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Magnetic Properties Change in Street Dust in Baghdad City, Iraq.

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Abstract

The magnetic properties of street dust in the north and south of Baghdad, Iraq, have been studied. Fifty soil samples have been collected from heavily Traffic streets. Mass-specific magnetic susceptibility (χ), frequency-dependent susceptibility (χ_{fd}%), anhysteretic remanent magnetization (χ_{arm}), saturation isothermal remanent magnetization (SIRM), and thermomagnetic analyses were investigated. Mass-specific magnetic susceptibility (χ) is 72.86×10^{-8} m^3kg^{-1} and 98.31×10^{-8} m^3kg^{-1} for northern Baghdad (BN) and southern Baghdad (BR) (mean values), respectively. χ is well correlated with χ_{arm} with correlation coefficients (R^2) of 0.96 and 0.83 for BN and BR, respectively. Grain size analyses show the existence of single-domain (SD) magnetite and maybe a small portion or absence of superparamagnetic (SP) grains in the samples. Thermomagnetic analyses clearly show a dramatic drop in the curve around 580°C during heating, which is the Curie temperature of magnetite. Results of concentration-dependent parameters, grain size, coercivity, and thermomagnetic analyses show the dominance of a soft magnetic phase like magnetite and the existence of a hard magnetic phase like hematite or goethite.

Keywords: Magnetic susceptibility, Baghdad city, street dust, Magnetite, traffic.

تغير الخواص المغناطيسية للغبار المتراكم في الشارع في مدينة بغداد، العراق

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الخلاصة

تم دراسة الخواص المغناطيسية للغبار المتراكم في شمال وجنوب مدينة بغداد، العراق. تم جمع عينات تربة بعدد 50 من شوارع ذات ازدحام مروري. تم دراسة الحساسية المغناطيسية، الحساسية ذات الترددات، المغناطيسية، المغنطة المتبقية اللاهستيرية، المغنطة المتبقية متساوية الحرارة والتحليلات الحرارية المغناطيسية. تراوحت قيم الحساسية المغناطيسية بين 72.86×10^{-8} م^{3} كغم$^{-1}$ و 98.31×10^{-8} م^{3} كغم$^{-1}$ لشمال بغداد وجنوب بغداد (القيم المتوسطة)، على التوالي. اظهرت الحساسية المغناطيسية ارتباطاً جيدًا بـ المغنطة المتبقية اللاهستيرية بمعاملات ارتباط بلغت 0.96 و 0.83 لشمال وجنوب بغداد، على التوالي. تُظهر تحليلات حجم

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الحبوب وجود المغناتايت أحادي المجال وقد يكون جزءًا صغيرًا أو غياب الحبوب فائقة المغنطيسية في العينات. تظهر التحليلات الحرارية المغناطيسية بوضوح أثناء التسخين انخفاضًا كبيرًا في المنحنى عند 580 درجة مئوية، وهي درجة حرارة كوري للمغناتايت.
تظهر نتائج معاملات التركيز المغناطيسية وحجم الحبيبات والقوة والتحليلات الحرارية المغناطيسية هيمنة الطور المغناطيسي الناعم مثل المغناتايت ووجود الطور المغناطيسي الصلب مثل الهيماتيت أو الجيوثايت.

الكلمات الدالة: الحساسية المغناطيسية، مدينة بغداد، غبار الشارع، المغناتايت، الازدحام المروري.

Introduction

Magnetic susceptibility measurements are considered a fast, effective, and trustworthy method to identify iron-bearing minerals depending on the quantity of iron-containing minerals found in the samples, which depends on the concentration and composition of magnetic minerals [1].

Measurements of soil magnetic susceptibility are sensitive to ferromagnetic, ferrimagnetic, paramagnetic, or diamagnetic properties [2]. Anthropogenic activities, such as emissions from traffic, can act as pollutants that reflect on the environment. The magnetic properties and their relation to anthropogenic activities in Shanghai, China, were studied by [3], and they concluded that the magnetic carriers were coarse-grain ferrimagnetic particles.

