# Recreational water quality in the Caspian Sea

Katherine R. Pond, Aidan A. Cronin and Steve Pedley

## ABSTRACT

Health-based monitoring of the Caspian Sea in Turkmenistan and Iran suggests that bathers are intermittently subject to increased levels of faecal pollution which may lead to gastrointestinal illness. This is the first co-ordinated monitoring programme of recreational waters in the Caspian region and highlights the need to extend such a programme to all countries bordering the Caspian Sea. The novel approach of monitoring that combines risk assessment (water quality monitoring plus a sanitary survey) and risk management, as applied here, allows the identification of possible sources of pollution and the levels of microbiological risk that bathers are subject to. Hence, this allows suitable management interventions to be identified and implemented in the long term.

**Key words** | Caspian Sea, Iran, recreational water, risk, Turkmenistan

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## INTRODUCTION

Surface and coastal waters are used for a variety of activities that are not always compatible with each other. Trends indicate that leisure activities, including water-based recreation, will continue to increase (Bartram & Rees 2000) and so the effects of the health hazards that recreational water users face will gain increased prominence in the future. Those responsible for monitoring and managing recreational waters are likely to face increasing challenges as the number of users increases and recreational uses diversify.

The Caspian Sea is situated between Europe and Asia; it is the largest salt lake in the world with a surface area of ~373,000 km$^2$ and is bordered by Kazakhstan, Turkmenistan, Iran, Azerbaijan and Russia (Figure 1). The Caspian's water surface lies 92 ft (28 m) below sea level. It reaches its maximum depth of 980 m in the south; the northern half averages only about 5 m depth.

The joint exploitation of the fossil fuel energy resources in the Caspian Sea have had, and will continue to have, considerable economic and ecological effects on the future of the countries bordering the water body (Effimoff 2000). In addition to petroleum contamination, the Volga River brings industrial, agricultural and domestic waste, including pesticides, detergents, heavy metals, oil, phenols and sewage into the northern Caspian (Efendiyeva 2000). Transboundary pollution is an important management issue and inevitably there are many potential health hazards. This has the potential to seriously affect all bordering countries although little research into this has been carried out in the region to date.

Countries surrounding the Caspian Sea have not previously monitored their bathing waters in a co-ordinated fashion or with standardised approaches. As tourism in the Caspian Sea is increasing, it is vital that all the bordering countries collect monitoring data in a compatible manner for future management initiatives.

To address these issues, the Caspian Environment Programme (funded by the international community through the Global Environment Facility) and the World Health Organisation (WHO) Collaborating Centre for Water Quality and Human Health (Robens Centre for Public and Environmental Health (RCPEH) at the University of Surrey, UK) jointly undertook to train laboratory staff from all five countries bordering the Caspian Sea in techniques to monitor bathing waters for microbiological pollution. Turkmenistan and Iran were selected to establish pilot projects. In both these countries national tourism is

