Bulletin of High Institute of Public Health
Vol. 32 No. 3 [2002]

Distribution of Plastic Pellets on Alexandria Beaches

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Abstract: Plastic pellets are the raw materials that are melted and molded to create plastic products. During packaging and transporting overseas, pellets may spill into the aquatic environment. They have been found distributed on some coastal areas around the world. Scientific awareness has been increased concerning the aesthetic, economic, and biological hazards associated with the persistent of plastic pellets in the aquatic environment. The aim of this work is monitoring the distribution of plastic pellets on Alexandria beaches. Also, a mathematical model for the surface water currents was designed and applied to determine the possible point sources of plastic pellets. The shoreline of Alexandria was divided into eight sectors. Each sector length and width was measured. The sampling program continued for one year. Samples were collected from each sector once a month. Two sample locations were taken each time from each sector. One square meter sand surface and five cm depth of sand was gathered and sieved at the spot. Plastic pellets were collected and counted. In an attempt to identify the point sources of plastic pellets, metrological data were collected for Alexandria city. A computer program was designed and verified to convert the collected data from the sampling program to a mathematical simulation model. There are many ports in Alexandria. These ports are active sources of marine debris, especially plastic pellets, due to mishandling of goods as well as that garbage which improperly get rid from the ships while docking on and out of these harbors. Six sites out of the studied 8 sites have recorded their maximum number of pellets per square meter of the sand surface during summer season. They are Agamy [132], EL-Max [182], Shatby [113], Stanly [116], Sidi Besher [120], and Mandara [95]. The minimum number of pellets has been recorded during winter in 5 sites. They are Agamy [25], Anfoshi [57], Shatby [56], Sidi Beshr [7], and Mandara [6]. The maximum number of pellets per square meter of the sand surface has been recorded on EL-Max [1198] followed by Anfoshi [225]. On the other hand, the minimum number of pellets has been recorded on Mandara [2]. The maximum average has been recorded in also EL-Max [196] followed by Anfoshi [129] and the minimum was on Abu-Kir [30] followed by Mandara [32]. The recorded values of the present study for all the sites ranged between 2 and 1198 pellets/ square meter of the sand surface. The overall average number of pellets distributed along Alexandria beaches was 40 pellets per square meter of the sand surface. The mathematical model has showed that the dense area of point sources of pollution from plastic pellets, are around the western harbor point. Also, minor point sources of pollution were found. The study ended by some recommendations, which will assist in controlling the discharge of plastic pellets, whether in the wastewater or solid waste into water streams.

INTRODUCTION

Plastic pellets are the raw materials that are melted and molded to create plastic products. Plastic pellets are spherical, ovoid, and cylindrical. The pellets are commonly clear, or white and sizes range of

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1 to 5 mm diameter. The most commonly produced resins include polyethylene, polypropylene, and polystyrene. During packaging and transporting overseas, pellets may spill into the aquatic environment. When released into the environment, these pellets are either float on or near the water surface, become suspended at mid-depths, or may sink to the bottom of water body. Several researchers have suggested possible sources of pellets to the aquatic environment, including: i] Direct discharges and improper wastewater disposal by the plastic industry. ii] Waste disposal and sewer discharge by cities. iii] Spillage from trucks, trains, and ships during loading, transporting, or unloading. iv] Improper use of pellets, such as for packing material, for insulation, and for bearings to facilitate the movement of cargo boxes and other heavy objects. Unfortunately, most studies focused on monitoring pellets distributions and abundances, and the source identifications were based mostly on empirical evidence rather than on direct evidence.[1] Plastic pellets are among the smallest items of debris discharged into the aquatic environment. They are, therefore, not as visible, aesthetically displeasing, or as obviously harmful as large forms of debris. They are ubiquitous in the oceans and on beaches. They have been reported in the sediments, the surface waters of coastal areas, and on beaches. They have been found distributed on some coastal areas around the world. In Atlantic Ocean, they have been distributed on some coastal areas of Southern New England,[2] Sargasso Sea .[3] Cape Cod to Cape Canaveral and areas South,[4] Eastern Canada and Bermuda.[5] and Cape Basin area of South Atlantic.[6] In Pacific Ocean, they have been found on North Pacific Ocean,[7] New Zealand,[8] Alaska ,[9]and North of Hawaii.[10] In Mediterranean Sea, they have been detected on beaches of Lebanon,[11] beaches of Costa del Sol, Spain,[12] and Cost of Spain.[13] In Gulf of Mexico and Caribbean Sea, they have been