Magnetic phases in road dust have been studied as the primary means of transporting potentially hazardous trace elements in Northern Greece [4]. The findings revealed that magnetite was the primary magnetic carrier due to the high concentrations of magnetic minerals in road dust.

Lake sediments have been studied to investigate the accumulation of heavy metals [5]. Concentration-dependent magnetic parameters suggest the predominance of hematite and small proportions of superparamagnetic minerals.

Another study by [6] determined the heavy metal accumulation in street dust in Amman, Jordan; the study revealed that local atmospheric deposition is the main cause of the content of street dust in Amman city.

Correlation between magnetic mineral and heavy metal concentrations in different environments has been studied by [7] using magnetic measurements, and the results revealed that the main source of pollution is related to power station fly ash and motor vehicle emissions.

The magnetic susceptibility of street dust at six urban sites in Bulgaria has been investigated [8]. The results revealed that magnetite is the main magnetic carrier, and the magnetic enhancement was associated with heavy metals, a strong correlation between the ratio anhysteretic remanent magnetization/ magnetic susceptibility (ARM/ χ) and Pb content, which implies that Pb is connected to emissions from brake and tire wear, releasing bigger particles and more Pb when braking and driving slowly. The population size significantly correlates with the bulk χ values of road dust per city.

Magnetic properties of shallow sediments have been studied for the effects of hydrocarbon contamination of groundwater in Prague, the Czech Republic [9]. The area is considered the main water supplier in Prague and is under remediation processes to clear the hydrocarbon. The results revealed that bacterial activity is responsible for magnetite formation. When the findings were compared with the results of a previous investigation carried out at the same location, it became clear that following remediation ended in 2008, the magnetic concentration had dropped, possibly due to magnetite dissolution.

Air pollution levels near the highway (Mohammad Al-Qasim) in Baghdad for 24 hours during working hours in March 2016 have been recorded and studied [10]. Different pollutants from vehicles, local generators, and construction have been recorded. The results indicate that due to the high sulfur content in the Iraqi fuel, concentrations of two sulphur compounds (H_2S and SO_2) were hazardous to human health.

This study aimed to examine the magnetic mineralogy of street dust on two industrial areas and heavily trafficked main roads that lie north and south of Baghdad city.

Materials and Methods

1. The Study Area

The study area is located in Baghdad, Iraq's capital. Two sites have been selected for sampling: the first sampling site is located after crossing the northern gate of Baghdad city (Al-Shaab checkpoint), with coordinates (33°25'45.31"N, 44°22'48.95"E), and the second sampling site is at Baghdad Road, which lies at the south of Baghdad starting from Al-Rasheed grocery markets near Al-Dora junction, heading to the southern governorates with coordinates (33°11'49.97"N, 44°22'24.24"E). Twenty-five samples from each site (named BN1-BN25 and BR26-BR50) were collected. The sampling followed the procedures as it should be one meter away from the main roads after removing the upper 0.3 meters of surface soil to avoid cross-contamination. Then, the samples were collected at intervals of two-meters and then dried and packed in plastic bags (Figure 1).