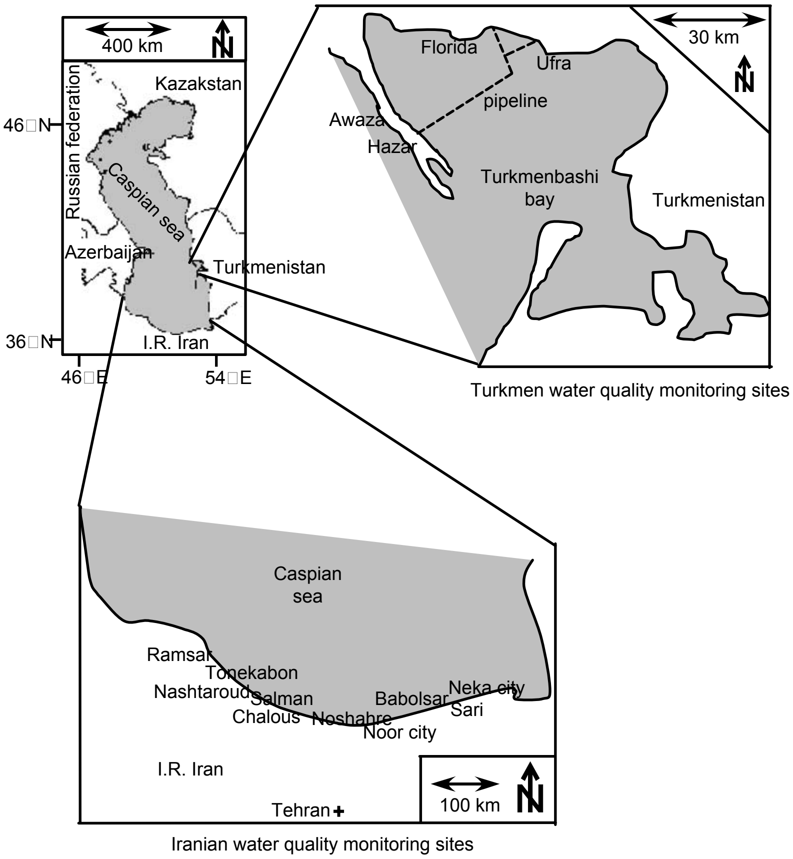


**Figure 1** | Location of the Caspian Sea and its bordering countries; also shown are the locations of the sites in Turkmenistan and Iran where bathing water quality was assessed as part of the pilot project.

increasing and, although there are active public health laboratories, bathing waters are not monitored systematically despite the recognition of the effects of population/industry on bathing water quality.

The programme focused on assisting in the implementation of the WHO/United Nations Economic Commission for Europe (UNECE) Protocol on Water and Health (UNECE 2000) in the Caspian Region. The Protocol aims to prevent, control and reduce the incidence of water-related diseases through collaboration on water management and protection of health and the environment. In order to do this, effective systems for monitoring and risk assessment should be set up including establishing 'sufficient safeguards for human health against water-related disease arising from the use of water for recreational purposes' (UNECE 2000).

The approach to monitor and regulate bathing waters is currently undergoing reforms in Europe and other parts of the world. The European Commission (EC) Bathing Water Directive (76/160/EEC; CEC 1976) is the legislation which countries in the European Union must comply with in order to safeguard human health against microbiological pollution of bathing waters. In recent years there has been considerable debate about which are the most appropriate faecal indicator bacteria to employ in monitoring marine and fresh recreational waters in order to protect human health. *Escherichia coli* (*E. coli*) is the traditional indicator used and is generally believed to be faecal in origin. It has been proposed by the EC as the most appropriate indicator for freshwaters (CEC 2000) although some studies have identified limitations associated with its use (Cornax *et al.* 1990; Hazen & Toranzos 1990; Ashbolt *et al.* 1997).

Recently, based on the results of a number of epidemiological studies undertaken around the world (for reviews see Prüss 1998; WHO 2003), it has been shown that intestinal enterococci provide the best dose-response relationship for both gastrointestinal illness and acute febrile respiratory illness. WHO recommend that this is the priority parameter to be monitored for in sea and fresh water quality monitoring programmes for protection of human health against faecal contamination (WHO 2003). The EC is considering developing a mandatory standard for intestinal enterococci in the revision of the Bathing Water Directive (CEC 2000); currently only a guideline value exists (Table 1).

The WHO Guidelines for Safe Recreational Water Environments (WHO 2003) propose values for the microbiological quality of marine recreational waters in conjunction with associated levels of accepted health risk (Table 2). These represent understood levels of risk based on the exposure conditions of key epidemiological studies (WHO 2003). For example, the value of 200 intestinal enterococci per 100 ml relates to an average probability of one case of gastroenteritis in 20 exposures (Table 4.1 in WHO 2003). This new approach addresses some of the acknowledged problems associated with the current regulatory processes used to define the 'safety' of a bathing water.

