Bacteriological studies on the potability, efficacy and EIA of desalination operations at Sharm El-Sheikh region, Egypt
Atef M. Diab

Botany Department, Faculty of Science, Suez Canal University, Ismailia, Egypt

ABSTRACT

   A six month-study was conducted on five desalination units in Sharm El-sheikh region. The final desalinated drinking water, the high salt brine discharge water, water from Sharm El-Maiya Bay and other seven different types of natural drinking bottled-water were bacteriologically analyzed in order to ; first investigate the degree of potability of the produced desalinated water, to assess the possible environmental impact of the brine discharge on the Bay water quality and living organisms and third to estimate the desalination efficiency of the studied units. Sharm El-Maiya Bay is a quite small water basin from which water is pumped to the desalination units and in which high salt brine is discharged. A total of 76 samples were tested for the presence of certain bacterial groups of hygiene and quality control importance. Total viable bacteria (TVB), total coliforms (TC), faecal coliforms (FC), faecal streptococci (FS), haemolytic faecal streptococci (HFS), *Salmonella* and *Shigella* (S&S), aeromonads (*Aerom.*) and *Vibrios* counts cfu/ 100 ml were estimated using 0.45 μm bacterial filter technique on agar plates containing plate count agar and other differential and specific culture media. Salinity was measured in all samples. Bacterial count results showed unacceptable water quality for drinking. TVB counts ranged from 100-800 cfu/100ml, *Aerom.* 5-600 cfu/100ml , S&S 4-300 cfu/100ml, vibrios 1-27 cfu/100ml were very far from both the national and international standards. Bottled water reached acceptable standards. The results of bacterial counts in the discharged brine were 7-10 times more than those detected in the Bay water (control samples) which represent the feed water to the desalination units. Brine salinity measurements were at twice as high as these of the feed water. Both the high bacterial counts and salinity values may cause risky environmental changes in the Bay ecosystem especially on coral reefs, in fish aquoria, as well as to affect swimmers, snorkellers and scuba divers. Despite the high efficiency (100%) of the reverse osmosis membrane technology in removing seawater salts, the investigated desalination systems were not satisfactory in producing bacteriologically- safe potable water.

KEYWORDS: bacteriological quality, desalination, drinking bottled-water, EIA

INTRODUCTION

Sharm El-Sheikh is quite a small developing community that depends mainly upon tourism. Sharm El-Maiya is one of its many small bays, only 50 km² (Fig.1 *A* and *B)*. The hotels and recreational resorts around the bay installed seawater desalination units for fresh water supply. All the studied in the present work are based on the reverse osmosis filtration technology (Fig. 2), just like many coastal cities around the world. Sharm El-Maiya bay represents the source of feed water to these and also receives their high-salt brine drain. Too little has been done on the bacteriological quality of the desalinated sea water using reverse osmosis facilities (Bunpuckdee 1988; Harker 1988), while chemically (Cadotte *et al.* 1978; El-Saie *et al.* 1981*;* Quinn 1982; Sekino 1989; Durham 1997) and economically (Foster &William 1969; Herbert 1970; Reside *et al.* 1974; US Congress. Office of Technology Assessment 1988 ; Hassan *et al.* 1999) too much research have been achieved. A lot of monitoring programs have been also adopted in order to develop the reverse osmosis membrane filtration technology and solve its maintenance problems (for example, chlorine corrosive action: Cadotte *et al.* 1978; Hassan *et al.* 1999), performance problems including some bacterial issues such as adhesion and fouling (El-Adsani 1973; Channabasappa 1976; Araki *et al.* 1989; US Congress). Office of Technology Assessment 1988; Sekino *et al.* 1989;

Araki *et al.* 1991; Boari *et al.* 1997; Durham 1997; Hassan *et al.* 1999*).* Virtually no bacteriological research has been carried out to deal with the associated health risks to humans of using the final reverse osmosis desalinated water in drinking, cooking or

showers or the environmental impacts of the disposed high salt brine on the nearby aquatic ecosystem. Three questions were initiated in this study: is the working sea water desalination units perform their job properly? is the water they produce potable? and what are the possible environmental impacts that brine may cause ?