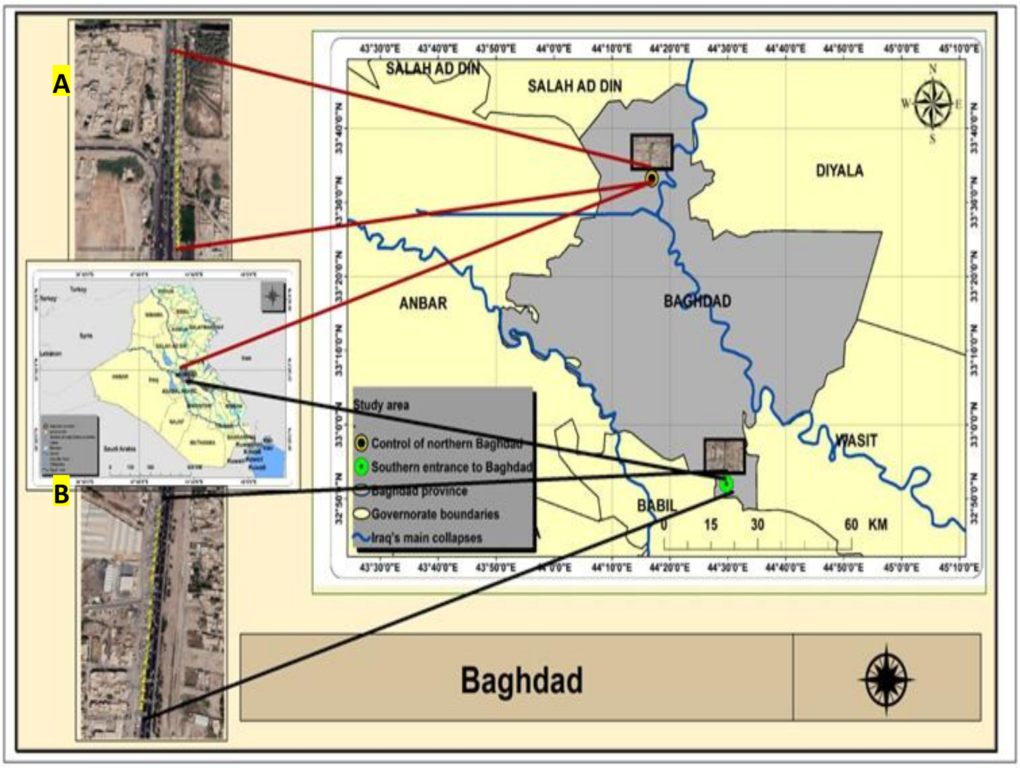

Figure 1: Location map of Iraq showing the sampling sites (A) north of Baghdad (the northern gate of Baghdad city (Al-Shaab checkpoint), (B) South of Baghdad (Baghdad Road, which lies south of Baghdad).

2. Laboratory Measurements

The samples were transported to Germany, Tübingen University, and the Department of Geosciences. Sample preparation procedures have been performed. The samples were sieved (removing the organic matter), packed into 10 cm^3 lidded cylindrical plastic containers, and tightly closed to perform a series of magnetic measurements.

Magnetic susceptibility was measured using the Cappabridge KLY-3 Bartington Instruments magnetic susceptibility meter, and then mass-specific magnetic susceptibility (χ) was calculated. Frequency-dependent susceptibility (χ_{fd}%) was measured at two different frequencies (976 Hz and 15616 Hz), and a peak field of 200 A/m was used with an AGICO MFK1 Kappabridge. Anhysteretic remanent magnetization (ARM) intensity was quantified using a 2G Enterprises superconducting magnetometer by applying a 40 µT DC bias field and 100 mT a peak alternating field. Isothermal remanent magnetization (IRM) was imparted using MMPM9 pulse magnetizer, and then IRM intensity was measured using a Molspin spinning magnetometer. S-ratio is a rock magnetic parameter employed to provide a relative measure of the contributions of low and high coercivity material to a sample's saturation isothermal remanent magnetization (SIRM), which is defined as $\chi_{fd}(\%) = [(\chi_{lf} - \chi_{hf}) / \chi_{lf}] \times 100$ [11], according to [12], S-ratio was determined by applying saturation isothermal remanent magnetization (SIRM) of 1000 mT and a backfield of 300 mT. Thermomagnetic curves allow the determination of the Curie temperature and the stability of the magnetic carriers upon heating. The high-temperature of magnetic susceptibility was measured using KLY3 Kappabridge connected to a CS-3 heating unit (from room temperature to a maximum temperature of 700°C).

Results and Discussion

Concentration-dependent magnetic parameters

Mass-specific magnetic susceptibility at the south of Baghdad (BR) site shows a higher mean value compared to the north of Baghdad (BN) site, as shown in the box and whisker plot (Figure 2). A relationship between soil contamination by emissions from cars, industrial activities, and other anthropogenic activities could be correlated with the magnetic mineralogy of soils, leading to enhancements in the magnetic susceptibility and other magnetic parameters [3].

