Use of GIS for Studying the Spatial Distribution of Pollutants around Safaniya Power Plant (KSA)

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Abstract: This study aims to use the Geographic Information System (GIS) for studying the spatial distribution of pollutants emitted from Safaniya Power Plant, KSA. To fulfill this objective the concentrations of Nitrogen, Carbon dioxide, Methane and Ethane were calculated at different distances from the Power Plant stack using the widespread Gaussian Plume Model (GPM). A digital data base of the plant was established using Arc-GIS 9.2 software. The concentration of pollutants and climatic data were attached to the database. The spatial analyst was used to map the spatial distribution of the pollutants around the stack. The areas affected by the high concentrations of pollutants were defined and the changes of pollutants concentration were discussed in detail. The results indicate that the areas affected by the high concentration are located to the distance of 10 – 750 meter from the stack. The impact of pollutants can be found at the distance of 1450 meter where it includes land surfaces and the water bodies of Arabian Gulf.

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1. Introduction

Since industrial revolution, concentrations of air pollutants have been increased by 15 to 30 %, this causes the radiative forcing increase of the atmosphere and accordingly increase of its temperature all around the world (Hurlock et al., 2004; Belić, 2006). Due to their impact on the atmosphere, vegetation, human health and materials, gases have received considerable research and regulatory attention. It is reported that about 90% of the anthropogenic emissions to the atmosphere are gaseous (Godish, 1997; Barnett, 2003; Jacobson, 2006). Because of their universally distribution Nitrogen, Carbon dioxide, Methane and Ethane are considered as the most important air pollutants (Khare and Nagendra, 2007). The Global atmospheric concentrations of carbon dioxide, methane and nitrous oxide have increased markedly as a result of human activities since 1750, where the global increases in air pollutants concentration are due primarily to fossil fuel use, land use change, agriculture and industrial activities (IPCC, 2007). The studies of the spatial distribution of the pollutants assess the decision maker to put suitable solutions to control the environmental degradation. Implementing the spatial distribution of pollutants under GIS environment is the strong features of GIS technology. The GIS techniques are capable to provide geospatial at any time and any location, where the output of the pollutant values can be obtained in the form of spatial records and digital maps (Agrawal et al., 2003; Hurlock, & Stutz, 2004).

Located at the coastal zone of Arabian Golf, Safaniya Power Plant considered as the greatest offshore oil field in the world (Figure 1). This study aims to study the spatial distribution of pollutants emitted from Safaniya Power Plant and assess their impact on the adjacent land cover using remote sensing data and GIS techniques.

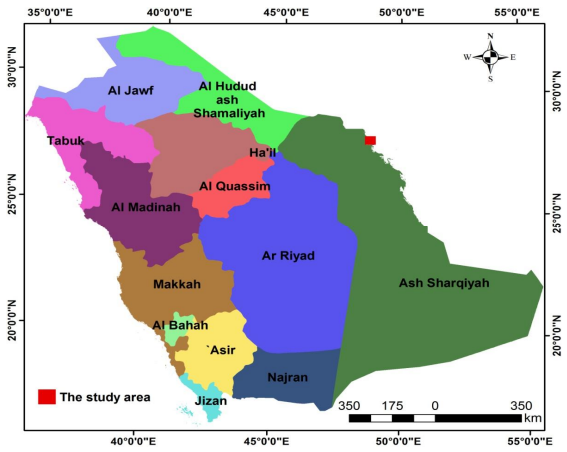

Figure (1) Location of the study area on the administrative map of Kingdom of Saudi Arabia

2. Materials and ethods

Remote sensing work

The Landsat ETM+ image (L72165041 - 04120070307) covered the area under investigation was used in this study (Figure 2). The Landsat ETM+ sensor records 7 bands of spectral data in the visible, infrared, and thermal portions of the electromagnetic spectrum. The spatial resolution of this sensor is 30 m, except the thermal band (6.1 & 6.2) of 60 m resolution.

