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ASSESSMENT OF URBAN SOIL CONTAMINATION USING MAGNETIC PROPERTIES IN THE SHU'AIBA AREA, BASRAH GOVERNORATE, SOUTH IRAQ

Nawrass N. Ameen

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ABSTRACT

The Basrah City and surrounding areas are reported to be seriously contaminated by emissions of oil industry and power plants. Magnetic measurements are carried out in this study for ninety surface soil samples from the Shu'aiba area near the Basrah City, southern Iraq. Detailed magnetic concentration parameters are measured to characterize the potentially polluted areas and explore their sources. These parameters include magnetic susceptibility (χ), frequency dependent-susceptibility (κ_{fd}%), Anhysteretic Remanent Magnetization (χ_{ARM}), Saturated Isothermal Remanent Magnetization (IRM) and temperature-dependent susceptibility. The results indicate that the magnetic minerals assemblage in the surface soil is heavily influenced by relatively high concentration of ferro(i)magnetic minerals, such as magnetite. The anhysteretic remanent magnetization (χ_{ARM}) and Saturated Isothermal Remanent Magnetization (SIRM) are significantly correlated with magnetic susceptibility (R^2= 0.94) and (R^2= 0.88) respectively, indicating a high contribution of ferro(i)magnetic minerals. This means that the magnetic mineral contents (such as magnetite and hematite) are enriched in the soil samples leading to increase in their magnetic properties which suggest contamination from fly ash produced by burning fossil fuel in the area.

دراسة التلوث في تربة المناطق الحضرية باستخدام الخواص المغناطسية في منطقة الشعيبة جنوب العراق

نورس ناهض امين

المستخلص

تفيد الدراسات السابقة بأن مدينة البصرة والمناطق المجاورة لها ملوثة بشدة بسبب الانبعاثات من الصناعة النفطية والمركبات ومحطات توليد الطاقة. أجريت قياسات مغناطيسية على تسعين عينة من التربة السطحية من منطقة الشعيبة قرب مدينة البصرة جنوب العراق. تم الاعتماد في هذه الدراسة على قياس معاملات مغناطيسية هي الحساسية المغناطيسية، الحساسية المغناطيسية التابعة للتردد، المغناطيسية المتبقية، المغناطيسية المتبقية الحرارية المشبعة وكذلك الحساسية المغناطيسية المعتمدة على درجة الحرارة. أشارت النتائج إلى ارتفاع تركيزالمعادن المغناطيسية المتجمعة في التربة السطحية وكانت نسبة الارتباط بين الحساسية المغناطيسية والمغناطيسية المتبقية هي (R^2= 0.94) وبين الحساسية المغناطيسية والمغناطيسية المتبقية الحرارية المشبعة هي (R^2 = 0.88) مما يشير إلى مساهمة عالية من المعادن المغناطيسية الحديدية (مثل الماغنيتايت و الهماتايت) ضمن المحتوى الكلي للمعادن الموجودة في النماذج وتسبب في زيادة الشدة المغناطيسية في التربة ويعتبر ذلك مؤشرا على التلوث الناجم عن انبعاثات حرق الوقود الاحفوري في المنطقة.

Faculty of Education for pure science, Al-Muthanna University, 66001 Samawa, Iraq,
e-mail: nawrass@mu.edu.iq

INTRODUCTION

Magnetic enhancement is a controlling tool for tracking air pollution from industrial fly ash and respiratory particles derived from vehicles (Evans and Heller 2003, Petrovský *et al.*, 2000). Air pollution became an important issue in the last decades due to urbanization and industrialization which emit fly ash particles carrying heavy metals that accumulate in soils. The accumulation of these particles in the soil will enhance magnetic mineral concentrations and consequently give rise to the magnetic signal. Soils naturally contain paramagnetic and diamagnetic minerals and anthropogenic activities produce magnetic fraction which will enhance the concentration of those magnetic materials in the soil. Ferrimagnetic minerals with high paramagnetic/ diamagnetic contents are considered as lithogenic and not anthropogenic (Meena *et al*., 2011). Fine Particulate Matter (FPM) in industrial areas are usually rich in heavy metals, such as Pb, Cr, Cu and Zn, and thus they could cause harmful effects on humans (Al-Hassen, 2011). Numerous studies have been conducted on soil pollution caused by different pollution sources. Here are some examples of these studies;

