Application of “Mussel Watch” Concept in Preliminary Survey of Hydrocarbon in Coastal Waters in the Vicinity of Jeddah, Saudi Arabia

SAMEER J. GHAZI
Meteorology and Environmental Protection Administration (MEPA), Jeddah, Saudi Arabia

ABSTRACT. Locally available bivalve molluscs (the mussel Modiolus auriculatus and the clam Barbatia decussata) were analysed for their tissue hydrocarbon content in this survey, which comprised 10 sampling stations covering about 50 km of coastline north of Jeddah. The results have shown that there was a clear association of hydrocarbon content and its distribution with the degree of severity of impact following the grounding of the Indian tanker “Kanchenjunga” on the reef adjacent to the Jeddah Islamic Seaport Anchorage. On the whole, the spatial trends in petroleum hydrocarbon concentrations in the collected bivalves reflected the effects of selective retention and depuration of different hydrocarbon classes, following this major spill, as well as variation in sources of recently accumulated hydrocarbons. Comparison of data from the current survey with those reported for some of the published surveillance and monitoring studies of coastal areas from various regions, suggested that the coastal area in the vicinity of north Jeddah might be considered as relatively unpolluted.

Introduction and Objectives

The Saudi Arabian Red Sea Coast has been developed for industrial, commercial and residential uses. As a result, there is little doubt as to what the future holds for the coastal and marine resources of the Red Sea if steps are not taken for their protection to be an important consideration during further development. Activities like industrial and urban expansion, heavy oil tanker traffic together with occasional oil spills, land-filling operations, dredging, deballasting, the discharge of industrial and municipal effluents (concentrated between Jeddah and Yanbu), if uncontrolled, could easily have adverse effects on the marine environment of the Red Sea. However, the effects of prolonged human use of the coastal and marine environment of the Red Sea, such as those mentioned, could be greatly managed and controlled. To start with, specific regulatory steps could be taken to ensure that coastal and marine resources are managed on a sustainable basis. Hence, monitoring of chemical pollutants of the Red Sea is the initial step to ensure that safe marine environment can coexist with necessary human activities.

The most direct approach to regional monitoring programmes is the measurement of contaminants in marine biota. Bioaccumulation of pollutants in marine biota can occur from seawater, from suspended particles, from sediments and through food chains. The rate at which accumulation occurs in an organism depends not only on the availability of the pollutant but also on a whole range of biological, chemical and environmental factors (Bryan, 1979). Therefore, monitoring of such contaminants must be performed through the use of selected bioindicator species whose biology, biochemistry and contaminant uptake characteristics are well known. The bivalve molluscs, especially mussels, have generally been accepted as the most suitable organisms for monitoring such pollutants, because of their sedentary nature, ability to concentrate pollutants in their tissues, world-wide distribution and abundance, robustness and suitability for routine chemical analysis (Lee, 1976; Goldberg et al., 1978). In priority terms, mussels have been recommended by many as the most suitable bioaccumulators of trace contaminants from marine or estuarine waters, since mussels lend themselves well to such studies because of (1) their world-wide distribution and ready availability; (2) the considerable amount of physical baseline data available; (3) their hardness as an ex-
perimental test organism; (4) their convenient size, which is small enough to sample adequately for use in laboratory experiments but large enough for specific organ dissection; (5) their position in the intertidal ecosystem as a major pathway for energy transfer utilizing phytoplankton and detritus; and (6) their known capacity for concentrating various pollutants from their environment and their slower metabolism (Lee, 1976; Goldberger et al., 1978; Awad, 1979). Consequently, mussels have been widely used in monitoring programmes the so-called “International Mussel Watch” (NAS, 1980).

Thus the “Mussel Watch” concept, that is the utilization of sentinel organisms for monitoring the concentration of selected pollutants in coastal environments and as an indicator of their bioavailability, was utilized in the study to obtain a preliminary assessment of the level of hydrocarbons, from both petroleum and biogenic sources, in the coastal zone of Jeddah, Saudi Arabia. The aim of this preliminary survey is to establish the state and the usefulness of the bivalve molluscs locally common there in large-scale monitoring national programmes. Hence, it is possible to investigate the distribution of hydrocarbons and to identify possible “hot spots” in the coastal zone of Jeddah.

General Materials and Methods

Sampling and Shipboard Procedures

The area of Jeddah’s coastal waters under investigation and the sampling sites used shown in Fig. 1. This area extends for about 50 km from the beginning of the North Cove (in the south) to Khor Salman (in the north). Ten sampling sites were chosen as much as possible to provide adequate geographical covering of the study area. Two different bivalves were collected for this survey within a period of two weeks, from 2nd to 15th September, 1990. The mussel Modiolus auriculatus was collected at all sites except No.7, inside Sharm Qahir (Qahre Creek), where the clam Ruditapes decussatus was collected instead. From each station a sample consisted of at least 35 individuals were collected, except from site No. 7 where only 25 individual clams were collected. Once specimens were collected, the outside of the shell was rinsed and freed from adhering sand or debris in clean ambient seawater and then placed in a clean plastic container already containing ambient seawater. As soon as the collection was completed, the specimens were wrapped with three sheets of clean heavy duty aluminum foil, where the dull side of the foil was in contact with the sample. A paper label bearing the station number, location, date and time of collection was prepared using pencil and placed on the middle layer of foil. The outer foil sheet covered completely the inner package, and a second label was affixed to this sheet by tape. The aluminium foil package was placed in a polyethylene bag and the same information written on the paper label was written on it using a permanent marker pen. The polyethylene bag was placed in an insulated box containing carbon dioxide “ice.” Upon return from the field these bags were stored in a deep-freezer at −20°C.

In order to ship the samples from Jeddah to the laboratory in Swansea, U.K., the polyethylene bags were taken out of the deep-freeze, at a convenient time just before the departure of a suitable flight and placed in the insulated box surrounded by solid CO2 (“dry ice”). During the flight, the box was kept in the plane’s large refrigerator.

Tissue Extraction

The procedure which was carried out in this work was taken from Warner (1976) with some modifications. Mussel tissue injected with a mixture of aliphatic and aromatic hydrocarbon components and then extracted by this method gave greater than 92% recovery.

