



Mound-Building Termite *Macrotermes Gilvus* of Southeast Asia: Characterization of Magnetic Properties

Mohammad Faris Mohammad Esa¹, Faszly Rahim², Ibrahim N. Hassan*³, Sharina Abu Hanifah²

¹School of Chemical Sciences and Food Technology, Faculty of Science and Technology, Universiti Kebangsaan Malaysia, Bangi, Selangor, Malaysia.

²School of Environmental Sciences and Natural Resources, Faculty of Science and Technology, Universiti Kebangsaan Malaysia, Bangi, Selangor, Malaysia.

³Department of Applied Chemistry, College of Applied Science, University of Fallujah, Fallujah, Iraq.

ARTICLE INFO

Received: 21 Mar 2025,

Revised: 11 Apr 2025,

Accepted: 25 Apr 2025,

Online: 13 Jun 2025

Keywords:

Magnetite, VSM, XRD, *Macrotermes gilvus*, diamagnetism.

ABSTRACT

Magnetic material such as magnetite are known as particles that respond to external magnetic field with their ferromagnetic properties as they are believed contribute to in responding to the geomagnetic field. These particles are used by terrestrial animals such as termites for navigation and orientation. Since our earth react as giant magnetic bar, the magnitude of this magnetic field present by intensity and direction (inclination and direction). The magnetic properties and presence of magnetite in termites *Macrotermes gilvus*, common mound-building termite were tested. *M. gilvus* termites was tested with a Vibrating Sample Magnetometer VSM to determine the magnetic properties of specimen. The crushed body sample was characterized with X-Ray Diffraction XRD to show the existent of magnetic material (magnetite) in the specimens. Results from VSM indicate that *M. gilvus* has diamagnetism properties. The characterization by XRD shows the existent of magnetic material in our specimen in low concentration.

1. Introduction

Termites are the major macrofauna that can be found in tropical countries especially in Peninsular Malaysia. They play important roles in our terrestrial ecosystems as lignocellulose and humus turnover which significant sources of global atmospheric methane and carbon dioxide [15]. Lee et al. (2007) reported 12 species of termites can be found around the building and structure (*Coptotermes* sp, *Macrotermes* sp,

Microtermes sp, *Globitermes* sp, *Odontotermes* sp, *Schedorhinotermes* sp and *Microcerotermes* sp). They act as decomposers as their sources of food ranging from leaf litter, tree and also other organic matter. Malaysia is situated in Equator, and both rhinotermitids and non rhinotermitids act as pest termite [10].

According to Roonwal and Chhotani (1961), *M*

Corresponding author:

E-mail addresses: ibnhum@uofallujah.edu.iq

2523-9376/© 2025 Global Scientific Journals - MZM Resources. All rights reserved.



This work is licensed under a Creative Commons Attribution Share Alike 4.0 International License.
<https://creativecommons.org/licenses/by-sa/4.0/legalcode>

gilvus is a common mound-building termites. They can be found in South-East Asia. Usually they build the dome shape mounds with brownish earth which makes the mounds very hard to destroy by the predator. *M gilvus* usually forage for food by tunneling underground to the source. They have a dimorphism, which have to form of soldier major and minor.

Foraging ability in social insect especially in termites is an interesting study as they are still capable of finding food and build their mound without having eyes. Termites have the ability to build elaborate constructions without having eyes, so the hypothesis that termites use the magnetoreception is attractive subject of study [8]. In many previous papers, this ability is caused by the effect of the geomagnetic field although the response of some living organisms to it is still unknown. The presence of magnetic nanoparticles in living cells was the main topic discussed in previous studies as they are believed to change some cellular structures and transmit the information to the entire nervous system of organisms. This complex system is known as magnetoreception as reported by previous study such as Wajnberg et al. (2005). Maher (1998) was reported experimental evidence for magnetite biomineralization and proved that the *Nasutitermes* sp specimens contained very small concentration of magnetic biomineral (ca 0.03-0.05 μm) with super paramagnetic behaviour. Comparative magnetic measurements using a SQUID magnetometer have been reported [5]. This study compared on the aspects of room temperature hysteresis loops and ferromagnetic resonance based on the prey- predator relationship of *Pachycondyla marginata* and *Neocapritermes opacus*.

Wajnberg et al. (2004) have shown that the antennae were the most sensitive and strongest magnetic part of *Pachcondyla marginata*, the migratory ants. This migratory ant is a termitophagous ant, hunting only termites specifically *Neocapritermes opacus*. The statistical and seasonal studies have been done on *Solenopsis* spp ants. In this study, the authors

faced the difficulties to measure the exact amount of magnetic material because of the very low concentration of this nanomagnetic material [1]. Magnetic study not only applied only in termites, but also in microorganism such as marine coccoid bacteria [6]. Due to this report, this macroorganism respond to geomagnetic field lines during movement. Another organism that responds to the magnetic field is the *Apis mellifera* [4], salmon fish [14].

