy waste removal and provides no incentive for waste reduction. Meanwhile the seas continue to be polluted with industrial waste.

There are however published guidelines for levels of heavy metals in sewage sludge to be spread on land, also there are levels for agricultural soils. These are quoted in table 2 as a comparison. The sediments from Venice lagoon in many cases exceed both the US EPA limits and the less stringent Italian limits for sludges spread on soils. However the equivalent EEC levels are not exceeded (EEC(2), Table 2). Also the majority of sediments from Venice lagoon exceed the accepted EEC levels for agricultural soil on which sludge may be used (EEC(1), Table 2).

Cadmium, mercury, chromium, lead and soluble copper compounds are included in the EEC's list of priority pollutants. The toxicity of these metals is well documented (Brown & Kodama 1987). Compounds of cadmium possess carcinogenic properties in common with hexavalent chromium compounds.

Heavy metals have been shown to accumulate in the sea surface microlayer (Hardy 1982), and as mentioned earlier, aerosols of seawater may contain enriched levels of toxins, bacteria and viruses. It is likely that bacteria will develop resistance to high levels of metals in this situation. Therefore aerosols produced by turbulence in Venice lagoon and by bubbles rising to the surface from anaerobic sediments are likely to contain enriched levels of heavy metals and resistant bacteria.

CONCLUSION

From the results of this study it is clear that the lagoon of Venice is suffering a high degree of environmental pollution due to insufficient regulation of both sewage and industrial inputs. The water is unfit for bathing and the taking of shellfish for human consumption is highly questionable because there is a high risk of ingesting pathogenic organisms. Breathing the sea air in Venice may be a health hazard due to bacterially and virally enriched aerosols.

It is clear that there is substantial variation in sediment contamination levels, reflective of point source discharges. In particular, sites 1, 11 and 3 furnish cause for concern and a more exhaustive investigation of the sources of Cd and Hg, both limited under EEC directive, should be undertaken. A comprehensive audit of metals and other contaminants entering Venice lagoon is required in order to implement a progressive control and protection programme. The status of fisheries in the lagoon should be urgently reviewed with respect to bacterial and chemical contamination.

The practice of dumping dredgings from the lagoon into the shallow enclosed waters of the Adriatic is clearly not acceptable as long as the pollutant loadings in the sediment remain so high. Adopting the precautionary principle and implementing clean production would eventually solve this problem. Meanwhile the dredging spoils from Venice lagoon should be treated as toxic waste.

ACKNOWLEDGEMENTS

Thanks to M.C. French at the Institute of Terrestrial Ecology, Monks Wood Research Station, Cambridgeshire, for mercury analysis.

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