Alqalam Journal of Medical and Applied Sciences. 2025;8(2):981-989
https://doi.org/10.54361/ajmas.258268

Original article

Iron and Steel Industry: A Suggestion for Raw Materials in Libya

Osama Shaltami[1]*, Firas Khamis[2], Kamal Abraheem[2], Mustafa Ben Hkoma[3]

[1]Department of Earth Sciences, Faculty of Science, Benghazi University, Libya
[2]Department of Earth Sciences, Faculty of Science, Omar Al-Mukhtar University, Libya
[3]Libyan Centre for Studies and Research of Sciences and Environment Technology, Middle Zone Branch, Zliten, Libya
Corresponding email. osama.rahil@yahoo.com

Abstract
The iron and steel industry is arguably the most significant component of a country's industrial economic infrastructure, and the amount of steel consumed per person serves as a proxy for both industrialization and advancement. There are two processes in the extraction of ferrous metals: (1) the Ironmaking process (reduction process); and (2) the Steelmaking process (oxidation process). This study aims to suggest uses for Libyan iron ores in the iron and steel industry. The study covered thirteen areas (Sabkhat Ghuzayil, Al Fuqaha, Sabha, Tanahmu, Idri, Qararat Al Marar, Hasi Anjiwal, Bir Anzawa, Tikiumit, Al Awaynat, Wadi Tanezzuft, Anay, and Ghat sheets). This work can be regarded as the first of its kind because no previous study has been done on the raw materials used in the iron and steel industry in Libya. Numerous formations have been found to contain iron ore (Hasawnah Formation, Melaz Suqran Formation, Tanezzuft Formation, Akakus Formation, Tadrart Formation, Wan Kasa Formation, Awainat Wanin Formation, Marar Formation, Zarzaitine Formation, Taouratine Formation, Mesak Formation, Al Hishah Formation, Old wadi deposits, and sabkha sediments). Given that the results showed that the Fe concentrations in the studied sediments ranged from 15.21 to 54.53%, it is feasible to use these sediments in the iron and steel industry.
Keywords. Iron and Steel Industry, Iron Ore, Libya.

Introduction

Steel and iron are utilized in numerous industries. The primary distinction between these two metals is that steel is an alloy of iron and carbon, whereas iron is a naturally occurring element. Moreover, iron is heavier, weaker, and less durable than steel. Pig iron, cast iron, and wrought iron are the three different varieties of iron. The steel industry is made up of four different types of steel: carbon, alloy, tool, and stainless [1,2].
Rocks and minerals that allow for the profitable extraction of metallic iron are known as iron ores. The most important types of iron ores are: (1) Magnetite (Fe_3O_4); (2) Hematite (Fe_2O_3); (3) Limonite ($FeO(OH).n(H_2O)$); (4) Goethite ($FeO(OH)$); (5) Ilmenite ($FeTiO_3$); (6) Pyrite (FeS_2); and (7) Siderite ($FeCO_3$) [3]. The following factors are taken into consideration when evaluating iron ore: (1) Ore richness; (2) Ore location; (3) Ore extent; (4) Ore size; and (5) Gangue minerals [4].
The main location for iron and steel production in Libya is the Libyan Iron and Steel Company (Lisco). This company is among the biggest producers of steel and iron in North Africa. It is owned and subsidized by the Libyan government and is located in Misratah, NW Libya. Geological studies have shown that iron ore is present in many Libyan areas [5-17]. Proposing raw materials for the iron and steel industry in Libya is the goal of this work. Thirteen areas were studied (Sabkhat Ghuzayil, Al Fuqaha, Sabha, Tanahmu, Idri, Qararat Al Marar, Hasi Anjiwal, Bir Anzawa, Tikiumit, Al Awaynat, Wadi Tanezzuft, Anay, and Ghat sheets, Figure 1).

