"THALASSOGENIC DISEASE" - HUMAN DISEASE CAUSED BY WASTEWATER POLLUTION OF THE MARINE ENVIRONMENT WITH SPECIAL REFERENCE TO THE MEDITERRANEAN

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Society generally views recreation at the seashore and ocean bathing, called by some thalassotherapy, as a positive health experience. However, there has been some degree of historical awareness of the potential human health problems associated with bathing and harvesting shellfish, which are often eaten raw, in marine coastal waters contaminated by urban wastewater discharges. In the past such forms of thalassogenic disease have been perceived primarily as isolated local problems. The issue of marine biotoxin poisonings associated primarily with toxic algae blooms has also been of concern. However, the global disease impact and the associated economic implications of these human health problems is estimated for the first time in this study aimed at developing a preliminary quantitative estimate of the impact of these pathways of disease transmission (1). These findings have been underscored by other recent studies (2).

Any comparison of health impacts from various sources must start with a sense of scale of the health problems. Which health impact is more important in human disease and social terms or in financial terms, and by how much? In this preliminary study, each of three negative health impacts has been evaluated in terms of the concept of Global Burden of Disease (GBD). The GBD is measured in units of Disability-Adjusted Life Years (DALYs), a new concept recently developed by the World Health Organization (3) and the World Bank (4, 5). This new approach calculates a) losses from premature death, which is defined as the difference between the actual age of death and life expectancy at that age in a low-mortality population, and b) years of loss of healthy life resulting from disability. It is difficult to estimate the social and economic loss of one year of productive life resulting from premature death or disability (or one "DALY"). There are numerous approaches for making such economic estimates. For the purposes of this study I have estimated , in consultation with the WHO, the money value of the economic loss of one productive year of life, or one DALY, as being about $4,000. This figure approximates the global mean annual GDP per capita, but it is not necessarily based on that figure (6). (See Box on how DALY'S are calculated)

How are Disability-Adjusted Life Years- DALY's calculated?

As an example we shall present the sample calculation of DALY's for a hypothetical marine pollution associated Disease X that has caused 1,000,000 clinical cases of disease per year globally with 10 days of incapacitation per case, 5% or 50,000 cases of life long severe disability (say partial paralysis) and 1% or 10,000 cases of death. If we assume the average age of onset of the cases of disability and death is 20 then it assumed by a special actuarial and discounting method that the years of lost healthy life when discounted is 40. A factor of disability weight must be estimated for each disease for the degree of incapacitation during the acute stage of illness and the degree of disability in the case of longer term sequellae resulting from the disease. The factor of disability weight varies from 1 for total disability or death to 0.05 for very mild cases of disease. In the case of Disease X we shall assume a factor or 0.3 (or 30%) for the 10 days of incapacitation during the acute stage of the disease and a factor of 0.5 (or 50%) as the degree of incapacitation for the cases of lifelong partial paralysis

Thus the calculation of DALY's for Disease X would be as follows:

a) Acute cases: 1,000,000 cases x10 day/365 days per year x 0.3 (factor of disability weight) = **8219 DALY's**

b) Life long disability: 50,000 cases of life long disability x 40 years of lost healthy life x 0.5 (factor of disability weight) = **1,000,000 DALY's**

c) Deaths: 10,000 cases of death x 40 years of lost healthy life x 1(factor of disability weight) = **400.000 DALY's**

Total for Disease X = **1.408,219 DALY's**

say **1.4 million DALY's**

From the above hypothetical example, it can be seen that the main weight factor in the calculation of the total number of DALY's results from the cases of disability for extended periods and/or cases of death. Only minor weight is given to the cases of acute disease with relatively short periods of incapacitation. This is logical for this particular new WHO/World Bank Global Disease Burden rating system since DALY is defined as- "Disability-Adjusted Life Years" which gives considerably greater weight to those diseases that cause greater long term (years) social and economic disruption and burden.

Thalassogenic Diseases Related to Bathing/Swimming in Marine Coastal Waters Contaminated by Wastewater Discharge

For the purposes of this paper we shall refer to all human diseases associated with sources of pollution –pathogenic microorganism and marine biotoxins, which are transported by marine waters or develop within marine organisms as 'Thallasogenic diseases" which in Latin means disease caused by the sea.

