Implementation of GIS and Remote Sensing Techniques for Air Quality Assessment

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Abstract: This paper aims to develop GIS analysis approach for air quality assessment. It is carried out z0078based on the integration of Geo-spatial data sets, such as different types of maps, remotely sensed data, field observations data using GPS and some other information. The Arc/GIS and ERDAS Imagine S/W packages are used to manage analysis and produce the different thematic layers, and integrate all the Geo-spatial and attribute data sets inside a comprehensive Geo-environmental database. The port of Damietta is situated near the eastern branch of the River Nile estuary, approx 70km west of Port Said, 250km east of Alexandria. The Port of Damietta is strategically located on the international transport lane as well as for domestic supply to Egypt. Field measurements were conducted using direct reading instruments for measuring major air pollutants. The instruments were taken to different stations inside and outside the project site. Measurements were analyzing and monitoring using GIS technique to obtain the concentration levels for major pollutants in the study area. It is concluded that the GIS and related technologies are very effective and powerful tools to illustrate the spatial distribution of major pollutants and compare their values with the allowable standards to support the decision making process.
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1. Introduction

Damietta Port Authority in Egypt is planning to establish a new containers terminal as an extension to Damietta Port. Damietta Port is located on the northeastern coast of the Nile delta, Egypt. The harbor was constructed in 1982 and is located about 9.7 km west of the Damietta Nile promontory with an area of approximately 9.3 km^2, of which 3.2 km^2 is water mass. A new container terminal with cargo quay walls, storage areas and new buildings are scheduled to be constructed in the concession area. The proposed area for the development is the Port of Damietta, Egypt and the proposed works comprise an extension of an existing basin within the port area Figure (1).

Figure (1): Proposed area for construction

The existing basin is to be extended by about 1.5km, widened to a total of 325m and deepened to about 18m. The proposed project will occupy approximately 130 hectares of the land behind the existing channel. The new container terminal is designed for two phases of development. The Environmental Baseline Survey (EBS) provides an overview of the existing Environmental conditions both inside and outside Damietta Port and is presented as part of the Environmental Impact Assessment (EIA) for the new extension of Damietta Port. EIA is one of the main types of environmental appraisal work that is required by the Egyptian Environmental Affairs Agency (EEAA). The EIA is the most significant tool and a multidisciplinary approach that helps in assessing the environmental impacts of the construction and operation of the port in regard with the project and identifying the mitigation measures. The Environmental Assessment is the primary objective of understanding the proposed project and their associated environmental consequences for adopting alternatives. The air quality assessment is one of the main items of the EIA.

The main objectives of this assessment study are:

1. Applying GIS; GPS and Remote Sensing techniques to monitor different air pollutants such as Total Suspended Particulate (TSP), Carbon Monoxide (CO), Nitrogen Oxides (NO_X), Sulfur Dioxide (SO_2), hydrogen sulfide (H_2S) inside and outside Damietta harbor and the sources of pollutants.

2. Data analyses and interpretation of the air pollution sources in the study area using GIS potential.
3. Producing a comparison map to compare the recorded levels of air pollutants with those in the Egyptian Environmental Law 4/94 for decision makers.

2. Material and Methods

The GIS techniques are used to integrate the geospatial data, Remote sensing image, GPS data and other available and relevant data to achieve the overall objectives of this study.

2.1. Data availability

3.1.1 Geospatial data

a. Boundaries of the study area
b. A high resolution Quick Bird image for the study area
c. Land use map of the study area
d. Topographic map

2.1.2 Descriptive Data

a. GPS observations for the selected Ground Control Points.
b. Observations of different air pollutants in the study area.
c. The allowable values of the different air pollutants in the Egyptian Environmental Law

2.2 GIS Technology Platform

This study was performed using Arc-GIS 9.1 running on Microsoft Intel based GIS. Also, ERDAS Imagine S/W was used in the processing of satellite images and produces the land-use/land-cover map.