- Meena *et al.*, (2011) tried to discriminate between anthropogenic and lithogenic magnetic minerals in urban soils in Delhi, India using environmental magnetism techniques. They found high concentration of magnetic minerals derived from industrial activities and heavy traffic.
- Magnetic measurements were used to identify the secondary ferrimagnetic mineral grain sizes in soil samples from Wales, UK (Dearing *et al.*, 1997).
- Magnetic mineralogy changes in sediments have been used to detect the hydrocarbon contamination at a former military air base in the Czech Republic (Ameen *et al.*, 2014).
- Accumulation of heavy metals was detected using the magnetic susceptibility method in the Sawa Lake in the Muthanna Governorate southern Iraq (Ameen *et al*., 2019).
- Magnetic susceptibility of soils and vegetation was used in the monitoring of air pollution in Kyiv, Ukraine. The results proved that this method could be used to control efficiency of environmental-protection measures in urban areas (Bondar *et al.*, 2010).
- Heavy metals (Cd, Co, Cr, Fe, Ni and Pb) concentration in soils from Basrah City was studied by Khwedim *et al.*, (2009). The results showed increased concentrations of Pb, Ni, Cr and Cd towards the west of Basrah City and they attributed this elevation to the neighbouring Shu'aiba oil refinery.

Basrah is the second largest populated city in Iraq, where over 2.6 million people live and consumes a huge amount of fossil fuel. This study aims to assess the soil contamination caused by flying ash produced from fossil fuel-burning and processing, expressed in the magnetic properties of the soil in the proximity of the Shu'aiba oil refinery, near Basrah City.

STUDY AREA

The Basrah City lies in southern Iraq, with coordinates (30° 30' 31" N, 47° 46' 49" E) (Fig.1a). The total area of the Basrah City is about 19070 Km^2 and it forms about 4.4% of the total area of Iraq (Khwedim *et al.*, 2009). The Basrah City is located within the Mesopotamian Plain which contains relatively thick Quaternary sediments of fluvial and aeolian origin. The thickness of the Quaternary sediments increases to more than 250 m in the south eastern part of the aquifer system near Basrah (Al-Hassen, 2011). The sediments consist of flood plain silts, clays and stacks of river channel sand bodies, with occasional marsh deposits. The Quaternary sediments overlie Mio-Pliocene molasses or Lower Miocene carbonates (Jassim and Goff, 2006). The study area is located in the Shu'aiba district (coordinates 30° 25' 47" N 47°40′56″ E), about 11 Km west of Basrah City, it contains an oil refinery and oil fields (Fig.1b).

