Monitoring and change detection of concentration values for zinc and lead minerals in soil of agricultural lands based on remote sensing analysis and GIS

Hashim Ali Hasab *

Al-Furat Al-Awsat Technical University, Al-Najaf Technical Institute, Department of Architectural Design and Decoration, Najaf-Iraq

*Email: hashim@atu.edu.iq

Abstract. The agricultural lands are an important source for the recovery of the economy system southern of Iraq. The neglect, lack of interest, and the wars in recent years are affecting on the soil quality of these lands. There are a few techniques are developed to detect and monitor the toxic minerals in soil of the agricultural lands south of Iraq. The integration of remote sensing data and Geographic Information System (GIS) techniques with the developed of mathematical equations were as a powerful tool to monitor spatial distribution and change detections the concentrations values for zinc (Zn) and lead (Pb) in soil of the agricultural lands during winter and summer seasons in year 2018. The concentrations values for (Zn) and (Pb) in soil have been lowest in winter and highest in summer season. The change detection of spatial distribution area for (Zn) between two seasons was by range (45.06) km² with the change ratio (37%), while the change detection of spatial distribution area for (Pb) between two seasons was by range (29.82) km², with the change ratio (25%). In conclusion, the developed systematic and generic approach may constitute a basis for determining the soil minerals in the agricultural lands worldwide.

1. Introduction
There are severely affected have been concern to the ecosystem, water resources and agricultural lands degradation such as indicators of environmentally destructive development, human non-ethical activities as industrial waste waters, inadequately discharges of sewage and soil pollutions [1]. Salinity and heavy minerals are most dangerous in environmental contamination. Hydrological, sedimentation, biological, chemical and morphological processes are affecting on surface water and soil quality of reservoirs, marshes and lakes [1-7]. [6] Said supply of poor soil and water quality severely affects the sanitation, which are causes of soil deterioration and soil erosions unless inhibited. There are more than 25,000 deaths occur daily in the world due to the effecting of contamination diseases [8-9].

[8,10] Integrated math model and Geographic Information System (GIS) together with the remote sensing techniques have been provided excellent a powerful tool for monitoring and assessment the agricultural lands and surface soil pollution as well as water quality problems in watersheds and agricultural lands.
The integrated of soil erosion models with the remote sensing data and GIS have been as powerful tools to assess the different of two NDVI layers as well as mapped and located the risk of soil erosion in Wadi Yalamlam Saudi Arabia [11]. Integrated between Landsat-8 images with developed algorithms as (OC-2 and Morel-3) used to estimate the concentrations of (SST and Chlorophyll-a, Kd-490) in the Persian gulf during four seasons of 2014 [12]. Used GIS and supervised classification method on Landsat satellite images for monitoring, assessment and change detection mapping of wetland dynamics in Chennai coast-India during three periods from 1988-2006-2016 [13].

Analyzed groundwater quality, measured nitrate concentrations and overlapping pollution risk map of Loor basin aquifer in Khouzestan province-Iran based on DRASTIC model and GIS [14], While used remote sensing, GIS techniques, geology, DEM and geomorphology to locate the hydrocarbon prospective zones in Caunery Basin-India [15]. The high resolution of remote sensing imagery with biophysical parameters to map NDVI parameters and extract P.juliflora, which is represented the major invader form invasive plant based on applied support vector machine classification SVM [16].

These techniques used also to simulate hydrological processes on a daily time step including surface water quality, runoff, evapotranspiration, soil erosion and agricultural lands pollutant [17]. Thus, proper management, assessment, monitoring and solving the problems of surface soil require an in-depth analyses of the agricultural lands soil, where an integrated agricultural approach is believed to play a major role [8,18]. Used remote sensing and GIS techniques with Analytical Hierarchy Process (AHP) for sustainable groundwater management by determine the groundwater areas in central India with extreme climate conditions [19].

Found a much stronger correlation between surface soil temperature (SST) and surface soil moisture (SSM) in two catchments one in UK and other in Australia based on the highly related between the surface soil temperature and soil depth of the diurnal change. SST is suitable to assess and monitor the variability of the (SSM) in both catchments. SST and SSM refer to the soil sample at small centimeter depth below the surface that will be different to the satellite land surface temperature. There are good correlations between the surface temperatures with the soil moisture below the surface than the soil temperature at below the surface. Temporal MODIS and NDVI data are used to locate the spatial distribution for the vegetation cover in Hanjiang river-China during 2000-2016 [20].

