Analytical Study of Total Organic Matter in Soil of Shuwaikh Industrial Area, State of Kuwait

Dr: Mishal A. Al-Meshan
Eng: F. Mahrous Ahmed

ARTICLES

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Abstract:

Measurements were made on 51 soil samples to determine the total organic matter (TOM), total moisture content (TMC) and pH in Shuwaikh and Al-Rai industrial areas (SRIA) of Kuwait in January 1997 to assess the contamination level in soil. The soil samples (about 2 kg each) were collected from fourteen locations selected to cover all sectors inside the study area. Soil samples from each location were collected from different depths of one-meter interval. Apart from these locations, soil samples were collected from one location at the outside boundary of the study area, in Yarmouk residential area. These samples can be considered as the natural background levels (reference samples), and were used in comparison with the other data obtained from the other samples taken from inside SRIA. The results showed that more than 75% from the total number of soil in the investigated localities inside the study area are more highly contaminated with organic matter than the reference soil samples collected from Yarmouk residential area. There is no significant variation in the pH for all the soil samples collected from Yarmouk residential area. There is no significant variation in the pH for all the soil samples. The values ranged from 7.5 - 9.5, this means that soil in the sites has a slightly alkaline pH range of 7.0-8.0, and moderate alkaline range of 8.0 - 9.0. There is no change in pH values in Yarmouk residential area and the values at all depths equal to 7.9. TMC for all investigated samples inside the study area ranged from

* Public Authority for Applied Education and Training, College of Health Sciences, Kuwait.
** Environmental Public Authority, Kuwait.

3.3 - 39.1% and the average values of moisture loss (ML) ranged from 0.95 - 9.86% While TMC in Yarmouk residential area ranged from 5.5 - 15.4%, more than 75% of the total number of analyzed samples in the study area have TMC higher than 15%. From the data we observe that the sites with high TMC are highly contaminated with TOM. This is the first study providing information on distribution of contamination levels in the soil of the oldest industrial area in Kuwait. It is recommended that appropriate measures be put in place by concerned industries to treat waste materials before discharging them into the immediate environment and to fund monitoring activities of research organizations in Kuwait.

KEYWORDS

Contaminated soils, physical properties, reclamation, remediation, hydrocarbon.

Introduction

The State of Kuwait is located at the northwestern corner of the Arabian Gulf and occupies an area of 17,830 km^2. It has undergone a rapid industrial expansion for the last 30 years. Many industrial areas and complexes have been built mainly in Shuaiba and Shuwaikh industrial areas. Most of these industries are concentrated on petrochemical and light industries. During the last 30 years, many scientific and environmental studies were implemented relating to air pollution, traffic and role and fate of trace metals from oil related industrial activities (Al-Meshan M., *et al.* 1999 & S. Al-Muzaini, 1996). After the Gulf War, there was great concern on oil splillage (M. Al-Sarawi, 1998) and wastes of hazardous and industrial sources (solid, semi-solid or liquid) that came out from the industries. Most of these wastes have leaked into the soil and water table within and around the areas causing probable contamination.

Contamination may have occurred in a number of ways, most prominent of which are due to industrial operations like fugitive emissions, accidental spillage and leaks, discharge of effluents and dumping of wastes (Kim H. Tan, 1994). This study contains technical data obtained from soil and samples gathered and analyzed for total organic matter. The main objective of the present study was to analyze and assess the environmental impacts of Shuwaikh and Al-Rai industrial areas. Also soil contamination levels mainly for hydrocarbons were taken into consideration.

Shuwaikh Industrial Area (SIA) has been a prominent commercial area in Kuwait since the early 1960s and its growth has matched that of metropolitan area of Kuwait City. Presently it has reached its maximum level of utilization and is surrounded by activities generally incompatible with industry. The area, which is located at the southwest (SW) direction of Kuwait City and few kilometers away from the city center, occupies an area of approximately 7.7 km^2 and is bounded by Jamal Abdul Naser Street, Airport Road, Fifth Ring Road and Mohammed Ibn Al-Qasem Street. It has also a frontage to the coastline of Shuwaikh Port (Kuwait Municipality, 1983), see map (Figure 1).

The study area is bounded by residential areas, except for Shuwaikh Port in the front coast and a small area adjacent to the Airport Road and Jamal Abdul Naser Street. The peripheral area comprises the residential areas of Shamiya, Keifan, Khaldiya, Yarmouk, Omariya, Rabiah and Riggae. Shuwaikh and Al-Rai industrial areas are among the fast growing and developing industrial areas in Kuwait. In that area most of the light industrial activities and commercial businesses operate along with most of the car engine repair, painting shops and a fair number of car washing and oil changing stations. Consequently large volumes of wastewater and considerable amounts of toxic wastes are generated (Alexander P. Economopouls, 1981).

2. Materials and Methods

2.1 Sampling Techniques: The study team surveyed the Shuwaikh and Al-Rai Industrial Areas (SRIA) to select the locations of sampling. Fifteen sites were selected (number A, B, C, etc.) to cover all sectors of the study area; fourteen sites were inside the SRIA and one site (number N) located outside the area, in Yarmouk residential area, which was considered as a reference one (natural background levels). The distribution of the sampling sites is illustrated in Figure (2). Different soil subsamples (al, bl, etc) were collected from each site at depths ranging from one meter to five meters, at one-meter interval from up to down, until the water table level is reached.