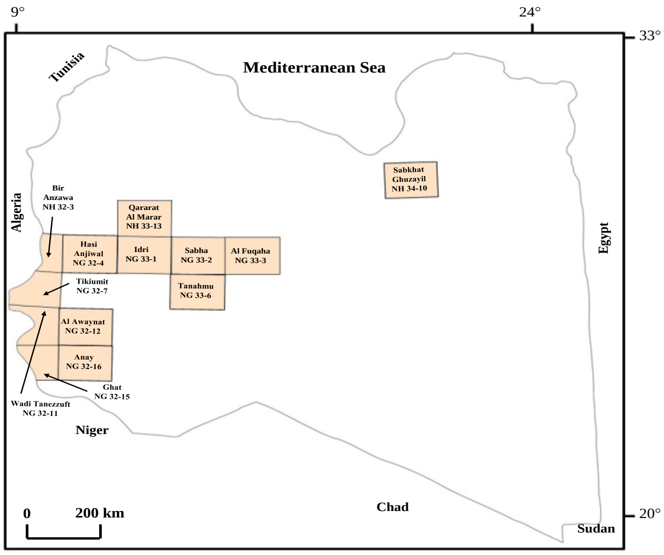

Figure 1. Location map of the studied areas.

***Received**: 27-03-2025 - **Accepted**: 22-05-2025 - **Published**: 30-05-2025*

https://doi.org/10.54361/ajmas.258268

Previously the following were studied: (1) Quality of the final product [18]; (2) Plant maintenance [19]; (3) Work injuries [20]; (4) The accessibility of the components needed to implement the balanced scorecard model [21]; (5) Sustainability [22]; and (6) Environmental impacts [23]. The information above makes it evident that no prior study has been done on raw materials; thus, this work can be regarded as the first study of its kind.

Methods

Sample Collection and Geological Setting

In this work, the authors used the Fe_2O_3 concentration found in the Sabkhat Ghuzayil, Al Fuqaha, Sabha, Tanahmu, Idri, Qararat Al Marar, Hasi Anjiwal, Bir Anzawa, Tikiumit, Al Awaynat, Wadi Tanezzuft, Anay, and Ghat sheets [5-17]. 63 samples were evaluated.

The study area encompasses multiple sedimentary formations across different geological sheets, including the Hasawnah Formation (Late Cambrian), Melaz Suqran Formation (Late Ordovician), Tanezzuft Formation (Early Silurian), Akakus Formation (Late Silurian), Tadrart Formation (Early Devonian), Wan Kasa Formation (Early Devonian), Awainat Wanin Formation (Middle-Late Devonian), Marar Formation (Early Carboniferous), Zarzaitine Formation (Late Permian-Early Triassic), Taouratine Formation (Jurassic), Mesak Formation (Cretaceous), Al Hishah Formation (Pleistocene), Old Wadi deposits (Quaternary), and sabkha sediments (Quaternary).

Field sampling was conducted across various locations within these formations to ensure representative coverage of iron-bearing lithologies. Samples were collected from outcrops and drill cores, with careful documentation of lithology, stratigraphic position, and geographic coordinates.

Analytical Methods

Iron Oxide (Fe_2O_3) Determination

The total iron oxide (Fe_2O_3) content in the sedimentary rocks was determined using X-ray fluorescence (XRF) spectrometry, a widely accepted method for bulk geochemical analysis. Samples were pulverized to a fine powder (<75 μm) to ensure homogeneity before analysis. Calibration was performed using certified reference materials to ensure accuracy.

Conversion to Fe Concentration

The Fe concentration was calculated from Fe_2O_3 values using atomic mass conversion:

$$Fe\ (\%) = Fe2O3(\%) \times (Molecular\ mass\ of\ Fe2O32 \times Atomic\ mass\ of\ Fe) = Fe2O3(\%) \times 0.6994$$

Sedimentary rocks with >15% Fe (or >21.4% Fe_2O_3) were classified as ironstones.

