Bull. Environ. Contam. Toxicol. (1992) 49:813–820

Environmental Contamination and Toxicology

Sources of Pollution at Mina al Fahal Coastal Area

Mohamed I. Badawy,[1] Marcelina D. Hernandez,[2] and Firdaus T. Al-Harthy[2]

[1]Water Pollution Department, National Research Center, Dokki, Cairo, Egypt and [2]Ministry of Environment, P.O. Box 323, Muscat, Oman

Mina al Fahal being a heavily oil industrialized region in the Sultanate of Oman is thought to receive large loads of oil pollution (ROPME 1984). In addition to oil, other waste discharges contribute to the general pollutant load. These have been identified as sewage discharge, chlorinated wastewater effluent from a refinery plant, dust fall-out and airborne particulate matter which contains lead and polyaromatic hydrocarbons. All these factors contribute to the pollution of water supplies by sedimentation, impaction and precipitation on land and water surfaces that may cause human health problems if concentrations are high (Lantzy and Mackenzie 1979; Ponat 1988). The Mina al Fahal area is considered a very rich fishing area. It lies adjacent to Al-Ghubra desalination plant which supplies drinking water to 90% of the population based in the Muscat area.

The present study represents an essential part of project to study the environment of the Mina al Fahal area. The aim of this study was to determine the loading of pollutants into the coastal water of Mina al Fahal.

MATERIALS AND METHODS

A high volume sampling method was used for collecting suspended particulates. In this method, previously weighed filter was placed inside a plate and was used to collect air samples over 24 hours. Details of this methodology are described by WHO (1976). The sampler was fixed on the roof of a building near Mina al Fahal beach.

A 3/4" x 8" strip from the previously exposed filter was cut by using a template and a pizza cutter and digested in 25 mL of 3M HNO3 at 80°C for 30 min. The treated sample was quantitatively transferred into a 100 mL volumteric flask and diluted with double - distilled water. The solution was allowed to settle for a minimum of one hour before proceeding with analysis. A Pye Unicam PU 9000 atomic absorption spectrophotometer was used for lead analysis at a wavelength of 283nm.

Particulate samples were extracted by using a soxhlet extractor with a mixture of 15% dichloromethane in hexane in methanol (1:1) for 12 hours. The

Send reprint requests to Mohamed I. Badawy at the above address

extracts were concentrated to 5 mL, elemental sulfur was removed by reaction with mercury and the extract was quantitatively transferred to a column chromatograph for separation into two fractions using 10g aluminum oxide over 10g silica gel (both deactivated with 5% water). Fraction one (F1), which included aliphatic hydrocarbons, was eluted with one column of pentane or hexane. Fraction two (F11), which contained aromatics, was eluted with one column of 15% dichloromethane in hexane followed by one column of pure dichloromethane.

Dust fall-out was collected by using a semiconical polyethylene bucket with an opening of 20 cm diameter filled with distilled water. The sampler was placed on the roof of the previously mentioned building using a steel holder.

Dust samples were washed and screened through sieve number 10(2mm) to remove insects and feathers, then dried at 80°C and weighed to determine the dust fall-out rate. Treated samples were analyzed for lead and total hydrocarbons (THC). For lead analysis , one gram of dry sample was digested in a mixture of hot HNO3 - HClO4 - HF for 8 hours. The sample was then centrifuged and the resulting solution diluted and analyzed using atomic absorption spectrophotometry. For THC determination, five grams of samples were extracted using a soxhlet extractor with a mixture of 15% dichloromethane in hexane and the method was completed as for particulate samples. The monthly amount of dustfall-out in tons/km2 was calcuated according to the following equation;

$$A = w \times 31.85$$

Where A is is the amount of dust fall-out in tons/km2 and w is the weight of dust fall-out in grams and 31.85 is the conversion factor to convert g/cm2 to tons/km2.

A Shimadzu RF-5400 Spectrophotometer was used for the analysis of THC. Quantification was made with excitation at 310 nm emission at 360 nm. Estimation of oil type was based on examination of the emission spectra at 310 nm excitation and synchronous excitation - emission scanning with a wavelength difference of 20 nm.

Analyses of polyaromatic hydrocarbons were carried out with a Pye-Unicam 304 Gas Chromatograph equipped with FID detector and a 25 m WCOT SE-54 column. The initial temperature was 100°C. After an initial hold for 2 min., the temperature was programmed to rise at 8°C / min to 280°C. The injector and detector temperatures were 250 C and 300°C, respectively. Helium was used as the carrier gas, at a flow rate of 2 mL/min. The identification and determination of polyaromatic hydrocarbons were carried out by comparison of the retention time with the authentic compounds.