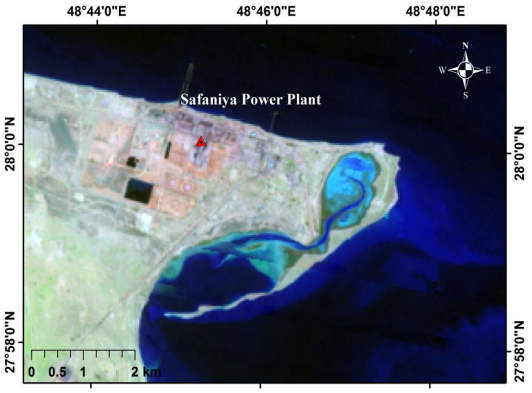

Figure (2) Landsat ETM+ (bands 7, 4, 2) of the study area

Pre-processing activities were performed to reduce some undesired variations / noises and to enhance other desired features. It commonly comprises a series of sequential operations, including radiometric correction or normalization, image registration, geometric correction, masking and image enhancement (e.g., for clouds, water, irrelevant features). Geometric rectification of the imagery was applied using ENVI4.7 software. This becomes especially important when scene to scene comparisons of individual pixels in applications such as change detection are being sought (ITT, 2009). Image enhancement techniques (e.g. contrast stretching, Gray-level threshold, Level slicing, and spatial stretch) were tested to improve the visual interpretability of the used images by increasing the apparent distinction between the features.

Land use/ cover classes are typically mapped from digital remotely sensed data through the process of a supervised digital image classification (Campbell, 1987; Thomas et al., 1987). The overall objective of the image classification procedure is to automatically categorize all pixels in an image into land use/ cover classes or themes (Lillesand and Kiefer, 1994). The maximum likelihood classifier quantitatively evaluates both the variance and covariance of the category spectral response patterns when classifying an unknown pixel so that it is considered to be one of the most accurate classifier since it is based on statistical parameters. Supervised classification was done using ground checkpoints and digital topographic maps of the study area. Then accuracy assessment was carried out using 75 points from field data and existing land cover maps. In order to increase the accuracy of land use/ cover mapping of the image, ancillary data and the result of visual interpretation was integrated with the classification result using GIS.

GIS work

Considering the plume rise, and climatic condition the Gaussian plume model (GPM) has been used to estimate the concentration of pollutants from both ground and elevated sources (IAEA, 1982 & IAEA, 1996). The model used to calculate the concentration of Nitrogen, Carbon dioxide, Methane and Ethane in 30 sites located at different distances around the stack (i.e. 1 – 1550 m) during October 2007. Then the outputs (pollutants concentrations of 30 sites) were used in GIS to produce the spatial distribution layers of Nitrogen, Carbon dioxide, Methane and Ethane using the spatial analyst functions of Arc-GIS 9.2 software. The impact of each pollutant on the different land use/ cover was extracted by matching the layers of pollutants with land use/ cover map (Graeme & Bonham, 1996).

3. Results and discussion

Concentration of pollutants

The ground level concentrations of pollutants (N, CO2, CH4 and C2H6) around Safaniya oil field were estimated at different distances around the stack (Table 1). The obtained data indicate that Nitrogen concentration differ from 13.99 to 291.97 µgram/ m^2, Carbon dioxide varies from 526.13 µgram/ m^2, Methane differ from 1850.06 to 38585.75 µgram/ m^2, and Ethane concentration ranges between 385.28 and 8035.6 µgram/ m^2. It is noticed that the pollutants reaches its minimum values at distance less than 101 meter from the stack while the maximum values were observed at a distance of 251 meter. The results indicate that Nitrogen, Carbon dioxide, Methane and Ethane are the main pollutants released from Safaniya oil field. The concentrations of these pollutants were determined at ground level, and then the results were used to map the spatial distribution of pollutants around the field. It is found that Methane has the highest concentration followed by Carbon dioxide, Ethane and Nitrogen; this is agreeing with the results obtained by Khare and Nagendra, (2007).

