CHAPTER 6
Microbial aspects of beach sand quality

Beaches represent the unconsolidated sediment that lies at the junction between water (oceans, lakes and rivers) and land and are usually composed of sand, mud or pebbles. From a recreational viewpoint, sand beaches are sought after. Especially in higher latitudes, a significant percentage of time is spent on the beach itself rather than in the water.

Microorganisms are a significant component of beach sand. Bacteria, fungi, parasites and viruses have all been isolated from beach sand. A number of genera and species that may be encountered through contact with sand are potential pathogens. Accordingly, concern has been expressed that beach sand or similar materials may act as reservoirs or vectors of infection (Nestor et al., 1984; Roses Codinachs et al., 1988; Mendes et al., 1997), although transmission by this route has not been demonstrated in epidemiological studies.

In this chapter, the incidence, dispersion and fate of microorganisms in beach sand are reviewed, as are potential management actions.

6.1 Microorganisms in beach sand

6.1.1 Faecal index microorganisms

Faecal index organisms are non-pathogenic microorganisms used to indicate the degree of faecal contamination. They are generally present in far greater numbers than pathogenic microorganisms and are easy to isolate, identify and enumerate. Faecal index organisms include coliforms (total coliforms, thermotolerant coliforms and *Escherichia coli*), intestinal enterococci (see Box 4.1), bacteriophages and clostridia.

The presence of total coliforms, thermotolerant coliforms, *E. coli* and intestinal enterococci in beach sand and the relationship between their counts in beach sand and their counts in adjacent waters have comprised a significant area of research, with apparently contradictory results. Total coliforms, thermotolerant coliforms and intestinal enterococci were isolated from surface sand samples in Marseilles and Agde, France. Counts of intestinal enterococci, probably originating from animals, were higher than counts of other indices (Conseil Supérieur d'Hygiène Publique de France, 1990). High numbers of thermotolerant coliforms and intestinal enterococci were isolated in beach sand along Taranto coastal waters in Italy (Signorile et al., 1992). Lower numbers of faecal index organisms were recorded in swimming areas in Tel Aviv, Israel, and in Barcelona, Spain (Figueras et al., 1992; Ghinsberg et al., 1994).

Low numbers of bacterial indices of faecal pollution were recovered in dry sand from a beach along the Thyrrenian coast (Italy). *E. coli* was recovered in 61% of the samples and enterococci outnumbered coliforms (Bonadonna et al., 2002).

In an Italian study, a significant correlation was found between contamination of beaches and contamination of adjacent seawaters, although the sand generally had higher bacterial counts than the water (Aulicino et al., 1985). A similar tendency was found at Barcelona beaches; in contrast to the Italian study, however, the level of contamination was not significantly different between sand and seawater (Roses Codinachs et al., 1988).

Papadakis et al. (1997) found no correlation between the indices of faecal pollution counted on the wet part of the beach and *Staphylococcus aureus* counts or the presence of fungi. A statistically significant correlation was detected between yeasts and molds, *E. coli* and enterococci, enterococci and spores of sulfite-reducing *Clostridium* and between clostridial spores and staphylococci in an investigation on wet and dry sands in Italy (Bonadonna et al., 2002). In an epidemiological study carried out on two beaches in Malaga, Spain, faecal index microorganisms, especially coliphages, were highly significantly correlated with dermatophyte fungi (microscopic fungi that grow on skin and mucous membranes) on one of the beaches. Only *E. coli* showed a significant correlation with *Candida albicans* (a pathogenic fungus). At the other beach, intestinal enterococci showed the best correlation with dermatophyte fungi. Again, coliphages were the indices that best correlated with *C. albicans* (Borrego et al., 1991).

6.1.2 Staphylococcus

According to some studies, *Staphylococcus* spp. predominate over other flora in the sand (Dowidart & Abdel-Monem, 1990). Of a total of 85 strains of Gram-positive cocci isolated from beach water and sand located at two popular beaches in Chile, 31% were classified as *S. epidermidis*, 9% as *S. haemolyticus*, 24% as *S. aureus* and 36% as *Staphylococcus* spp. (Prado et al., 1994).

The origin of *Staphylococcus* in beach sand is attributed to human activity. Its occurrence has been found to correlate with the number of swimmers on the beach, and the counts of *S. aureus* were found to correlate with the presence of yeasts of human origin in sand samples (Papadakis et al., 1997). Higher counts of *S. aureus* were recovered from the sand and water in summer, when there was a higher density of swimmers on the beach, than in winter. Also, higher counts of *S. aureus* were recovered from sand than from water samples (Ghinsberg et al., 1994; Papadakis et al., 1997).