Statistical and Spatial Analysis

The Fe concentration data were tabulated and analyzed to compare variations across formations and geographic sheets. Spatial distribution maps were generated to highlight regional differences in iron enrichment.

Results and discussion

Sedimentary rocks containing more than 15% Fe, or 21.4% Fe_2O_3, are called ironstones [24]. The Fe_2O_3 concentration in the studied areas is presented in Table 1. The atomic mass was used to calculate the Fe concentration. Iron ore is found in the Hasawnah Formation (Late Cambrian), the Melaz Suqran Formation (Late Ordovician), the Tanezzuft Formation (Early Silurian), the Akakus Formation (Late Silurian), the Tadrart Formation (Early Devonian), the Wan Kasa Formation (Early Devonian), the Awainat Wanin Formation (Middle-Late Devonian), the Marar Formation (Early Carboniferous), the Zarzaitine Formation (Late Permian-Early Triassic), the Taouratine Formation (Jurassic), the Mesak Formation (Cretaceous), the Al Hishah Formation (Pleistocene), Old wadi deposits (Quaternary), and sabkha sediments (Quaternary).

The sabkha sediments in the Tikiumit Sheet contain the lowest Fe concentration (15.21%), whereas the highest concentration (54.53%) is detected in the Hasawnah Formation in the Ghat Sheet. The Awainat Wanin Formation in the Sabha Sheet contains iron reserves of about 5 billion metric tons [25]. Figures 2 and 3 display the average Fe concentration in the areas and formations, respectively. Moreover, the difference in the Fe concentration in each formation in the various areas is shown in Figures 4-12. From the foregoing, it is evident that the studied deposits contain raw materials that are appropriate for use in the iron and steel industry.

In a blast furnace, the reduction of iron ore with coke yields impure iron. The result is hot metal, also referred to as liquid iron, which is used as a raw material to make steel. Steel is created by refining hot metal through an oxidation stage. Pig iron is the term for the small ingots made when hot metal solidifies. Because of its high carbon content, pig iron is extremely brittle by nature and should only be used as a casting for certain components by modifying their composition. Iron ore, metallurgical coke, limestone, air,

***Received**: 27-03-2025 - **Accepted**: 22-05-2025 - **Published**: 30-05-2025*

and water are the primary raw materials used in the blast furnace ironmaking process [4]. Figure 13 shows a simplified representation of a blast furnace.

Table 1. Iron concentration (wt%) in the studied sediments [after 5-17]