There is massive epidemiological evidence that enteric and respiratory diseases can be caused by bathing/swimming at marine coastal beaches contaminated with pathogenic micro-organisms, i.e., exposure to pollution from domestic wastewater sources (7,8,9). The evidence from 22 highly credible epidemiological studies clearly supports the conclusion that the rate of infections and disease among bathers increases steadily with increasing concentrations of indicator micro-organisms of fecal pollution in a dose-response relationship (9). These studies also support the conclusion that bathers face the risk of enteric and respiratory infection and disease even in lightly polluted coastal waters meeting current microbial standards of the EEC/European Union (10) and USEPA (11). Based on an extensive and careful evaluation of the available credible epidemiological evidence, WHO (7) estimated that bathing in what had previously been considered "acceptable" marine waters with a mean concentration of 50 faecal streptococci/100 ml will result in infection and illness in 5% of the healthy adult bathers after a single marine bathing exposure. In this study I have estimated a 50% higher risk-of-disease rates for: children who are known to be much more susceptible than adults; for adults visiting beach resorts in countries with high endemic disease rates in the local population; and for a certain percentage of highly contaminated beaches with microbial levels higher than is considered acceptable from a public health point of view.

Based on official reports from the World Tourism Organisation (12) and estimates from other sources, I have estimated that there are some 1-2 billion marine-exposure-days spent at beach resorts each year by local residents and foreign tourists. From these global figures, and based on the WHO risk estimates for gastroenteritis and respiratory infections at various levels of beach pollution, a highly tentative estimate has been made that some 250 million clinical cases of mild gastroenteritis and upper respiratory disease is caused every year by bathing in contaminated seawater. Calculated in terms of DALYs this results in some 400 thousand DALY units. The economic impact or financial loss resulting from this amount of disease has been estimated at some $1.6 billion/year.

Why has this situation gone unnoticed and unreported for so long? Epidemiological studies have revealed that minor cases of gastroenteritis are rarely seen by medical care professionals and even less frequently reported to health authorities. The ratio of actual clinical cases to reported cases of mild gastroenteritis can be 1000:1.

Thalassogenic Diseases Related to the Consumption of Seafood Harvested in Marine Coastal Waters Contaminated by Wastewater Discharge

Seafood, particularly molluscs normally eaten uncooked, is a commonly implicated vehicle for the transmission of infectious diseases caused by enteric micro-organisms (including bacteria and viruses) that enter the marine environment through the disposal of urban/domestic wastewater. Pathogenic bacteria can remain viable in the sea for days to weeks, and viruses can survive in the marine environment or in the tissues of fish and seafood for months (13).

Filter-feeding shellfish, whose breeding areas are often placed near sources of nutrients, such as wastewater outfall sewers or polluted estuaries, are highly prone to concentrate high levels of pathogens. A series of studies involving the assay and detection of viruses in shellfish in the United States detected enteric viruses in 19% of 58 pooled samples taken from waters meeting current United States bacteriological standards for shellfish growing and harvesting. A mean virus concentration in the shellfish meat of 10 PFU (plaque forming units)/100 grams of shellfish meat was observed (14). One unpublished survey of enteric viruses in shellfish in a Paris market in 1978 indicated that 25% were contaminated with pathogenic enteroviruses. Infectious hepatitis A (HAV), a most serious and debilitating disease of the liver, is the most grave virus disease which is very frequently transmitted by shellfish.

Conventional depuration techniques are used to aid in cleaning shellfish harvested in contaminated waters. Shellfish are held in clean, disinfected water tanks for 36-48 hours of self cleansing, and this is partially effective in removing bacterial contamination. This is less effective for viruses, which are tightly adsorbed to the internal tissues of the molluscs (15). Thus, eating raw or lightly steamed shellfish harvested from such contaminated - but considered acceptable - marine waters can cause infection and disease in a significant percent of the exposed population. Several studies have indicated that so called light steaming of shellfish does not in most cases lead to the total inactivation of infectious viruses adsorbed onto the shellfish tissue.