Although, the large number of paper have been reported on behavior and magnetic effects on animals, The ability on how the animals detects to magnetic field is still unknown (Esquivel et al 2003). Yet, it become a polemic. To the best of our knowledge, magnetic particles from termites especially in Malaysia has not been reported. In this paper, the magnetic properties and magnetic particles characterizations will be conduct using vibrating sample magnetometer and X-Ray Diffraction to show magnetic properties of *M gilvus* specimens

MATERIALS AND METHOD

Macrotermes gilvus were collected from selected mound areas at Endau Rompin Plantation (LER) as FIGURE 1 Termites were then placed in vials and preserved in ethanol (90%) until they were used. Before characterization, termites were washed with ethanol 90% and rinsed with distilled water to ensure the exclusion of another mineral from outer part of specimens. Termite samples were dried at 30°C in oven. After drying, specimens were divided into three groups: i) head ii) thorax and abdomen and iii) whole body. These three specimens were characterized with vibrating sample magnetometer (VSM) and X-ray diffractometer (XRD). VSM measurements were carried out at room temperature. A thin layer of crushed samples were placed between transparent adhesive tapes. The hysteresis loop was recorded and plotted by computer. For XRD characterization, a few grams of crushed samples were prepared in pellet form. Specimen was characterized for XRD pattern using Bruker AXS Germany, D8 advance with Cu anode. The XRD pattern analyzed using EVA procedure.



FIGURE 1. *Macrotermes gilvus* mound in Endau Rompin Plantation (LER)

RESULTS AND DISCUSSION

Interpretation from VSM gives relationship between magnetic moment (emu) and applied magnetic field B (Gauss). At room temperature, we assumed that our specimens would show ferromagnetism properties. This is because magnetite can show the ferromagnetic properties in ambient. Magnetic field applied to the samples was much stronger (12,000 G) than natural magnetic field (0.25- 0.65 G). Characterization of separated part showed, a negative straight line with negative slope obtained as in FIGURE 2. Our results showed that the separated part of *M gilvus* did not have ferromagnetic properties because hysteresis loop not observed. The specimens parts oppose to the applied magnetic fields resulted the diamagnetic property.

In this study, the diamagnetism property was shown with the contribution of hysteresis observed as negative slope for head, thorax and abdomen and also whole body. Having in mind,

most material has own diamagnetic properties. The diamagnetism properties also have reported in migratory ants *Pachycondyla marginata* [5] and *Rhodinus prolixus* [7]. Besides paramagnetism have been reported in *Neocapritermes opacus* [5] compared as our result shown diamagnetism. A saturation of ferromagnetism easily observed besides absence of coercivity thus no hysteresis loop indicates an absence of ferromagnetic materials [7]. This is the first study of magnetic properties in termite's sample using VSM, others have used SQUID Magnetometer, Magnetic Remanance MR

[2] and Ferromagnetic resonance [1]. Even SQUID is more sensitive, VSM is still reliable approach to get the information about magnetic property. On the other hand, Giraldo et al. (2013) has shown the hysteresis curve from *Apis Melifera* abdomen using VSM. The *A melifera* acts as control for this experiment confirms the presence of ferromagnetic material.