The χ values range between (175.10 - 44.24) × 10^{-8} m^3kg^{-1} with a mean value of about 72.86 × 10^{-8} m^3kg^{-1} and between (128.08 - 64.92) × 10^{-8} m^3kg^{-1} with a mean value of approximately 98.31 × 10^{-8} m^3kg^{-1} for BN and BR respectively, as shown in Figure-2. The results of χ indicate a significant amount of ferrimagnetic minerals like magnetite in the samples of the two sites [7].

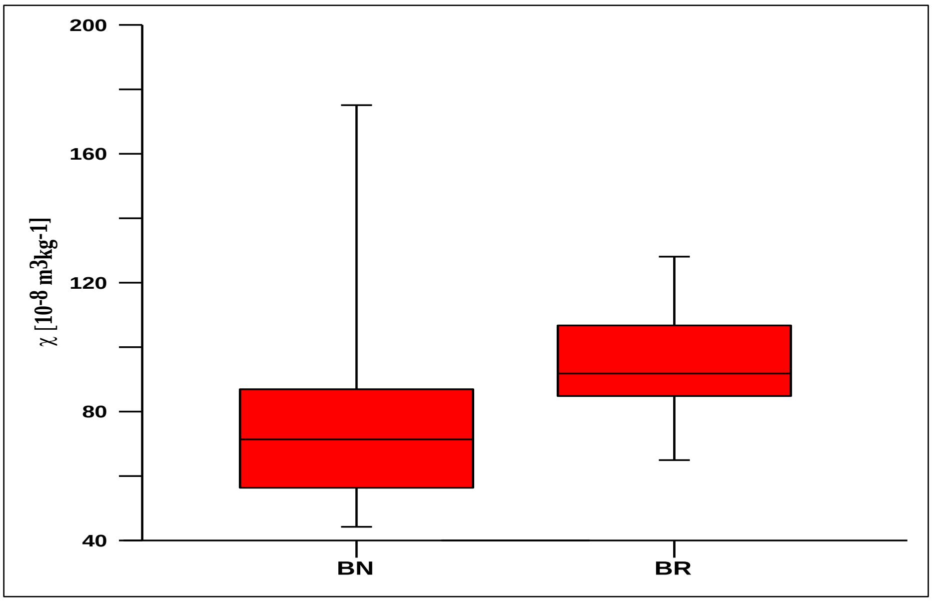

Figure 2: Box and Whisker plot of magnetic susceptibility North of Baghdad (BN) and south of Baghdad (BR).

A correlation between low-field magnetic susceptibility (χ_{lf}) versus the percentage of frequency-dependent susceptibility (χ_{fd}%) North of Baghdad (BN) (red dots) and south of Baghdad (BR) (black dots) is shown in Figure 3 and indicates that there is a mixture of a stable single domain (SSD) to multi-domain (MD) grain sizes and low χ_{lf} values (less than 5%) for most of the samples indicate the absence of superparamagnetic grains in the samples [13]. This helpful parameter could be used to detect ferrimagnetic particles of anthropogenic activities (such as emissions from vehicles and street dust).

There is a strong correlation between the χ and the susceptibility of Anhysteretic remanent susceptibility (χ_{arm}) with correlation coefficients (R^2) of 0.96 and 0.83 for BN and BR, respectively(Figure 4), which suggests that superparamagnetic minerals contribute in a small portion and ferro(i)magnetic minerals like magnetite are the major contributors [14].

Wang et al. [15] mentioned that the remanence (hard to soft) relative amounts could be represented by the S-ratio, which serves as a predictable parameter of the contribution of ferromagnetic minerals. The S-ratio represents the relative amounts of high to low coercivity (hard to soft) remanence; the S-ratio estimates the comparatively existing ferro(i) magnetic minerals. The results show that the S-ratio lies between (0.99–0.90) with a mean value of 0.96 and (0.99–0.83) with a mean value of 0.94 for BN and BR, respectively. These results indicate the dominance of soft magnetic phases like magnetite, especially in BN, and the contribution of hard magnetic phases, which could be hematite (Figure 5).