Investigations carried out along the Tyrrhenian coast (Italy) showed higher densities of *Staphylococcus* spp. in sand of areas characterized by breakwaters than in sands found in open areas. *S. epidermidis* was the predominant species (Bonadonna et al., 1993a).

6.1.3 Pseudomonas aeruginosa

In a study in Israel, both seawater and sand on a number of beaches were found to contain various levels of *Pseudomonas aeruginosa*. The isolation of *P. aeruginosa* and of other *Pseudomonas* spp. was proportionally higher in sand than in seawater samples (Ghinsberg et al., 1994). *P. aeruginosa* was isolated from sandy beaches in Portugal under various tidal conditions, all beaches containing similar counts (Mendes et al., 1993).

6.1.4 Vibrio *spp.*

Vibrio parahaemolyticus isolates have been found in marine or brackish water and sand specimens collected from sand banks in Africa (Aldova, 1989). *Vibrio harvey* has been isolated from seashore water and sand samples collected on coarse sand or pebble beaches (Aldova, 1989; see also chapter 5).

6.1.5 *Enteric bacteria*

Species of bacteria that can cause gastroenteritis have been isolated from sand samples. However, their presence constitutes no apparent health threat to sunbathers. Sand beaches in Portugal contained similar counts of *Clostridium perfringens* under various tidal conditions (Mendes et al., 1993). Bonadonna et al. (1993b) suggested that *C. perfringens* could be a good index of faecal contamination in sand sediment. Low levels of *Campylobacter jejuni* were recorded in both coastal waters and sand on a number of Israeli beaches, with the beach sand containing higher counts than adjacent shore waters (Ghinsberg et al., 1994). In the United Kingdom, intertidal zone sediments appeared to serve as a substantial reservoir for thermophilic campylobacters, which could contribute significantly to bacterial numbers in surface waters, especially in rough weather (Obiri-Danso & Jones, 1997). Dabrowski (1982) isolated *Shigella* spp. from beach sand and water in the bay of Gdansk (Poland).

6.1.6 *Fungi*

Fungi that are often found in the environment as saprophytes may act as opportunistic pathogens, especially in immunocompromised patients (Hoog et al., 2000). Studies by Soussa (1990) in the Portuguese central coastal area showed dermatophytes in 42% of the sand beaches analysed. The most common were *Trichophyton mentagrophytes*, *T. rubrum* and *Microsporum nanum*, all isolated from sandy, non-flooded areas with organic residues. These species are all associated with skin infections, with *T. mentagrophytes* being the most common agent of dermatomycosis in Europe and *T. rubrum* the most common agent worldwide (Hoog et al., 2000). Saprophytic fungi (*Aspergillus candidus*, *A. ochraceus* and *A. fumigatus*) were isolated in the flooded and intermediate areas in high tidal conditions (Izquierdo et al., 1986).

Candida albicans and other *Candida* spp. have been isolated from sand beaches in the south of France (Bernard et al., 1988). In the same study, 8 keratinophilic fungi (i.e., those able to grow on keratin, a characteristic common to dermatophytes) and 11 non-keratinophilic species, all potential pathogens, were isolated. Izquierdo et al.

(1986) isolated 16 species of fungi from beach sand along the northeastern Mediterranean coast of Spain, among them some potentially pathogenic strains. Most of the species belonged to the genera *Penicillium*, *Aspergillus* and *Cladosporium*.

In Israel, Ghinsberg et al. (1994) isolated fungi in all beach sand samples, but not in seawater samples. In a study in Guadeloupe, Boiron et al. (1983) investigated fungal species in seawater and seashore sand, concluding that the similarity of bacterial species in sand and seawater, in conjunction with the fact that no *Candida albicans* was isolated, corroborated their hypothesis that the isolated yeasts were of marine origin. The isolated fungi belonged to the species *C. tropicalis*, *C. parapsilosis*, *C. langeronii*, *C. guilliermondii*, *Trichosporon cutaneum* and *Torulopsis* sp. The most frequently isolated genera from beach sand samples in a Spanish study were *Penicillium*, *Aspergillus*, *Cladosporium*, *Altenaria*, *Mucor*, *Monilia*, *Cephalosporium*, *Verticillium* and *Chrysosporium* (Roses Codinachs et al., 1988). Absence or low incidence of *C. albicans* has also been recorded by other researchers (Roses Codinachs et al., 1988; Figueras et al., 1992).