Sheet	Area	Formation	Lithology	Fe_2O_{3T}	Fe*
Sabkhat Ghuzayil	Ghurd Muqaryaf	Al Hishah	Conglomerate	27.77	19.44
Al Fuqaha	S of Qarqaf Al Aqwaz	Awainat Wanin	Sandstone	39.05	27.34
Al Fuqaha	SSW of Qarqaf Al Aqwaz	Awainat Wanin	Oolite	67.04	46.93
Sabha	NNW of Dabdab	Awainat Wanin	Oolite	62.86	44.00
Sabha	WSW of Khasm An Niqwi	Awainat Wanin	Sandstone	51.33	35.93
Sabha	N of Bir Al Ghalmayah	Awainat Wanin	Conglomerate	49.18	34.43
Sabha	WSW of Tarut	Awainat Wanin	Oolite	43.41	30.39
Sabha	WSW of Tarut	Awainat Wanin	Oolite	46.59	32.61
Sabha	NNW of Qarat Al Baddadah	Awainat Wanin	Conglomerate	48.35	33.85
Sabha	N of Ash Shab	Awainat Wanin	Conglomerate	44.48	31.14
Sabha	NE of Bir Al Ghalmayah	Awainat Wanin	Oolite	61.27	42.89
Sabha	SW of Bir Al Ghazal	Awainat Wanin	Siltstone	58.41	40.89
Sabha	NNW of Qarat Al Baddadah	Marar	Conglomerate	49.50	34.65
Tanahmu	Sarir Al Qattusah	Mesak	Sandstone	39.23	27.46
Idri	W of Idri	Awainat Wanin	Sandstone	57.38	40.17
Idri	NE of Bir Al Qasr	Awainat Wanin	Sandstone	41.72	29.20
Idri	Wadi Ash Shati	Awainat Wanin	Oolite	45.64	31.95
Idri	Wadi Ash Shati	Awainat Wanin	Ferrolite	62.89	44.02
Idri	Wadi Ash Shati	Awainat Wanin	Oolite	68.68	48.08
Idri	Wadi Ash Shati	Awainat Wanin	Ferrolite	46.80	32.76
Qararat Al Marar	W of Qararat Al Marar	Marar	Sandstone	51.13	35.79
Qararat Al Marar	W of Qararat Al Marar	Awainat Wanin	Sandstone	32.58	22.81
Qararat Al Marar	W of Qararat Al Marar	Tadrart	Sandstone	26.72	18.70
Hasi Anjiwal	E of Bir Bu Raswan	Marar	Sandstone	31.11	21.78
Bir Anzawa	E of Tahughatin	Zarzaitine	Sandstone	25.68	17.98
Tikiumit	S of Taramhi Al Haj	Melaz Suqran	Sandstone	26.10	18.27
Tikiumit	W of Ilagh Naql	Melaz Suqran	Sandstone	35.75	25.03
Tikiumit	SW of Wadi Wayn Kali Janit	Melaz Suqran	Sandstone	40.25	28.18
Tikiumit	SE of Wadi Wayn Kali Janit	Akakus	Sandstone	26.60	18.62
Tikiumit	Bir Tazibzabin	Marar	Phosphate concretions	35.90	25.13
Tikiumit	N of Tikatanhar	Sabkha sediments	Silt	21.73	15.21
Al Awaynat	SW of Qarat Wadi Amisrajan	Tadrart	Sandstone	30.92	21.64
Al Awaynat	SW of Qarat Wadi Amisrajan	Tadrart	Sandstone	29.94	20.96
Al Awaynat	S of Bir Awbrkat	Wan Kasa	Sandstone	51.97	36.38
Al Awaynat	E of Qarat Wadi Amisrajan	Wan Kasa	Sandstone	47.41	33.19
Al Awaynat	S of Al Awaynat	Wan Kasa	Sandstone	46.68	32.68
Al Awaynat	S of Al Awaynat	Wan Kasa	Sandstone	38.30	26.81
Al Awaynat	NW of Wadi Wraymahat	Taouratine	Sandstone	38.92	27.24
Al Awaynat	S of Wadi Intahaha	Mesak	Sandstone	33.63	23.54
Wadi Tanezzuft	Wadi Maghidat	Tanezzuft	Siltstone	47.77	33.44
Wadi Tanezzuft	NE of Mashru Attullah	Akakus	Sandstone	39.47	27.63
Wadi Tanezzuft	NNE of Tin Alkharmah	Akakus	Sandstone	32.73	22.91
Wadi Tanezzuft	E of Wadi Tanezzuft	Akakus	Sandstone	35.00	24.50
Wadi Tanezzuft	Tin Alkharmah	Akakus	Sandstone	59.40	41.58
Wadi Tanezzuft	E of Wadi Tanezzuft	Akakus	Sandstone	48.20	33.74
Wadi Tanezzuft	E of Wadi Adaranjlku	Tadrart	Sandstone	33.12	23.18
Wadi Tanezzuft	S of Bir Damus	Old wadi deposits	Conglomerate	58.94	41.26
Wadi Tanezzuft	W of Ghat Airport	Old wadi deposits	Sandstone	23.02	16.11
Wadi Tanezzuft	W of Jabal Abu Lai	Old wadi deposits	Sandstone	24.45	17.12