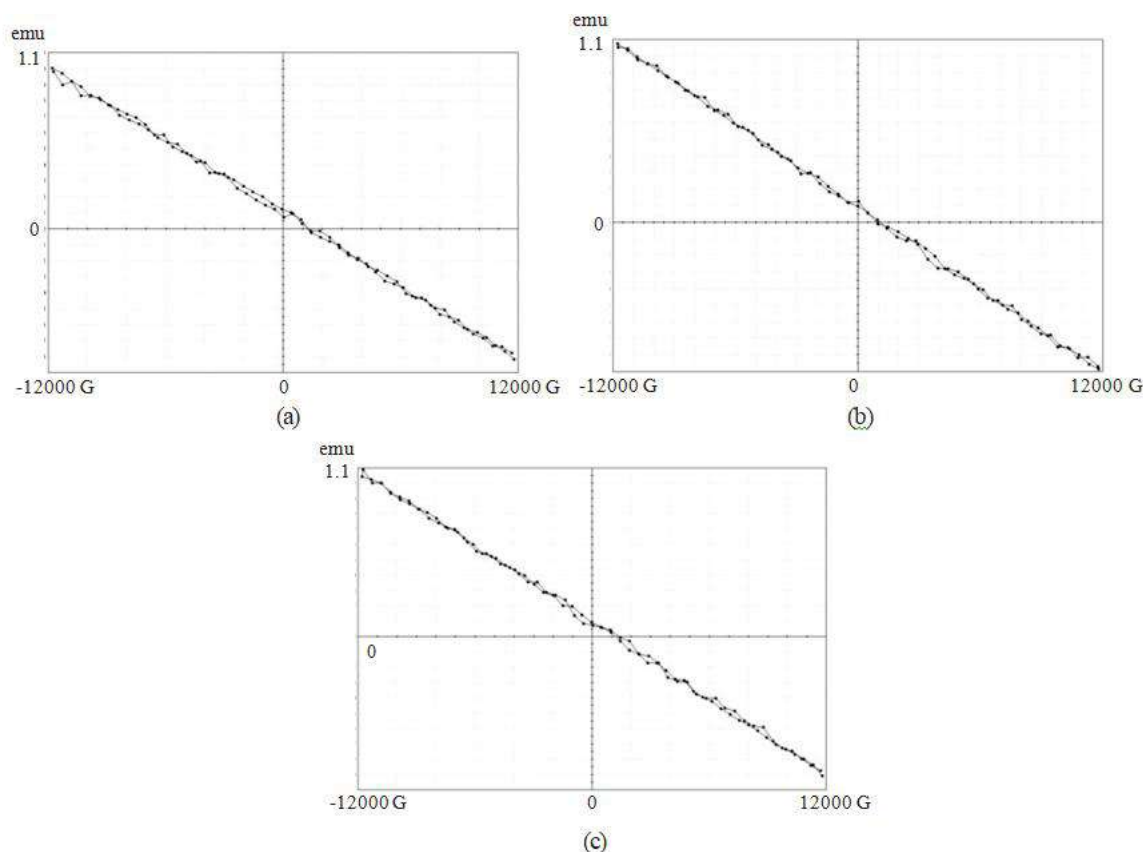


FIGURE 2. Dendogram of individual *M. gilvus* a) Head b) Thorax and abdomen c) Whole body. The x-axis refers to Magnetic Field applied (Gauss); y-axis is magnetic moment (emu)

In XRD evaluation, our specimen was evaluated using search and match in EVA software. In EVA software, we have quality marks and have an option chemical filter to choose for the elements present: green as the most reliable in sample or present in sample, grey indicate that elements that can be present and absent while red the element must be absent in our sample. We limit the measurement for only specific materials, ferum oxide in the specimens without considering presence of other materials. Diffractograms for crushed *M. gilvus* as FIGURE 3 It seems that head and thorax have similar pattern compared to abdomen. As we choose for the most reliable elements in our XRD characterization of crushed sample, the existent of magnetite particles still detected. However, the peak not clearly observed. The relatively low concentration of magnetic material in special region which make it difficulty in measuring magnetic material amount in living beings [1] Therefore the ability of termites to respond to magnetic field using this magnetic material become plausible mechanism. The ability to show the ferromagnetic and conducts electricity like metal make magnetite as

biologically unique [9]. The diverse in stoichiometry of magnetite from this crushed specimen determined as Fe_3O_4 , $\text{Fe}_{2.93}\text{O}_4$ and $\text{Fe}_{2.946}\text{O}_4$ in head; Fe_3O_4 , $\text{Fe}_{2.964}\text{O}_4$ and $\text{Fe}_{2.946}\text{O}_4$ for Thorax; Fe_3O_4 , $\text{Fe}_{2.904}$, $\text{Fe}_{2.946}\text{O}_4$ for abdomen.

This study shows the diamagnetism properties with the contribution of hysteresis observed as negative straight line with a negative slope in head, thorax+abdomen and whole body. All material has their own diamagnetic properties. Diamagnetism properties also have reported in migratory ants *Pachycondyla marginata* and reduvidae *Rhodinus prolixus* [7] We have applied magnetic field up 1200 mT(1200G) which about 1000 higher than the earth magnetic field. Under this condition, a saturation of ferromagnetism was easily observed besides the absence of coercivity without a hysteresis loop to indicate an absence of ferromagnetic material [7]. This is the first study of magnetic properties in termites sample using VSM compared to a SQUID magnetometer and Magnetic Remanance MR [2]

and Ferromagnetic resonance [1]. Although SQUID is more sensitive, VSM is still a reliable approach to get the information about magnetic properties. On the other hand, Giraldo et al (2013) have shown sensitivity of VSM in detecting ferromagnetic properties of *Apis mellifera*

abdomen. *A. mellifera* react as a control for this experiment to confirm the presence of ferromagnetic material.