The fungal density of 180 samples of sand collected from 42 Spanish Mediterranean beaches was found to reach several hundred thousand colony-forming units per gram of sample. The most commonly isolated genera were *Penicillium*, *Cladosporium*, *Aspergillus, Acremonium, Altenaria* and *Fusarium* (Larrondo & Calvo, 1989). In a study carried out in the Attica area of Greece, fungal isolates included *Candida albicans*, *C. krusei*, *C. tropicalis*, *C. puilliermondi*, *C. rugosa*, *Pitirosporum orbiculare*, *Fusarium*, *Penicillium*, *Mucor*, *Helminthosporium* and *Aspergillus niger* (Papadakis et al., 1997), a number of which are pathogenic (Hoog et al., 2000).

6.1.7 Viruses and parasites

Very little information exists concerning the presence of viruses and parasites in beach sand. In a three-year study in Romania by Nestor et al. (1984), the incidence of enteroviruses was found to depend on season, with no viruses being present in water and beach sand during non-vacation seasons. In a study of two sand beaches in Marseilles, France, *Toxocara canis* was found to be the most common parasite, being present on average in 150 g of sand (Conseil Supérieur d'Hygiène Publique de France, 1990). However, in a study carried out on "dog beaches" in Perth, Australia, a total of 266 samples showed no traces of *Toxocara canis* eggs or other eggs/larvae of parasitic nematodes (Dunsmore et al., 1984). It was emphasized in this study that the major risk to humans was from an environment in which puppies, not older dogs, were found. The presence of other parasites transmitted by water (Marshall et al., 1997) that have not been investigated in recreational sand areas may be potentially significant.

6.2 Dispersion and fate of microorganisms in beach sand

The growth of microorganisms in beach sand is limited by nutrient input. Laboratory studies have shown that nutrients pass through the bacterial community into the protozoan and metazoan community (Khiyama & Makemson, 1973). Further studies have shown that microbial contamination is higher in sand than in adjacent waters, as the sand behaves as a passive harbour for cumulative pollution (Oliveira & Mendes, 1991, 1992; Oshiro & Fujioka, 1995). Higher levels of coliforms, *E. coli* and enterococci in sand from Hanauma Bay (Hawaii) were thought to originate from run off from the cliffs surrounding the bay (Oshiro & Fujioka, 1995). Faeces from pigeons and mongoose were also thought to be a source of beach sand contamination. This study concluded that the contaminated sand could be the major source of the periodically high levels of bacteria in the water. Sand contamination is highly variable over short distances, making interpretation of results difficult (Aubert et al., 1987; Figueras et al., 1992; Oshiro & Fujioka, 1995).

The survival of enteric bacteria on the surface of dry sand may essentially be of short duration, the bacteria being destroyed mostly by environmental pressure. Wet sand, the area where young children typically spend most of their time on the beach, is the most relevant. Wet sand, enriched with organic substances, provides a favourable environment for enteric bacteria, which enables them to survive longer than in seawater (Papadakis et al., 1997).

Various factors have been proposed as encouraging the survival and dispersion of faecal index microorganisms and pathogens on beach sand. These include the nature of the beach, tidal phenomena, sewage outlets, the season, the presence of animals and the number of bathers. Water movement, for example, causes erosion, transportation and deposition of beach sediment and redistribution of associated microorganisms. Obiri-Danso & Jones (1997) analysed sediment samples in the United Kingdom for thermophilic campylobacters and faecal index microorganisms before and after tidal cover over a 12-month period. Fifty-three per cent of the samples were positive for campylobacters before tidal cover; this figure was significantly lower than the 64% recovered after tidal disposition. However, there was no significant difference in index organism numbers with respect to samples taken before or after tidal cover. In the same study, a seasonal variation was observed in campylobacters, with the highest isolation rate in winter (100%), followed by secondary peaks in spring (33–67%) and autumn (67–78%). The lowest counts were found in summer, which correlated with the incidence of campylobacters in surface waters. In contrast, Mendes et al. (1993) studied the influence of tides on counts of faecal index microorganisms and pathogens in sand without finding any clear differences. Nestor et al. (1984) found that the incidence of some pathogens depended on the season, with no viruses present in seawater and sand of beaches outside the holiday season. Borrego et al. (1991) reported higher bacterial counts and longer survival time in beaches close to sewage outlets.