There is firm epidemiological evidence for numerous sporadic cases of infectious hepatitis (IH) transmission by eating raw or lightly steamed shellfish not reported as part of epidemics. In the study by Koff *et al.* (1967) it was reported that some 25% of all the cases of IH during a non-epidemic period in Boston were apparently associated with the ingestion of raw or lightly steamed shellfish. Similar figures were found in England (16).

Rose and Sobsey (14) have written the seminal work on the development of the methodology for quantitative risk assessment associated with exposure to virus contamination in shellfish. They have estimated that the risk of infection for infectious hepatitis virus A (IHA) for individuals who consume one raw shellfish serving of 60 grams harvested from approved waters in the United State is about 1 per 100, or 1%. The risk from highly polluted waters is greater.

Based on reports from the FAO, it has been estimated that some 8 million tons of molluscs, including clams, oysters, mussels and cockles, are harvested and marketed globally each year. Assuming that one kilogram of gross shellfish, including shells, is required for each shellfish meal or serving, I have estimated that some 8 billion shellfish meals are consumed globally per year. Based on the assumption that some 90% of the shell fish are harvested in clean safe waters and/or are not eaten raw, and based on the risk of infection and disease drawn from the risk estimate study of Rose and Sobsey (1993), I have estimated that each year there are about 2.5 million clinical cases of infectious hepatitus globally, with some 25,000 fatalities and 25,000 cases of long term disabilities from liver damage caused by eating contaminated shellfish. This level of disease results in some 1.8 million DALYs with an estimated economic impact of $7.2 billion per year.

Thalassogenic Diseases Associated with Contamination of Shellfish and other Seafood with Toxins from Toxic Algae Blooms

Marine biotoxins apparently cause a large number of poisonings in humans annually, many with serious sequelae and frequent fatalities. While toxic algae blooms, often associated with marine pollution by urban wastewater, are the source of some of the marine biotoxins that cause human disease, there are other factors and sources. Most of these poisonings are in the subtropical/tropical circumglobal belt region bounded by Florida, the Mediterranean and Japan in the north and the northern edge of Australia, the southern tip of Africa and Chile in the South.

The human diseases most frequently associated with marine biotoxins are paralytic shellfish poisoning (PSP), ciguatera poisoning, and the more recently identified neurotoxic shellfish poisoning (NSP) and diarrheic shellfish poisoning (DSP) (3). Most of these diseases are apparently associated with fish and seafood that feed on toxic marine algae and toxic algae blooms such as red tides. PSP in particular can lead to severe neurotoxic effects, paralysis and death. The death rate for PSP and some of the other marine biotoxin diseases appears to be in the 10%-20% or greater range, while serious long-term sequels such as neurotoxic effects and paralysis are common.

At this time there is little data or agreement among experts on the true extend of the global impact of diseases associated with contamination of shellfish and other seafood with toxins from toxic algae blooms. I have based my tentative estimates of the global impact on data and estimates from various authoritative sources including World Health Organization studies, the opinions of scientists and some official governmental reports. There have been numerous local reports of outbreaks and high endemic incidence of ciguatera poisoning in small communities and islands in the Pacific, such as Tahiti, Hawaii, Samoa and New Guinea, where the incidence has been estimated to be about 500 per 100,000 population. A similar incidence was reported in Dade County, Florida (17). Higerd (18) estimated that 10,000-50,000 individuals are afflicted worldwide each year by ciguatera poisoning alone. Tu (1988) estimates that the true rate of ciguatera poisonings for the South Pacific is likely 2,500 per 100,000. The case fatality rate is low (about 0.1%). It is estimated that the total population in the circumglobal belt where the disease is endemic is about 400 million people, 10% of whom live near seacoasts and frequently eat locally caught fish and seafood. If the incidence rate of ciguatera poisonings in that limited exposed population alone is 500/100,000, then the global incidence might be 200,000 cases a year. If the rate is 2500/100,000 as estimated by Tu, then the global incidence might be 1,000,000 cases a year. In the latter situation, a case fatality rate of 0.1% would result in 1,000 fatalities per year.