To our knowledge, this is the first study to use the XRD instead of microscopy to show the existent of magnetite in specimens. Maher (1998) reported the existent of magnetite from extracted crushed body samples but the detail of location of this particle within the insects has not been discussed. They found very small black particles attracted to rare-earth (cobalt-samarium) magnet bar. This procedure requires a lot of samples and repeated

extraction steps to get sufficient pure samples. With XRD characterization, the existent of magnetic material in specimen can be possibly detected without any extracting procedure. The presence of magnetic material (magnetite) as magnetosensory still relevant to be studied because magnetite is well distributed in our nature microorganisms from human tissues [9] until microorganism level such as bacteria [3, 6, 13, 18]. As Billen (2006) also have reported about variety of signal for communication in social insects including magnetic orientation base on magnetite particles.

VSM has been shown to detect even the low magnetic moments [7]. We have shown the existent of magnetite in our specimens' in low concentration using XRD. The relatively low concentration of magnetic material in special region make it difficult to measure magnetic material in living being [1].

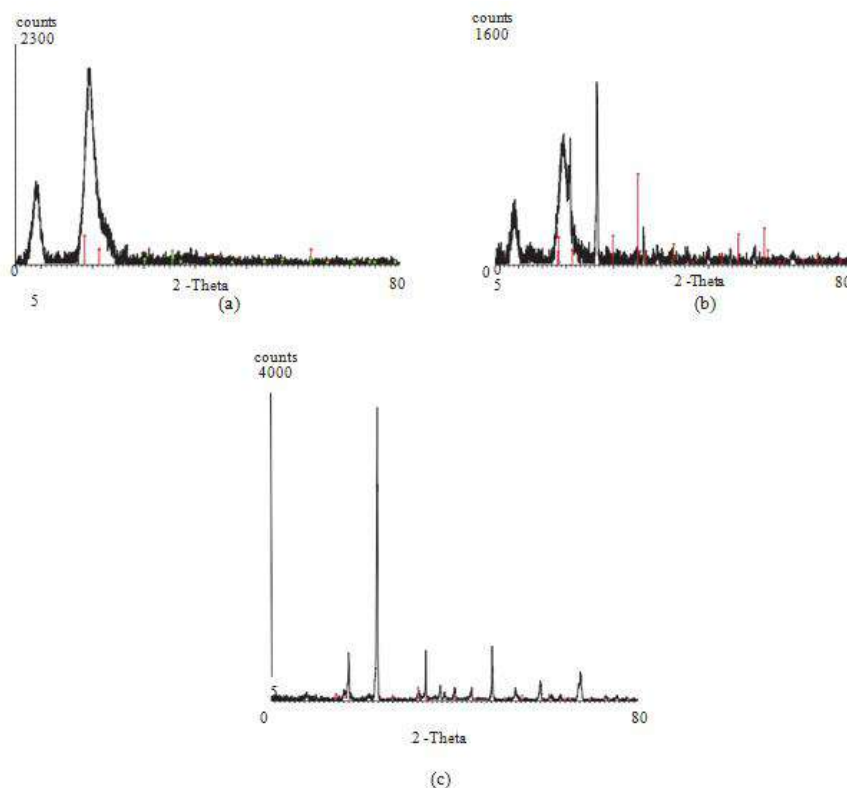


FIGURE 3. XRD Diffractogram for *M. gilvus* (a) Head; (b) Thorax; (c) Abdomen

CONCLUSION

In this study, we report the determination of magnetic materials in termites especially in

tropical area, and in our knowledge, this is the first data recorded in South-East Asia region. As a conclusion we can tell that our samples have the same diamagnetic properties by VSM

characterization as reported by Giralado (2013). VSM have shown the negative sloop (diamagnetic) from our magnetic properties measurement which shows *M gilvus* itself not showing ferromagnetism as reported as in *A. Meliffera*. The respond of animal on magnetic field especially in this social insects like *M gilvus* (Termites) considerable degree of complexity since the behavioral studies and their navigation/ foraging activity are not considered. Even from the magnetic measurement have shown that *M gilvus* with their diamagnetic properties, the existent of magnetite in sample using XRD make the plausible this magnetite-base mechanism as a navigation tools to look forward to study