Gulf Inspection International Comapny was responsible for the drilling operations and providing the equipment necessary for collecting the soil samples from boreholes (BH). All the borings were drilled with truck mounted drill, type ACKER AD II (Figure 3). The samples were collected from the cuttings recovered, by using flight auger of sizes 4.5-inch diameter. Both powered and non-powered augers were used in obtaining solid samples from depths greater than one meter. Augers come in different sizes, and samples can be obtained directly from the auger cuttings. Soil cuttings were carefully removed after drilling to avoid cross contamination between soil layers (Edward J. Calabrese *et al.,* 1992). The samples were taken in January 1998 and the results obtained are shown in Table (1).

The collected samples were kept in non-contaminated plastic bags, which were tightly closed to avoid any contamination. The study staff were responsible for collecting samples from sites and transferring them directly to the laboratories at ‘‘The Public Authority for Applied Education and Training College of Health Sciences-State of Kuwait’’ for analysis. The total number of collected soil samples was 51 (about 2 kg each).

2.2 Sample Preparation and Analysis: Sample preparation encompasses all physical handling of samples following the actual collection. This includes.

* Transfer from the collection devices.
* Selecting and using containers.
* Preservations.
* Drying methods and procedures.
* Mixing/Sieving procedure.
* Archiving (storage).

Also sample preparation involved physical operations such as sieving, blending, curing, drying and/or chemical operations such as dissolution, extraction, digestion, fractionation, pH adjustment, and the addition of preservatives, standards or other materials. These physical and chemical treatments not only add complexity to the analytical process, but also prevent potential sources of bias, variance, contamination and mechanical loss (EPA, 1989 & William, *et al.,* 1992).

The collected 51 soil samples (about 2 kg each) were spread over a sheet of heavy paper for air-drying in a closed room which is not used for any analysis or to store any chemicals (such as balances room), i.e. a room free of dust and chemical fumes. The large coagulated particles were broken. After drying and mixing properly, the coning and quartering method was used to reduce the sample to about 50 grams (ROPME, 1989). This involves the following steps; (a) pour the sample onto a flat surface to form a cone, (b) use a straight edge to divide cone into two halves, (c) divide the two halves into quarters, and (d) remove alternate quarters, reform cone and repeat the above steps until the approximate desired weight is obtained. Thereafer it was taken as a representative soil sample for laboratory investigation. The representative soil samples were then crushed and ground using agate mortar, passed through 200-mesh size sieve, and stored in a light small glass bottle ready for any investigation.

2.3 Total Organic Matter (TOM): A rough measure of organic matter in soils can be obtained by igniting dry soil and determining the loss in weight (M. Walaa El-Reedy, 1984). This technique is applicable to most soils except those containing carbonates, which decompose when ignited. Total organic matter (TOM) was quantified by extraction method. After removing the total moisture content from the collected samples, the samples were prepared by extraction procedure to remove the total extractable materials from them by Carbon Disulfide which was used as the extraction solvent. The samples were then washed using high-purity deionized water and air-dried in a Cabinet at 105°C until constant weight was obtained. The difference in weights of the treated samples before and after the extraction process gives the total organic matter (TOM) in the samples (M. Walaa El-Reedy, 1984). The results obtained are shown in Table (1) and Figure (4).

2.4. The pH values: Determination of the soil physical and chemical properties in site characterization is a major part of evaluating the fate and transport of contaminants in the soil system. Fate and transport studies of soil contaminants are directly used for developing exposure assessments, risk assessments, and remedial design strategies. Sorption of chemicals can vary with concentration, pH, moisture content, and sorbing (Marten N. Sara, 1994). The soil pH is the most important factor governing heavy metals behavior such as solubility increasing as pH decreases, near neutral soil pH will also prohibit the formation of dichromates and the pH affects removal of lead from the soil by changing its solubility and motility (Eve Riser-Roberts). Factors, which limit the success of remediation of contaminated soils, include type of soil, soil pH, soil moisture and temperature (Edward J. Calabrese *et al.,* 1992). Heavy metals such as V, Ni, Cr, Pb.. etc were measured in the first phase of that project (Al-Meshan M., *et al.* 1999).

The pH values were determined in 1: 5 (Soil - Water) suspension using a pH meter with a combined glass and calomel electrode. Ten grams from each powdered sample were taken in 50-mL of deionized water and stirred vigorously and then kept aside for 6 hours with intermittent stirring every half-hour. The sample solution was then taken after 12 hours for determining the soil - water suspension pH by standard pH meter (J. Beek *et al.* 1978 & Lawrence H. Keith 1991). The pH data for the studied soil samples are presented in Table (1) and Figure (5).

2.5. Total Moisture Content (TMC): The quantity of water present in soil has great importance in clarifying the ability of soil to absorb and hold water for a short or long period depending on the nature of the soil. Soil moisture is located in the macro-and micro pores between the grains of the soil. When the soil is saturated with water, all the pores are filled with water. Water is present in micro pores in the form of a thin film around solid particles. Water is held in the pore spaces by forces of attraction exerted by the soil matrix, by attraction to the ions, and by surface tension in the capillaries (Ludwig Luckner *et al.,* 1991).

The saturation percentage (maximum saturation capacity) is a measure of the total water content of soil. It is the mass of water in the saturated paste expressed as a percentage of the oven-dry mass of soil. When soil is saturated (wet) all the pores can conduct water and conductivity is at its maximum, termed the saturated hydraulic conductivity. Infiltration rate depends on the hydraulic conductivity of a saturated soil (M. Al-Sarawi, *et. al.,* 1996). The quantity of water that is present in soil due to the environmental condition is defined as ‘‘Total Moisture Content (TMC)’’. The total moisture content is determined by drying a weighed subsample to constant weight at 105 - 110°C and then expressed in a percentage from the subsample weighed (Paul T. Kostecki *et al.*, 1991). ASTM Method D-2216 determines the free water or pore water content as a percentage based on moist and oven dried soil weight differences (Martin N. Sara, 1994).