To complement the Guidelines for Safe Recreational Water Environments and to assist in the implementation of effective monitoring programmes, the WHO, in collaboration with the US Environmental Protection Agency, have developed a risk assessment and risk management approach to monitoring recreational waters known as the Annapolis Protocol (WHO 1999). This combines microbiological water quality monitoring with a sanitary survey to identify the sources of pollution and has been adopted for use in the current programme. The approach has been tested previously in a number of European countries (results unpublished) but this is the first time this novel approach has been used in risk identification in the Caspian region.

**Table 2** | WHO guideline values for microbiological quality of recreational waters, adapted from WHO 2003; (Table 4.1)

| 95th percentile value of intestinal enterococci (cfu 100 ml$^{-1}$) | Estimated risk of illness in 20 exposures |
|---|---|
| 41–200 | 1–5% GI[1] illness |
| | >1.9% AFRI[2] illness risk |
| 201–500 | 5–10% GI illness |
| | 1.9–3.9% AFRI illness |
| >500 | >10% GI illness risk |
| | >3.9% AFRI illness rate |

1 = gastrointestinal; 2 = acute febrile respiratory illness

## METHODS

### Background

Turkmenistan and Iran were selected for pilot bathing water quality assessment programmes with the intention that the lessons learnt would then be used to design a programme for all the Caspian countries. Country co-ordinators were identified and a number of bathing beaches were selected

**Table 1** | Current EC microbiological water standards (from EC Directive 76/160/EEC; CEC 1976)

| | Mandatory standard | Guideline standard |
|---|---|---|
| Total coliforms (cfu 100 ml$^{-1}$) | 95% < 10,000 | 80% < 500 |
| Faecal coliforms (cfu 100 ml$^{-1}$) | 95% < 2,000 | 80% < 100 |
| Intestinal enterococci (cfu 100 ml$^{-1}$) | No standard | 100 |
| *Salmonella* | 0 per litre | No standard |
| Enterococci (cfu 100 ml$^{-1}$) | 90% < 100 | No standard |
| Enteroviruses | 0 PFU per litre | No standard |

for monitoring. The sole criterion for selection was that the beach was used regularly for bathing and that it was within reasonable distance from the selected laboratory to allow regular monitoring. Ten bathing beaches were chosen for monitoring in Iran (Figure 1): Ramsar Beach, Salman Shahr Beach, Noshahre Beach, Nashtaroud Beach, Chalous Beach, Tonekon Beach, Noor Beach, Zagh-e-Marz (Neka City), Khazar Abad (Sari City) and Parcking 2 Beach (Babolsar). Owing to the distance between the sites, analysis was conducted in two laboratories: the Chalous Environmental Centre, Chalous, and the laboratories of the Department of the Environment in Sari. The bathing beaches in Iran are well developed for tourism but there appears to be very little management of solid and liquid waste disposal. There are many hotels and settlements along the coastline discharging waste directly into the sea. In addition, run-off and river discharges are perceived to contribute significantly to the contamination of the Caspian Sea.

There is less development in Turkmenistan but national tourism is increasing in the Turkmenbashi region. Four bathing beaches were identified for sampling (Figure 1): Hotel Florida, Hotel Awaza and Hotel Hazar were chosen as sites which are most popular with bathers; the Resort Ufra is an oil base used by ships to dump their waste but is also frequented by bathers. Analyses were conducted by the public health laboratory in Turkmenbashi.

Monitoring began in Turkmenistan in June 2001. The start of the monitoring was delayed in Iran until September 2001. Results of the water quality sampling and sanitary surveys were forwarded from each laboratory to both the Caspian Environment Programme in Baku, Azerbaijan, and to the RCPEH in the UK on a monthly basis.

### Sampling

Samplers collected 500 ml of seawater in sterilised sample containers from the same point at their chosen bathing beaches, at the same time on a weekly basis. Sampling was carried out in accordance with the standard procedures recommended in *Standard Methods* (1995) and the EC Directive for the quality of bathing waters (CEC 1976). Samplers were also asked to record the number of bathers, meteorological conditions, temperature and pH of the water at the time and point of sampling as outlined in the Annapolis Protocol (WHO 1999).