3. Methodology

3.1. Data acquisition and collection

The primary data used in this study was remotely sensed image. There are a variety of imagery types that could be used and, normally, images with higher spatial and/or spectral resolutions are preferred for coastal land-use. For this purpose, a high resolution image from Quick Bird has been ordered especially for study of the port area and the proposed new extension. The Quick Bird spacecraft, owned and operated by Digital Globe ^{TM} Inc., collects the highest resolution imagery commercially available (Volpe 2004, Digital Globe 2006). The Quick Bird; which launched in October 2001, acquires images in 4 multispectral bands of 2.44 m resolution and one panchromatic band (Pan) of 61 cm resolution. The selected Quick Bird image covers an area of 38 km^2 and acquired on 4 December 2005 in 4 multispectral bands (2.4 m resolution) and 1 pan band (60 cm resolution) as shown in Figure 2. The image was delivered in Geo-TIFF 8-bit enhanced standard format and geo-referenced to the Universe Transverse Mercator (UTM) Zone 36 as projection and WGS 84 as datum. Standard Quick Bird products are radio-metrically corrected, sensor corrected, geometrically corrected, and mapped to a cartographic projection. In addition to satellite data, a 3-days field visit guided with hand held Global Positioning System (GPS) was conducted in the port and surrounding area during the period from 24 to 26 July, 2006 in order to acquaint with and identify all important elements and land-uses which could later identified using remotely sensed data.

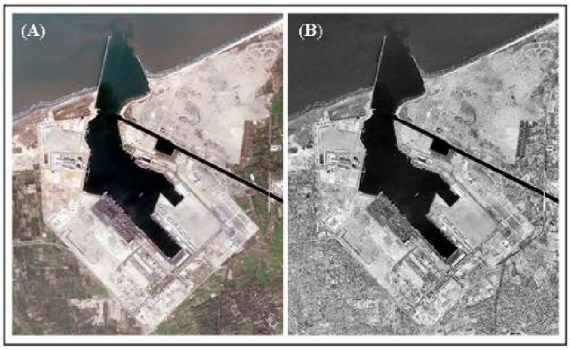

Figure (2): The selected Quick Bird image

Other supplementary information utilized for this study included: land-use map produced by the Port Authority showing the main features and amenities of the port and Topographic map of scale 1:25 000 covering the study area.

3.2 Image preprocessing and analysis

The image processing steps which applied in this study included: preparation of the satellite data for viewing and analysis, merging multispectral bands (2.4 m) with the pan band (0.6 m) to enhance spatial details while preserving the spectral information, determination of the classification scheme, visuals interpretation and digitization, editing of the image classes and categories, and finally producing spatial map for the study area.

All of the digital image processing and subsequent mapping of remote sensing data were performed using ER Mapper 7.1 as image processing software. The ER Mapper is one of the most powerful software systems that can combine digital image processing routines with raster geographic information system (GIS).

3.3 Classification scheme design

Due to some limitations such as shortage of the time and extensive efforts and time needed for processing of image classification techniques, classification of the land-cover and land-use types of the study area was based essentially on visual interpretation and digitization of the Quick Bird image. Computer assisted classification (unsupervised) was conducted in some cases, as well.

After interactive interpretation of the Quick Bird image on computer screen, different land-use maps were produced in different scales and stored in ESRI shape format for GIS applications.

3.4 GPS observations

The coordinates of the selected eight sites were determined in WGS 84 using GPS hand held receiver (GARMIN) with 3 m accuracy.

3.5 Air quality assessment

3.5.1 Air quality standards

The standards approved by the Law 4/1994 for the ambient air quality are applicable to Damietta Port for the residential areas. The industrial air quality standard is applicable due to the fairly small distance between the nearest industrial area (Port Industrial Area, 8.5 Km) to Damietta City. The EEAA approved limit concentrations for NO_2, SO_2 and particulate matter for hourly, daily and annual averages are presented on Table (1) as applicable.

Table (1): Egypt Ambient Air Quality Standards.

Parameter	Hourly µg/m^3	Daily µg g/m^3	Annual µg g/m^3
NO_2	400	150	---
SO_2	350	150	60
Particulate Matter	---	70	---

3.5.2. Field measurements (Mobile Laboratory)

Field measurement was conducted using air quality mobile laboratory. The lab consists of direct reading instruments for measuring major air pollutants. The lab was taken to the different stations inside and outside Damietta Port. After conducting several field trips to the area thereby considering the characteristics and distribution of pollutant sources as well as the directional characteristics of the prevailing wind, sampling locations were chosen. Eight sites have been selected and defined as presented in Figure (3). The monitoring has been carried out through two weeks of measurements. All given data expressed as a time weighted average. The huge instantaneous readings data are recorded for subsequent processing and analysis. The downwind stations were represented with stations 1 to 4, stations (3&4) are highly impacted due to being very near to source of air pollution while stations (1&2) are impacted with other sources such as traffic and smoke. Stations (5&6) could be considered upwind from the proposed location for the project. Site of stations (7&8) are outside the Port and are impacted only from the traffic and other anthropogenic activities.