distributed on Costa Rica and Caribbean Sea.[14] In other Coastal areas, they have been noticed on harbors of the United States,[15,16] Sanitary systems in Philadelphia, PA and Boston, MA,[17] and sewage outlet pipes at factories near Long Island, NY.[18] Scientific awareness has been increased concerning the aesthetic, economic, and biological hazards associated with the persistent of plastic pellets in the aquatic environment. There are several documents describing pellet and other plastic debris ingestion by wildlife, most notably by seabirds and sea turtles. Generally, impacts or biological effects of the pellets have not been clearly defined in most wildlife, and, to date, direct correlations between pellet ingestion and effects have not been demonstrated conclusively. This may be attributable to the fact that the studies typically use beached animals, and most animals that die at sea either sink to the bottom or are consumed by predators before investigation by humans.[1]

The aim of this work is monitoring the distribution of plastic pellets on Alexandria beaches. Also, a mathematical model for the surface water currents was designed and applied to determine the possible point sources of plastic pellets. The possibilities of plastic recovery and reuse are also evaluated.

MATERIAL AND METHODS

The shoreline of Alexandria was divided into eight sectors. Only one striped area from each sector was selected to represent the sector. These sectors are Agamy, El-Max, Anfoshi, Shatby, Stanly, Sidi Beshr, Mandara, and Abu-kir. Each sector was named by one of its famous beaches included in the sector. Also, only sandy beaches were investigated in the study. Because of the location of Alexandria harbor, El-Max beach was taken as a base point for the longitudinal distance of Alexandria shoreline. Each sector length and width was measured. Figure [1] shows the location,

length, width, and name of these sectors. Sampling program was designed and conducted during year 1999. Samples were collected from each sector once a month. The sampling program stared on December 1998 and ended on September 1999. Two sample locations were taken each time from the same beach. The first was at the tide area and the other from back area. One square meter sand surface and five cm depth of sand was gathered and sieved at the spot. Plastic pellets were collected and counted.

In an attempt to identify the point sources of plastic pellets, metrological data were collected for Alexandria city for the period between year 1952 and year 1966. These data included the percentage frequency and mean monthly wind speed 19. A computer program was designed and verified to convert the collected data from the sampling program to a mathematical simulation model. The Mediterranean Sea borders the long beaches of Alexandria. The city was mapped and the water surface was divided into smaller square area of 1.2 Km widths. Database was designed to control the collected data from the conducted sampling program and the metrological data as well as the calculated results of the mathematical model. Finite different method was applied to solve the applied mathematical equations.

RESULTS AND DISCUSSION

The dominating physical features of Alexandria area are the Mediterranean Sea, a segment of the lower Nile Delta, Lake Maryut, a bedrock ridge, which parallels the cost, and the eastern segment of the vast Western Desert. Figure [2] shows a satellite image of Alexandria beaches and its vicinity [1995]. There are many ports in Alexandria. The main is the western harbor. Other small harbors are the eastern harbor, New-Dekheilla port, and Abu-Kir port. These ports are active sources of marine debris, especially plastic pellets, due to mishandling of goods as well as that garbage which improperly get rid from the ships while

docking on and out of these harbors.

1. Distribution Of Plastic Pellets On Alexandria Beaches

The eight sampling locations, which have been selected for the study, are shown in figure [1]. The collected sand from each spot were gathered and sieved, and only plastic pellets were collected and counted. The total counts of pellets are illustrated in table [1]. It is clear from the table that six sites out of the studied 8 sites have recorded their maximum number of pellets per square meter of the sand surface during summer season. They are Agamy [132 during July], EL-Max [182 during August], almost Shatby [113 during June], Stanly [116 during July], Sidi Besher [120 during June], and Mandara [95 during July]. The other two sites have their maximum number of pellets per square meter of the sand surface during Autumn [Anfoshi with 225] and Winter [Abu-Kir with 74]. On the other hand, the minimum number of pellets per square meter of the sand surface has been recorded during winter in 5 sites. They are Agamy and Anfoshi [25 and 57 during February, respectively], Shatby [56 during December], Sidi Beshr [7 during January], and Mandara [6 during February]. The remaining three site have recorded their minimum count during Autumn [13 for EL-Max during October, and 11 and 6 for Stanly and Abu-Kir during November. The recorded maximum counts during summer may be attributed to that Alexandria is the main tourist area in Egypt and a large resort area, and people coming on its beaches during summer. This led to the increasing in plastic manufacturing to satisfy the people consumption.