The collected soil samples were air-dried and finely ground. At least 10 grams of the final powdered sample were heated in a drying cabinet at 105°C for at least 3 hours or until constant weight is obtained. The loss in weight is considered as Moisture Loss (ML). The moisture loss or content is expressed as a percentage of the oven-dry weight (Suzanna Lesage *et al.,* 1992 and M. Walaa El-Reedy, 1984). The data calculated for (TMC) and (ML) for the collected samples are given in Table (1) and illustrated in Figure (6).

3. Results And Discussions

Most of the organic chemicals that are found in the soil system result from human activities. When a pure organic contaminant is released onto or into the ground, the main force that affects the movement of the compound is gravity. As the ground is porous the spill will move downward and the speed of movement will depend on the viscosity of the material spilled and the porosity of the soil (Kim H. Tan, 1994). The common sources of organic chemicals present in the soil of industrial site attributed to atmospheric deposition include automobiles, power plants, municipal incinerators, refineries and paint manufacturing industries. Moreover, sewage and septic systems discharge a large quantity of domestic and industrial wastewater into the soil. Benzene, Toluene, Xylene and Chlorinated organic chemicals are often detected in the organic solvents generally used for commercial and household purposes (Suzanna Lesage *et al.,* 1992). Sites polluted with organic compounds often contain metals, such as arsenic, mercury, lead, and zinc, (Eve Riser-Roberts, 1998). About 50% of the contaminated sites contain such inorganic pollutants, which may persist in the soil after biodegradation of the organic contaminants or which may inhibit the activity of native organisms or introduced organic compound degrades.

3.1. Total Organic Matter: From the data in Table (1) and Figure (4) we can see that:

* The average concentrations of total organic matter (TOM) in the soil samples collected from uncontaminated soils (Natural Background Levels), i.e. site N which is located outside the study area in Yarmouk residential area, ranged from 10.90-7.90 mg/gram soil i.e. from 1.1 - 0.79% of the sample weight which has been taken from top to bottom.

* About 6% of the total soil samples analyzed have a TOM content higher than or equal to four times (44 mg/gram) the organic content in site N. These samples were mainly collected from 3 sites, namely A, H and I. It is found that at site a3 at depth 3 meters from surface, the total organic matter content was 54.296 mg/gram, i.e. 5.43%; at site h1 at depth one meter, the total organic matter content was 48.499 mg/gram i.e. 4.85%; and at site i2 at depth 2 meters, the total organic matter content was 50.459 mg/gram. (Figure 4).

* About 10% of the total soil samples analyzed have a TOM content higher than or equal to three times (33 mg/gram) the organic content in site N. These samples were mainly collected from sites a4 at depth 4 meters from top, b2 at depth 2 meters, c2 at depth 2 meters, and g2 at depth 2 meters.

* About 20% of the total samples analyzed have a TOM concentration higher than or equal to twice the organic matter content (22 mg/gram soil) in site N. These samples were mainly collected from locations C, F, H, K.
* About 39% of the total number of the analysed samples have a TOM content higher than or equal to the organic matter content (11.0 mg/g soil) in site N. These samples were collected mainly from locations G, B, D, M, E, F.
* About 25% of the total number of the analyzed samples have a total organic matter content (TOM) less than or equal to the contents of the samples collected from location number N, i.e. 8.0 mg/gram soil. These samples were collected from sites L, M, J, which are located at the boundary of the study area.

From the above results and discussions of the total organic matter contents, it is clear that more than 75% of the soil in the investigated localities inside the study area are contaminated with higher levels of organic matter than the soil samples collected from the reference site (Yarmouk residential area). From the field survey of the study area, we find that the highly polluted sites are close to car washing stations and car repairing shops. The observations of colors of these contaminated soil samples show that the color changed from pale brown to dark brown and black. However, uncontaminated soil samples have a color ranging from yellowish to white that indicates the main source of this organic matter is the spent oil reaching the soil.

3.2. pH Behavior: The data presented in Table (1) and Figure (5) for measurements made on 51 soil samples to determine the pH values illustrated that there is no significant variation in the pH for all the soil samples. The values ranged from 7.5 - 9.5 which means that the soil in the sites has a slightly alkaline pH ranging from 7.0 - 8.0 to moderately alkaline ranging from 8.0 - 9.0. There is no change in pH values in Yarmouk (site N) and the value at all depths equal to 7.9. In some contaminated sites such as A, C, F, etc, with high organic matter content the pH values decrease from top to down. The pH values measured were about 8.0 in the soil samples which contain higher levels of total organic matter (TOM), at certain sites and depths (a3, a4, b4, f2, h1, i2, k3).

3.3. Total Moisture Contents (TMC) and Moisture Loss (ML): From data presented in Table (1), it can be seen that TMC for all investigated samples inside the study area ranged from 3.3 - 39 1% and the average values of moisture loss (ML) ranged from 0.95 - 9.86%. While in Yarmouk (site N) the range was from 5.5 - 15.4%, and more than 75% of the total number of the analyzed samples have TMC higher than 15%. From the data we can see that the sites of high TMC, highly contaminated with TOM, are site a3 at depght 3 meters which records (TMC 34.20%, ML 4.74%) contains 54.296 mg/gram, 5.43% TOM; site a4 at depth 4 meters which records (TMC 36. 10%, ML 5.88%) contains 38.231 mg/gram, 3.82% TOM; site b2 at depth 2 meters which records (TMC 31.10%, ML 3.10%) contains 35.940 mg/gram, 3.59% TOM; and site h1 at depth 1 meter which records (TMC 30.30%, ML, 4.43%) contains 48.499 mg/gram 4.85,% TOM. It is clear from the above discussions that there is a correlation between the sites of high contamination of TOM and the sites of high TMC. The high TMC in the soil samples is directly related to high level of surface water or leakage of water from damaged sewage system in the area. Usually the water contents of soils range from 5-35% However, for soil types that contain a high percentage of clay or organic material, very high water content may be observed. In general, the water content depends on void ratio, particle size, clay minerals, organic content, and groundwater conditions (Martin N. Sara 1994).