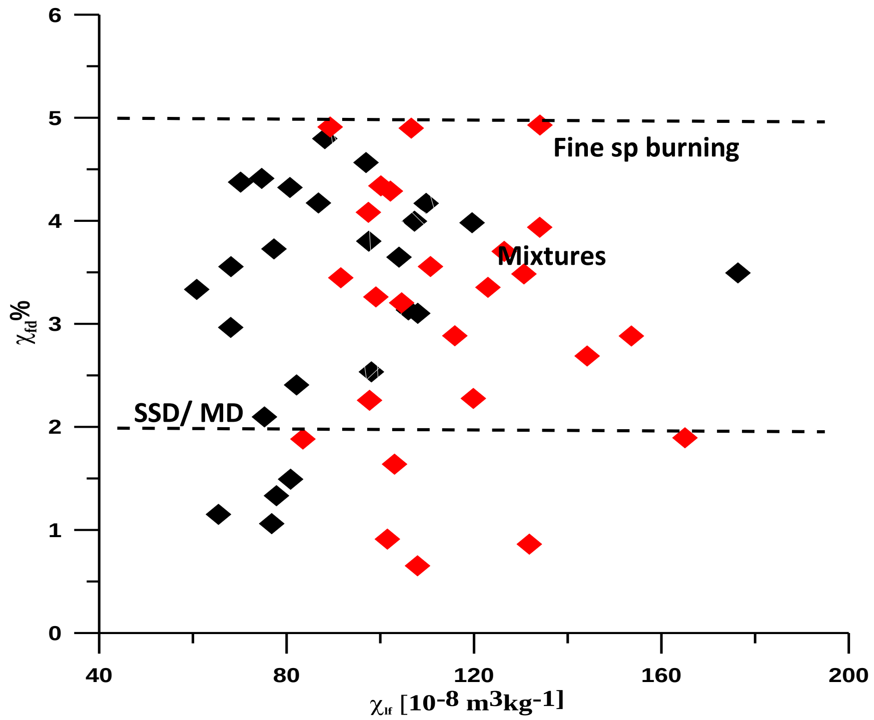

Figure 3: Correlation between low-field magnetic susceptibility versus the percentage of frequency-dependent susceptibility north of Baghdad (BN) (red) and south of Baghdad (BR)(black).