Mussels, which had been superficially cleaned and stored frozen, were first thawed. The whole mussels were shocked and the drained body was weighed; the shell and shell liquor were discarded. The body tissues, whose weight ranged from 5 to 10 g, were transferred into a 50 ml glass centrifuge tube with a Teflon-lined screw cap and homogenized by tissue-mixer (Ultra-Turrax, Janke & Kunkel) at about 12,000 rpm. Then the blade was washed with a little of 6 ml volume of 4N sodium hydroxide (which had been pre-cleaned twice with dichloromethane and a third time with n-hexane). The washed and rest of the 6 ml of sodium hydroxide was added to the centrifuge tube. One tube with 6 ml sodium hydroxide only was used as a reagent blank. Each tube was capped tightly and shaken vigorously by hand for at least 2 minutes, then placed in an oven at 30°C for 18 hours (overnight); again shaking thoroughly by hand for at least 1 minute from time to time. It was then cooled to room temperature and shaken vigorously for 30 seconds to check completeness of digestion. Fifteen ml of deionized water were added to each tube; the tubes were re-capped tightly and shaken for 1 minute. The tubes were then centrifuged at 300 rpm for 10 minutes. The clear upper phase (ether extract) was transferred, using a Pasteur pipette, to a 25 ml glass stoppered flask, avoiding any carry over of the lower aqueous phase. Anhydrous sodium sulphate (0.5 g) was added to each flask without agitation of swirling. The extraction was repeated with a further 10
ml of diethyl ether and the fresh extract added to the first one. The flasks were then stoppered tightly, swirled briefly and allowed to settle for 10-15 minutes. Then the ether extract was concentrated by rotary evaporator to about 2 ml. Two ml of n-hexane was added, followed by concentration to about 1 ml to remove ether completely. The 1 ml n-hexane was transferred to a pre-cleaned 3 ml vial.  

Silica Gel/Alumina Gel Chromatography  
Silica gel (100-200 mesh) and alumina activity grade I, neutral (70-240 mesh) were first activated by heating
in a glass beaker in an oven at 150°C for 18 hours. Sec-
ondly, they were partially de-activated by adding 5% v/ v distilled water (pre-washed with n-hexane 3 times) while they were still. They were well mixed with the water and left to equilibrate overnight, then stored in a desiccator and used within 1 week or less.

The column was prepared immediately prior to use by first pushing down a small piece of glass wool to plug the bottom of a 50 ml glass burette, using a long clean glass rod; fifteen ml of dichloromethane was then poured into the burette with its tap closed. Eight grams of prepared silica gel was weighed in a 50 ml beaker and 25 ml of dichloromethane were added, swirling vigorously to make a slurry. A small glass fun-
nel was placed into the column and the slurry poured quickly through the funnel, then washing in any re-
siduum material with more dichloromethane (about 5 ml). The absorbent particles settled quickly at the bot-
tom of the column. When the settling front extended upwards about 2 cm from the glass-wool, the stopcock was slowly opened to flow at a rate of 1-2 drops/second and the inside wall of the burette was washed down with more dichloromethane (about 5 ml). The silica gel was encouraged to settle by gentle tapping. The prepared alumina was then packed over the top of the silica, using the same procedure (for a 1 cm diameter column, 8 g of silica gel gives an absorbent bed as deep as the 12 ml calibration; the same weight of alumina adds a further 8 ml). Finally, a few grams of anhydrous sodium sulphate (enough to make x thin layer not more than 0.5 ml) were added through the funnel on top of the column and the inside wall was washed down again with dichloromethane (about 5 ml) to in-
corporate it into the column. The dichloromethane was drained until the solvent level lay just above the sodium sulphate layer. One ml of n-hexane was added, using a Pasteur pipette, and allowed to drain through. When the liquid level again almost reached the top of the sodium sulphate layer, 40 ml of n-hexane were added and elution continued until the solvent level was 0.5 ml above the top of the column. Then the stopcock was closed and eluent discarded.

Sample Chromatography and G.C. Sample Analysis

The sample extract, which was reduced to 1 ml in n-
hexane solution in a 3 ml vial, was carefully transfer-
red with a Pasteur pipette to the top of the silica gel/ alumina column and eluted into a 50 ml round-bottom flask. It should be taking into consideration that the liquid never fall below the upper surface of its column packing. The vial was rinsed with 1 ml of n-hexane, which was added to the column. The stopcock was then opened and the eluate collected in the 50 ml round-bottom flask. As soon as the liquid level nu-
tially reached the top of the column, the rest of 20 ml of n-hexane was carefully added without disturbing the upper surface of the material in the column. The eluted 20 ml n-hexane is referred to as fraction I (FI), which contains the saturated hydrocarbons (alpha-
tics). When the liquid again just reached the top of the column, 35 ml of 20% dichloroethane in n-hexane were added carefully and were eluted at 2.4 ml/min after the collecting flask was replaced with a second one. The 35 ml eluate is referred to as fraction II (FII) which contains the unsaturated and aromatic hydro-
carbons. Fractions I and II were concentrated by rotary evaporator to 0.5 ml and an internal standard solution (an appropriate amount of hexamethyl ben-
zeine C(CH3)6) was dissolved in n-hexane to give a con-
centration of 0.01 µg µl⁻¹) was added. The final vol-
ume depended on the type of oil and components of interest in G.C. analysis, was then transferred to a 3 ml prewashed vial. One to five µl of the mixture sample was then injected onto the column via the septum by means of an SGE fixed-needle syringe.

The following conditions were used for both frac-
tions:

Column: 2 m glass to metal seal
I.D.: 3 mm; O.D.: 6 mm
Liquid phase: Dexsil 300 G.C.
Support solid: Chromosorb G.C. (AW-DMCS)
(100-120 mesh)
Loading: 4%
Start temperature: 70°C
Programme delay: 3 min
Programme rate: 4°C/min
Final temperature: 280°C and hold for 10 minutes
Injector temperature 260°C
Detector temperature (FID): 300°C
Carrier gas flow (N2): 30 ml min⁻¹
Fuel (H2) flow: 30 ml min⁻¹
Air flow: 300-400 ml min⁻¹
Chart speed: 300 mm hr⁻¹; (5 ml min⁻¹)
G.C. Range: 2 x 30
Attenuation: 16

Results

The concentration of individual detected n-alkanes in bivalve tissue lay in the range 0.0003 µg g⁻¹ C-19 at station No. 2 to 1.4560 µg g⁻¹ C-26 at station No. 7 weight (see Table 1). Those showing a distinctively high tissue content were C-21, C-17, C-15, C-26 and C-28, whilst those with the least tissue content were C-22, C-19, C-20, C-18 and C-16. On the other hand, the range of individual detected aromatic hy-
drocarbons in the tissues lay between 0.0002 µg g⁻¹ of dibenzothiophene at station No. 8 to 0.5082 µg g⁻¹.
diphenylphenanthrene at station No. 3 wet weight (see Table 2). Unsurprisingly, aromatic compounds with two and three rings were dominant in the tissues of almost all the bivalves collected.