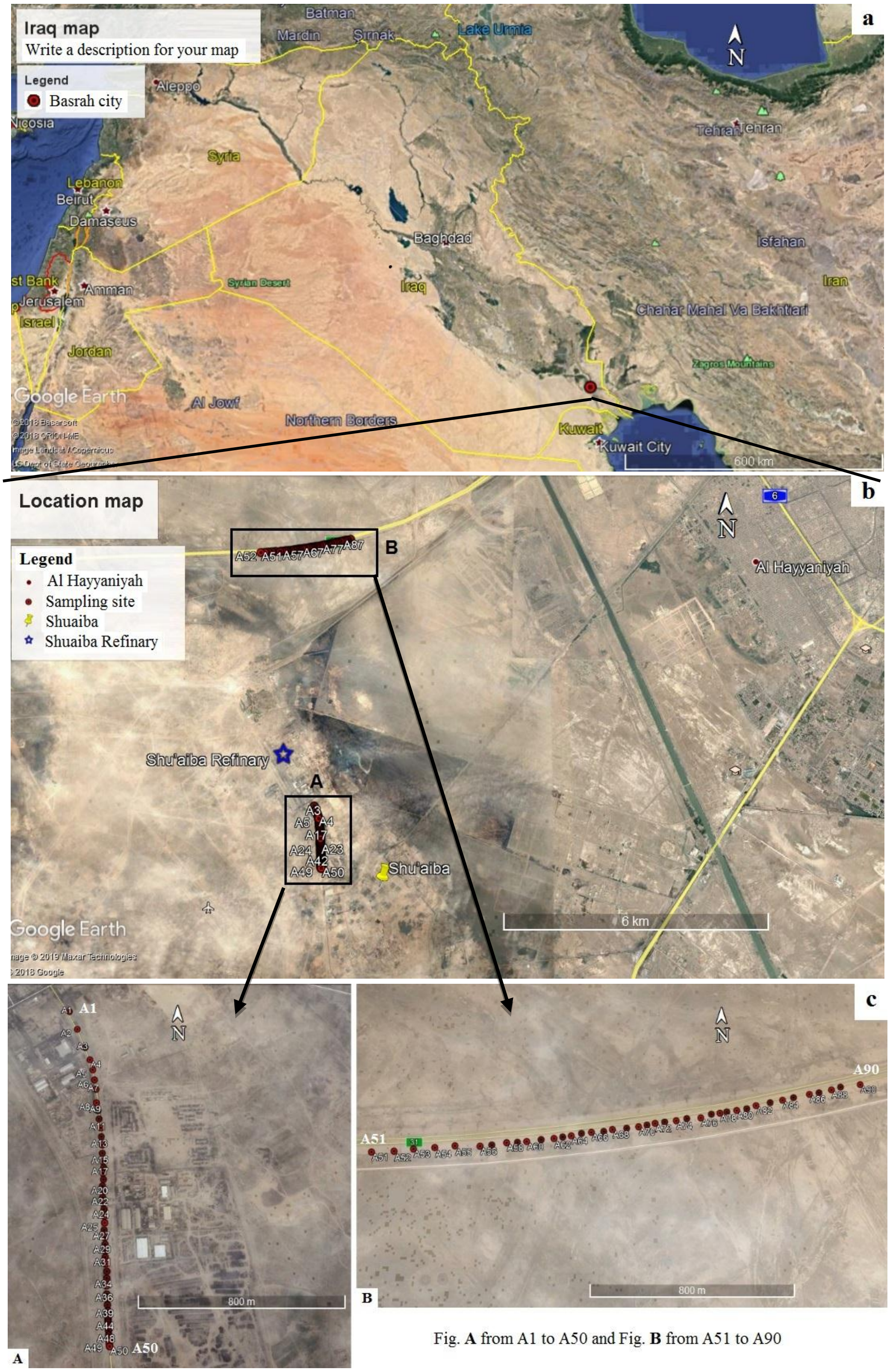

Fig. **A** from A1 to A50 and Fig. **B** from A51 to A90

Fig.1: Google Earth image of Iraq showing Basrah City with inset images showing details of the region and sampling sites (https://www.google.com/earth/)

METHODOLOGY

Ninety soil samples are collected for this study from road sides (about one meter away from the paved road) after removing the surface layer and careful sampling was made to avoid cross contamination. The samples were kept in plastic bags and. prepared at the University of Al-Muthanna (Muthanna Governorate), where they were air-dried and packed. The samples were sieved to -2 mm and packed into 10 cm^3 nonmagnetic cylinders for the following series of magnetic measurements. Magnetic measurements were done in the magnetic laboratories at the University of Tübingen, Germany. Mass-specific magnetic susceptibility (χ) was measured using KLY3 kappabridge magnetic susceptibility meter. Frequency dependent magnetic susceptibility (κ_{fd}) was measured using MFK1- FA kappabridge at two different frequencies of 976 Hz and 15.616 Hz in a peak field of 200 A/m, where κ_{fd}% was calculated according to Bloemendal *et al.*, (1992) $\{\kappa_{fd}\% = (\kappa_{lf} - \kappa_{hf})/\kappa_{lf}) \times 100\}$ (the percentage of frequency dependent of susceptibility = low field magnetic susceptibility- high field magnetic susceptibility/ low field magnetic susceptibility). Thermomagnetic analyses (κ-T) was measured using MFK1- FA kappabridge attached to CS3- heating unit from room temperature to 700 °C. Anhysteretic Remanent Magnetization (ARM) was imparted using long-core cryogenic magnetometer (2G Enterprises Model 755-1.65UC) with a peak alternating field of 100 mT and DC biasing field of 0,04 mT, then the Anhysteretic Remanent Magnetization (χ_{ARM}) was calculated. Saturation Isothermal Remanent Magnetization (SIRM) at 1 T was carried out and reverse fields of -300 millitesla (mT) using MMP5 pulse magnetizer. Magnetic results provide information about the concentration, type and grain size of magnetic minerals in samples according to Thompson and Oldfield, (1986) and Evans and Heller, (2003).