4. Conclustions and Recommendations

The results showed that more than 75% of the total 51 soil samples collected from the investigated localities inside the study area are highly contaminated with organic matter compared to the soil samples collected from the reference area (Yarmouk, site N). There is no significant variation in the pH for all the soil samples. The values ranged from 7.5 - 9.5, which means that the soil in the sites has a slightly alkaline pH ranging from 7.0 - 8.0, and moderately alkaline ranging from-8.0 - 9.0. There is no change in pH values in the reference site (Yarmouk, site N) and the values at all depths equal to 7.9. TMC for all investigated samples inside the study area ranged from 3.3 - 39.1% and the average values of moisture loss (ML) ranged from (0.95 - 9.86%). While TMC in Yarmouk ranged from 5.5 - 15.4%, more than 75% of the total number of analyzed samples in the study area have TMC higher than 15%. From the data we observe that the sites with high TMC are highly contaminated with TOM.

4.1. The methods of disposal of wastes within the area, especially the oily and hazardous wastes, should be controlled to avoid unfavorable environmental effects. The Environment Public Authority and Municipality of Kuwait should enforce appropriate laws to regulate and control the collection and disposal of waste oil and other polluting substances.

4.2. For collecting spent lubricating oil, the Municipality should adopt a disciplined system. This could be achieved by encouraging collectors and by appointing contractors to collect the oil from its sources on regular basis and deliver it to specified stations for transferring to refineries for recycling (Lesage *et al.,* 1992).

4.3. Car washing stations in the vicinity of Shuwaikh and Al-Rai Industrial Areas (SRIA) should be convinced either by law enforcement or through an environmental awareness campaign to abandon the use of diesel or kerosene for washing car engines to decrease the contamination of volatile hydrocarbons (Kuwait Municipality, 1983).

4.4. The small vacant land areas and spaces existing within SRIA should be constantly observed and checked to prevent any illegal use of these areas for activities such as maintenance, repair of cars and heavy trucks, changing oil, etc., in order to eliminate any possible soil contamination from oil spills or any other toxic wastes.

4.5. The Kuwait Municipality (KM) in cooperation with other concerned ministerial departments, such as Ministry of Public Works

(MPW), should consider paving sandy soil found in the vicinity of SIRA to reduce any soil contamination caused by oil or toxic spills.

4.6. Ministry of Public Works (MPW) should inspect and renew the sewage system inside the area.

4.7 Considering the above mentioned points, the rehabilitation of the area could be achieved through reduction of its density by removing some industrial activities and establishing new parking lots so that traffic emissions could be reduced inside the area.

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Table (1)
The Concentration of Parameters in the Soil Samples Collected from Sites in Shuwaikh Industrial Area and Yarmouk Residential area

Sr. No	Borehole No.	Sample No.	Soil Depth (m)	Total Organic Matter (TOM)		pH	Total Moisture Content (TMC)	Moisture Loss (ML)
				mg/gram	%		%	%
1	A	a1	1	19.166	1.92	8.20	9.30	1.91
2		a2	2	19.727	1.97	7.80	18.90	4.05
3		a3	3	54.296	5.43	7.70	34.20	4.74
4		a4	4	38.231	3.82	7.80	36.10	5.88
5	B	b1	1	18.456	1.85	9.10	8.50	2.63
6		62	2	35.940	3.59	7.90	31.10	3.10
7		b3	3	41.050	4.11	8.00	31.50	7.25
8		b4	4	29.481	2.95	8.00	33.40	6.36
9	C	c1	1	17.470	1.75	8.80	17.70	3.59
10		c2	2	33.883	3.39	8.40	21.50	3.93
11		c3	3	15.942	1.59	8.20	18.00	2.75
12	D	d1	1	23.370	2.34	9.50	10.30	4.11
13		d2	2	18.071	1.81	8.20	30.50	3.45
14		d3	3	9.339	0.93	8.10	31.20	5.27
15	E	e1	1	9.545	0.95	8.50	14.50	2.66
16		e2	2	15.713	1.57	8.20	18.70	3.69
17		e3	3	11.511	1.15	8.10	22.90	3.23
18	F	f1	1	14.854	1.49	8.50	22.80	3.08
19		f2	2	28.476	2.85	8.20	30.80	4.48
20		f3	3	13.822	1.38	8.10	37.60	12.07
21	G	g1	1	19.143	1.91	7.70	13.00	3.10
22		g2	2	34.058	3.41	7.80	26.70	4.82
23		g3	3	27.436	2.74	7.80	24.60	3.84
24	H	h1	1	48.499	4.85	7.80	30.30	4.43
25		h2	2	28.686	2.87	7.90	21.30	6.06
26		h3	3	10.993	1.10	8.50	17.40	4.74
27	I	i1	1	21.752	2.18	8.40	25.80	1.91
28		i2	2	50.459	5.05	8.10	28.30	6.51
29		i3	3	20.861	2.09	8.30	39.10	5.28
30	J	J1	1	7.990	0.80	8.60	12.20	2.29
31		J2	2	7.032	0.70	8.80	16.00	2.30
32		J3	3	7.155	0.72	8.60	13.40	1.77
33	K	k1	1	16.415	1.64	7.80	24.20	2.00
34		k2	2	21.807	2.18	7.80	31.90	4.78
35		k3	3	24.462	2.45	7.90	34.70	9.86
36	L	11	1	10.507	1.05	8.60	4.80	2.08
37		12	2	11.153	1.12	9.00	4.90	1.27
38		13	3	5.465	0.55	8.90	3.30	2.17
39		14	4	5.889	0.59	8.70	12.70	1.49
40		15	5	5.744	0.57	8.80	10.50	1.36
41	M	m1	1	20.746	2.07	8.70	6.80	1.62
42		m2	2	17.531	1.75	9.00	7.50	1.34
43		m3	3	9.415	0.94	8.20	15.00	1.52
44		m4	4	5.471	0.55	8.20	15.80	1.30
45	*N	n1	1	10.889	1.09	7.80	7.00	1.44
46		n2	2	9.124	0.91	7.90	5.50	1.60
47		n3	3	7.928	0.79	7.90	15.40	1.45
48		n4	4	8.732	0.87	7.90	14.50	1.09
49	O	o1	1	15.003	1.50	8.10	13.20	1.34
50		o2	2	17.324	1.73	8.3	14.70	0.95
51		o3	3	14.723	1.47	9.40	13.40	3.10