RESULTS AND DISCUSSION

In the Mina al Fahal area, domestic sewage discharges come from two sewage treatment plants. The first one is located in Mina al Fahal and is designed to treat raw sewage from a residential area of 3,000 people. The second one is located at Darsait area near the Mina al Fahal (Figure1) and is designed to treat raw

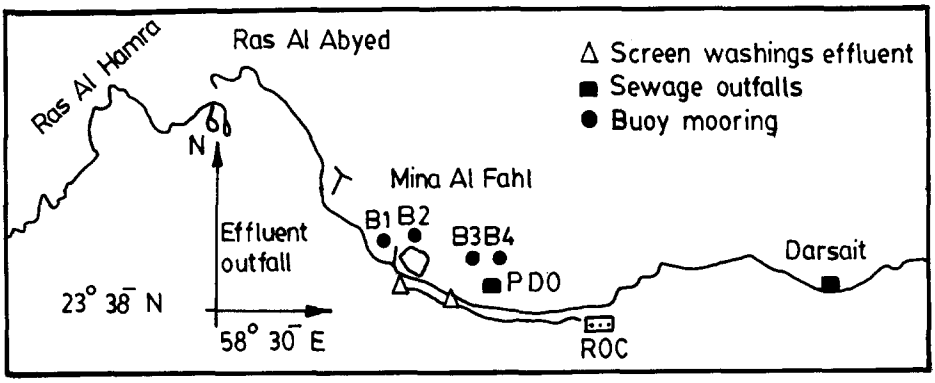

Figure 1. Schematic map showing locations of effluent outfalls.

sewage from the Mutrah residential area of 80,000 people. The final effluent water from these plants is used for irrigation of parks and roadside gardens. Approximately 6,000 m3/day of treated domestic waste from both STPs are discharged daily into the sea in the Mina al Fahal area. It contains 76 kg of solids, as well as 100 kg total organic load, 340 kg total inorganic load, 17.4 kg phosphate, 1.3 kg ammonia, 3.9 kg trace metals and traces of phenolic and petroleum hydrocarbon compounds (Table 1). These results demonstrate that the pollution problems from domestic treated wastewater are very limited. In the case of refinery effluent, however, about 80,000 m3/day of chlorinated wastewater from oil refinery cooling systems were discharged daily into the sea. It was estimated that as much as 3,280 kg of total inorganic load, 984 kg of organic load, 2,000 kg of solids, 0.6 kg of phenols, 384 kg of dissolved petroleum hydrocarbons and 245 kg of trace metals were discharged per day. Therefore, more emphasis should be given to the refinery effluent as far as pollution abatement is concerned.

A baseline study of the marine environment in the Mina al Fahal area was carried out in 1983 (Stanley et al. 1983). This study stated that the proposed effluent outfall discharge of the refinery above the low water mark would provide very poor dispersion. The increase in temperature of the cooling water combined with possible contaminants could have a signficant effect on organisms immediately around the discharge area; therefore, consideration should be given to extend the effluent pipe into deeper water.

The mean and average of the total suspended particulate (TSP)load, total lead and total hydrocarbons throughout the Mina al Fahal area are presented in Table 2. Data show that the average concentration of TSP during the period of study was 118.5 μg/m3. The lowest concentration of TSP was reported in January (72 μg/m3). Generally,TSP levels were lowest during January and February and began to increase until it reached the highest level in May. This finding may be related to the wind speed and rainfall rate. Wind speed during winter is 41 km/day from the mountains to the coastal zone, while it is 77 km/day during summer. The rainfall rate during winter is about 41 mm with an annual average of 3 mm throughout the year. A previous survey carried out by WHO in 1980 indicated that cities in countries with high rainfall have a much

Table 1. Range and mean concentration of some constituents in the Darsait sewage treatment plant (DSTP) , Petroleum Development of Oman sewage treatment plant (PDOSTP) and Oman Refinery sewage treatment plant (ORCSTP)

Constituent	Unit	DSTP		PDOSTP		ORCSTP	
		Range	Mean	Range	Mean	Range	Mean
pH	mg/L	6.2-7.1	6.8±0.4	7.6-8.3	8.0±0.2	6.6-8.3	7.5±0.6
TSS	mg/L	8.1-15.0	11.5±2.6	14.6-28.9	19.0±5.0	12.0-93.2	25.0±25.0
NH3-N	mg/L	0.1-0.2	0.13	4.3-9.0	7.0±1.7	NIL	NIL
P04	mg/L	0.3-4.3	2.9±1.5	0.6-3.0	1.7±1.1	NIL	NIL
BOD	mg/L	9.9-18.0	15.7±3.0	10.8-20.0	16.0± 3.2	6.1-20.0	12.3±6.0
COD	mg/L	30.0-82.8	56.7±19.9	35.2-70.7	46.5±13.0	33.0-70.7	41.0±12.0
THC	µg/L	0.9-24.8	17.2±4.3	1.4-39.0	31.3±12.0	11.4-153.1	47.4±39.3
Phenols	µg/L	2.5-12.7	7.4±3.2	1.2-6.0	4.0±2.7	1.2-15.0	6.8±4.8
Fe	µg/L	190.0-290.0	267.0±76.0	250.0-1380.0	480.0±450.0	250.0-2400.0	1070.0±870.0
Pb	µg/L	20.0-70.0	51.0±15.0	310.0-850.0	620.0±270.0	310.0-900.0	690.0±210.0
Cd	µg/L	28.0-120.0	42.0±34.0	NIL	NIL	NIL	NIL
Cu	µg/L	20.0-60.0	33.0±12.0	30.0-180.0	60.0±60.0	3.0-40.0	13.0±12.0
Ni	µg/L	50.0-110.0	82.0±38.0	310.0-1180.0	670.0±40.0	31.0-1230.0	73.0±41.0
Zn	µg/L	100.0-260.0	148.0±65.0	20.0-40.0	20.0±20.0	20.0-50.0	20.0±20.0