The investigated of the vegetation covers were depending on meteorological and topographical data. Major climatic data such as topographic temperature and rainfall are employed for analyzing the driving forces of (NDVI) changes. NDVI has been negatively correlated with elevation but positively correlated with rainfall and temperature [21]. Monitored of the soil moisture in Mongolian Plateau during period of 1981–2012 from remote sensing data based on developed a general of vegetation indexes and Ts-NDVI, then evaluated the spatio-temporal variations of temperature vegetation dryness index (TVDI) regions distributions with changes in land use land cover types as well as vegetation cover and latitude in same area [22].

They simulated and evaluated urban expansion based on combined three GIS model and free remote sensing Landsat images from 1972- 2013 for land cover land use change in the GAZA Strp. The change of Land use and land cover is a major global issue of environmental change as well as the projecting changes are essential for assessing of the environment [23]. Used (nemerow, pollution load, geo-accumulation and ecological risk) indexes and (enrichment and contamination) factors with (ICPMS) inductively coupled plasma-mass spectrometer to investigated heavy metals contamination such as Cu, Mn, Ni, Cr, Co and Pb for assessing the pollution levels of agricultural soil in Singhbhum area-India. The enrichment factor verified very high accurate to calculate all minerals indexes in agricultural soil [24].

GIS and Analytical hierarchy process used to evaluate Salinity, pH, CEC, OC indicators for sustainable and management of activity in the agricultural land of Tadla plain-Morocco. Analytical hierarchy process based on pairwise comparison matrix used to identify the weight of each indicator. GIS used to map generate the soil quality environmental [25].
The huge agricultural lands southern of Iraq are considered as an enriched resource to produce several crops and represented as significant impact on the ecosystem. 74% of these lands were suffered from high degree of the salinity and minerals. The industrial activities, remnants wars from the previous decades and the toxic metals have a significant effect on the agricultural lands quality [26-31]. These agricultural lands in the last few decades were suffered from discharges of industrial and sewage waste waters, lack with the poor public awareness of agricultural lands management and water resources protection [2,6,32].

Recent advancement in remote sensing towards data acquisition and integration of spatial and temporal soil models provided a renewed prospect for managing and evaluating the surface soil quality problems in the agricultural lands of marshes zone southern of Iraq. It is greatly potential for estimating, monitoring and mapping zinc (Zn) and lead (Pb) in soil of the agricultural land. The object of this study to monitor and change detection the concentration values for zinc (Zn) and lead (Pb) in soil of the agricultural lands southern of Iraq during two seasons of year 2018, based on integrated between remote sensing data and GIS with mathematical equations of minerals.

2. Study Area
The agricultural lands are located at southern of Iraq with coverage area more than 3000 Km² as illustrated in figure 1. The agricultural lands are represented as an important source to produce several types of the crops which are considered as a provider of habitat for living creatures. These lands are irrigating by the water from Al-Hawiza marsh which is surrounding them. In last ducat these lands were suffering from increment of the concentration values of zinc (Zn) and lead (Pb) because the water pollution, that was affecting on the activities of several types of the agricultural crops and the humanity in these areas [26-31,33].

Figure 1. Satellite image showing the agricultural lands southern of Iraq.
3. Collection Data
Data used are including satellite image which is illustrated the position of soil sampling stations. There are 60 soil samples collected by used Global Positioning System (GPS) and positioned at different regions covering the overall soil of the agricultural lands during two (winter and summer) seasons of 2018 as shown in figure 2.

![Figure 2. Satellite image showing the position of soil sampling stations.](image)

4. Methodology
The methodology of this study are including important steps such as (pre-processing of remote sensing data (satellite images), ancillary data (ground data), processing of the mathematical equations, data validation, spatial distribution by used GIS, data visualization and changes detection) these should be applied respectively as illustrated in the flowchart below figure 3.