Data represented in Table 3 indicate that the range for total hydrocarbon (Ft + FI) tissue content lay between 0.67 at station No. 4 and 5.68 µg g⁻¹ at station No. 1 wet weight, with an average content of 2.49 µg g⁻¹. The total aliphatic fraction (FI) was higher than the corresponding aromatic fraction (Ft) in all bivalves collected, with the exception of mussels collected at Station No. 4; it ranged from 0.30 µg g⁻¹ at station No. 1 to 4.06 µg g⁻¹ at station No. 3, with an average content of 1.70 µg g⁻¹ wet weight. In the case of total aromatic (Ft) tissue content, the range was between 0.34 µg g⁻¹ at Station No. 2 to 1.69 µg g⁻¹ at Station No. 1, with an average content of 0.78 µg g⁻¹ wet weight.

Chromatograms of the aliphatic fractions (FI) from tissue extracts of collected bivalves (see Fig. 2) displayed almost the same pattern. This pattern is characterized by the same range of chain length (from C-15 to C-30); the presence of major peaks, which appear to be for C-24, C-17, C-15 and occasionally C-26 to C-28; the presence of a distinctive unidentified peak or peaks, was arising between C-20 and C-22; and also was rising above the rest of the peaks, all in almost all the chromatograms; the presence of a smooth peak distribution in the range C-22 and C-30, with an exception in the chromatograms of the aliphatic fraction from tissue extracts of bivalves collected from Station Nos. 6 and 7; and the absence of C-16 from almost all the chromatograms. An Unresolved Complex Mixture (UCM) envelope is typical of the chromatograms of the aliphatic fraction (FI) from tissue extracts of the bivalves collected from the first six samplings stations: in the rest of the chromatograms, the UCM envelope developed clearly beneath alkanes peaks from around C-17 to the end of the chromatograms.

| Station | FI | Ft | C-15 | C-16 | C-17 | C-18 | C-19 | C-20 | C-21 | C-22 | C-23 | C-24 | C-25 | C-26 | C-27 | C-28 | C-29 | C-30 |
|---------|----|----|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
|         |    |    | 0.097| 0.078| 0.073| 0.060| 0.045| 0.039| 0.031| 0.026| 0.022| 0.020| 0.018| 0.016| 0.014| 0.012| 0.010| 0.008| 0.006|
|         |    |    | 0.084| 0.082| 0.080| 0.078| 0.076| 0.074| 0.072| 0.070| 0.068| 0.066| 0.064| 0.062| 0.060| 0.058| 0.056| 0.054| 0.052|
|         |    |    | 0.055| 0.052| 0.050| 0.048| 0.046| 0.044| 0.042| 0.040| 0.038| 0.036| 0.034| 0.032| 0.030| 0.028| 0.026| 0.024| 0.022|
|         |    |    | 0.022| 0.020| 0.018| 0.016| 0.014| 0.012| 0.010| 0.008| 0.006| 0.004| 0.002| 0.000| 0.000| 0.000| 0.000| 0.000| 0.000|
|         |    |    | 0.121| 0.109| 0.098| 0.086| 0.075| 0.064| 0.053| 0.042| 0.031| 0.020| 0.010| 0.000| 0.000| 0.000| 0.000| 0.000| 0.000|
|         |    |    | 0.452| 0.395| 0.339| 0.282| 0.225| 0.168| 0.111| 0.054| 0.000| 0.000| 0.000| 0.000| 0.000| 0.000| 0.000| 0.000| 0.000|
|         |    |    | 0.766| 0.684| 0.599| 0.518| 0.437| 0.356| 0.275| 0.195| 0.115| 0.035| 0.015| 0.000| 0.000| 0.000| 0.000| 0.000| 0.000|

* Concentrations expressed as mean ± standard deviation. **: *<br>***: *<br>****: *<br>*****: *<br>******: *<br>*******: *<br>********: *<br>*********: *<br>**********: *<br>***********: *<br>************: *<br>*************: *<br>**************: *<br>***************: *<br>****************: *<br>***************: *<br>*****************: *<br>******************: *<br>*******************: *<br>********************: *<br>*********************: *<br>**********************: *<br>***********************: *<br>************************: *<br>***********************: *<br>*************************: *<br>**************************: *<br>***************************: *<br>****************************: *<br>***********************: *<br>***********************: *<br>***********************: *<br>***********************: *<br>***********************: *<br>***********************: *<br>***********************: *<br>***********************: *<br>***********************: *<br>***********************: *<br>***********************: *<br>***********************: *<br>***********************: *<br>***********************: *<br>***********************: *<br>***********************: *<br>***********************: *<br>***********************: *<br>***********************: *<br>***********************: *<br>***********************: *<br>***********************: *<br>***********************: *<br>***********************: *<br>***********************: *<br>***********************: *<br>***********************: *<br>***********************: *<br>***********************: *<br>***********************: *<br>***********************: *<br>***********************: *<br>***********************: *<br>***********************: *<br>***********************: *<br>***********************: *<br>***********************: *<br>***********************: *<br>***********************: *<br>***********************: *<br>***********************: *<br>***********************: *<br>***********************: *<br>***********************: *<br>***********************: *<br>***********************: *<br>***********************: *<br>***********************: *<br>***********************: *<br>***********************: *<br>***********************: *<br>***********************: *<br>***********************: *<br>***********************: *<br>***********************: *<br>***********************: *<br>***********************: *<br>***********************: *<br>***********************: *<br>***********************: *<br>***********************: *<br>***********************: *<br>***********************: *<br>***********************: *<br>***********************: *<br>***********************: *<br>***********************: *<br>***********************: *<br>***********************: *<br>***********************: *<br>***********************: *<br>***********************: *<br>***********************: *<br>***********************: *<br>***********************: *<br>**************
### Table 2. Aromatic (FII) content, in µg g⁻¹ (wet weight), of mussels, *Modiolus aurantiacus* and clams, *RHUSA DRUSA* 2 from the vicinity of Jeddah, Saudi Arabia.