* Broehole N is located in Yarmouk Residential Area.

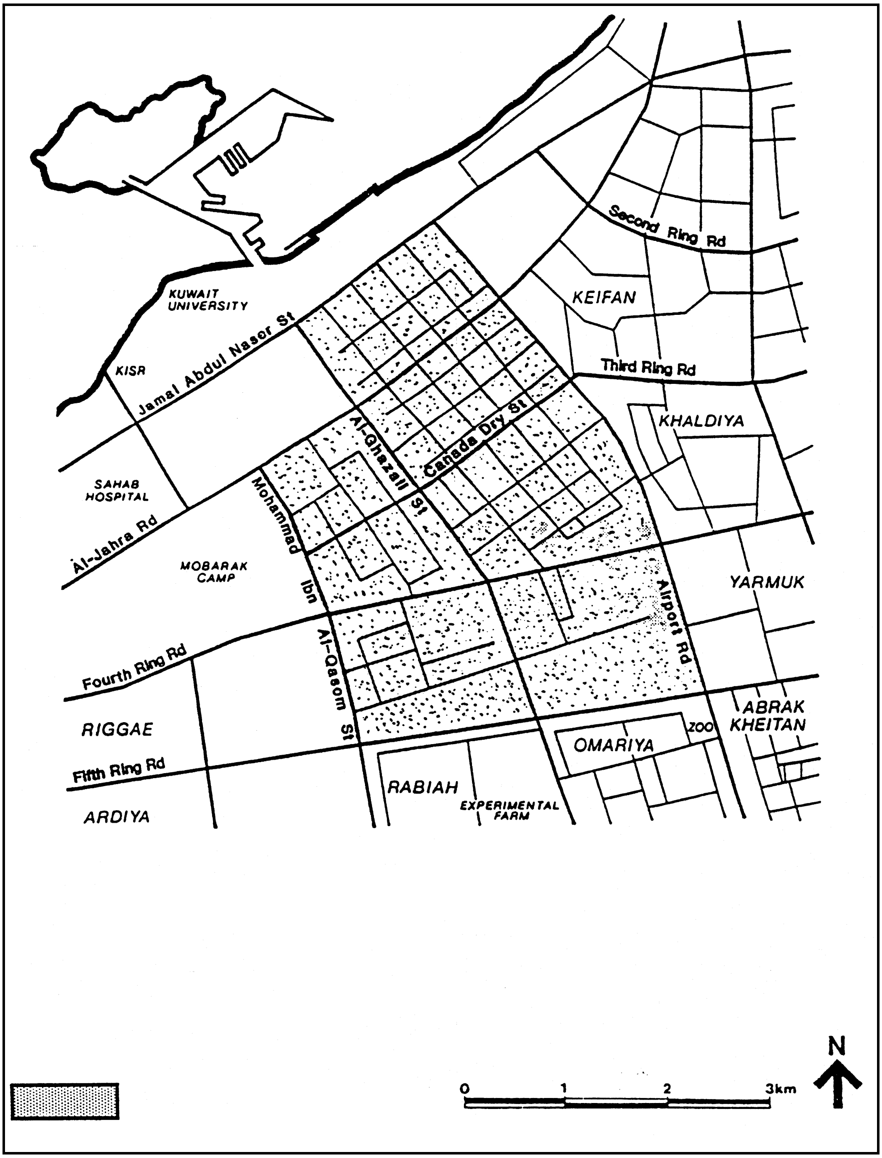

Fig. 1. Shuwaikh & Ray Industrial Area.