Fig. 1. Location of the working area and the sampling sites. A- an over view of South of Sinai, B- Sharm El-Maiya in relation to Sharm El-Sheikh, C- A,B,C,D and E are the sites where desalinated water samples were collected and D- a,b,c,d and e are the sites where brine was continuously discharged.

MATERIALS AND METHODS

Sharm El-Sheikh is located in the South of Sinai. (Fig. 1 A and B) *and* is well-known for its underwater coral and marine parks. The coastal part is characterized by sharms and bays which interrupt the coastal line. Sharm El-Maiya is one of Sharm El-Sheikh bays. It is a semi-enclosed bay with a limited water circulation situated approximately at 34° 17' 30" East and 27° 51' 36" North (Fig.1D*).* The perimeter of the bay is about 2150 metres long with 800 by 500 meters main dimensions, and with a small opening to the west south of about 300 meters width. It is relatively shallow and characterized by the existence of tidal flats along most of the shoreline area. It is economically and to a less extent ecologically available area. The bay is dominated by a number of recently-built hotels and recreational resorts, (Fig. 1C) which depend mainly upon desalinated water sea as a sole source of water fresh for all human uses. The largest five sea water desalination units were studied, which all those take their feed water

from and drain their high salt brine water to Sharm El-Maiya bay. All of the five studied units are based upon the reverse osmosis filtration technology. Treatment capacities of these sea water desalination units to producing desalinated water ranged between 500 and 5000 m³/day. The final desalinated water from sites A,B,C,D and E (Fig. 1C) the feed water to the sea water desalination units site (II), the high salt brine drains from sites a,b,c,d and e and one more control site (I) at the middle of the mouth of the bay (Fig. 1D) were sampled monthly for six months using appropriate sampling techniques (glass wears, handling and transportation lines guide of the APHA 1992). Each of the 12 sites under investigation was sampled six times over the six months study period started in August 2000 until January 2001. Furthermore, the most common seven types of bottled natural water were bacteriologically investigated following the same procedures. Plate-count agar, McConkey agar,endo-agar base, azide agar base, *Salmonella & Shigella* (S&S) agar, *Aeromonas* differential agar and thiosulphate-citrate-bile salt (TCBS) differential agar culture media were adopted from Scharlau (2000) for enumeration, isolation and preliminary identification of the bacteria in the collected water samples as well as the chosen bottled natural water. Water samples (100 ml) were filtered through bacterial membrane filters (Micro-Filtration Systems Comp. Ca. No. Ao 45-Do, 47 Dia. pore size 0.45µm). Filters were placed face up onto different agar plates and incubated at 37 °C for 24 hr after which the resulted bacterial counts cfu/100 ml were recorded.
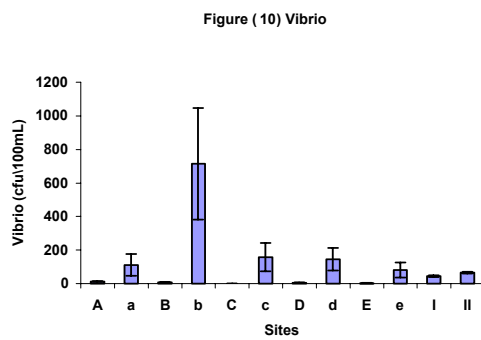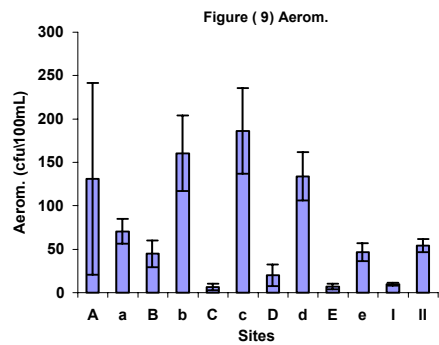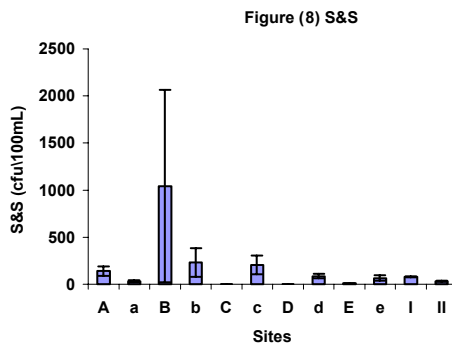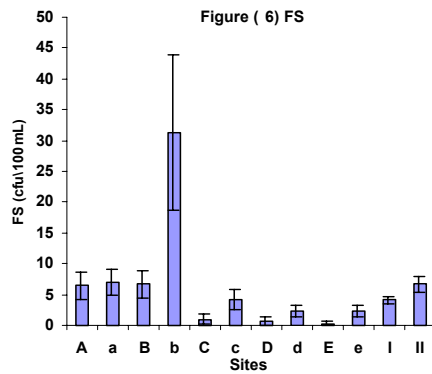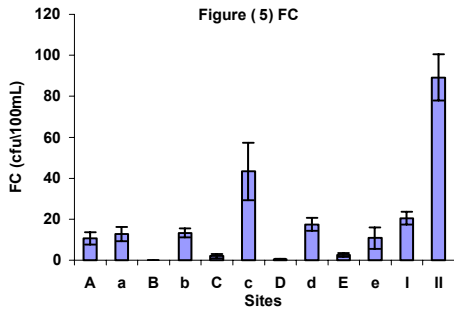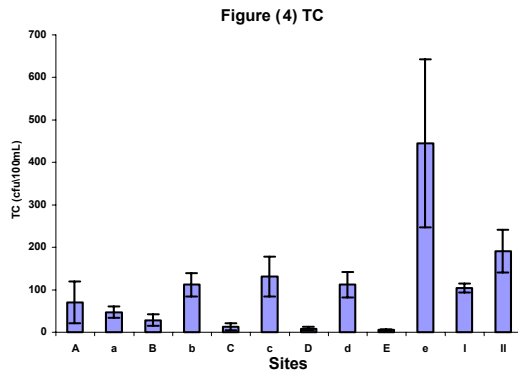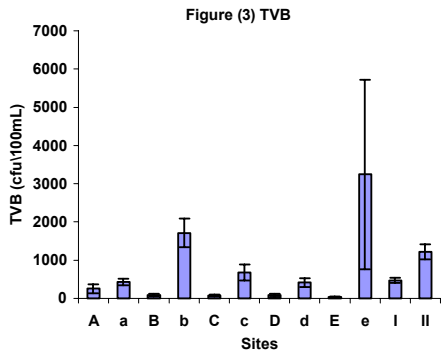
RESULTS