Field workers were asked to complete a sanitary inspection of the bathing beach area using a standard form at the same time as water sample collection. The aim of the sanitary inspection was to identify sources of existing and potential microbiological hazards that could affect the safe use of the bathing beach or recreational water. Training in sanitary inspection as well as water sampling and laboratory analysis techniques was provided by the authors with follow-up assistance three months after sampling first began.

### Laboratory analysis

Water samples were processed for *E. coli* and intestinal enterococci using the standard membrane filtration technique as described in Report 71 (PHLS 1994) and the ISO methods: ISO 9308-1 (1999) – detection and enumeration of total coliforms, *E. coli* using the membrane filtration method and ISO 7899-1 (1998) – detection and enumeration of intestinal enterococci using the membrane filtration method. Slantez and Bartley media (Oxoid, UK) was used for detection of intestinal enterococci and membrane lauryl sulphate broth (Oxoid, UK) for detection of *E. coli* bacteria. In addition, to ensure results would be comparable between countries, standard recording forms and instructions for the methodology were issued to each co-ordinator.

## RESULTS

### Iran

The water quality results from Iran reflect the more developed tourism and higher populations in this region of the Caspian Sea. Noticeable peaks in concentrations of indicator bacteria were recorded at all sites (Figures 2 and 3) and this may be attributed to a number of parameters such as weather conditions, particularly heavy rainfall or onshore winds, sewage or riverine discharge. Based on these preliminary results, bathers were exposed to an estimated risk of gastrointestinal illness of between 5 and 10% (Table 3). However, it is acknowledged that a comparatively small sample size was taken and sample sizes should be increased towards 100 to increase the precision of the estimate of the 95th percentile. Unfortunately, no sanitary survey forms were returned from Iran. It is therefore not possible to report on this aspect of the programme.

### Turkmenistan

Sampling was conducted from June 2001 to September 2002 and the results are explained in detail below (Figure 4). The main findings from the sanitary surveys are given in Table 4. This highlights the potential sources of contamination. Water temperatures at all sites sampled in Turkmenistan ranged from 9 to 31°C and averaged 18.5°C. pH values generally ranged between 8.2 and 8.5.

### Hotel Florida

Table 4 compares the results of the water quality sampling with the current standards and guidelines for bathing waters (Tables 1 and 2). Presumptive *E. coli* counts varied between 0 and 276 colony forming units per 100 ml (cfu 100 $ml^{-1}$) with the 95th percentile at 149 cfu 100 $ml^{-1}$. Intestinal enterococci counts varied between 0 and 87 cfu 100 $ml^{-1}$ with the 95th percentile at 56.6. Based on the WHO Guidelines (WHO 2003) bathers at this site were exposed to a risk of between 1 and 5% of contracting a gastrointestinal illness from faecal contamination of this site during the time of sampling or an average probability of one case of gastroenteritis in 20 exposures.

### Resort Ufra

Water quality results were in compliance with the mandatory standards set by the EC under the Bathing Water Directive (CEC 1976) for *E. coli* (Table 4). On two occasions, the water quality exceeded the mandatory standard for *E. coli* of 100 cfu 100 $ml^{-1}$. However, based on these results and according to the WHO Guidelines, there was overall very little risk (<1%; Table 4) to the health of bathers in terms of contracting gastrointestinal illness caused by faecal contamination of this bathing area during the sampling period, although there were noticeable peaks in concentration of intestinal enterococci (Figure 4).

### Hotel Hazar

In general, the water quality results showed only small variations over time and only 3% of the water samples taken from this bathing water site exceeded the EC Guideline for faecal coliforms (Table 1). Peaks in *E. coli* results were recorded in August 2001 and June 2002 (Figure 4). The exact reason for these peaks is not clear but it is probable that increased bather density contributed as these periods coincide with the height of the bathing season, though further investigation is required. All samples passed the EC mandatory standard. Based on the levels of the intestinal enterococci counts recorded at this site there was less than a 1% risk of bathers contracting a gastrointestinal illness caused by faecal contamination of this bathing water during the sampling period (Tables 1 and 4).