The concentrations of plastic pellets for the different locations are illustrated in table [1]. It is evident from the table that for all the studied sites, the maximum number of pellets per square meter of the sand surface has been recorded on EL-Max [1198] followed by Anfoshi [225]. On the other hand, the minimum number of pellets has been recorded on Mandara [2]. The maximum

Table 1: Accounted Numbers of Plastic Pellets Collected.

Beach Name	Length ms	Width ms	Accounted Numbers of Plastic Pellets Per one Square Meter of Sand Surface												Average	
			Winter			Autumn			Summer			Spring				
			12	1	2	3	4	5	6	7	8	9	10	11		
Agamy	2000	40													Sum	856.00
			31	43	25	53	65	75	107	132	119	71	53	82	Mean	71.33
															St.Div.	33.90
El-Max	225	20													Sum	2362.00
			95	82	110	152	1198	138	194	65	182	63	13	70	Mean	196.83
															St.Div.	319.70
Anfoshi	250	45													Sum	1557.00
			108	74	57	143	178	82	156	188	157	225	88	101	Mean	129.75
															St.Div.	52.33
Shatby	400	30													Sum	1044.00
			56	106	95	102	78	95	113	63	69	95	116	56	Mean	87.00
															St.Div.	21.74
Stanly	250	30													Sum	735.00
			70	60	53	57	116	74	57	116	60	45	16	11	Mean	61.25
															St.Div.	31.88
Sidi Beshr	1000	30													Sum	501.00
			10	7	18	66	10	16	120	105	98	12	12	27	Mean	41.75
															St.Div.	42.97
Mandara	500	25													Sum	393.00
			66	32	6	31	2	32	57	95	32	11	13	16	Mean	32.75
															St.Div.	27.60
Abu-Kir	750	20													Sum	370.00
			31	46	74	45	18	32	19	16	44	32	7	6	Mean	30.83
															St.Div.	19.49