***Received**: 27-03-2025 - **Accepted**: 22-05-2025 - **Published**: 30-05-2025*

Wadi Tanezzuft	Wadi Maghidat	Sabkha sediments	Jarosite	46.62	32.63
Anay	NW of Bab Tashuwant	Akakus	Sandstone	32.08	22.46
Anay	Mamar Abhuha	Marar	Sandstone	33.68	23.58
Anay	Mamar Abhuha	Marar	Sandstone	28.02	19.61
Anay	SE of Wadi Afzajar	Tadrart	Sandstone	30.13	21.09
Anay	Bab Tashuwant	Tadrart	Sandstone	25.61	17.93
Anay	Wadi Talmisayn	Mesak	Sandstone	27.30	19.11
Ghat	S of Aissayn	Tanezzuft	Hematite	55.83	39.08
Ghat	SW of Ghat	Hasawnah	Hematite	77.90	54.53
Ghat	Wadi Bab Tashuwant	Tadrart	Sandstone	25.03	17.52
Ghat	S of Aissayn	Old wadi deposits	Conglomerate	23.70	16.59
Ghat	SSW of Aissayn	Old wadi deposits	Sandstone	21.92	15.34
Ghat	SW of Ghat	Melaz Suqran	Shale	23.03	16.12

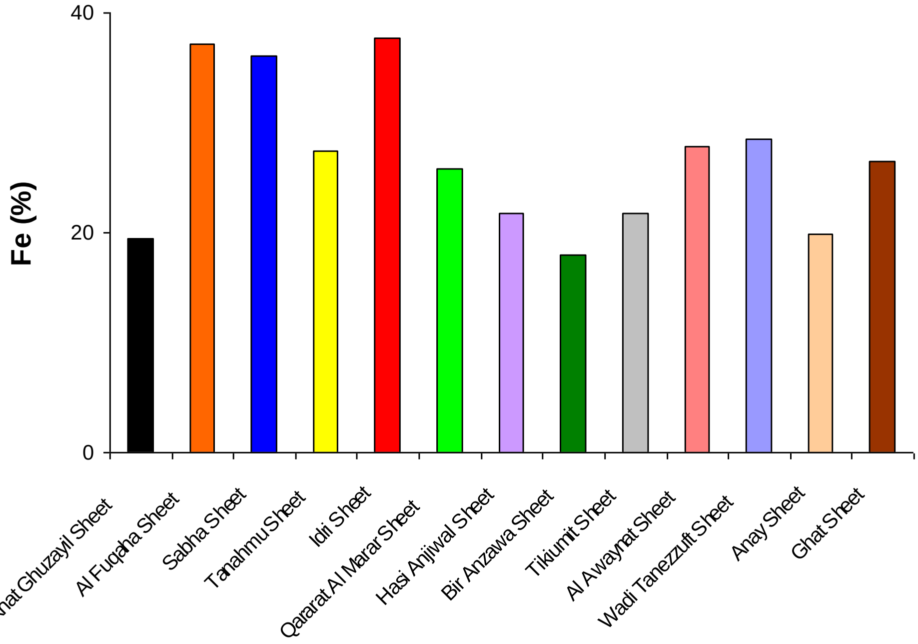

Figure 2. Average Fe concentration in the studied areas.