As outlined in the previous section, fungi are often encountered in sand, and their survival is longer than that of enteric bacteria due to their capacity to form resistant spores. It has been suggested that the presence and the level of fungi is related to direct or indirect contamination originating from the residues/detritus from beach users and/or tidal influence (Mendes et al., 1998). In an *in vitro* study, Anderson (1979) found that four pathogenic fungi (*Trichosporon cutaneum*, *Candida albicans*, *Microsporum gypseum* and *Trichophyton mentagrophytes*) survived for at least 1 month in non-sterile sand inoculated with propagules of such fungi. In a similar study, five species of dermatophytes (*Epidermophyton floccosum*, *Microsporum canis*, *M. gypseum*, *Trichophyton mentagrophytes* and *T. rubrum*) and *Scopulariopsis brevicaulis* survived for between 25 and 360 days (Carillo-Muñoz et al., 1990).

Intensively used water recreation areas provide opportunities for person-to-person transmission of pathogens (e.g., dermatophytes). Transmission may occur because individuals shed pathogens onto sand, by direct contact or through other means, although, with the exception of transmission via contaminated water (as discussed in chapter 4), none of these has been positively demonstrated. Papadakis et al. (1997) collected water and sand samples from two beaches—one more popular than the other—in summer and winter, and the numbers of swimmers present on the beaches were counted. Coliforms, thermotolerant coliforms, enterococci, *S. aureus*, yeasts and moulds were also investigated. Water and sand samples were very low in index organisms of faecal pollution. Human species of yeasts were present in water and sand samples from both sites. *S. aureus* was isolated from water and sand samples only twice in winter, when swimmer presence was exceptional. A significant correlation appeared between swimmer numbers present on the beach and *S. aureus* counts in water samples, the correlation being more pronounced on the more popular beach. In sand samples, *S. aureus* counts correlated with the number of swimmers present on the beach only at the more popular beach. Yeasts of human origin correlated with the number of swimmers on the more popular beach, both in water and in sand samples.

6.3 Guideline values

Bacterial indices of faecal pollution and several pathogens have been isolated from beach sand. However, the capacity of pathogens in beach sand to infect beach users remains undemonstrated, and the real extent of their threat to public health is unknown. There is, therefore, no evidence to support the establishment of a guideline value for index organisms or pathogenic microorganisms in beach sand. However, preventative measures, such as education campaigns, and the management actions described in section 6.5 are important precautionary measures.

6.4 Research and monitoring

Epidemiological evidence for health risks from exposure to sandy beaches has not been found. Epidemiological studies aimed at investigating cause–effect or at examining a possible dose–response relationship linking the microbial quality of beach sand with skin, eye, ear and gastrointestinal symptoms would improve understanding in this area.

Experience with systematic beach surveillance as part of pollution control is relatively limited, and routine monitoring of beach sand for index organisms is generally not justified. However, it has often been recommended for research. WHO/UNEP (1992, 1994) indicated that wet beach sand and sediments should be part of epidemiological and microbiological studies correlating recreational water quality with health effects, but evidence to date indicates that beach sand does not appear to constitute an infectious hazard (Chabasse et al., 1986; Conseil Supérieur d'Hygiène Publique de France, 1990).

6.5 Management actions

The principal microbial risk to human health encountered on beaches and in similar areas is that arising from contact with animal excreta—notably that of dogs, where, for example, such areas are used for exercising pets. Regulations, often local in character, may restrict access on a seasonal basis to frequently used beaches or place an obligation upon the owner to remove animal excreta. Increased public awareness may help to reduce exposure, especially among young children. While beach cleaning may contribute to the removal of animal excreta, it is more often undertaken for aesthetic reasons or to attempt to remove litter or sharp materials, such as broken glass. The majority of beach management award schemes would not give an award to a resort beach that allowed dogs during the swimming season.

In some countries, particularly at resort areas, mechanical sand cleaning is a common practice that can eliminate visible rubbish mixed with sand, reducing the amount of organic matter and therefore reducing the further development of microorganisms (Bartram & Rees, 2000 chapter 12). However, mechanical cleaning may disturb sand ecology (Llewellyn & Shackley, 1996). Studies that have investigated the microbiological quality of sand have shown that a clear improvement was achieved as a result of raising the general levels of hygiene and cleanliness (Fernandez & Ferrer, 1982).

Chemical products such as disinfectants are sometimes applied to sand without regard to their effectiveness or possible ecotoxicological effects. The Conseil Supérieur d'Hygiène Publique de France (1990) has argued that there is not enough evidence to demonstrate the need for and efficiency of sand disinfection. When sand treatment is necessary, simple methods, such as sweeping and aeration, could be applied (Figueras et al., 1992), together with constant beach supervision in order to prevent access by animals. The use of clean towels for use on the beach, good personal hygiene, the prohibition of animals and regular mechanical cleaning are considered, by some authorities, to be important (e.g., Conseil Supérieur d'Hygiène Publique de France, 1990).

6.6 References

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