Land cover classification

A total of 77 km2 around Safaniya oil field have been classified into five land cover units using remote sensing data as represented in Figure 3. The obtained classes are (1) water bodies of the Arabian Golf which extends about 1 – 4 km from the shore line, representing 54.55 % of the mapped area, (2) shallow water which found closed to the shore line (0.2 to 0.5 km) representing 6.49 % of the total area, (3) vegetation cover occupying about 14.29 % of the total area, this type of land cover in general exhibits creation parts near to the Arabian Golf, (4) wetlands in different patches within the studied area representing 5.19 % of the total area and (5) bare land occupying 19.48 % of the mapped area, it is mainly found at the western parts of the area.

Table 1: Ground level concentrations of the pollutant at different distances from the stack

No	Distance from stack (m)	Concentration of pollutants (µgram/ m^2)			
		N	CO2	CH4	C2H6
1	51	0.00	0.001	0.003	0.001
2	101	13.99	526.13	1850.06	385.28
3	151	137.79	5178.62	18209.10	3792.28
4	201	252.54	9491.40	33375.31	6950.50
5	251	291.97	10973.17	38585.75	8035.6
6	301	286.86	10781.10	37910.29	7894.92
7	351	264.21	9930.32	34918.75	7271.93
8	401	237.10	8910.85	31333.90	6525.37
9	451	210.76	7921.10	27853.41	5800.55
10	501	187.03	7029.34	24717.77	5147.55
11	551	166.31	6250.41	21978.77	4577.14
12	601	148.43	5578.44	19615.87	4085.06
13	651	133.06	5000.89	17585.00	3662.16
14	701	119.84	4504.15	15838.28	3298.37
15	751	108.44	4075.63	14331.45	2984.56
16	801	98.57	3704.44	13026.19	2712.74
17	851	89.97	3318.39	11890.23	2476.17
18	901	82.45	3098.87	10896.80	2269.29
19	951	75.85	2850.59	10023.77	2087.50
20	1001	70.01	2631.38	9252.92	1926.95
21	1051	64.84	2436.93	8569.17	1784.55
22	1101	60.23	2263.71	7960.04	1657.70
23	1151	56.20	2108.75	7415.14	1544.22
24	1201	52.41	1969.58	6925.78	1442.31
25	1251	49.10	1844.14	6484.68	1350.45
26	1301	46.10	1730.67	6085.68	1267.36
27	1351	43.31	1627.70	5723.58	1191.95
28	1401	40.81	1533.95	5393.94	1123.30
29	1451	38.54	1448.36	5092.97	1060.62
30	1501	0.00	0.00	0.00	0.00
31	1551	0.00	0.00	0.00	0.00

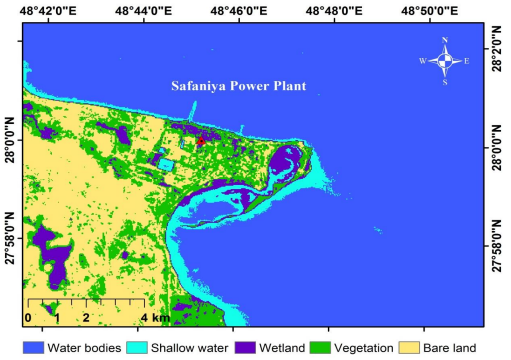

Figure (3) The main land cover units in Safaniya area

Spatial distribution of pollutants over the land cover

The spatial distribution of Nitrogen, Carbon dioxide, Methane and Ethane concentration around the stack are represented in Figures 4, 5, 6 and 7. The data represent that all pollutants take the same trend around the stack, where they reached to maximum values at 251 meter from the stack then they decreased gradually to reach their minimum level at 1500 meter far from the stack. The analysis of the spatial distribution indicate that the ground level of pollutants affect only 9.86 % of the total area (i.e. 7.60 km^2) distributed as 1.92 km^2 of Arabian Golf, 0.46 km^2 of coastal shallow water, 0.87 km^2 of wetlands, 2.77 km^2 of bare land and 1.58 km^2 of the vegetation cover.