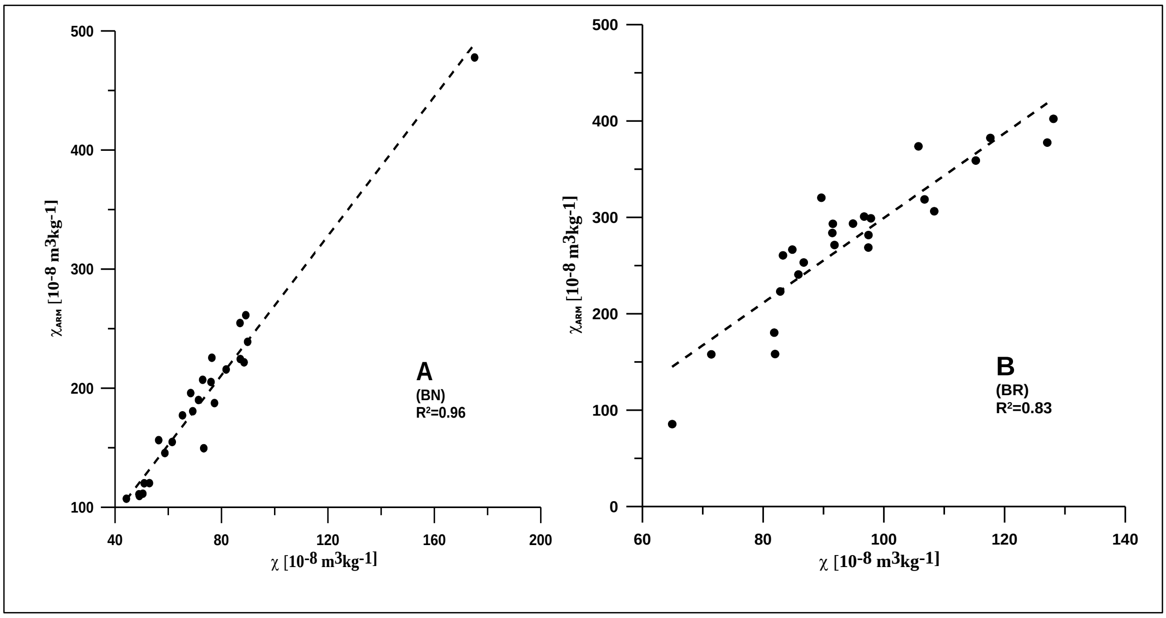

Figure 4: Correlation between mass-specific magnetic susceptibility (χ) versus the susceptibility of Anhysteretic remanent magnetization of (A) North of Baghdad (BN), (B) south of Baghdad (BR), the correlation coefficient is shown.

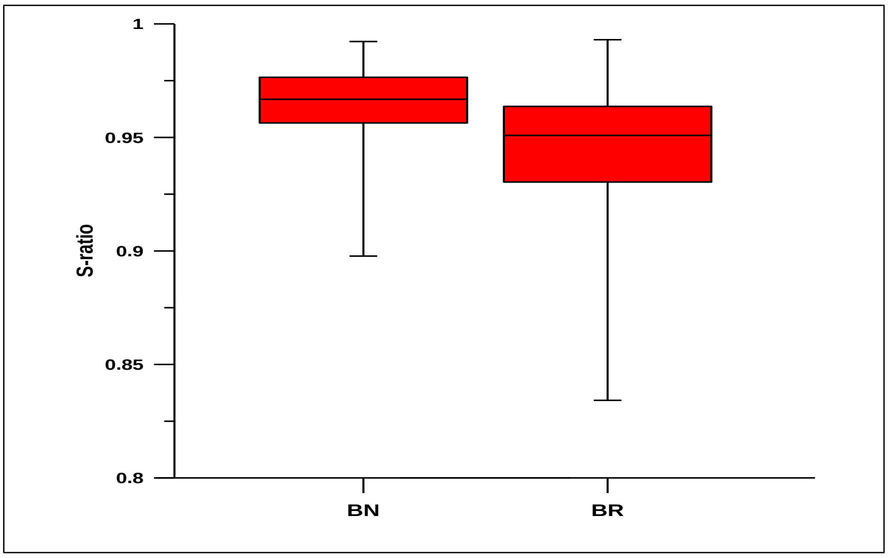

Figure 5: Correlation of the S-ratio of (A) North of Baghdad (BN), (B) south of Baghdad (BR)

The acquisition of isothermal remanent magnetization (IRM) curves was conducted by applying stepwise-increasing uniaxial fields to selected samples with different χ (Figure 6). This parameter provides an important tool for the investigation of coercivity contributions [16]. When applied magnetic fields are lower than 300 mT, IRM values significantly rise, and they saturate at 1 T, which indicates the presence of a soft magnetic phase like magnetite, but some samples did not saturate even when applying 1 T, which indicates the presence of a hard magnetic phase like hematite or goethite.