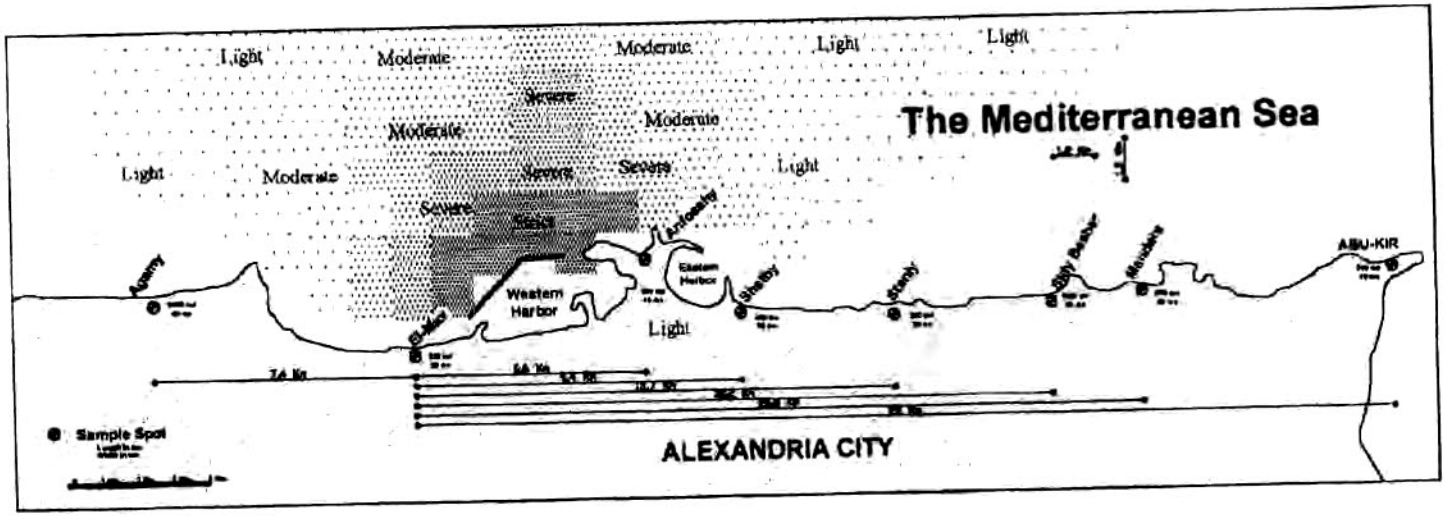

Figure (1) Location of Point Sources of Pollution.

Figure [2] shows a Satellite Image of Alexandria Beaches and its Vicinity [1995].

average has been recorded in also EL-Max [196] followed by Anfoshi [129] and the minimum was on Abu-Kir [30] followed by Mandara [32].

The high concentration in EL-Max could be due to most of the big plastic manufacturing companies are locating near this area. It is also could be due to when the solid waste collectors are delaying in collection, manufacturers are dumping their solid waste on the banks of the drains connected to the sea at this area. Also plastic pellets are finding their way to the sea at EL-Dekheila port during loading and unloading the ships. Also the Dehkeila port is an active source of marine debris, especially plastic pellets, due to mishandling of goods as well as that garbage which improperly get rid from the ships while docking on and out of this harbor. In Anfoshi, as this area is one of the oldest area in Alexandria it included a big number of small plastic enterprises. Therefore, all the effluents of these manufacturing activities are finding their way directly to the nearest surface water, which is the sea. These interpretations agreed with,[2]