The main sources of air pollution at this area are the flare (Incinerator) of Sea Gas Company, truck movements and the uploading and downloading of the Grain dock. All the previously mentioned sources were located upwind from site of stations (3&4).

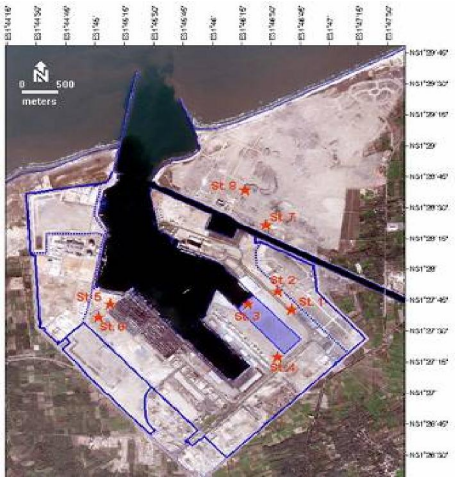

Figure (3): The selected sites

4. Results and Discussion

4.1. Total Suspended Particles

The levels of total suspended particulates (TSP) at the selected stations inside the Port are shown in Table (2). The average concentration of TSP ranged between 217 to 812 µg/m^3. The highest levels were detected at stations (3& 5). These two stations are under the direct impact of the NW winds carrying high amounts of suspended materials as direct results of truck movements due to Port activities while the lowest was at station 2 being protected from the effect the wind and sources of pollution Figure (4). All recorded levels exceeded the AQL (230 µg/m^3) except at stations (1&2) as shown in Figure (5). It is worthy to mention that TSP levels are always higher than AQL in most locations of Egypt.

Table (2): Levels of TSP at various sites

Site No.	*Site Description*	*Air Quality Limit AQL=230 µg/m^3 Average TSP (µg/m^3))*
1	N 31° 27 43 E 31° 46 37	217
2	N 31° 27 53 E 31° 46 23	210
3	N 31° 27 49 E 31° 46 24	812
4	N 31° 27 14 E 31° 46 36	421

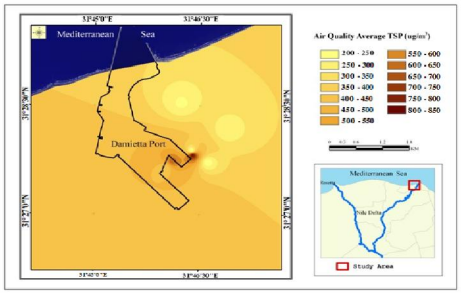

Figure (4): Distribution of TSP

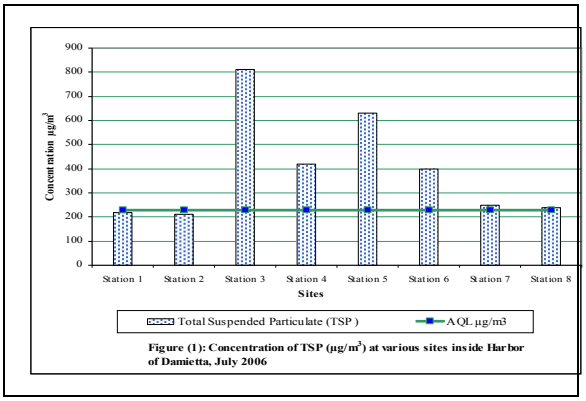

Figure (5): Concentrations of TSP

4.2. Gas Monitoring (VOC – CO- NO- NO_2 NOx- H_2S)

Five inorganic gases in addition to volatile organic compound are presented in Table (3). The recorded levels of all gases did not exceed the AQL as stipulated in the Egyptian Environmental Law 4/94. However, the sites had different values of gases. Stations from one to 4 had higher values than the remaining sites from (5 to 8). In general the inorganic gases H_2S, NO_x, SO_2 and CO recorded levels near the background at stations from (5 to 8). On other hand stations from (1 to 4) considered to be contaminated impacted by various air pollution sources. However, all levels still far below AQL. Figures (6 to 12) are showing the distribution of different measured parameters at Damietta Port. It is important to mention that the peaks of pollutants levels are almost at the proposed site or nearby.