Four different categories of water samples were bacteriologically analyzed. An environmental category was represented by the feed water to the sea water desalination units from Sharm El-Maiya bay site II, and a control sample from the mouth of the bay site I (Fig.1 *D)*. A wastewater category was represented by the high-salt brine discharged into the bay (Fig 1*D)*. A treated drinking water category was represented by the desalinated seawater, and finally a recommended drinking water category represented by bottled natural water available in the local market.

Sharm El-Maiya bay water: TVB and TC counts in the two bay sampled sites I and II showed in Figures 3 & 4. All readings for all the studied bacterial groups were higher at site II than in site I except for S&S bacteria that found to be 68.3 cfu/100ml at site I and 24.3 cfu/100ml at site II. Salinity also showed higher figures at site II (32‰) than at site I (26 ‰) (Fig.11).

High-salt brine wastewater: Sites a,b,c,d and "e" Fig.1*D* referred to brine samples coming out from the five studied sea water desalination units . Bacterial counts ranged between 471.2 at "a" and 5945.3 cfu/100ml at "e" for TVB (Fig.3), 44.3 at site "d" and 639.1 cfu/100ml at "e" for TC (Fig.4). Counts of FC found high at "c" **(**Fig.5). Site "b" had the highest FS, HFS and *Vibrios* counts being 27.4, 3.7 and 752.6 cfu/100ml respectively (Figs. 6,7 and 8). *Aeromonas* and S&S counts were high at all sites and reached their maxima at site "c" 211.6 and 333.3 cfu/100ml (Figs.8 and 9). Salinity readings ranged between 32.3 ‰ at site "e" and 53.6 ‰ at site "c".