No . of samples=7

Table 2. Total suspended particulate, lead and total hydrocarbons in air samples collected from the Mina al Fahal area (μg/m3).

Date	No. of samples	TSP Mean	Lead Mean	THC Mean
1/1-31/1	26	72±28	0.22±0.10	0.27±0.08
7/2-28/2	24	85±39	0.12±0.04	0.24±0.06
2/3-31/3	23	90±23	0.15±0.13	0.30±0.11
1/4-30/4	24	117±34	0.25±0.09	0.32±0.18
1/5-30/5	24	208±144	0.39±0.13	0.16±0.04
1/6-30/6	24	139±51	0.21±0.11	—

- not analyzed

Table 3. Monthly dust (tons/km2), lead and total hydrocarbon (kg/km2) fallout in the Mina al Fahal coastal area.

Parameter	Jan.	Feb.	March	April	May	Mean
Dust	16. 4	8. 0	4. 2	4. 3	4. 1	7. 4
Lead	4. 8	5. 1	9. 2	5. 6	4. 8	5. 9
THC	6. 4	5. 4	7. 6	—	—	6. 5

-not analyzed

lower concentration of TSP in air than in dry countries where there is considerable dust in the air.

The concentration of TSP in air has been reported in several areas of the world. The annual average of TSP for Calcutta (India), Tehran (Iran) Kuwait and Baghdad (Iraq) were 400, 270, 500 and 505 μg/L, respectively (WHO 1980). The levels of TSP detected in the Mina al Fahal area were lower than in those reported areas, but were higher than the permissible limits and concentration detected throughout Los Angeles (EPA 1971; Gordon 1976).

Table 2 shows the levels of lead in air samples collected from the Mina al Fahal coastal area. The mean concentration of lead was 0.223 μg/m3 during the period of study (from January to June 1991). The lowest concentration was detected in February (0.12 μg/m3), while the highest was reported in May (0.39 μg/m3). When lead is emitted to the atmosphere it remains in the environment, i.e., it circulates both in ambient air and contaminates the soil and water by secondary deposition or fallout. Lead in the environment has been the subject of many investigations. EPA (1980) reported that the annual average of lead concentration in the USA in urban suspended particulate matter was as high as 7.5 μg/m3. Levels detected in Saudi Arabia ranged between 0.7 to 2.3 μg/m3 (Arab Bureau of Education for the Gulf States 1987), while in the present study the mean concentrations ranged between 0.12 to 0.39 μg/m3. These results

Table 4. Levels of polyaromatic hydrocarbons in air samples (ng/m3).

Compound	1/1/1991	14/1	2/2	13/2	1/3	27/3	Mean
Naphthalene	10.05	16.30	8.6	3.69	6.56	3.94	8.19
1-Methylnaphthalene	9.63	24.60	n.d.	5.3	9.42	9.50	9.7
1- Ethylnaphthalene	13.61	20.17	12.1	n.d.	9.74	24.36	13.3
Acenaphthalene	n.d.	n.d.	11.0	n.d.	4.73	6.46	3.7
Acenaphthene	n.d.	n.d.	22.5	n.d.	n.d.	24.16	7.8
2,3,6Trimethylnaphthalene	30.75	30.30	16.5	7.83	n.d.	n.d.	14.2
Fluorene	15.17	16.09	n.d.	8.63	56.98	12.82	18.3
Phenanthrene	18.77	n.d.	n.d.	55.50	99.00	99.68	45.5
Anthracene	94.88	56.19	54.42	41.50	105.32	113.49	77.63
2-Methylphenathrene	n.d.	n.d.	74.53	n.d.	89.51	106.74	45.4
1-Methylphenanthrene	96.00	n.d.	81.20	44.55	63.18	183.60	78.1
3,6-Dimethylphenanthrene	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Fluoranthene	n.d.	n.d.	54.42	56.25	68.75	56.25	37.8
Pyrene	n.d.	n.d.	32.02	37.50	39.10	43.36	25.3
Total	289.00	164.00	367.29	260.75	551.85	686.61	386.6

n. d. = not detected

indicate that the level of lead in the Mina al Fahal area was lower than levels reported in other world areas and less than the permissible limits, 1.5 ug/m3 (EPA 1977). Generally, lead level does not pose a threat to natural organisms. However, accumulation of lead from anthropogenic sources has caused some concern that lead may represent a potential long-term threat to both aquatic and terrestrial ecosystems.