### Hotel Awaza

The water quality at the Hotel Awaza showed the lowest average counts of intestinal enterococci and *E. coli* of the four sites sampled. Despite this, a noticeable peak in concentration of *E. coli* counts was visible in June 2002 and a slight peak in intestinal enterococci counts in August 2001 (Figure 4). This, as in the case of Hotel Hazar, coincides with the height of the bathing season and so it is plausible, as indicated by the sanitary inspection, that the increase in bather density is likely to contribute to the increase in contamination. Only 2% of the samples failed the EC Guideline for faecal coliforms and all samples passed the mandatory standard. Comparing the 95th percentile of the intestinal enterococci counts with the WHO Guidelines it is estimated that bathers had a <1% risk of contracting a gastrointestinal illness from faecal contamination at this site during the period of sampling (Tables 1 and 4).

## DISCUSSION

The water quality results from both Turkmenistan and Iran showed considerable temporal and spatial variation indicating variable health risks. This highlights the inherent

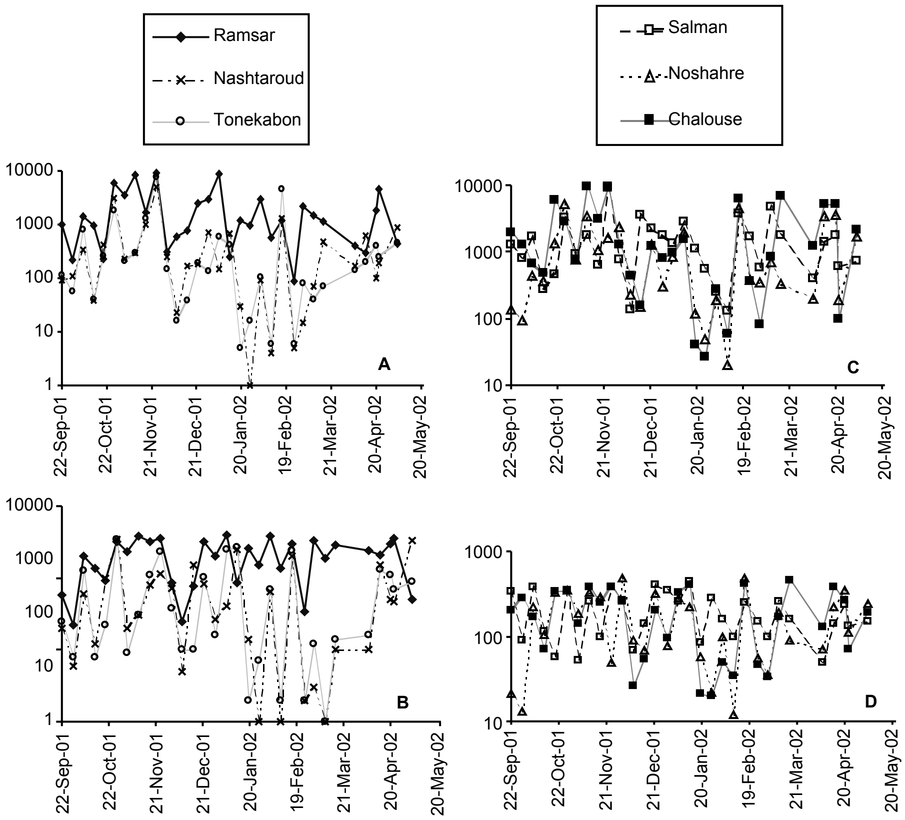


**Figure 2** | Monitoring results from the Iranian bathing sites (Chalous laboratory). (a, b) E. *coli* cfu 100 ml$^{-1}$ results from the monitoring sites samples by the Chalous laboratory; (c, d) intestinal enterococci cfu 100 ml$^{-1}$ from the monitoring sites samples by the Chalous laboratory.

difficulties associated with the commonly used practice of defining a bathing water as passing or failing a defined microbiological standard and, hence, the WHO advocate moving away from a single standard (WHO 2003).