<table>
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<th>Sample</th>
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<th>&quot;FII&quot;</th>
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* = Concentrations expressed as mean ± standard deviation (n = 4 for Station No. 1 & 2, n = 3 for Station No. 3 & 4, each consisting of 5 individuals).

### Table 3. Hydrocarbon (FII + FIII) content, in µg g⁻¹ (wet weight), of mussels, *Modiolus aurantiacus* and clams, *RHUSA DRUSA* 2 from the vicinity of Jeddah, Saudi Arabia.

<table>
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<th>4</th>
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<th>8</th>
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<td>NO</td>
<td>NO</td>
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<tr>
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<td>NO</td>
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</table>

* = Concentrations expressed as mean ± standard deviation (n = 4 for Station No. 1 & 2, n = 3 for Station No. 3 & 4, each consisting of 5 individuals).
Fig. 2. Chromatograms of the aliphatic fractions (F) from tissues extracts of the collected bivalves.
Chromatograms of the aromatic fractions (FII) from tissue extracts of the collected bivalves (see Fig. 3) display almost the same pattern, characterized by the same range of aromatic carbon number; the abundance of fluorene, 2-methyl phenanthrene and 3,6-dimethyl phenanthrene peaks; and the predominance of 3,6-dimethyl phenanthrene peak, at in almost all the chromatograms. A UCM envelope is unrecognizable in the chromatograms of the aromatic fraction from tissue extracts of the bivalves collected from the first six sampling stations (going from north to south), and it is not very apparent in the chromatograms from bivalves collected from Station Nos. 8-10, but it is clearly developed in those from extracts of clams collected from Station No. 7.

Discussion

The ranges for total hydrocarbon (F1 + FII) and aliphatic (FII) content in the present survey were shorter than the corresponding ranges reported in some of the published surveillance and monitoring studies of coastal areas from various regions (see Table 4). Furthermore, the least mussel content of total hydrocarbons (F1 + FII) and aliphatic hydrocarbons (FII) found in the present survey were still less than their corresponding content in Table 4, excluding data reported in the table as "not tested." Observed hydrocarbon (F1 + FII) content and aliphatic (FII) content in the clams, collected at only one station, in the present survey were compatible with the minimum content reported in clams as shown in Table 4, with the exception of the minimum for clams collected from Port Valdez, Alaska, U.S.A. in the year 1981 (Shaw et al., 1980). Nevertheless, the calculated average of total hydrocarbon content and total aliphatic content for the current survey (1.49 µg g⁻¹ and 1.70 µg g⁻¹ wet weight, respectively) were less than the lowest average of total hydrocarbon and aliphatic content amongst the studies reported in Table 4 (6.24 µg g⁻¹ wet weight by Singh et al. 1992, and 5.26 µg g⁻¹ wet weight by Law and Andrulewicz, 1983). The average of the aromatic (FII) content in the present survey (0.78 µg g⁻¹ wet weight) is relatively equivalent to the lowest average for aromatic content (0.205 µg g⁻¹ wet weight in mussels and clams (Law and Andrulewicz, 1983). Comparison between the highest tissue content observed in the present survey and data for tissue content reported in Table 4 indicates that even the highest value (i.e., for total hydrocarbon content, aliphatic content and aromatic content) in the present survey lies between the range of minimum concentrations in bivalves collected from various regions. Accordingly, the coastal area in the vicinity of north Jeddah, Saudi Arabia, might in this sense be considered as less polluted in comparison with similar areas mentioned in Table 4.

The content of identified n-alkanes in mussels during the current survey, which ranged between 0.33 and 0.54 µg g⁻¹ wet weight with an average of 0.33 µg g⁻¹, was less than the recorded level of n-alkanes in mussels from clean and urban sites in Scotland, U.K.; both sites gave mean values of 3 µg g⁻¹ wet weight, with ranges of 0.9 to 7.1 and 0.4 to 5.7, respectively (Mackie et al., 1980). These values were more closely equivalent to the content in mussels from the Monterey Bay area of central California, U.S.A., which ranged from 0.13 to 0.71 µg g⁻¹ wet weight with an average of 0.27 µg g⁻¹, which is suggested to be generally low (Martin & Castle, 1984). Similarly, the content of identified n-alkanes from clams collected in the present survey was at least less than the higher values recorded in mussels from Scotland. In the case of the content of identified aromatic hydrocarbons in the bivalves collected during the current survey, the average content (0.22 µg g⁻¹ wet weight) was equal to the average content of PAHs in mussels collected from urban areas in Scotland, U.K., but the range of this content (0.05-0.62 µg g⁻¹ wet weight) overlapped the range of the clean and urban sites (0.06-0.14 and 0.11-0.36 µg g⁻¹ wet weight) and extended to include small portions of the range of PAHs in mussels collected from industrial sites (0.26-2.80 µg g⁻¹ wet weight, Mackie et al., 1980). Nevertheless, the average content of total identified aromatics in the current survey is almost equal to the corresponding average in mussels from remote sites across Yaquina Bay Oregon, U.S.A. (i.e., 0.27 µg g⁻¹ wet weight (Mix & Schaffer, 1983a).