Two parameters (χ and IRM) provide information about the concentration of magnetic minerals, whereas, (κ_{fd}%) and (χ_{ARM}) are applied to estimate magnetic grain size. Thermomagnetic analyses provide information about the type of magnetic minerals. Magnetic properties change with temperature, where under certain temperature (the Currie temperature) ferrimagnetic minerals become paramagnetic and loose magnetization and this property can be used to diagnose the type of magnetic minerals as mentioned by Xia *et al.*, (2012).

RESULTS AND DISCUSSION

Statistical analysis is applied to process the magnetic properties measurements of the samples (Table 1). The χ varies between (78.19×10^{-8} and 731.12×10^{-8}) m^3kg^{-1} with mean value of 317.92×10^{-8} m^3kg^{-1} (Table 1). Figure (2) shows the contour map of χ values. The κ_{fd}% varies between 1.02 to 2.29 with mean value of 2.11 suggesting low or even negligible proportion of ultrafine superparamagnetic grains (SP) (< 0.01 m) and admixture of single domain (SD)/ pseudo single domain (PSD) and multidomain (MD) (Fig.3). Thus it is expected that soft ferrimagnetic minerals dominate the samples as suggested by Dearing *et al.*, (2001). The χ_{ARM} varied from 68.12×10^{-8} to 241.66×10^{-8} 10^{-8} m^3kg^{-1} with mean value of 113.04×10^{-8} 10^{-8} m^3kg^{-1}, and the χ_{ARM} and SIRM are well correlated with χ with correlation coefficient (R^2 = 0.94) and (R^2 = 0.88) respectively (Fig.3). The significant correlation of magnetic susceptibility with ARM and SIRM indicates that the ferro(i)magnetic minerals contributed significantly to the magnetic minerals rather that superparamagnetic minerals according to Gang *et al.*, (2013).

Grain size of magnetic minerals can be indicated by the ratios of ARM/χ and SIRM/χ (Thompson and Oldfield, 1986; Evans and Heler, 2003). The low values of ARM/χ and SIRM/χ (Table 1) indicate coarse grains of magnetic particles in soil samples, whereas high values of magnetic susceptibility and coarse grains of magnetic minerals point out that the source of pollution could be of anthropogenic origin as mentioned by Hu *et al.*, (2008) and Gang *et al.*, (2013).

Table 1: Basic statistics of the magnetic parameters for 90 soil samples collected from the study area; χ (magnetic susceptibility), κ_{fd}% (frequency dependent-susceptibility), χ_{ARM} (Anhysteretic Remanent Magnetization) and SIRM (Saturated Isothermal Remanent Magnetization). SD: Standard deviation

	χ (10^{-8} m^3kg^{-1})	κ_{fd}%	χ_{ARM} (10^{-8} m^3kg-1)	SIRM (10^{-5} Am^2kg^{-1})	S- ratio	ARM/χ	SIRM/χ
Minimum	78.19	1.02	68.12	26.67	0.91	0.36	0.24
Maximum	731.12	3.39	288.76	241.66	0.99	0.95	1.13
Mean.	317.92	2.11	152.39	113.04	0.96	0.52	0.38
SD	159.02	0.56	55.65	52.13	0.02	0.12	0.12