The analysis of the obtained data indicates that concentration of pollutants affect 9.86 % of the total area. It is found that the impact of pollutants on the bare land, vegetation cover and water bodies are high compared with wetland and shallow water.

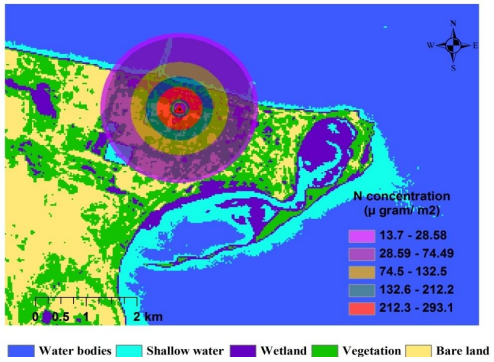

Figure (3) Spatial distribution of Nitrogen concentration

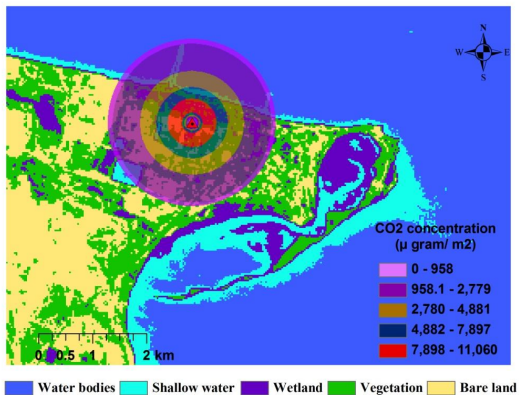

Figure (4) Spatial distribution of Carbon dioxide concentration

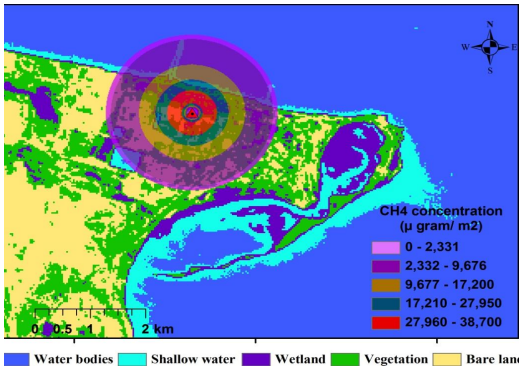

Figure (5) Spatial distribution of Methane concentration

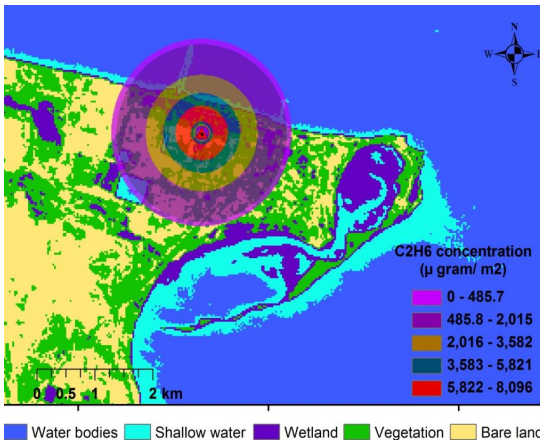

Figure (5) Spatial distribution of Methane concentration

Conclusion

According to the obtained data, it could be concluded that the use of remote sensing data and GIS techniques in the study of spatial distribution of the pollutants over the land cover allow to give more attention to the areas which highly affected by pollutants. This is the cornerstone to realize the environmental sustainability.

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