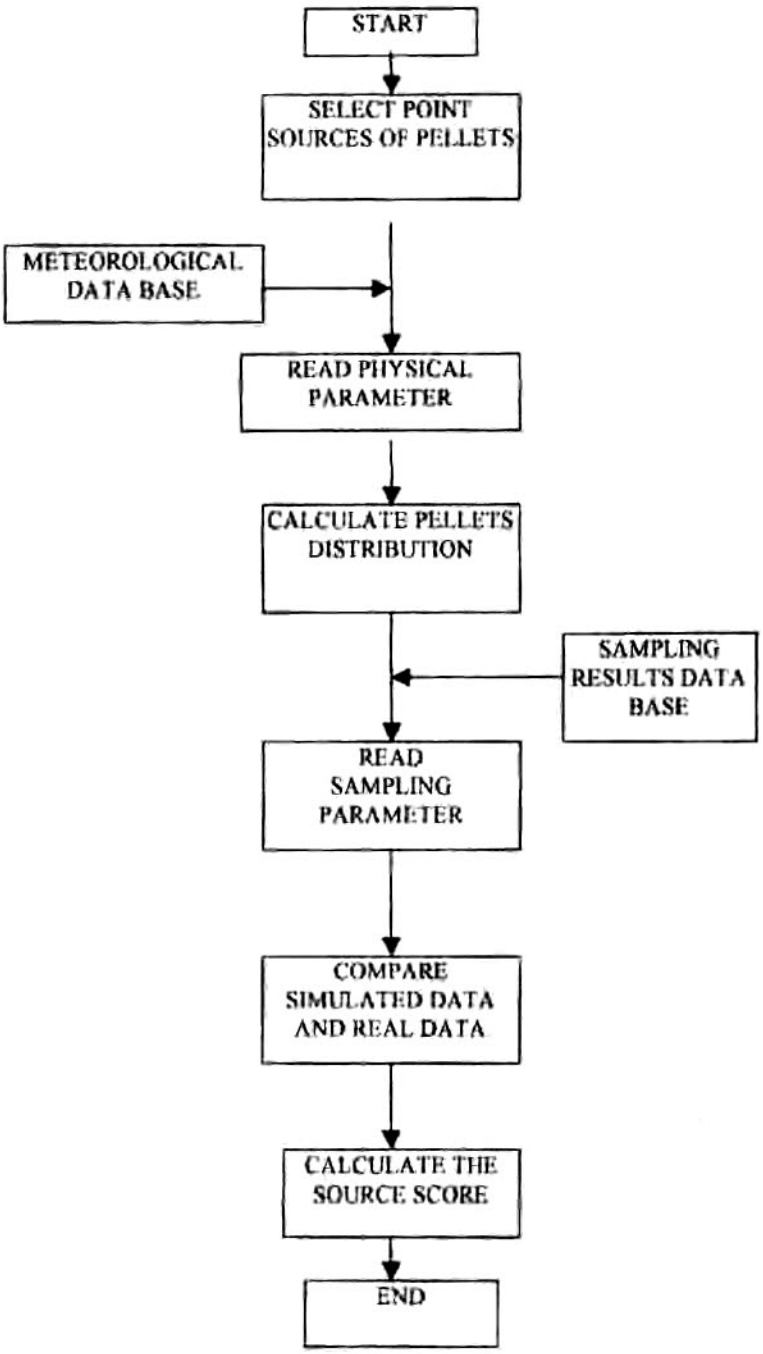

Figure [3] The Flow Chart of the Computer Program.

Table [2]: The average Wind Speed and Percentage And Frequency [1952-1966]

Months	Wind Speed ms / s	North	Northeast	East	Southeast	South	Southwest	West	Northwest	calm
1.0	4.4	5.2	8.1	4.6	10.0	4.2	29.3	11.9	19.7	5.9
2.0	4.6	9.4	14.3	8.5	10.1	3.9	14.8	8.0	27.3	2.9
3.0	4.7	9.0	17.2	8.1	9.3	2.5	6.7	8.8	34.8	2.4
4.0	4.3	12.4	18.4	7.2	8.6	1.5	3.4	4.2	40.4	2.7
5.0	4.1	19.6	19.4	4.1	6.5	1.0	2.1	8.3	39.1	3.8
6.0	4.1	18.6	5.2	0.8	1.6	0.4	1.8	1.8	65.8	2.3
7.0	4.4	16.2	3.7	0.2	0.3	0.2	0.7	3.5	71.6	2.3
8.0	4.0	16.6	2.6	0.3	0.5	0.4	0.9	2.2	70.4	4.2
9.0	3.6	28.2	8.3	0.9	1.8	0.6	1.3	0.6	51.2	4.8
10.0	3.2	26.0	22.9	4.9	4.5	1.6	4.8	2.1	25.1	5.2
11.0	3.4	12.6	24.7	6.3	6.4	2.9	11.2	4.8	24.2	5.0
12.0	4.1	6.7	18.1	6.7	7.9	4.2	27.1	4.9	16.9	5.5

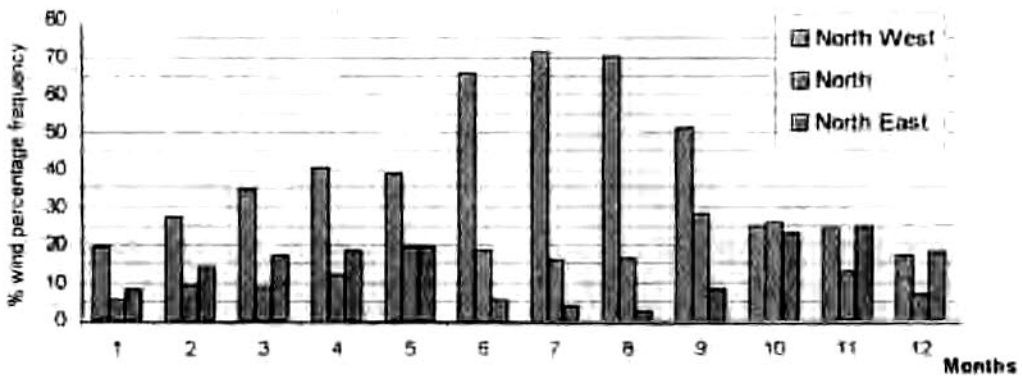

Figure [4] the average Wind Speed and Percentage And Frequency.

study which stated that the source of plastic pellets on some Southern New England coasts were due to effluent from plastic manufacturers, and with Southern New England[2] study which declared that they are from the waste dumping from cities or Cargo ships. The findings also are in compliance with other studies,[4,11,12,13,14] where they all agreed that plastic pellets are from the wastewater discharge from plastic plants. They also complied with Gregory study,[5,8] which commented that the source of plastic pellets was due to spillage at ports. They are also in agreement with Day, R.h.,[7,9] who said that plastic pellets on the beaches and in water were due to effluent of plastic manufacturers and during loading and unloading of ships at ports.