Figures 3-11 graphic presentations for different studied bacterial groups showing comparatively the difference between drinking and brine water qualities; as well as the standard of each, where:

TVB	Total Viable Counts.	Aerom.	*Aeromonas*
TC	Total Coliform	A,B,C,D & E	Final Produced Drinking Water
FC	Faecal Coliform	a,b,c, d & e	High Salt (Brine) Drain Water
		I	Mouth of the Bay (Control)
FS	Faecal Streptococci		
HFS	Haemolytic Faecal Streptococci	II	Middle of the Bay (Control)
S & S	*Salmonella & Shigella*		

Figure (3) TVB

Figure (4) TC

Figure (5) FC

Figure (6) FS

Figure (7) HFS

Figure (8) S&S

Figure (9) Aerom.

Figure (10) Vibrio

Figure (11) Salinit
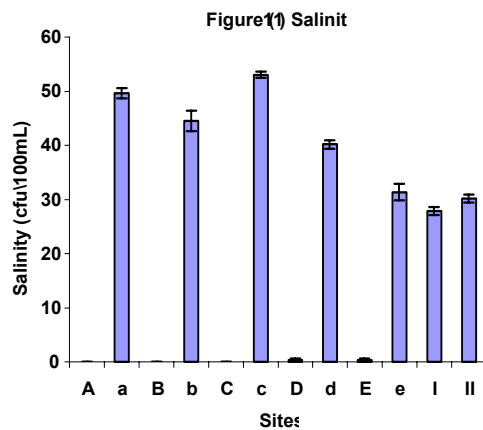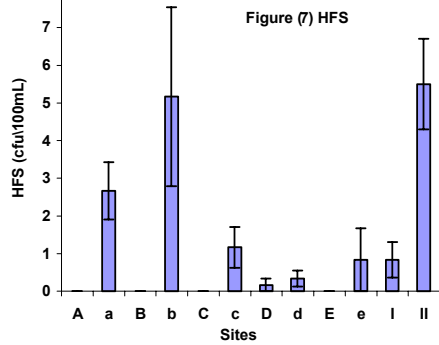
Desalinated water: Sites A, B, C, D and E referred to samples of desalinated water collected from taps of five well known hotels. TVB counts ranged between 106.3 at "C" and 331.5 at "A" Fig 3. TC counts showed a maximum of 2.3 cfu/100ml at site "E" and a maximum of 117.6 cfu/100ml at site "A" Fig.4. Low counts were detected for the FC, FS, HFS and vibrios, Fig. 5,6, 7 and 10 where high counts of S&S and aeromonads were detected Fig 8 and 9. For salinity, sites "D" and "E" gave a reading of 0.6 ‰ while the rest of the sites showed zero ‰ salinity readings Fig.11.

Bottled natural water: Except for one out of the seven studied types of bottled natural water results of bacterial counts cfu/100ml and salinity ‰ were zero, after 24 hr incubation at 35°C. The detected counts were 3 aeromonads and 1 coliform /100ml.