![Figure 3. Methodology flowchart of this study.](image)
Landsat-8 images with resolution 30 m are used in study area. Image pre-processing of satellite data including the several respectively steps such as atmospheric corrections, reflectance calibration, radiometric calibration, dark subtraction, layer stacking, geo-referencing and image enhancement. The ancillary data are represented the ground data of laboratory results for zinc (Zn) and lead (Pb) during winter and summer of year 2018. The laboratory results for both of these minerals have been lowest level in the winter and highest level in the summer as shown the minimum and maximum of the concentration values for these minerals in Table 1. Remote sensing data after correction are must to be integrated with the ancillary data by the mathematical equations in the mathematical equations Process section then pass to next step of data validation. If the output results of the minerals were outside of the limitation range should be repeated to step of (mathematical equations Process), While if the results of the minerals are during the limitation range will be pass to the next step of (spatial distribution by used GIS) to visualize the output results of the minerals as mapping of spatial distribution on the satellite images finally to do change detection between them during two seasons.

### Table 1. Max and Min concentrations values of metals in the soil during summer and winter.

| Minerals  | Summer | Winter |
|-----------|--------|--------|
|           | Min(ppth) | Max(ppth) | Min(ppth) | Max(ppth) |
| Zinc (Zn) | 5 | 550 | 15 | 80 |
| Lead (Pb) | 5 | 80 | 5 | 18 |

5. **Mathematical Equations**

There are two mathematical equations used to retrieve zinc (Zn) and lead (Pb) concentration values based on the integration between these equations with the remote sensing data, GIS techniques and ancillary data. These equations are called zinc equation (ZE) and lead equation (LE) as details illustrated bellow.

Zinc equations (ZE) are based on (B3, B4 and B5) bands of Landsat-8 images. B3 is the green band in the wavelength range of (0.53-0.59). It is important for Emphasizes peak vegetation and useful to assess plant vigour. B4 is the red band having wavelength between (0.64-0.67), which is used to discriminating the vegetation slopes. B5 is Near Infrared band having wavelength between (085.-0.88) used to emphasizes biomass content and shorelines [34,35]. These equations are used to calculate the concentration values of zinc (Zn) in soil of the agricultural lands during winter and summer seasons as shown below in equation (1) and equation (2), respectively.

Lead equations (LE) are based on (B3, B4 and B5) bands of Landsat-8 images as mention in up paragraph. These equations are used to calculate the concentration values of lead (Pb) in soil of the agricultural lands during winter and summer seasons as shown below in equation (3) and equation (4), respectively. All the numbers in these equations are constants. These constants are based on the concentrations levels of minerals in ground data.

ZE in winter = \{0.059*82.43* EXP (127.6* √B3² +B4² +B5² ) -10]^{0.690} + 10.3\} (1)

ZE in summer = \{0.008*(3E+12*( √B3² +B4² +B5² )^{6.382} + 423.2 - 0.304 - 2.4\} (2)

LE in winter = \{0.610*[82.43* EXP (127.6* √B3² +B4² +B5² ) -10]^{0.328} +0.96\} (3)

LE in summer = \{0.001*(3E+12*( √B3² +B4² +B5² )^{6.382} + 423.2) + 2.549 + 0.914\} (4)

6. **Results and Discussion**

The estimation of (Zn) and (Pb) values in soil of the agricultural lands are depending on the integration between remote sensing data, GIS techniques and mathematical equations. These results are represented the spatial distribution and change detection of the concentration values for (Zn) and (Pb) during summer and winter as illustrated bellow.
6.1. Spatial Distribution

The spatial distribution of (Zn) and (Pb) are observed based on (Green, Red and NIR) bands of Landsat-8 images. B3 is the green band in the wavelength range of (0.53-0.59). It is important for Emphasizes peak vegetation and useful to assess plant vigour. B4 is the red band having wavelength between (0.64-0.67), which is used to discriminating the vegetation slopes. B5 is Near Infrared band having wavelength between (0.85-0.88) used to emphasizes biomass content and shorelines [34,35]. These bands appeared as possible bands to relate with and retrieve the minerals from satellite images.

Figure 4, illustrates the spatial distribution and profile section for (Zn) from satellite image during two seasons of year 2018 by used GIS techniques depending on the output results of the mathematical equations. Figure 4(A), shows the spatial distribution with the profile section of the concentration values for (Zn) from satellite image during winter season, which was by the minimum and maximum values between (13-83) ppth, while the spatial distribution with the profile section of the concentration values for (Zn) during summer season by the minimum and maximum values between (1-601) ppth as illustrated in figure 4(B).