REFERENCES

- [1]. Abracado L.G., Esquivel D.M.S., Alves O.C. and Wajnberg E. 2005. Magnetic material in head, Thorax and abdomen of *Solenopsis sustituta* ants: A ferromagnetic resonance study. *Journal of Magnetic Resonance* **175**: 309-316.
- [2]. Alves O.C., Wajnberg, E., Oliveira J.F. and Esquivel D.M.S. 2004. Magnetic material arrangement in oriented termites: a magnetic resonance study. *Journal of Magnetic Resonance* **168**: 246-251.
- [3]. Blakemore R.P. 1982. Magnetotactic bacteria. *Annual Reviews Microbiology*. **36**:217-238
- [4]. Esquivel D. M. S., Wajnberg E., Cernicchiaro, G. R., Acosta-Avalos D., and Garcia B.E. 2002. Magnetic Material Arrangement In *Apis Mellifera* Abdomens. *Materials Research Society Symposium Proceedings* **724**, N7.2.1.
- [5]. Esquivel, D. M. S., Wajnberg, E., Cernicchiaro, G. R., and Alves, O. C. 2004. Comparative magnetic measurement of migratory ant and its only termite prey. *Journal of Magnetism and Magnetic Materials* **278**: 117 –121.
- [6]. Frankle, R. B. Bazylinski, D. A., Johnson, M. S., and Taylor, B. L. 1997. Magneto-Aerotaxis in Marine Coccoid Bacteria. *Biophysical Journal* **73**: 994-1000.
- [7]. Giraldo D., Hernandez C., Molina J. 2013. In search of magnetosensitivity and ferromagnetic particles in *Rhodnius prolixus*: Behavioral studies and vibrating sample magnetometry. *Journal of Insects Physiology* **59**: 345-350.
- [8]. Grigg G., Jacklyn P., and Taplin L. 1988. The effects of buried magnets on colonies of *Amitermes* spp. building magnetic mounds in northern Australia. *Physiological Entomology* **13**: 285-289.
- [9]. Kirschvink J.L. 1981. Ferromagnetic crystal (magnetite) in human tissue. *Journal of experimental biology*
- [10]. **92**: 333-335
- [11]. Lee C.L., Vongkaluang C & Lenz M. 2007. Challenges to Subterranean Termite Management of Multi- Genera Faunas In Southeast Asia and Australia. *Sociobiology* **50**(1): 213-221
- [12]. Maher, B. A. 1998. Magnetite biomineralization

Therefore The behavioral and ecological study for this kind of social insects and how do they respond to magnetic field extensively need to observed.and studied.

ACKNOWLEDGMENT

We would like to thanks to all the co-researchers in this project with for their useful discussion. We would like to thank to Yayasan Pahang specifically Ladang Endau Rompin for provide the facilities to conducting the field observation and specimens collecting. We also thank to Dr Chia Chin Hua, School of Applied Physics, Faculty Sciences and Technology, UKM for useful discussion in VSM.

- in termites. *Proceedings of Royal Society London* **265**: 733-737.
- [13]. 733-737.
- [14]. Roonwal M.L., and Chhotani O. B., 1961. The termite *Macrotermes gilvus malayanus* (Haviland) (Termitidae) in Burma. **27**(5),308-316 (1961)
- [15]. Schuler, C., and Frankel, R. B. 1999. Bacterial magnetosomes: microbiology, biomineralization and biotechnological applications. *Appl Microbiol Biotechnol* **52**: 464- 473.
- [16]. Tanski A. , Formicki, K., Agata Korzelecka-Orkisz, A., and Winnicki, A. 2005. Spatial orientation of fish embryos in magnetic field. *Electronic journal of ichthyology* **1**: 21-34.
- [17]. Vu. A. T., Nguyen N. C., Leadbetter J .R. 2004. Iron reduction in the metal-rich gut of wood feeding termites. *Geobiology* **2**: 239-247.
- [18]. Wajnberg, E., Cernicchiaro, G. and Esquivel, D. M. S. 2004. Antennae: the strongest magnetic part of migratory ant. *Biometals* **17**: 467–470.
- [19]. Wajnberg,E., Alves, O. C., Harada, A. Y., and Esquivel, D. M. S. 2005. Brazilian ants diversity and the local geomagnetic field: a ferromagnetic resonance study. *Biometals* **18** : 595–602.
- [20]. Zhang, C., Vali, H., Romanek, C. S. Phelps, T. J. and Liu, S. V. 1998. Formation of single-domain magnetite by a thermophilic bacterium. *American mineralogist* **83**:1409–1418.
- [21]. Halboos, M. H. N. 2015. Synthesis of New Schiff Base to Determination of Cadmium Ion. *Global Scientific Journal of Chemistry*. **1**: 1-6.