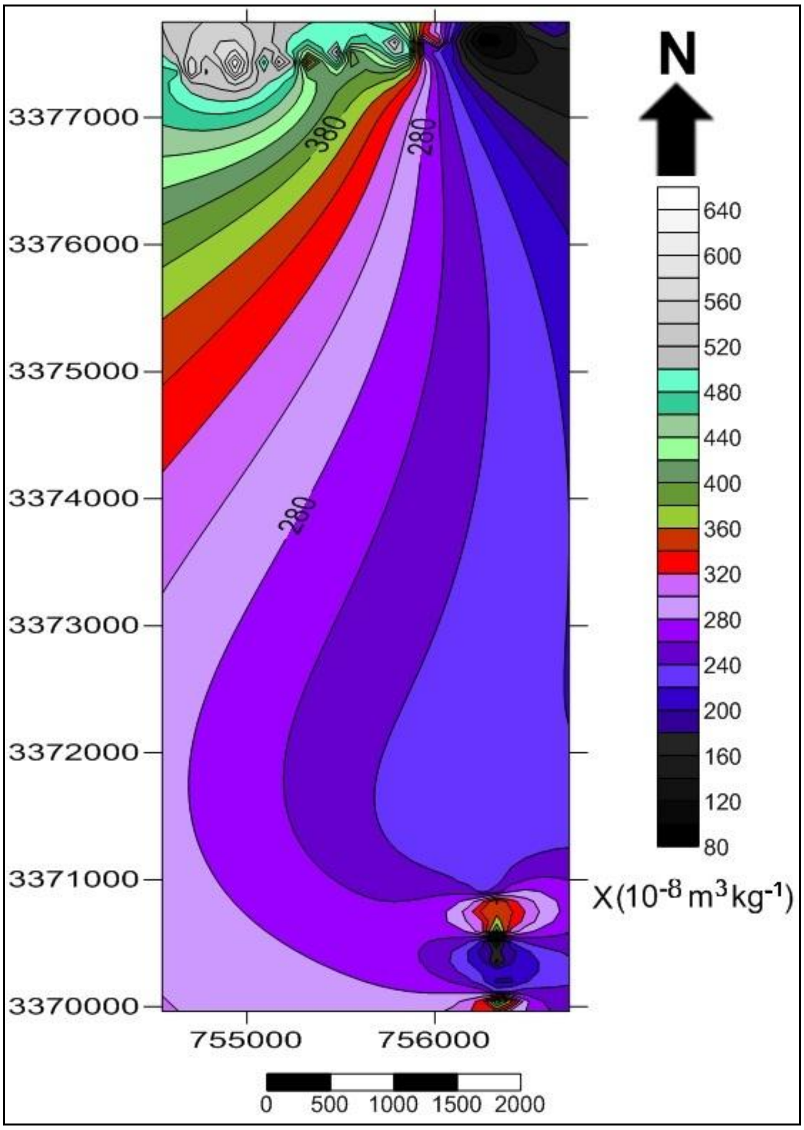

Fig.2: Contour map showing the distribution of magnetic susceptibility values [χ (10^{-8} m^3kg^{-1})] for the study area samples