The effect of atmospheric dust on the environment range from pollution of air to the possible impact on climate. The effects of dust on air quality have been discussed by many authors (Lauger and Mackler 1972; Bowes et al. 1977). Dust can also act as a carrier for various types of pollutants. The monthly amounts of dust fall-out per unit area throughout the Mina al Fahal area was calculated and listed in Table 3. The mean concentration was 7.4 tons/ km2. The highest concentration was detected in January, while the lowest level was reported in May. When a comparison was made with the level of dust fall-out detected in other Gulf areas, it was found that the level in Oman is lower than the rate detected in Saudi Arabia, Kuwait and Iraq (Linden et al. 1990). It was estimated that the quantities of 7.4 tons/ km2, 5.9 kg/km2, and 6.5 kg/km2 from dust, lead and THC, respectively, were received monthly in the Mina al Fahal coastal area.

The high volume air sampler was used to collect samples of airborne particulate matter throughout the Mina al Fahal area during the period from 1/1/1991 to 31/3/1991. The samples were extracted and analyzed for identification and determination of 16 PAHs. Benzo [a] pyrene, chrysene and 3,6-dimethylphenanthrene were not detected in any samples. The concentration of the total identified compounds was 386.6 ng/m3 (Table 4). It is evident that the levels of PAHs were subjected to considerable variation with respect to time of sampling. The highest concentration was detected in March (686.6 ng/m3), while the lowest level was in January 14 (164 ng/m3). Results in Table 4 demonstrate that the levels of PAHs in airborne particulate matter throughout the Mina al Fahal area were among the highest levels detected in other world areas (Gordon 1976).

Acknowledgments. The authors thank the authorities of the Ministry of Environment in the Sultanate of Oman for their support and facilities.

REFERENCES

Arab Bureau of Education for the Gulf States (1987) Proceedings Symposium on Environment and its Protection From Pollution in Arab Gulf States Organization P.O Box 3908 Riyodh 11484, Saudi Arabia

Bowes DD, Langer AM, Rohl AN (1977) Nature and range of mineral dusts in the environment. Royal Society of London, Philosophy Transaction Series A286: 593-610

EPA, US (1977) Air quality criteria. Environmental Protection Agency, Air Pollution Control Office, Washington DC 20460

EPA, US (1980) Lead in gasoline and its environmental effects and impacts. Field Operation and Support Division, Office of Mobile Sources. EPA, USA

Gordon RJ (1976) Distribution of airborne polycyclic aromatic hydrocarbons

throughout Los Angeles. Environ Sci Tech 10 : 370-373
Lantzy Ro, Mackenzie FT (1979) Atomospheric trace metals: global cycles and assessment of man's impact. Geochim Cosmochim Acta 43 : 511-525
Lauger MM and Mackler AD (1972) Mineral particles and human disease. In : Fairbridge RW (ed) Encyclopedia of Geochemistry and Environmental Science, Van Nostrand Reinhold, New York
Linden O, Abdulraheem MY, Gerges MA, Alam I, Behbehani M, Borhan MA, AL Kassab LF (1990) State of the marine environment in the ROPME sea area. UNEP Regional Seas Reports and Studies No. 112
Ponat A (1988) Effects of water soluble crude oil fractions on cirral beat frequency in Balanus balanoides. Bull Environ Contam Toxicol 41:759-764
ROPME (1984) Evaluation of the present situation on land-based sources of pollution within KAP member states. Report, Regional Organization for the Protection of the Marine Environment, 1984, P.O. Box 26388, AL-Safat, Kuwait: 280 pp
ROPME (1989) Manual of oceanographic observation and pollutant analysis methods. Regional Organization for the Protection of the Marine Environment, P . O . Box 26388, Al-Safat, Kuwait: 458 pp
Stanley SO, Edwards A, Stanley I, Duncan G, Gale A (1983) Survey for extension of cooling water outfall at Mina al Fahal. Oman Refinery Company, P.O.Box 551 Muscat, Oman
WHO (1976) Selected methods of measuring air pollutants. Publication NO 24, Geneva
WHO (1980) Air monitoring programme design for urban and industrial areas. WHO, Geneva: 200 pp

Received September 30, 1991; accepted June 15, 1992.