The findings were more complex than can be explained by distance from suspected sources alone. However, hydrocarbon content (total hydrocarbon content (F1 + FII, aliphatic (FII) and aromatic (FII) content)) and its spatial distribution showed an unexpectedly clear association with the degree of oiling severity after the Simula clean-up operation of the impacted shoreline following the grounding of the Indian tanker (Kanchenjunga) on the reef adjacent to Jeddah Islamic Seaport anchorage (MEPA, 1989). Thus, the observed variations on hydrocarbon content between stations probably reflect differences in deposition rates of accumulated hydrocarbons following this major spill and are also possibly related to biological variation in accumulation from chronic exposure. For example, the high content in bivalves collected at Stations No. 1, 3 and 7, in comparison to other stations, may reflect small inputs of petrolum hydrocarbons from the fishing boats of nearby coastal villages or from leisure boats and other small crafts or yachts.
<table>
<thead>
<tr>
<th>Species</th>
<th>Location</th>
<th>Hydrocarbon analysed</th>
<th>Hydrocarbon concentration (wt. %)</th>
<th>Method of analysis</th>
<th>Reference</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mysidops rostratus</td>
<td>Venice, Italy (ligurian)</td>
<td>Aliphatics</td>
<td>0.8-0.17</td>
<td>GC</td>
<td>Geller &amp; Lucas (1974)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Miebina rostrata</td>
<td>San Francisco Bay, California, USA</td>
<td>Aliphatics</td>
<td>1.2-6.6*</td>
<td>TLC, TLC</td>
<td>Dunbabin (1978)</td>
<td>x = 2.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>11.5-30.1*</td>
<td></td>
<td></td>
<td>x = 8.8</td>
</tr>
<tr>
<td>Miebina rostrata</td>
<td>East of the entrance of the Kiel Fjord, Germany</td>
<td>Aliphatics</td>
<td>3 (0.7)</td>
<td>GC/MS, GC/MS, GC/MS</td>
<td>Orthrader &amp; Hummert (1975)</td>
<td>in April 1973</td>
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<td></td>
<td></td>
<td></td>
<td>0.8-10.8</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Miebina rostrata</td>
<td>Coastal areas around England</td>
<td>Total hydrocarbons</td>
<td>0.3-1.50</td>
<td>UV</td>
<td>Murray &amp; Lane (1978)</td>
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</tr>
<tr>
<td>Miebina rostrata</td>
<td>Around the Scottish coast</td>
<td>n-Alkanes</td>
<td>0.8-4.10</td>
<td>GC/MS, GC/MS, GC/MS</td>
<td>Mackie (1988)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>n-Alkanes</td>
<td>0.4-5.7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total/PAnes</td>
<td>0.12-0.13</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total/PAnes</td>
<td>0.24-2.40</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Miebina rostrata</td>
<td>Spanish / Western Mediterranean Sea</td>
<td>Aliphatics</td>
<td>1.6-54.2*</td>
<td>GC, GC</td>
<td>Albargues et al. (1982)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.2-14.9*</td>
<td></td>
<td></td>
<td>x = 39.4</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>2.2-17.7*</td>
<td></td>
<td></td>
<td>x = 31.92</td>
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<td>Miebina rostrata</td>
<td>Port Phillip, Australia</td>
<td>Total hydrocarbons</td>
<td>0.8-36.9*</td>
<td>GC</td>
<td>Hart &amp; Smith (1980)</td>
<td></td>
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<tr>
<td>Miebina rostrata</td>
<td>Southern Baja Sea</td>
<td>Aliphatics</td>
<td>2.3-3.74</td>
<td>GC/MS, GC/MS, FS</td>
<td>Low &amp; Aldrich (1983)</td>
<td>x = 0.56</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>0.12-0.31</td>
<td></td>
<td></td>
<td>x = 0.25</td>
</tr>
<tr>
<td>Miebina rostrata</td>
<td>Yaquina Bay, Oregon, USA</td>
<td>Total PAnes</td>
<td>0.274-0.808</td>
<td>HPLC</td>
<td>Mo &amp; Schaeffer (2006)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>average conc. from female sites/industrial footprint</td>
<td></td>
</tr>
<tr>
<td>Miebina rostrata</td>
<td>Algoa Bay, Central California, USA</td>
<td>Aliphatics</td>
<td>0.02-0.32</td>
<td>GC</td>
<td>Martin &amp; Cauda (1984)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>x = 0.78</td>
</tr>
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<td></td>
<td></td>
<td></td>
<td>x = 7.67</td>
</tr>
<tr>
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<td></td>
<td></td>
<td></td>
<td>x = 7.75</td>
</tr>
<tr>
<td>Miebina rostrata</td>
<td>Finnish Archipelago Sea</td>
<td>Total PAnes</td>
<td>0.055-0.110</td>
<td>GC/MS</td>
<td>Hansell (1986)</td>
<td>x = 0.102</td>
</tr>
<tr>
<td>Miebina rostrata</td>
<td>Port Valdez, Alaska, USA</td>
<td>Total hydrocarbons</td>
<td>0.4-4.8*</td>
<td>GC/MS</td>
<td>Meys &amp; Dyer (1978)</td>
<td>x = 16.5 (1900)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>24.1-25.8*</td>
<td></td>
<td></td>
<td>x = 71 (1920)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>24.1-173.5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Miebina rostrata</td>
<td>The vicinity of North Sea, central at Sullom, Voe, Shetland, UK</td>
<td>Total PAnes</td>
<td>0.80-1.65</td>
<td>HPLC</td>
<td>Wild &amp; Donald (1987)</td>
<td>x = 60</td>
</tr>
<tr>
<td>Miebina rostrata</td>
<td>Around the Cape peninsula, South Africa</td>
<td>Total hydrocarbons</td>
<td>2.27*</td>
<td>FS</td>
<td>Marsee (1990)</td>
<td></td>
</tr>
<tr>
<td>Miebina rostrata</td>
<td>Spanish Atlantic coast (Galicia)</td>
<td>Aliphatics</td>
<td>0.12-2.96*</td>
<td>GC, GC</td>
<td>Sánchez et al. (1989)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.6-1.96*</td>
<td></td>
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<td>x = 70 (0)</td>
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<td></td>
<td></td>
<td></td>
<td>x = 16.34</td>
</tr>
</tbody>
</table>

x = 32.80, y have been recorded.
<table>
<thead>
<tr>
<th>Species</th>
<th>Location</th>
<th>Hydorcarbon analyzed</th>
<th>Hydrocarbon extraction yield</th>
<th>Method of analysis</th>
<th>Reference</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mussels</td>
<td>Tyrrital West Indies</td>
<td>Total Hydrocarbons</td>
<td>3.2% of wet weight</td>
<td>FS</td>
<td>Voight et al. (1982)</td>
<td>S = 0.34</td>
</tr>
<tr>
<td>Clams</td>
<td>Nautoncoast Bay, Mex.</td>
<td>Total Hydrocarbons</td>
<td>5% of wet weight</td>
<td>GC</td>
<td>Yeung &amp; Dein (1973)</td>
<td>S = 0.44</td>
</tr>
<tr>
<td>Vines gallesia</td>
<td>Spanish River, Mexico</td>
<td>Aliphatic Aromatics</td>
<td>Total Hydrocarbons 75.6%</td>
<td>GC</td>
<td>Abreu et al. (1982)</td>
<td></td>
</tr>
<tr>
<td>Marine life</td>
<td>Crete, Greece, USA</td>
<td>Total Hydrocarbons</td>
<td>0.8% of dry weight</td>
<td>HPLC</td>
<td>Apoil &amp; Schaffer (1987)</td>
<td>S = 0.34</td>
</tr>
<tr>
<td>Marvelous life</td>
<td>Port Valdez, Alaska, USA</td>
<td>Total Hydrocarbons</td>
<td>18.2% of dry weight</td>
<td>GC</td>
<td>Jee et al. (1984)</td>
<td>in 20% tetrachloroethane 10% acetone in HPLC</td>
</tr>
</tbody>
</table>