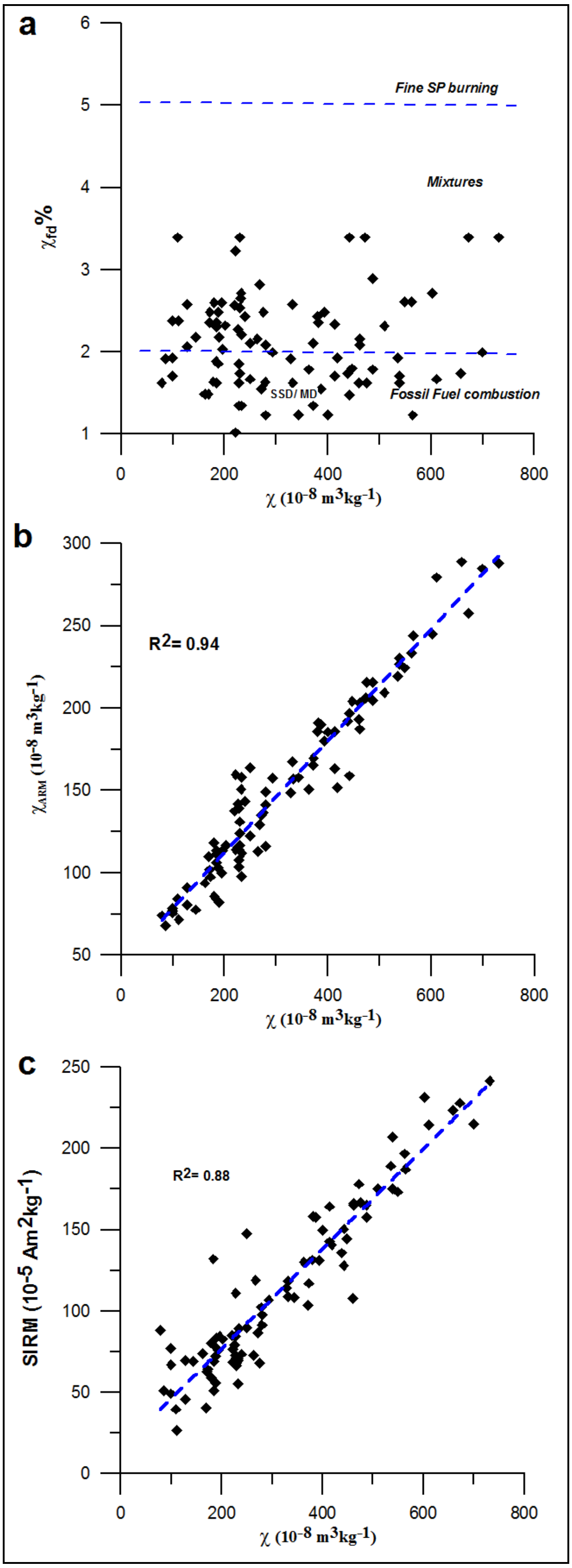

Fig.3: Relation between **(a)** χ_{fd}% versus χ; **b)** χ_{ARM} versus χ; and **c)** SIRM versus χ of soil samples collected from the Shu'aiba field site

The high temperature dependent susceptibility curves for selected samples are shown in Fig. (4). For all samples, the magnetic susceptibility in the heating curves decreased when reaching to 580 °C which is the Currie temperate of magnetite. Thompson and Oldfield, (1986) indicated that the dominant magnetic mineral in such case is magnetite in the samples. It is clear that in the cooling curves at a temperature below 500 °C the magnetic susceptibility still higher than that of heating curves suggesting that additional magnetic minerals might be formed when heating (Hu *et al.*, 2008; Gang *et al.*, 2013).