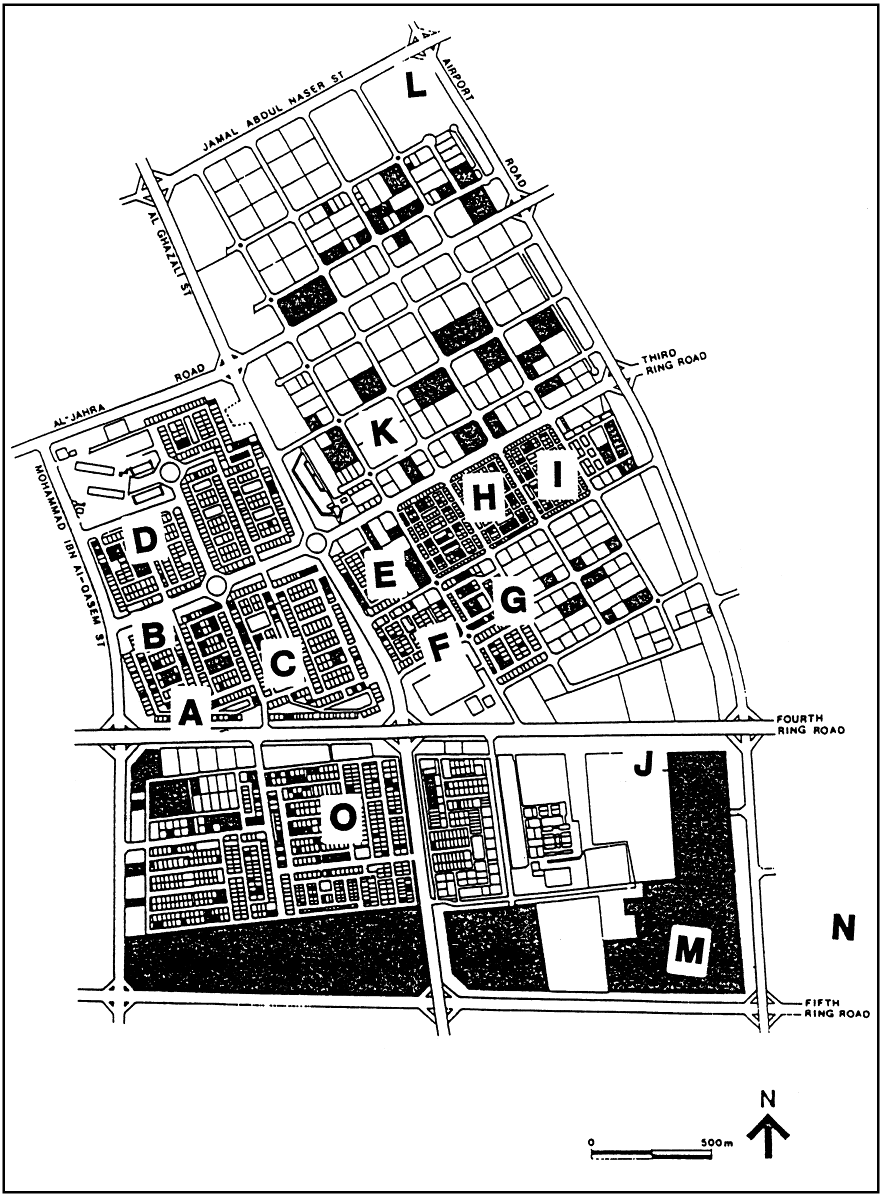

Fig. 2. Sampling Sites.

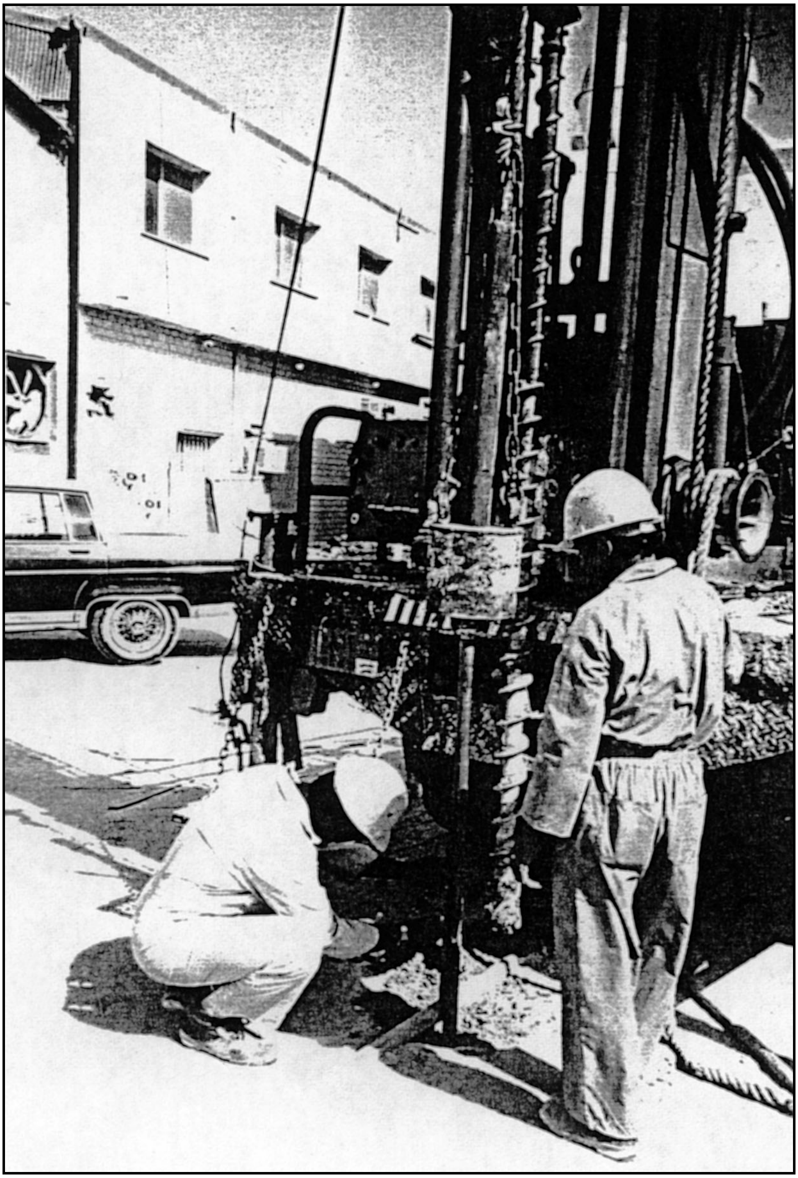

Fig. 3. Sampling Techniques for Soil Samples.