Notes: Extraction yield = weight of hydrocarbons / weight of fish. GC = gas chromatography; UC = ultracentrifugation; UV = ultraviolet spectrometry; MS = mass spectrometry; IN = infrared spectrometry; HPLC = high pressure liquid chromatography; GLC = gas chromatography.

Based on the data provided, it is relatively easy to make significant general observations on the relationships between hydrocarbon content and suspected inputs. These results are much more difficult to ascribe to a likely source because the suite of alkanes and aromatic hydrocarbons actually recorded, a problem which will be discussed below.

It was assumed that the use of different species (i.e., mussel and clam) during this survey would not have any significant effect on the interpretation of results, because almost all the samples taken were mussels. However, the possible differences in tissue hydrocarbon uptake between the two species must be taken into account to permit valid comparisons between sites, since rates of uptake differ between species and appear to be related to differences in filtering rates, lipid content and perhaps also differences in metabolic activity (Lee et al., 1977 and Broman & Ganning, 1980).

Data from the present survey indicate that the content of mussels and aromatic hydrocarbons do not correlate. This is not surprising since the former in- cludes both anthropogenic and biogenic sources (Solet et al., 1989) besides, there are marked differences in the relative abundance of those two groups of compounds in petroleum and fossil-fuel combustion products (Farrington et al., 1985). It is well known that hydrocarbons are polluting the coastal areas by both biogenic and anthropogenic sources. The task of determining the source of hydrocarbons is environmental samples, as in the current survey, is often difficult due to the multiplicity of sources that might be present due to the potential interference of suspected environmental modification of source materials (NAS, 1985).

Like other filter-feeding organisms, mussels may be expected to ingest biogenic as well as pollutant hydrocarbons, concentrating them in body tissue; such biogenic hydrocarbons should show a relationship with the mussels' diet, since a wide variety of hydrocarbon distributions are found in marine organisms (Clark & Blumer, 1967, Blumer et al., 1971, Youngblood et al., 1971, Youngblood & Blumer, 1973)). N-alkanes in organisms often exhibit a characteristic predominance of odd-numbered homologues over even number ones (Youngblood & Blumer, 1973), with the possible exception of the C22-23 alkane peak at low concentrations in marine bacteria (Haw & Calvin, 1969). Marine phytoplankton and algae are characterized by predominating n-alkanes at C15, C17, C19 and C21, while in zooplankton, the presence of C19 and C20 branched alkanes and alkenes have been recorded (Clark & Blumer, 1967, Blumer et al., 1973). From the limited number of studies of biogenic hydrocarbons in mussels reported, a very few generalizations can be made. Lee et al. (1972) referred to a series of straight and branched chain hydrocarbons (C16-C26) in Mytilus edulis, the major components being pristan (C21, 10, 14-tetramethyl pentadecane), eicosane (C20:1) and heneicosahexane (C21:6). Ehrhardt and Heneinmann (1975) reported n-heptadecane (C-17), pristanate, C21 to C24 mono-, tri- and tetracenes and a C25 tetracene.
rane of presume biological origin in *Mytilus edulis* species from Kiel Bight, USA. Also, several alkenes of unknown structure eluting on GC between C-20 and C-22 have been found in mussels from the Cape Cod Canal, Massachusetts, U.S.A. (NAS, 1980) and substantial amounts of biogenic pristane have been noted in mussels from Alaska (Wise et al., 1980). It seems likely that the pristane content of mussels may well show a seasonal variation and that may be related to changes in zooplankton abundance (Ehrenfeld & Heinemann, 1975; Rowland & Volkmann, 1982). Tibbet et al. (1982) observed, in an investigation of the source of aliphatic hydrocarbons in mussels from North Sea oil production platforms, that C-18, C-20 and C-22 n-alkanes are present in some of the mussels in unusually high abundance compared with their odd carbon number homologues. They hypothesized that the reason for this distribution may be the result of ingestion of algal detritus, perhaps bacterially degraded in the water column, or a direct contribution of bacterioid lipids.

In the current survey, biogenic aliphatic hydrocarbons are present in almost all of the chromatograms of the aliphatic fraction. For example, most are characterized by predominance n-alkanes at C-19, C-17 and C-21, occasionally along with C-26 to C-28; also, the presence of a distinctive unidentified peak or peaks arising between C-20 and C-22 is presumed to be of isoprenoid alkanes. The n-alkane C-16, which is rarely found in biolipids (Thompson & Eglington, 1978), is absent from almost all of the chromatograms. The smooth distribution of n-alkanes in the range C-22 to C-30, observed in almost all the chromatograms of the aliphatic fraction from extracts of the mussels collected (Fig. 2, 3), They also reported in marine bacteria (Han & Calvin, 1969). The single specimen of the clam *Barbula decussata* showed, in addition to the pattern mentioned above, a significant predominance of a group of n-alkanes ranging from C-26 to about C-31 (especially C-26) suggesting possible bacterial contamination (Shaw & Wiggs, 1980). Nevertheless, biogenic inputs are often indicated by the predominance of a single isoprenoid, usually pristane, which is close to the C-17 peak. This branched aliphatic hydrocarbon is a common constituent of mineral oils, but also occurs quite frequently in marine organisms (Avigan & Blumer, 1968). On the other hand, phytane (2, 6, 19, 14-tetramethylhexadecane), which elutes close to the C-18 peak, has not been found so far as a natural component of marine organisms. The ratio of pristane to phytane is a useful indication of hydrocarbon sources, but unfortunately the column used in this study was unable to separate C-17 from pristane or C-18 from phytane as individual peaks, making it impossible to confirm the source of the accumulated hydrocarbons.