The recorded values of the present study for all the sites ranged between 2 and 1198 pellets/ square meter of the sand surface. The overall average number of pellets distributed along Alexandria beaches was 40 pellets per square meter of the sand surface.

All the recorded concentrations of plastic pellets in the present study are higher than that recorded in Carpenter's study [2] [average 0.01-1 pellets/cm3], and Colton's study[4] [0.061-0.148pellets/cm2]. On the other hand, some of the recorded results in the present study lied within the range found by Carpenter, et al.[3] [0.05-12 particles/m2], Morris, R. j.[6] [1.33-3.6 pellets/m2], and Day et al.[7] [6.5 pellets/m2]. However, all the recorded values in the present study are much less than reported at New Zealand.[8] Gregory, M. R.[9] found that the number of pellets ranged from 10,000 to 40,000 per meter on beaches in narrow zone along drift line or spread across the back beach. Also, at Eastern Canada and Bermuda, Gregory, M.R.,[5] the pellets averaged 5000 pellets per linear meter of beach. The concentrations of pellets found during studying the selected sites showed that a bad effect can be happen for birds and turtles. They also can have economic and aesthetic effects. Therefore, further study is being carried out to study these effects deeply. These effects have been mentioned in many studies. Ryan, P. G.,[20] said that the ingestion of pellets by seabirds has been reported worldwide, and seabirds ingest plastic pellets more frequently than do any other birds. Sileo et al.,[21] reported that 80 species, or approximately one-quarter of all seabird species, are known to ingest plastic debris. Pellets are the most common form of plastic debris ingested by seabirds Ryan, P. G.[20] Balazs G.H.,[22] found that marine turtles ingest many items of floating debris, including plastic pellets. Evidence suggested that plastic material passes through the digestive tracts and are voided naturally. However, Balazs G.H.[22] also reported that ingested debris might cause potentially serious problems in sea turtles, such as lost nutrition, reduced absorption of nutrients, and adsorption of plastic. In addition, small plastic fragments may adversely affect turtles during digestion when pellets or fragments are ground together by muscular contractions,

and pinocytotic absorption of the resulting microscopic plastic particles could occur.[22,23]

Carr, A.,[14] discussed the significance of non-degradable debris, including pellets, to sea turtles during early developmental stages. Because manmade and natural debris and planktonic organisms accumulate along convergences, he concluded that young, advanced sea turtles are vulnerable to the presence of pellets in the oceans owing to the turtles close association with the convergences. The findings of Plotkin, P.[24] and Plotkin, P.[25] support Carr's[14] conclusion.

Several authors have documented the human aesthetic and economic impacts of pellets in the environment.[5,25] The quantities of plastic pellets present and their persistence in the environment are cause for notice. Gregory, P.,[8] speculated that someday man would sunbathe on plastic sand beaches. A final impact of pellets in the environment may be measured in terms of economic costs. The loss of feedstock and the costs of replacing the feedstock may be counterbalance only if the pellets are recaptured and recycled instead of replacing them.[25]

2. Transporting of Plastic Pellets

As shown in table [2], prevailing winds are from the northwest during most of the year. The mean annual wind speed is about 4 m/second. . Figure [3] shows the percentage and frequency of wind direction through the year. From April through September, the winds are principally from the north to northwest. During the rest of the year, they are more variable and occasionally come from the southwest and northeast as well. Weather patterns are quite constant from year to year. Winter storms arrive with predictable frequency.

3. Mathematical model

The main objective of the applied model is to identify the possible point sources of plastic pellets. The floating solid wastes have the same transporting and dispersion phenomenon of plastic pellets along the Mediterranean Sea. Consequently, plastic

pellets can be used as an indicator of possible debris point sources of pollution. The horizontal transportation of plastic pellets by current action can be simulated using the following equation [27]

$$C_0 / C_{max} = \{ \text{erf} [1.5 / G^3 - 1] \}^{1/2} \quad \ldots\ldots[1]$$

$$G = 1 + [8 E T / W^2] \quad \ldots\ldots[2]$$

$$T = V . X \quad \ldots\ldots[3]$$

$$E = 0.01 W^{4/3} \quad \ldots\ldots[4]$$

Where: C_0= the pellets concentration before diffusion,

C_{max} = the concentration after travel time T,

E = initial value of diffusion coefficient,

W = the width of initial diffusion [1200 ms in the present case],

T = traveling period,

V = current speed,

X= traveling distance.