DISCUSSION

Final desalinated water quality examined in this study is unacceptable for human consumption. Bacterial counts of the eight pollution indicator groups, TVB, TC, FC, FS, HFS, S&S, *Vibrio* and *Aeromonas* spp. were extremely higher than the recommended international standards (WHO 1993) without almost no signs of diseased cases admitted. Desalinated drinking water quality could be described as unpotable even if no cases of gastroenteritis were recorded (Harker 1988). Using of such poor quality of water that heavily loaded with toxin–producing bacteria in drinking and/or cooking will, of course, cause serious toxinological disturbances in humans. This is in line with what Diab *et al.* 1995; discussed when they proved the destructive effect of heat-treated and untreated haemolysins and cytotoxins produced by these bacterial species, *Aeromonas hydrophila* and *Aeromonas sobria*, in particular, on rat heart cells. Not least important the high possibility of infection during the reverse osmosisutine daily shower due to the high counts of *Aeromonas* sp., this has been referred to by Seidler *et al.* 1980; when they isolated, enumerated and characterized *Aeromonas* sp. encountered in diving operations. Efficacy of the studied sea water desalination units in removing sea water soluble salts is absolutely good as the salinity readings were almost zero in the final produced water. This was expected because of the great efforts paid allover the world for improving the performance of reverse osmosis technology. Araki *et al.* 1989; Araki *et al.* 1991; Boari *et al.* 1997; Durham 1997; Hassan *et al.* 1999. Ridgway *et al.* 1986; stated that the reverse osmosis was designed to remove the majority of the ionisable salts from the water supply and 99% of all bacteria, particulate matter and dissolved organic. Salinity of the salt brine is usually around 270 ‰ . Brine in the present study recorded salinities of 32.3 ‰ to 53.6 ‰. This big difference may indicate that the dilution regime recommended for the sea water desalination units is followed before discharging their brine into the bay, (in site collected data). Dilution with the bay water itself ,as said, is doubtful. One reason is that the mean salinity figure of the bay water is 28 ‰, nearly one-tenth the expected salinity of the brine. The possibility of mixing brine with bay water 1/10 v/v, is very difficult. Another reason is the high bacterial counts detected in the brine; five times the counts in the bay water in average, this is contradicted with the dilution concept. This pointed out the possibility of having a highly contaminated fresh water source with bacteria other than the bay water, kitchen and /or swimming pool drains for example. It may also indicate a bad fouled condition of the running reverse osmosis membranes. In such a case the reverse osmosis membrane become a source of contamination (Durham 1997; Tua 1996). In many cases reverse osmosis is the heart of a high water purity system. The very high

load of pathogenic bacteria in the brine, such as *Salmonella*, *Shigella*, *Vibrio* and *Aeromonas* are virulent against both human and fish Diab *et al.* 1995. It is clear that the bad environmental impacts (EIA) on the studied ecosystem is expected, if not recognizable now it would be later.

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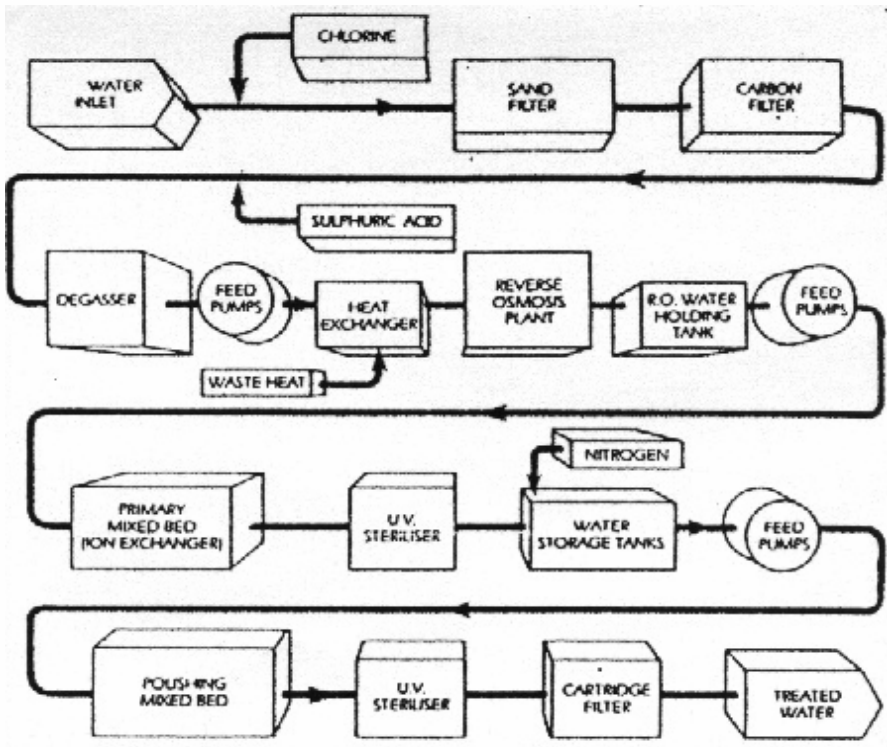World Health Organization (WHO) (1993) International Standards for Drinking Water. 3ed edition USA.

Fig. 2: Diagramatic representation of the different facilities and treatment sub-units in a reverse osmosis-based desalination unit.

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