The combined use of sanitary surveys and water quality analysis has been previously used to good effect in the assessment of potable waters; drinking water distribution systems and sanitary protection of wells are good examples (WHO 1997). However, this is a new approach for recreational waters. The advantage of this method over using water quality monitoring alone is that the existing and potential microbiological hazards that could affect the safe use of the recreational water or bathing beach can be identified. The approach provides the basic requirements for designing a water quality monitoring programme and valuable information required to interpret the results. In addition, it provides public health authorities with information required to help select sampling points, sampling times and frequencies. This will ultimately help to better assess water quality and make sound management decisions regarding risk to human health.

In general, the sites that were chosen for the project are developed or being developed for tourism. It is not possible to comment on the level of treatment of sewage entering the Caspian Sea since this information was not made available from any of the countries involved. However, it is clear from the sanitary survey forms that there is a high possibility of sporadic water contamination from sewage in many of the bathing areas.

The indications from the water quality results presented here are that the bathing beaches monitored by counterparts in Turkmenistan were of generally acceptable quality over the period of monitoring when compared with standards applied in Europe. Some seasonal peaks in faecal contamination occurred, particularly at Hotel Hazar and Hotel Florida, and these correlated with the peak of the

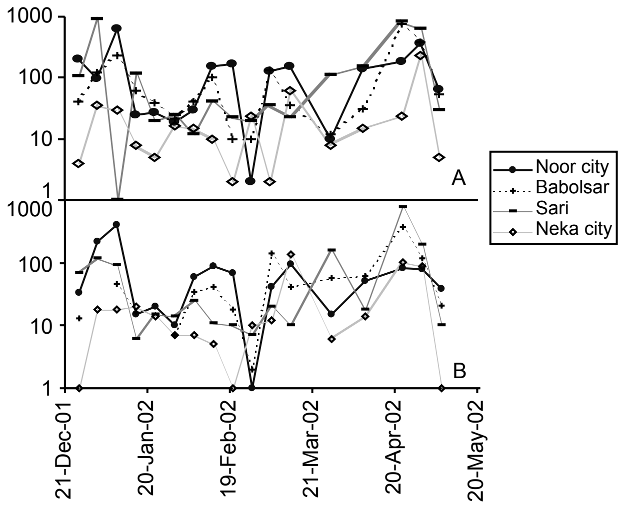


**Figure 3** | Monitoring results from the Iranian bathing sites (Sari laboratory). (a) *E. coli* cfu 100 ml$^{-1}$ from the monitoring sites samples by the Sari laboratory; (b) intestinal enterococci cfu 100 ml$^{-1}$ from the monitoring sites samples by the Sari laboratory.

bathing season. The information gathered on the sanitary inspection forms appears to imply that the high counts at the Hotel Florida may be at least in part due to animal and bird contamination, as this appears to be the distinguishing factor contributing to the microbiological hazards identified at this site (Table 4). This site and the Hotel Hazar are located in residential areas. Contamination from private housing may also be contributing to the high faecal contamination of the water in this area.

The bathing waters monitored in Iran were generally more contaminated although the results provide only an indication of the water quality over a limited period of time. Results were provided from Turkmenistan over a complete year and thus could be considered more representative.

Long-term monitoring should be continued in both countries to identify the effect of seasonal patterns on water quality. The ongoing revision and updating of detailed sanitary surveys is encouraged in order that all potential sources of pollution are identified. If the monitoring is continued it should be possible to identify long-term trends in the water quality and identify flexible and rapid response management options to reduce pollution of the water and, thus, protect the health of bathers.