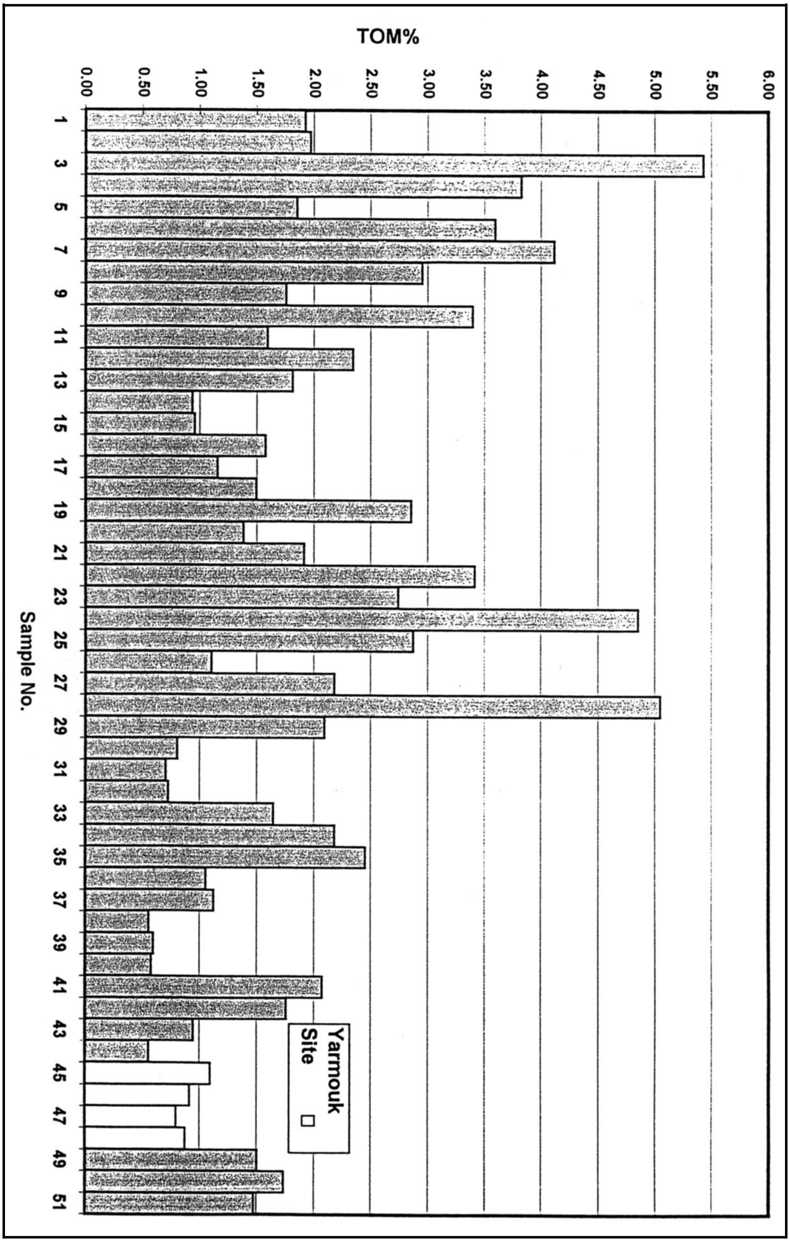

Fig. 4. Percentage of total organic matter (TOM) content in soil samples collected from Shuwaikh & AL-Rai industrial areas (SRIA), and Yarmouk residential area.