A typical low UCM envelope was observed in chromatograms of the aliphatic fraction (FI) from tissue extracts of the bivalves collected from the first six sampling stations (running north to south), while a well-developed one is present in the remainder of the chromatograms, underlying the n-alkanes from near C-17 to the end. This unresolved ‘hump’ has been described by others (Risberg et al., 1983) as representing a complex mixture of hydrocarbons, principally of petroleum origin, and higher concentrations of hydrocarbons in the UCM enveloped are generally thought to reflect petroleum contamination (Farthing et al., 1983). Thus the UCM envelope is a characteristic GC feature of some fresh oils and most weathered oils. As weathering proceeds and resolved components decrease in concentration, the UCM becomes more prominent. Burwood and Speers (1974) observed an increase in UCM content of samples as photo-oxidation proceeded. Additionally, most non-spill-related environmental samples containing anthropogenic inputs and many geochemical samples contain UCM material (NAS, 1985). The shape of the UCM envelope and its molecular weight range can provide information on the nature of the contaminant oil (Clark & Finley, 1973).

The sum of identified n-alkanes shows patterns which quantitatively do not quite correspond to the UCM profile of the aliphatic (FI) chromatograms. This suggests that the distribution of hydrocarbons through stations is determined by both the temporal variation in hydrocarbon input rate and by the bivalves’ ability to discharge contaminants. Thus, among factors influencing their depuration rate, two stand out: first, lower molecular weight and more soluble compounds are discharged more rapidly. Second, animals exposed to petroleum deplete rapidly to low residual concentrations while chronically exposed animals deplete slowly and have higher residual concentrations which are lost very slowly, if at all (Farthing et al., 1982a). In other words, mussels containing relatively less of the normal alkanes and more UCM are under chronic exposure conditions within the study areas (located at sites with a relatively high human population). This pattern (with the sum of identified n-alkanes not quite corresponding quantitatively to the UCM profile of chromatograms of the aliphatic fraction) probably reflects a very low depuration of high residual concentrations, while the total of n-alkanes at all sites represents the fluctuation in levels of biogenic hydrocarbons.

Generally, the findings of the present survey indi-
cate mainly the presence of naturally occurring aliphatic hydrocarbons, with a contribution from weathered oils as indicated by the presence of a distinct UCM envelope in bivalve samples from close to urban areas. The concentration of these naturally occurring hydrocarbons, which seem to control the level of total of hydrocarbons, varies from station to station, reflecting a fluctuation in biogenic input. Nevertheless, analysis of aliphatic hydrocarbons in organics may not always be the best method for detecting petroleum pollution in the aquatic environment since, under environmental equilibrium conditions, low-level persistent petroleum pollutants may be difficult to detect when the rate of biological degradation of ρ-alkanes is equivalent to the rate of pollutant input (Clark and Finley, 1973). Further differentiation between sources of pollutants requires the collection of ciliate bivalves from uncontaminated offshore areas. This should be tried but, unfortunately, neither of the species collected in the present survey has been found on any of the remote islands which were visited and they do not occur deeply sublittoral.

The aromatic hydrocarbons or effectively, the PAHs offer another indication of hydrocarbon pollution in coastal areas. Although PAHs are produced by natural processes, a wide variety of human activities increases the environmental load of these substances (Neff, 1979). Such activities include incineration of industrial and domestic wastes, forest and grass fires, power generation from fossil fuels and the use of fuels in internal combustion engines. These anthropogenic PAHs may reach the aquatic environment in industrial and domestic sewage effluents, surface runoff from land, deposition of airborne particulates and spillage of petroleum or its products into water bodies (Neff, 1979). Consequently, the relative abundance of individual aromatic hydrocarbons or specific groups of them can be of interest as a means of providing information on what may be major sources of these hydrocarbons within the bivalves. The degree of alkylation within a homologous series of PAHs is the main characteristic that permits the differentiation of combustion-related inputs from fresh and weathered petroleum (Hies and Beiman, 1975; Youngblood & Blumer, 1975; Blumer, 1976; Lee et al., 1977). Alkylated PAHs (e.g., C-1 and C-2-phenanthrenes) are usually abundant in petroleum sources, whereas the unsubstituted PAH (e.g., parent phenanthrene) are produced by combustion and pyrolysis sources. In addition, combustion sources contain relatively low quantities of 2-alkyl PAH (e.g., naphthalenes). Thus, the relative inputs of petroleum and combustion sources can be discerned, in some cases, from alky homologue distribution plots of 2- to 5-ringed aromatic hydrocarbons (Boehm, 1983). In most cases where concentrations of aromatic hydrocarbons are present in bivalves the distribution of phenanthrenes, together with fluoranthene, pyrene and also chrysene, indicates a pyrogenic source for many of them. In spite of this, alkylated PAHs present in small quantities in dibenzoanthopinanes are sometimes the prominent aromatic components of weathered petroleum (Berhow et al., 1983).

Results from the present survey indicate that PAHs with two and three rings dominate the tissue content of almost all the bivalves collected, with fluorene, 2-methyl and 3,6-dimethyl phenanthrenes being the most abundant components present and the latter being the most prominent at almost all sampling stations (Tables 1, 2, 3). Nevertheless, the PAH chrysene (4 rings) showed a significant contribution when it occurred. GC analysis also reveals that the UCM envelope is either unrecognizable (as in the first six stations), or inexplicit (as in the last three stations), but developed clearly in the chromatogram of the aromatic fraction from the tissue extract of clams collected from Station No. 7. It is not surprising that PAH with two and three rings are dominant in the current survey, since other researchers (e.g., Farrington et al., 1982a, b; Mix & Schaffer, 1983a, b; Mason, 1988) observed that their UCM fractions had a composition similar to that of the synthetic standard, they therefore concluded that the components present in mussel tissue exposed to chronic hydrocarbon contamination are mostly 2- and 3-ring compounds and that the heavier PAH are present only in small concentrations. Mason (1988) added that the presence of heavier compounds would indicate that the contamination includes undissolved petroleum hydrocarbons in the form of particulates, oil slicks or films. However, the pre-eminence of phenanthrenes was expected, since they are the most abundant aromatic constituents of weathered oils (Farrington et al., 1982a, b; Mix & Schaffer, 1983a, b; Chorn, 1988). Viewing these findings in the light of what was said earlier regarding the characteristics of hydrocarbons from combustion-related sources and petrogenic sources, it seems likely that the accumulated PAH may reflect weathered petroleum. However, it is also possible that airborne particulate matter, which has been shown to contain large amounts of chrysene relative to pyrene (Van Vaeck & Van Cauwenberge, 1978) could be another source of some of the accumulated hydrocarbons in the bivalves collected, although the inexplicit appearance of the UCM envelope in chromatograms of aromatic fractions suggests an ultimate depuration of acute exposure.