The sanitary surveys identified chemical contamination as a threat to water quality at the bathing sites in

**Table 3** | Summary statistics for bathing water quality, Iran

| Beach | Number of samples | 95th percentile for *E. coli* (cfu 100 ml$^{-1}$) | 95th percentile for intestinal enterococci (cfu 100 ml$^{-1}$) | % > EC mandatory standard[1] | % > EC guideline[2] | Estimated risk[3] |
|---|---|---|---|---|---|---|
| Ramsar | 31 | 8600 | 380 | 32% | 100% | 5–10% |
| Salman | 31 | 4300 | 390 | 23% | 100% | 5–10% |
| Chalous | 31 | 8000 | 411 | 32% | 100% | 5–10% |
| Tonekabon | 31 | 3205 | 257 | 6% | 65% | 5–10% |
| Noshahre | 31 | 4045 | 417 | 19% | 90% | 5–10% |
| Nashtaroud | 31 | 2230 | 290 | 26% | 65% | 5–10% |
| Babolsar | 17 | 458 | 187 | 0% | 29% | 5–10% |
| Noor City | 17 | 418 | 258 | 0% | 47% | 5–10% |
| Sari City | 17 | 846 | 316 | 0% | 41% | 5–10% |
| Neka City | 17 | 93 | 109 | 0% | 6% | 5–10% |

[1]Percentage of samples exceeding EC Mandatory standard for faecal coliforms
[2]Percentage of samples exceeding EC Guideline standard for faecal coliforms
[3]Estimated risk of gastrointestinal illness after 20 exposures according to WHO guidelines for safe recreational waters (WHO 2003)

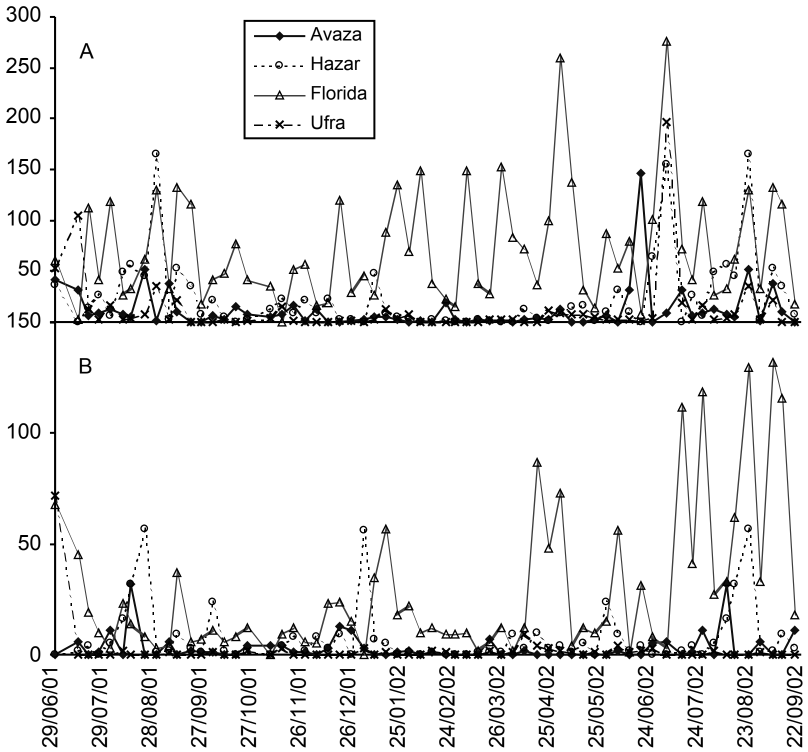


**Figure 4** | Monitoring results from the Turkmenistan bathing sites. (a) *E. coli* cfu 100 ml$^{-1}$; (b) intestinal enterococci cfu 100 ml$^{-1}$.

Turkmenistan. Such contamination is likely to be carried into the bathing site by currents at Awaza and Hazar. At the Resort Ufra and Hotel Florida sites in Turkmenbashi direct contamination is possible from the nearby industrial sources. Further investigation of their impact on water quality is recommended. Again, if the sanitary surveys are continually updated and checked against local conditions, then future monitoring programmes can allow quantification of the results in a sanitary risk score. This has proved very beneficial in other water system types to aid interpretation of the available water quality information and develop remedial action (e.g. Howard *et al.* 2003; Cronin *et al.* 2004). Once the water quality programmes are well established the results of the monitoring should be made available to the users. This could be done by posting the results on notice boards at the bathing area with an explanation. In the future a scheme of officially identifying beaches for bathing that are monitored on a regular basis may be considered.