Table (3): Multi Gas Levels (MGL) (ppm)

Site No.	*Site Description*	*Concentration of Different gases*					
		VOC mg/m^3	CO mg/m^3	NO $\mu g/m^3$	NO_2 $\mu g/m^3$	NO_x $\mu g/m^3$	H_2S $\mu g/m^3$
1	N 31° 27 43 E 31° 46 37	0.14 -2.3	0.48-2.2	47.5	10.7	57.9	5.5
2	N 31° 27 53 E 31° 46 23	0.48 –2.18	0.24-2.8	37.7	20.4	57.7	5.5
3	N 31° 27 49 E 31° 46 24	1.98-2.24	3.7-6.8	55.2	8.6	63.8	8.0
4	N 31° 27 14 E 31° 46 36	1.98 – 2.24	3.6-4.9	41.2	7.2	48.4	6.0
5	N 31° 27 44 E 31° 45 07	1.72 – 1.86	2.6-4.7	5.6	2.7	6.1	2.0
6	N 31° 27 38 E 31° 45 01	1.71 – 1.79	1.8-3.4	5.3	3.0	8.3	2.5
7	N 31° 28 10 E 31° 46 53	0.014 – 0.28	0.31-1.4	4.2	3.0	7.2	2.5
8	N 31° 28 32 E 31° 46 14	0.018-0.305	0.5-1.9	4.1	2.5	6.6	2.7