Figure 5, illustrates the spatial distribution and profile section for (Pb) from satellite image during two seasons of year 2018. Figure 5(A), shows the spatial distribution with the profile section of (Pb) from satellite image during winter season by minimum and maximum values between (5-19) ppth, while the spatial distribution with the profile section of (Pb) during summer season by minimum and maximum values between (4-84) ppth as illustrated in figure 5(B).

Figure 4. Spatial distribution and profile section for (Zn) from satellite image during two seasons.
Figure 5. Spatial distribution and profile section for (Pb) from satellite image during two seasons.

Maximum and minimum values of (Zn) and (Pb) have been observed from satellite image during two seasons of year 2018 are illustrated in Table 2. These results have been lowest values during winter and highest values in summer depending on the temperatures and the water amounts, which are flowing from Al-Hawizeh marsh during both of seasons. This indicated the water amounts have been a low flow in summer and a high in winter. The high temperatures in summer caused to dry of the soil, which lead to increase the Zn and Pb values in summer and decrease in winter. That indicated refer to the reverse relation between minerals values in soil of the agricultural lands and the water level in marsh, while the positive relationship between the temperatures and minerals values in the soil of the agricultural lands [36,37,38].

Table 2. Min and max of the concentrations values for minerals from satellite images.

| Minerals | Summer | Winter |
|----------|--------|--------|
|          | Min(ppth) | Max(ppth) | Min(ppth) | Max(ppth) |
| Zinc (Zn) | 1 | 601 | 13 | 83 |
| Lead (Pb) | 4 | 84 | 5 | 19 |
6.2. Change Detection
Table 3 shows the change detection results for (Zn) and (Pb) in soil of the agricultural lands from satellite images during two seasons (winter and summer) of year 2018. These results are depending on the output for the spatial distribution of minerals from satellite images during these seasons.

Figure 6(A) displays the change detection image of the spatial distribution for (Zn) between two seasons, which are found to be by range (45.06) km² and change ratio (37%). Figure 6(B) presents the change detection image of the spatial distribution for (Pb) between two seasons, which are found to be by range (29.82) km² and change ratio (25%) from the total area of the agricultural lands. From the previous results for (Zn) and (Pb) have been increased in summer and decreased in winter depending on the temperatures and the water amounts, which are flowing from Al-Hawizah marsh period both of seasons. This indicated the (Zn) and (Pb) values in summer larger than in winter.

| Seasons                     | Area size in Change detection (km²) | Percentage % |
|-----------------------------|-------------------------------------|--------------|
| Zinc (Zn) during (Winter & Summer) | 45.06                              | 37           |
| Lead (Pb) during (Winter & Summer)  | 29.82                              | 25           |

Figure 6. Images of change detection distribution area for (Zn & Pb) during two seasons.

7. Conclusion
The agricultural lands are considered a habitat provider for several types of living creatures and are an enriched resource of the production of several crops. The neglect, lack of interest, and the wars in last years are all factors that can lead to increase the concentration values of many minerals in these lands. The integration between remote sensing data, GIS techniques and ground data with mathematical equations were representing as a powerful tool to determine spatial distribution and change detections for (Zn) and (Pb) in the soil of agricultural lands southern of Iraq during summer and winter seasons of year 2018. The spatial distribution and change detection results of (Zn) and (Pb) are observed based on (Green, Red and NIR) bands of Landsat-8 images. These bands appeared as possible bands to relate with and retrieve the minerals from satellite images. Maximum and minimum values of (Zn) have been observed from satellite image during winter and summer seasons are found to be (13-83) ppth and (1-601) ppth, respectively. Maximum and minimum values of (Pb) have been observed from satellite image during winter and summer seasons are found to be (5-19) ppth and (4-84) ppth, respectively. The change detection of spatial distribution area for (Zn) between two seasons was by range (45.06) km² from the total area of the agricultural lands with the change ratio (37%), while the
change detection of spatial distribution area for (Pb) between two seasons was by range (29.82) km² from the total area of the agricultural lands with the change ratio (25%). These results have been lowest values during winter and highest values in summer depending on the temperatures and the water amounts, which are flowing from Al-Hawizeh marsh during both of seasons. This indicated of the water amounts have been a reduction flow in summer and a rise flow in winter season. The high temperatures in summer caused for drying of soil, which lead to increase the Zn and Pb values in summer and decrease in winter. The future direction of this study for improving and developing these equations based on the B6, B7 and B11 from Landsat-8 images to assess and monitor others minerals in soil of the agricultural lands.