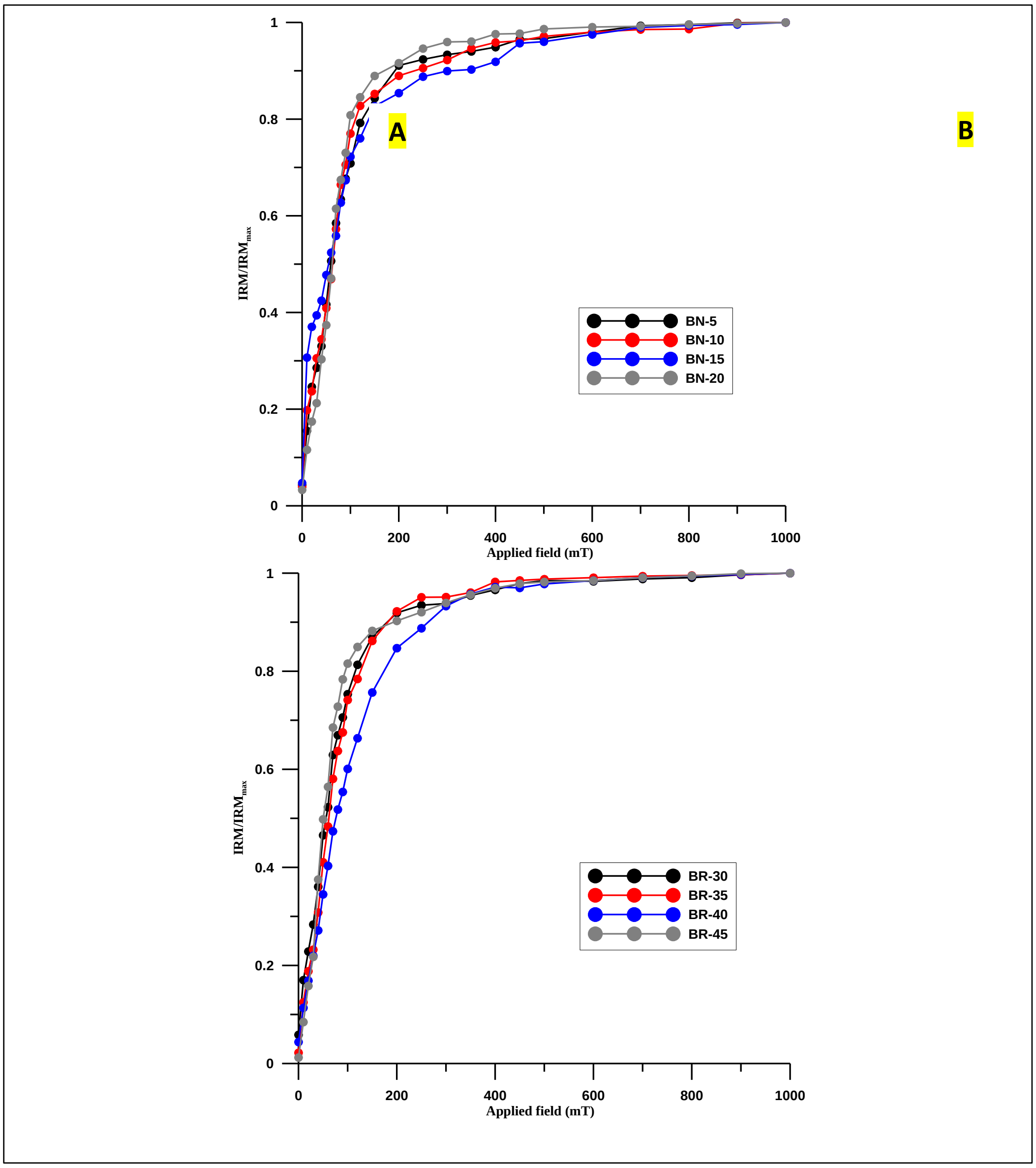

Figure 6: Acquisition curves of isothermal remanent magnetization of selected samples: (A) North of Baghdad (BN), (B) south of Baghdad (BR).

Magnetic minerals could be identified in samples by measuring their temperature-dependent susceptibility based on Currie temperature using high-temperature-dependent magnetic characteristics [17]. The samples were exposed to heating and cooling and showed behaviour during heating from 0 to 700 °C, where a strong drop in the curve could be seen (Figure 7). Four samples from each site (BN, BR) exhibit a reduction near the temperature of 580°C, reaching their baseline at about 580°C, which is the Curie temperature of magnetite [18]. The results of the thermomagnetic analysis indicate that all samples have more magnetite; more magnetic minerals may occur during heating from 0 to 700°C because cooling curves are more sensitive than heating curves [19].