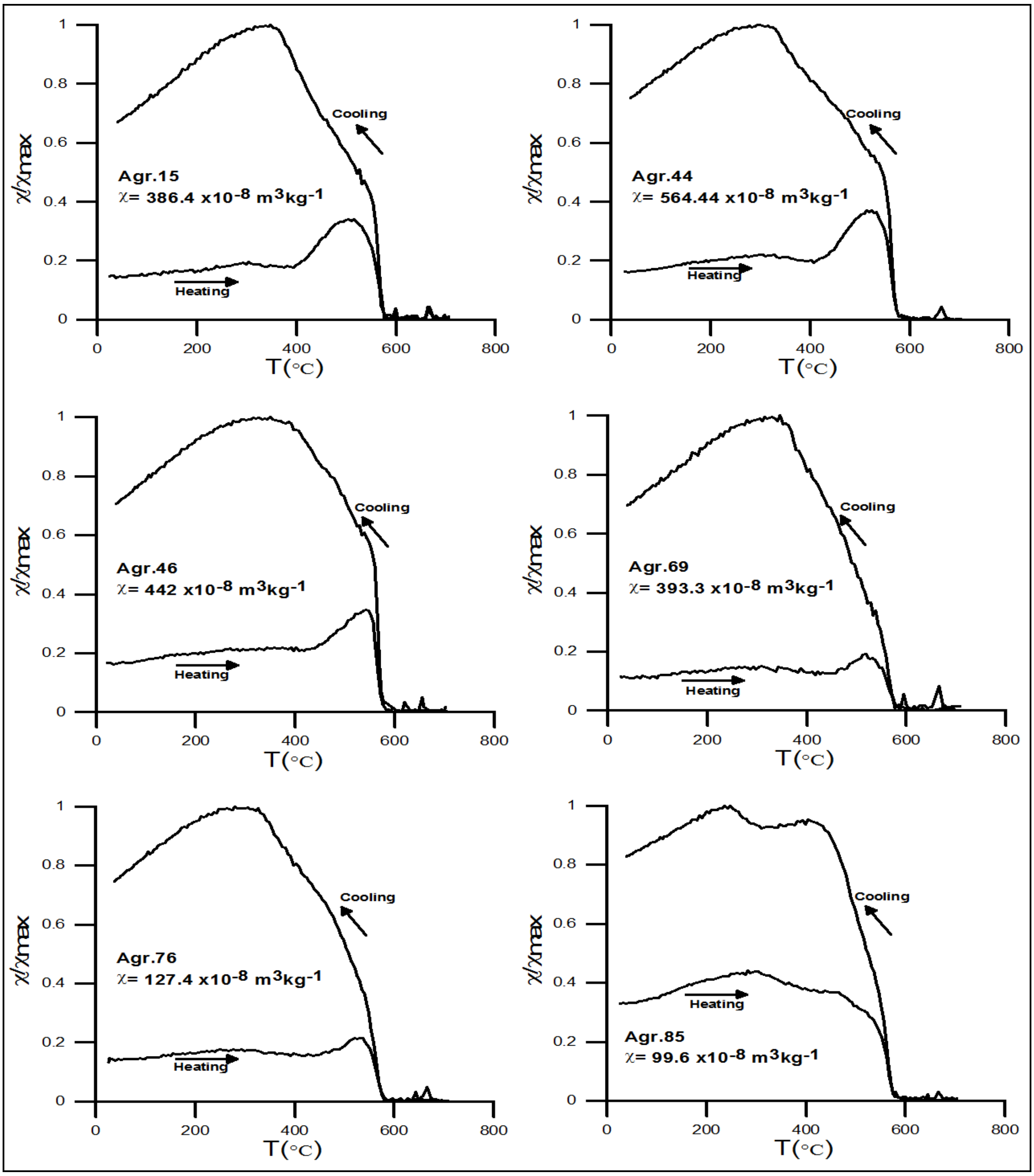

Fig.4: High temperature-dependent on magnetic susceptibility of selected samples collected from the study area, T is the temperature and χ/χ_{max} is the magnetic susceptibility divided by its maximum value of magnetic susceptibility (heating and cooling) for each sample, the sample number and its magnetic susceptibility are indicated

Based on the results above, the high magnetic susceptibility values in the Shu'aiba area could be attributed to the existence of many oil industrial activities in the area, especially oil extraction and refining industries. That can cause accumulation of metals-rich fly ash in the soils and consequently increase the concentration of magnetic minerals.

CONCLUSIONS

The results of this study lead to the following concluding remarks;

- Enhancement of magnetic susceptibility in the soils of the Shu'aiba area is mainly attributed to anthropogenic activities, which are mainly the industrial utilization of the oil fields, especially oil extraction, refining and transportation of petroleum products.
- The main magnetic mineral which dominates the samples is coarse-grained magnetite in single domain to multidomain grains.
- The results indicate the efficiency of magnetic measurements as prospective and reliable tool for observing pollution.

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About the author

Nawrass N. Ameen is an Assistant Professor at Al-Muthanna University, Iraq. He is a Ph.D. holder in geophysics from Tübingen University, Germany (2014). He holds a B.Sc. in Geology (1998) and M.Sc in Geophysics (2006) from the University of Baghdad, Iraq.

E-mail address: nawrass@mu.edu.iq
Mailing address: Al-Muthanna University, 66001 Samawa, Iraq