References
[1] Azab, A.M 2012 Integrating GIS, Remote Sensing, and Mathematical Modelling for Surface Water Quality Management in Irrigated Watersheds: UNESCO-IHE PhD Thesis. CRC Press. chapter 6 pp 173–214
[2] Kerekes, J.P. and Baum, J.E 2005 Full-spectrum spectral imaging system analytical model. IEEE Transactions on Geoscience and remote sensing, 43(3), pp.571-580.
[3] Mather, P.M. and Koch, M 2011-a Computer processing of remotely-sensed images: an introduction. John Wiley & Sons.
[4] Mather, P.M. and Koch, M 2011-b Computer processing of remotely-sensed images: an introduction. John Wiley & Sons.
[5] Ongley, E.D 2000 April. Water quality management: design, financing and sustainability considerations-II. In Invited presentation at the World Bank’s Water Week Conference: Towards a strategy for managing water quality management.
[6] Ustin, S.L. ed 2004 Manual of remote sensing, remote sensing for natural resource management and environmental monitoring (4). John Wiley & Sons.
[7] Zacharias, I. and Gianni, A 2008 Hydrodynamic and dispersion modeling as a tool for restoration of coastal ecosystems. Application to a re-flooded lagoon. Environmental Modelling & Software, 23(6), pp.751-767.
[8] Hasab, H.A. and bin Ahmad, A 2015 Developing Hydrological Model for Water Quality in Iraq Marshes Zone by using Geographic Information System and Remote Sensing. network, 1(9), p 12.
[9] Mujumdar, N.A 2001 World development report, 2000/2001: attacking poverty. Indian Journal of Agricultural Economics, 56(1), p.146.
[10] Ammenberg, P., Flink, P., Lindell, T., Pierson, D. and Strombeck, N 2002 Bio-optical modelling combined with remote sensing to assess water quality. International Journal of Remote Sensing, 23(8), pp.1621-1638.
[11] Bahrawi, J.A 2018 Evaluation of distinctive normalized difference vegetation indices in soil erosion estimation using remote sensing concepts in Wadi Yalamlam, Saudi Arabia. Indian journal of Geo Marine Science, 47(01), pp2087-2093.
[12] Dehmordi, L.M., Savari, A., Dostshenas, A., Asgari, H.M. and Abasi, A 2018 Remote chlorophyll-a, SST and kd490 retrieval in Northwest Persian gulf using landsat 8 satellite data. Indian journal of Geo Marine Sciences, 47(01), pp148-169.
[13] Jacinth, T., Rajasree, S.R., Kumar, J.D. and Sriganesh, J 2019 Assessment of wetland change dynamics of Chennai coast, Tamil Nadu, India, using satellite remote sensing. Indian journal of Geo Marine Sciences, 48(08), pp1258-1266.
[14] Ravanbaksh, M., Nadooshan, M.A., Radnezhad, H. and Sarvarinezhad, S.B 2018 Pollution potential assessment using GIS-based DRASTIC model in the aquifer of Loor basin, Khuzestan province, Iran. Indian journal of Geo Marine Sciences, 47(08), pp1652-1657.
[15] Prabaharan, S., Lakshumanan, C. and Subramani, T 2017 Geoscientific study to locate hydrocarbon prospective zones in a part of Cauvery Basin using Remote Sensing and GIS techniques. Indian journal of Geo Marine Sciences, 46(07), pp1447-1453.
[16] Vidhya, R., Vijayasekaran, D. and Ramakrishnan, S.S 2017 Mapping invasive plant Prosopis juliflora in arid land using high resolution remote sensing data and biophysical parameters. Indian journal of Geo Marine Sciences, 46(06), pp.1135-1144.

[17] Quilbé, R. and Rousseau, A.N 2007 GIBSI: an integrated modelling system for watershed management? sample applications and current developments. Hydrology and Earth System Sciences Discussions, 4(3), pp.1301-1335.

[18] Haith, D.A. and Tubbs, L.J 1981 Watershed loading functions for nonpoint sources. Journal of the Environmental Engineering Division, 107(1), pp.121-137.