The well-developed UCM envelope appertaining
chromatograms of aromatic fraction from tissue ex-
tracts of the clams collected at Station No. 7 may re-
fect, in part, differences in depuration rates between
the two species, but is more probably related to low
chronic exposure. On the whole, comparison of PAH
profiles for source identification should be carried out
with caution, since selective uptake and depuration of
various hydrocarbon structures by bivalves have been
noted by Vaughan, 1973; Neff et al., 1976 and Lee et al.,
1978 in addition to the absence of information
about inputs in the different locations.

Conclusions

Data from the current survey indicate that the aver-
age of hydrocarbon concentration in the collected
bivalves from the coastal water of Jeddah, Saudi
Arabia is less and the range narrower than those re-
ported for some of the published surveillance and
monitoring studies of coastal areas from various reg-
ions of the world. Furthermore, this comparison
showed that the highest tissue content recorded in the
present survey lies around the minimum concen-
tration in bivalves collected from elsewhere. Accord-
ingly, the coastal area in the vicinity north of Jeddah,
might in this sense be considered as relatively less pol-
luted. However, it should be borne in mind that the
current survey is restricted to ten sampling stations
covering about 50 km of coastline which does not re-
cieve a significant input from the main sources of pol-
ution, such as domestic sewage and refinery effluent
which discharge from central or south of Jeddah.
Despite the narrow range of hydrocarbon content re-
corded at these stations, there are significant differ-
ences. Variations between most stations is not great,
but the results show that the situation is more complex
than can be explained by distance from the suspected
sources alone. Although results from regression
analyses indicate a general decrease in content from
north to south, there is clear association of hydrocar-
bon content and its partial distribution with the degree
of severity of impact following the grounding of the Eutro-
dian tanker Kanchejungha on the reef adjacent to the
Jeddah Islamic Seaport Anchorage. Thus, the ob-
served variations probably reflect differences in depu-
rination rates of accumulated hydrocarbons, following
this major spill, superimposed on differences in ac-
cumulation from chronic exposure.

On the whole, the findings of the current survey in-
icate mainly the presence of naturally occurring
alkaline hydrocarbons, with a contribution from weathered oils. However, analysis of the alkaline hydrocarbons may not always be the best method to
identify oil pollution in the marine environment since,
under environmental equilibrium conditions, low-
level persistent petroleum pollutants may be difficult
to distinguish when the rate of pollutant input is equal
to the rate of biological degradation of n-alkanes. On
the other hand, it seems likely that the accumulated
aromatic hydrocarbons, with two and three ring PAH
dominating the tissue content of almost all bivalves
collected, may reflect weathered petroleum or possi-
ibly airborne particulate matter, although the in-
explicit appearance of the UCM envelope in chromato-
grams of the aromatic fraction, may reflect in part dif-
fferences in depuration rate between clams, which
were collected only at this station, and the mussel col-
clected elsewhere; but it is more probably to the low
level of chronic exposure at this station. Generally, re-
semblance of PAH (and aliphatic hydrocarbons) pro-
files for source identification should be carried out
with caution, since selective uptake and depuration of
hydrocarbon components have been noted (as was
emphasized in the previous section). In addition, there
is a lack of information about inputs in different loca-
tions and samples of control bivalves from uncontami-
nated areas were not available.

The survey established the practicability of a Mossel
Watch approach to monitor oil pollution along the
South Arid Sea coast and established the current state
and the usefulness of the bivalve mollusc locally avail-
able in the area for such a programme. Furthermore,
the survey provides a preliminary assessment of the
level of hydrocarbons, from both petroleum and to
some extent biogenic sources, in a restricted area of
the coastal zone of Jeddah which could serve as a
baseline study for future comparisons. The suggestion
is made that there is much to be gained from repeating
this survey on a larger scale in the near future, since
the mussel watch technique is known to be useful as
a quantitative integration of pollution by oil and in iden-
tifying sources of pollution. An intensive survey on
a large scale, using either indigenous mussel popula-
tions or introduced uncontaminated caged mussels
from a single stock, should provide a useful tool for
the identification of biologically available contaminants.
Studies of this nature should be considered as a priori-
ty task in any future mussel watch type programme.
This work could be developed over the next few years
and, hopefully, various national laboratories will play a
major role.

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تطبيق ميداني مراقبة بلوغ البحر (MUSCLE WATCH) للتلوث البري في المنطقة الساحلية لمدينة جدة بالمملكة العربية السعودية

سليم جميل هافي
مصلحة الأرصاد وحماية البيئة - جدة - المملكة العربية السعودية

المستخلص: تم في هذه الدراسة لتحديد مندوب من نوع 3 كم ونتيجة بعد مراقبة من بداية الكراني Nessilus aestel理事会 and Barbauna decorata العشان خاصي التلوث البشري للمياه وأماكن مجاورة في المواقع مثالية للسلطات المحلية والكشف عن التلوث. وتشير النتائج إلى وجود نزع من النترات في الماء العذب لبعض المناطق، وتشعر التشعيب منطقة ثانية KANCHENJUNGA (KANCHENJUNGA) بتفOLT دفع جروب السفينة الهدهده في جدة الإسلامي.

عموما فإن الإفلاك المكتبي للتركيز في الكهرباء كلوبيات بالأصداف البحرية التي يمكن أن تكون معرضة للاختلاط واللحاء الهيدروكربونات، وذلك عقب حادثة التلوث المذكورة أعلاه. إضافة إلى الاختلاف في مصدر الهيدروكربونات المركب لاحقا.

ومع ذلك، العلاج التحليلي عدليا من النشاط الناجم للنوع المضيف الشموعة والمياه والصرف المراقبة داخل ساحلية لتحديد إذا الدراسة تشير أن المنطقة الساحلية لمدينة جدة يمكن اعتبارها منطقة غير ملوثة للنفط.