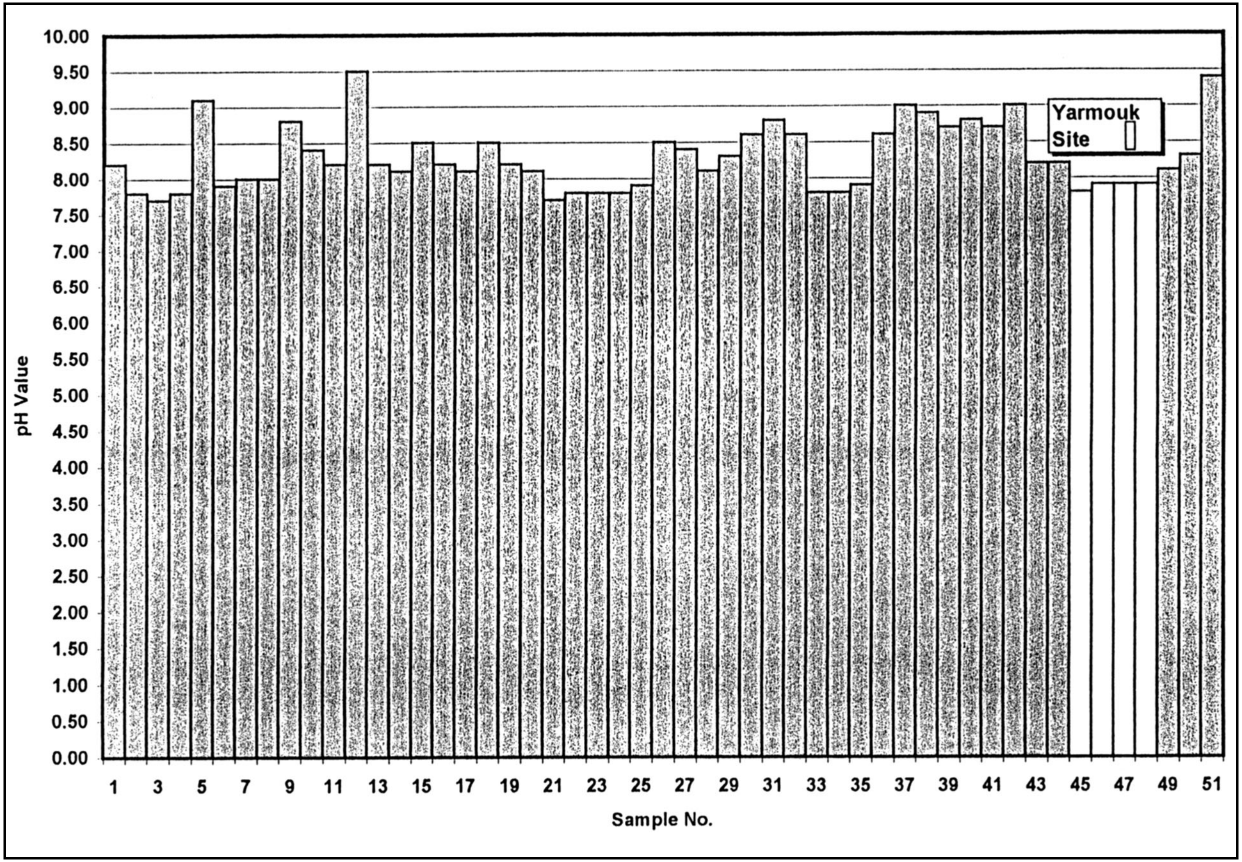

Fig. 5. The pH values of the soil samples collected from Shuwaikh and AL-Rai (SRIA) industrial areas and Yarmouk residential area.

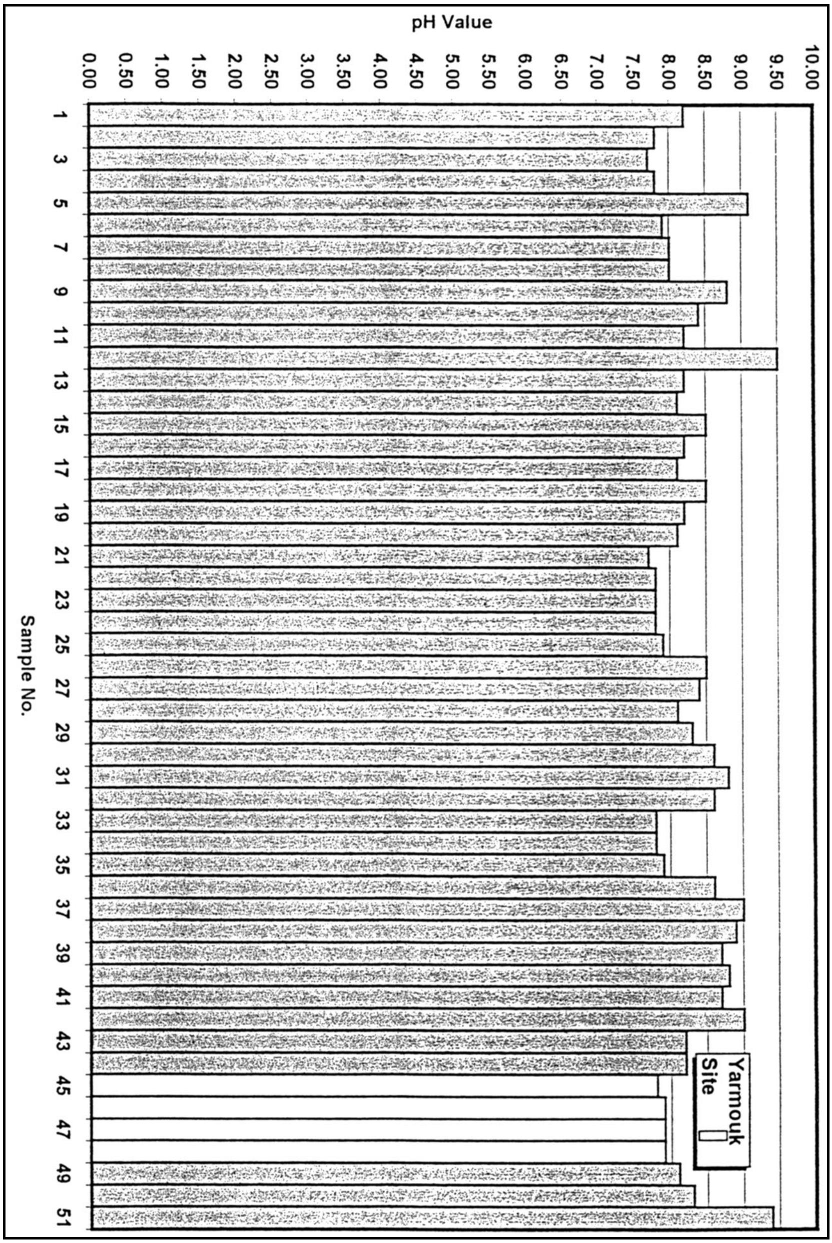

Fig. 6. Percent of total moisture content (TMC) in the soil samples collected from Shuwaikh and AL-Rai (SRIA) industrial areas and Yarmouk residential area.