Future investigations could also focus on aesthetic aspects of the bathing beach areas. Litter, in particular, was noted as an issue in both countries and especially Iran. Public participation projects to reduce the quantities of litter on the coastline would both benefit the coastline and help to promote environmental education programmes in the Caspian region (e.g. as in the Coastwatch initiative in Europe; Pond & Rees 1994). The number of skilled staff available should be expanded with the assistance of the laboratory staff involved in the current project.

## CONCLUSIONS

This was the first co-ordinated monitoring programme of recreational waters in the Caspian Sea. Based on the results of the sampling programme recreational water users in Iran and Turkmenistan were exposed to varying risks of contracting gastrointestinal illness from microbiological contamination of the Caspian Sea ranging from an average probability of one case of gastroenteritis per 20 exposures to a greater than 10% chance of illness per single exposure in

**Table 4** | Summary of sanitary survey and water quality results for the four sites (70 samples in total) surveyed in Turkmenistan

| Summary of sanitary survey findings | | | | | | | | | Water quality results | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Site | Typical bathing density (person per m²) | Nearby land type | To[1] | Sh[2] | LB[3] | Microbiological hazards | Chemical hazards | Sand quality threats | Pollution transport mechanism | 95p *E. coli*[4] | 95p IE[5] | % > EC MS[6] | % > EC G[7] | Risk[8] |
| Hotel Florida | 20 to 25 | Residential, industrial (including fish factory) | 0 | 0 | 15 | Long sea sewerage outfall, birds and animals, storm drains | Urban and industrial run-off, water craft | Algae, plastic residue | Onshore winds | 149 | 56.6 | 0% | 28% | 1 to 5% |
| Hotel Hazar | 30 to 35 | Residential | 3 | 5 | 6 | Communal sewage disposal facilities, storm drains, natural drainage, wastewater from toilets and showers | Urban run-off | Algae, plastic and other residue | Onshore winds, currents | 60.9 | 32 | 0% | 3% | <1% |
| Hotel Avaza | 20 to 50 | Rural though two hotels nearby | 0 | 0 | 3 | Communal sewage disposal facilities, natural drainage, birds and animals | – | Algae | Onshore winds, currents | 40.6 | 11 | 0% | 2% | <1% |
| Resort Ufra | 30 | Industrial (oil base) | 1 | 0 | 3 | Communal sewage disposal facilities, storm drains, natural drainage | Urban and industrial run-off, water craft | Algae, plastic residue | Onshore winds, currents | 44.9 | 3.6 | 0% | 3% | < 1% |

[1,2,3] Number of toilets, showers and litter bins, respectively, on the beaches; [4,5] 95th percentile values (cfu 100 ml$^{-1}$) for *E. coli* and intestinal enterococci (IE), respectively; [6,7] Percentage of samples exceeding EC mandatory and EC guideline standards for faecal coliforms, respectively, [8] Estimated risk of gastrointestinal illness after 20 exposures according to WHO Guidelines for safe recreational waters (WHO 2003)

some bathing areas. The use of a sanitary inspection to identify pollution sources is a new approach to monitoring bathing waters but proved valuable in aiding the interpretation of laboratory results. Although not conclusive, the sanitary inspection approach seems to support the results of the water sampling in this instance. The results have shown a need to continue monitoring recreational waters in the Caspian Sea and to implement management measures to reduce levels of contamination.

The programme was successful in increasing capacity building in the region and strengthening technical co-operation between countries. It has established the infrastructure for a long term programme of monitoring and data collection and provided a launch pad for the promotion of discussion and co-operation between bordering countries of the Caspian Sea to better manage this unique resource.

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