[19] Roy, A., Keesari, T., Sinha, U.K. and Sabarathinam, C 2019 Delineating groundwater prospect zones in a region with extreme climatic conditions using GIS and remote sensing techniques: A case study from central India. Journal of Earth System Science, 128(8), p.201.

[20] Zhuo, L., Han, D. and Dai, Q 2017 Exploration of empirical relationship between surface soil temperature and surface soil moisture over two catchments of contrasting climates and land covers. Arabian Journal of Geosciences, 10(18), p.410.

[21] Liu, H., Zheng, L. and Yin, S 2018 Multi-perspective analysis of vegetation cover changes and driving factors of long time series based on climate and terrain data in Hanjiang River Basin, China. Arabian Journal of Geosciences, 11(17), p.509.

[22] Cao, X., Feng, Y. and Wang, J 2017 Remote sensing monitoring the spatio-temporal changes of aridification in the Mongolian Plateau based on the general Ts-NDVI space, 1981–2012. Journal of Earth System Science, 126(4), p.58.

[23] Abuelaish, B. and Olmedo, M.T.C 2016 Scenario of land use and land cover change in the Gaza Strip using remote sensing and GIS models. Arabian Journal of Geosciences, 9(4), p.274.

[24] Giri, S., Singh, A.K. and Mahato, M.K 2017 Metal contamination of agricultural soils in the copper mining areas of Singhbhum shear zone in India. Journal of Earth System Science, 126(4), p.49.

[25] Ennaji, W., Barakat, A., El Baghdaadi, M., Oumenskou, H., Aaadraoui, M., Karroum, L.A. and Hilali, A 2018 GIS-based multi-criteria land suitability analysis for sustainable agriculture in the northeast area of Tadla plain (Morocco). Journal of Earth System Science, 127(6), p.79.

[26] Green, E.A 1993 Hydropolitics in the Middle East and US policy. NAVAL WAR COLL NEWPORT RI.

[27] Lowi, M.R 1995 Rivers of conflict rivers of peace’ Journal of International Affairs, pp 123-144.

[28] Malthby, E. ed 1994 An Environmental & Ecological Study of the Marshlands of Mesopotamia: Draft Consultative Bulletin. AMAR appeal Trust.

[29] Nicholson, E. and Clark, P., 2003. Iraqi Marshlands. Politico’s Pub.

[30] Partow, H 2001 The Mesopotamian marshlands: demise of an ecosystem.

[31] Marghany, M., Hasab, H.A., Mansor, S. and Sharif, A.R.B.M 2016 Developing hydrological model for water quality in Iraq marshes zone using Landsat-TM. In IOP Conference Series: Earth and Environmental Science, 37(1), p. 012073.

[32] Schwarte, C 2003 Environmental protection in Islamic law: an overview on potential influences for legal developments in Iraq. Local Environment, 8(5), pp.567-576.

[33] Al-Handal, A. and Hu, C 2015 MODIS observations of human-induced changes in the Mesopotamian Marshes in Iraq. Wetlands, 35(1), pp.31-40.

[34] USGS 2013 Using the USGS Landsat-8 product. USGS. Science for a changing world, U.S. Department of the Interior, Geological Survey. http://landsat.usgs.gov

[35] USGS 2016 Landsat 8 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS). Frequently Asked Questions about the Landsat Missions. USGS. Science for a changing world. http://landsat.usgs.gov

[36] Hasaba, H.A., Ahmada, A., Marghany, M. and Ziboon, A 2015 Landsat TM-8 Data for retrieving salinity in AL-HUWAIZAH marsh, south of IRAQ. Jurnal Teknologi, 75(1), pp 201-206.

[37] Hasab, H.A., Dibs, H., Dawood, A.S., Hadi, W.H., Hussain, H.M. and Al-Ansari, N 2020 Monitoring and Assessment of Salinity and Chemicals in Agricultural Lands by a Remote Sensing Technique and Soil Moisture with Chemical Index Models. Geosciences, 10(6), p 207.

[38] Hasab, H.A., Jawad, H.A., Dibs, H., Hussain, H.M. and Al-Ansari, N 2020 Evaluation of water quality parameters in marshes zone southern of Iraq based on remote sensing and GIS techniques. Water, Air, & Soil Pollution, 231, pp.1-11.