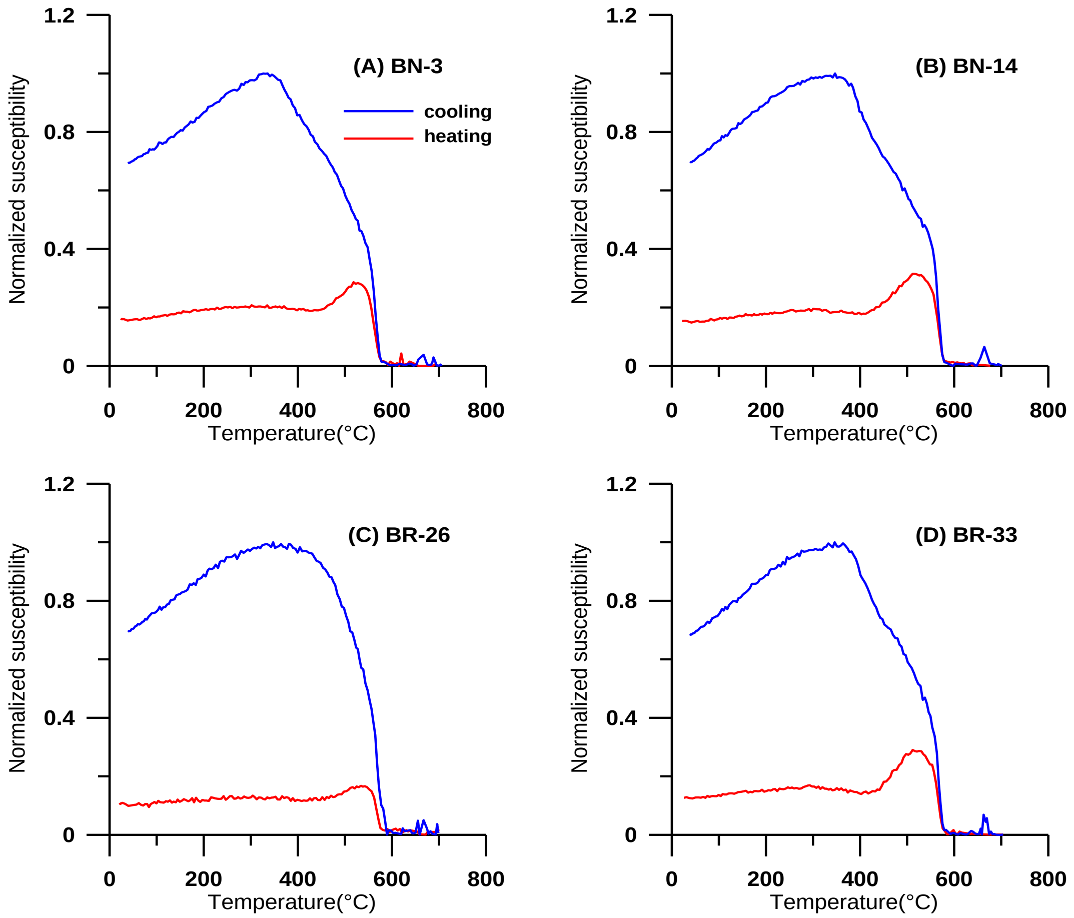

Figure 7: Thermomagnetic analysis of magnetic susceptibility for soil samples (dust) from BN (A, B) and BR (C, D) sites, showing heating and cooling curves using fast and slow heating rates.

Conclusions

The mean values of χ were 72.86×10^{-8} m^3kg^{-1} and 98.31×10^{-8} m^3kg^{-1} for Northern Baghdad (BN) and southern Baghdad (BR), respectively, with single-domain (SD) or stable-single-domain (SSD) grain sizes and the absence of superparamagnetic (SP) grains in the samples (χ_{fd}% less than 5%).

The χ is strongly correlated with the χ_{arm}, which suggests the absence of SP grains or a low contribution. S-ratio, which describes the coercivity (hard remanence to low remanence), was above 0.93 for both sites, indicating a soft magnetic phase like magnetite as the main magnetic mineral in samples from BN with no SP grains. At the same time, in BR the S-ratio shows the dominance of magnetite and the existence of small portions of hard magnetic phase like hematite or goethite. High-temperature analyses show typical curves of magnetite and heating curves reach a Curie temperature of 580°C.
Concentration-dependent magnetic parameters show the dominance of soft magnetic phases like magnetite as the main magnetic carrier, with small amounts of hard magnetic phases like hematite or goethite.

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Conflict of Interest: The authors declare that they have no conflicts of interest.

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