In Canada, which has one of the best marine biotoxin monitoring and control programs, there are an estimated 1000 cases per year of illness caused by seafood toxins, with 150 cases per year of PSP and 350 cases of ciguatera poisoning (Ewen Todd, Canada, personal communication, 27 July, 1999). If the incidence for Canada of about 3.3 cases/100,000 of all marine biotoxin poisonings per year is representative of the temperate zones globally, then it might be possible to extrapolate the minimum global incidence for the world population of some 6 billion persons at about 200,000 cases per year, with some thousands of fatalities and thousands of cases with serious life long sequels. This would be a minimum since the rate for the tropical belt where these diseases are highly endemic would be expected to have a much higher rate.

It should be noted that while the death rate from ciguatera poisoning is only about 0.1% that of paralytic shellfish poisoning (PSP) is 10-20%.

In light of the above very scanty data on global incidence of marine biotoxins disease, I have been able to make only a very rough first approximation of the GDB. I have estimated that marine biotoxins associated primarily with toxic algae blooms cause some 100,000 to 200,000 serious cases of intoxications/year globally, and some 10,000 to 20,000 cases of death and a similar number of cases with very serious neurological sequels - paralysis, etc. More accurate or reliable global information is not available at this time. This crude first estimate of the GDB and the DALYs based on the above suggests that it might be as high as one million DALYs per year, with an estimated global economic impact of some four billion dollars.

Estimated Global Impact of Thalassogenic Disease

The total estimated impact of the illness associated with land based marine pollution may be about 3.2 million DALYs/year, with an estimated economic loss of some 13 billion dollars per year. Table 1. presents these estimates along with estimates for other known diseases of global public health importance for which DALYs have been calculated (4). Note that the loss of life years and their associated economic loss is very significant, with the impact being similar to that from upper respiratory tract infections and intestinal nematodes.

Since the Mediterranean plays such a very significant role in both world tourism and in particular recreation at marine coastal areas, including bathing and the consumption of seafood, particularly shellfish it would not be far fetched to estimate that a significant portion of the global burden of THALasSOGENIC disease associated with wastewater pollution of the marine environment occurs in Mediterranean countries. Possibly as much as one quarter of the world total of coastal/beach recreation tourism is in Mediterranean countries. No firm data is available on this point but it would not be incorrect to estimate that some billions of dollars of health damage occur yearly as a result of wastewater pollution along the Mediterranean shores.

It must be pointed out that the estimates above are at best only rough first approximations which must be taken with reservations and used with caution. They may serve as a basis for determining a rough

Table 1. Marine Contamination-Related Thalasogenic Diseases

Comparison of estimated Disability-Adjusted Life Years - DALYs - per year and their economic impact for marine contamination-related diseases and a number of other diseases on a global scale. A mean value to $4000 per DALY is used worldwide for the economic impact estimates. The potential impact of marine pollution-related diseases is quite apparent

Disease	Estimated DALYs per year (millions)	Estimated Economic Impact (billion dollars)
Diphtheria	0.36	1.4
Japanese Encephalitis	0.74	3.0
Dengue Fever	0.75	3.0
Trachoma	1.0	4.0
Upper Respiratory Tract Infections	1.3	5.2
Marine Contamination-Related Diseases	**3.2**	**13**
Bathing/Swimming-Wastewater Related	(0.4)	(1.6)
Seafood Consumption-Wastewater Related	(1.8)	(7.2)
Sea-food Consumption-Toxic Alga Blooms	(1.0)	(4.0)
Intestinal Nematodes (ascaris, etc.)	5.	20.
Stomach Cancer	7.7	31.
Trachea, Brachia and Lung Cancer	8.8	35.
Diabetes	11.	44.
Malaria	31.	124

order of magnitude of the global scope of the problem, which appears to be very much larger than previously estimated. The very provisional economic evaluation of this impact of marine pollution must be viewed with caution, since it is based on such a very preliminary and unconventional economic approach. However, it might suggest that we are dealing with a global problem with major economic implications in the multi-billion dollar range every year.

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