According to the selected mish size, the width of initial diffusion will be 1200 ms. A computer program was designed to solve the mentioned equation using finite element process.The mathematical model was based on the following assumptions:

i] The surface water currents are the principal force for pellets horizontal transportation,

ii] The seawater surface current speed is 10% of the average wind speed,

iii] The calculation based on the north, northeast, and northwest wind direction, and

iv] The calculation based on the percentage frequency and mean monthly wind speed.

The Flow Chart of the Computer Program is illustrated in figure [4]. In the first stage, the model assumes a presumptive location as a point source of pellets. The physical parameters are obtained form the prepared database. The second stage, the program simulates the dispersion occur to plastic pellets and predict the concentration of the dispersed pellets along Alexandria beaches. The last stage is to compare the predicted values with the values obtained from the conducted sampling program. According to

the comparison process, scour is given to the selected location, e.g. strict, severe, moderate and light. The program assumes another location as a point source of pellets. The results of this process show the possible sources of plastic pellets. Figure [1] shows the location of these point sources of pollution. The dense area around the western harbor point out the severe point sources of pollution. Also, minor point sources of pollution were found, which indicated that onshore movement of solid waste generated from the Mediterranean Sea.

CONCLUSION AND RECOMMENDATIONS:

1- There are many ports in Alexandria. These ports are active sources of marine debris, especially plastic pellets, due to mishandling of goods as well as that garbage which improperly get rid from the ships while docking on and out of these harbors.

2- Six sites out of the studied 8 sites have recorded their maximum number of pellets per square meter of the sand surface during summer season. They are Agamy, EL-Max, Shatby, Stanly, Sidi Besher, and Mandara.

3- The minimum number of pellets per square meter of the sand surface has been recorded during winter in 5 sites. They are Agamy, Anfoshi, Shatby, Sidi Beshr, and Mandara.

4- The maximum number of pellets per square meter of the sand surface has been recorded on EL-Max [1198] followed by Anfoshi [225]. On the other hand, the minimum number of pellets has been recorded on Mandara [2].

5- The maximum average has been recorded in EL-Max [196] followed by Anfoshi [129] and the minimum was on Abu-Kir [30] followed by Mandara [32].

6- The overall average number of pellets distributed along Alexandria beaches was 40 pellets per square meter of the sand surface.

7- All the recorded concentrations of plastic pellets in the present study are higher

. than that recorded in some studies [range between 0.01-1 pellets/cm^2] and some lied within the range of other studies [0.05-12 particles/m^2]. However, all the recorded values in the present study are much less than reported at New Zealand [ranged from 10,000 to 40,000] and Eastern Canada and Bermuda [averaged 5000 pellets per linear meter of beach].

8- The concentrations of pellets found during studying the selected sites showed that a bad effect can be happen for birds and turtles. They also can have economic and aesthetic effects.

9- A mathematical model has showed that the dense area of point sources of pollution from plastic pellets, are around the western harbor point. Also, minor point sources of pollution were found.

Based on the following conclusions, the following is recommended:

1. Industries should be enforced to follow the environmental regulations, which demand them to keep an environmental register and to treat their effluent before discharge.
2. Enforcement should be carried out to plastic manufacturers not to dump their solid or liquid waste in the water or on the banks on the lakes connected to the sea.
3. Contamination of the water streams by plastic pellets should be monitored periodically.
4. Trucks and ships should be followed during loading, unloading, and transporting to prohibit spillage of plastic pellets in the water.
5. A strict program for collection of unintentionally dumped plastic pellets on the beaches for remanufacturing should be formed.
6. A health education programs for the citizens should be done to inform them about the dangerous of plastic pellets disposal and sewer discharge.
7. Improper use of pellets to facilitate the movement of cargo boxes and other heavy objects should be conserved.
8. Cooperation between regarding ministries for managing the problem of plastic wastes disposal is a must.

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