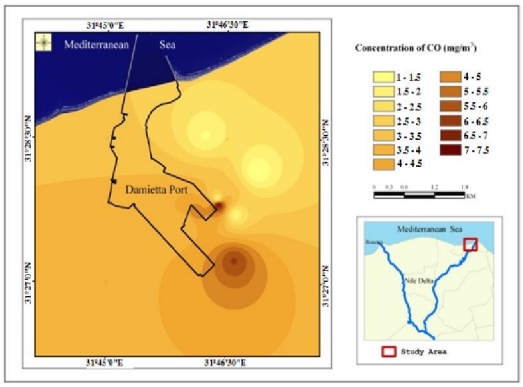

Figure (6): Distribution of CO

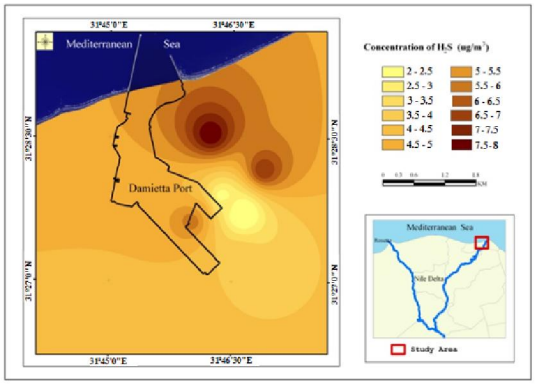

Figure (7): Distribution of H_2S

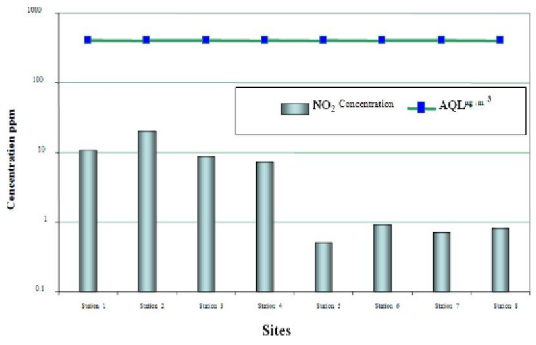

Figure (8): Concentration of NO_2 ppm

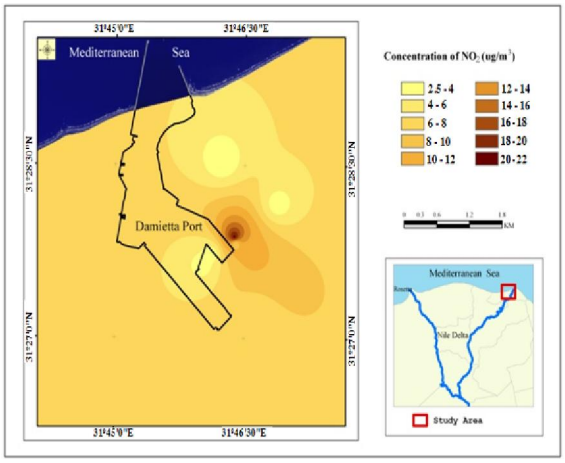

Figure (9): Distribution of NO_2

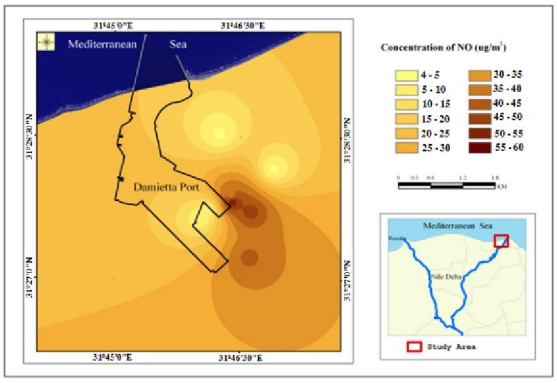

Figure (10): Distribution of NO

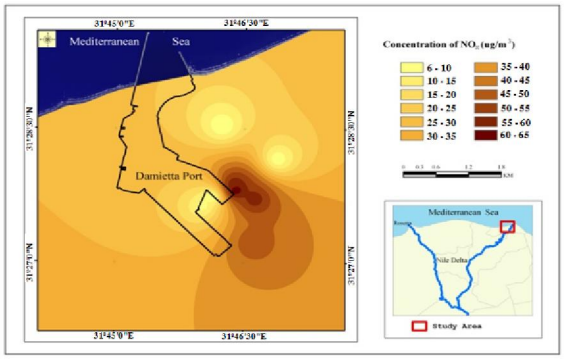

Figure (11): Distribution of NOx

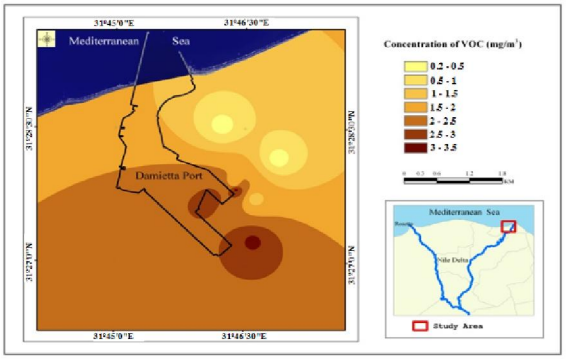

Figure (12): Distribution of VOC

5. Conclusions

The mobile laboratory of Alexandria University was used for field measurements in the vicinity of the proposed study site. The measurements data were analyzing and monitoring using GIS technique to illustrate the concentration level for major pollutants in the area.

The measured values for both SO_2 and NO_2 were well below the standard values provided by EEAA-Egypt. Damietta City is located 8.5 km south-east of the existing Damietta Port. The prevailing wind is from the northwest which might provides moderate concentrations of both NO_2 and SO_2 in this locality that blow most of the emitting pollutes toward the land downwind.

The levels of both total suspended particulate (TSP) and particulate matter less than 10 micron (PM_{10}) were higher than air quality limits (AQL) as recommended by Egyptian Environmental law 4/94 in some sites which exposed to air pollution sources.

The final results of the investigation showed that Geographic Information System (GIS) is an effective tool to analyze and visualize the different parameters of environmental issues and their impact. Also, it could monitor the results in such way to support the decision making process. The utilization of GIS and related technologies is becoming very urgent to face the expected impact and risk from the air pollutants.

References

1- Andrew, S., 2002, Environmental Modeling with GIS and Remote Sensing, London, 2002.
2- EEAA (Egyptian Environmental Affairs Agency) 2005. Egypt state of the environmental report in 2004, ch.1, Air pollution.
3- El-Gamily, H.I., S.M. Nasr and M. El-Raey. 2001. An assessment of natural and human induced changes along Hurghada and Ras Abu Soma coastal zone, Red Sea, Egypt. Int. J. Remote Sensing, v. 22(15): 2999-3014.
4- Gibson, P., and Clare P., 1999, Introductory Remote Sensing: Digital Image Processing and Applications.
5- Misra, P., Burke, B., and Partt, M. 1999. GPS performance in navigation. Proceeding of the IEEE, January 1999, vol. 87.

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