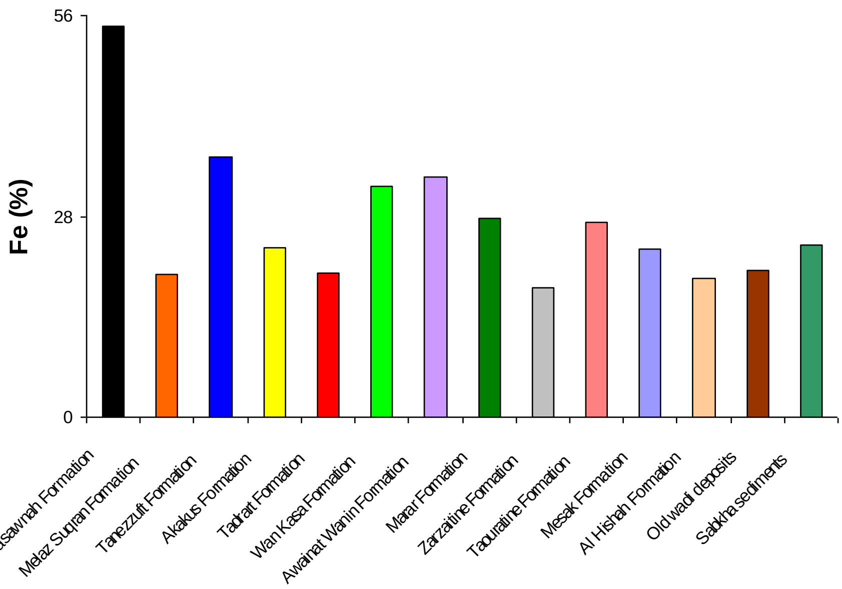

Figure 3. Average Fe concentration in the studied sediments.

Received*: 27-03-2025 -* ***Accepted****: 22-05-2025 -* ***Published****: 30-05-2025*

Figure 4. Fe concentration in the Melaz Suqran Formation.

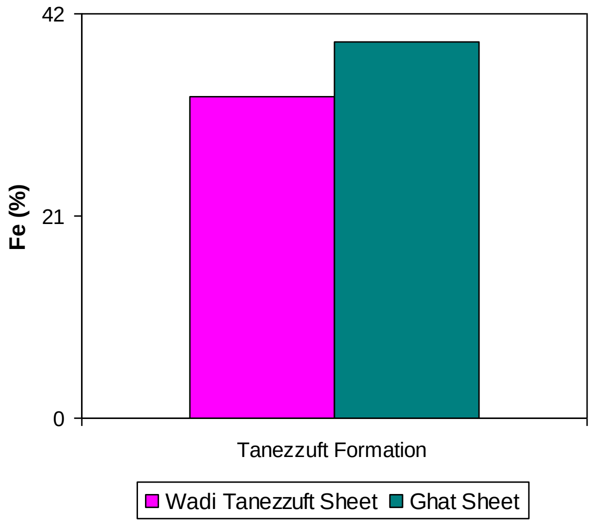

Figure 5. Fe concentration in the Tanezzuft Formation.

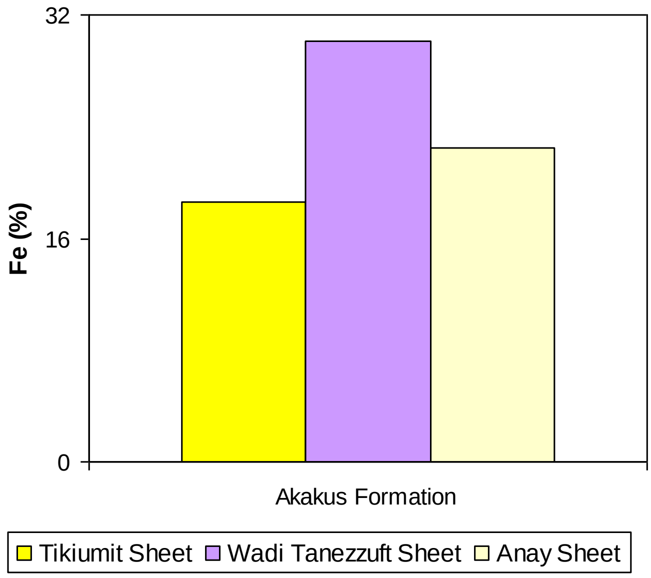

Figure 6. Fe concentration in the Akakus Formation.

Received*: 27-03-2025 -* ***Accepted****: 22-05-2025 -* ***Published****: 30-05-2025*

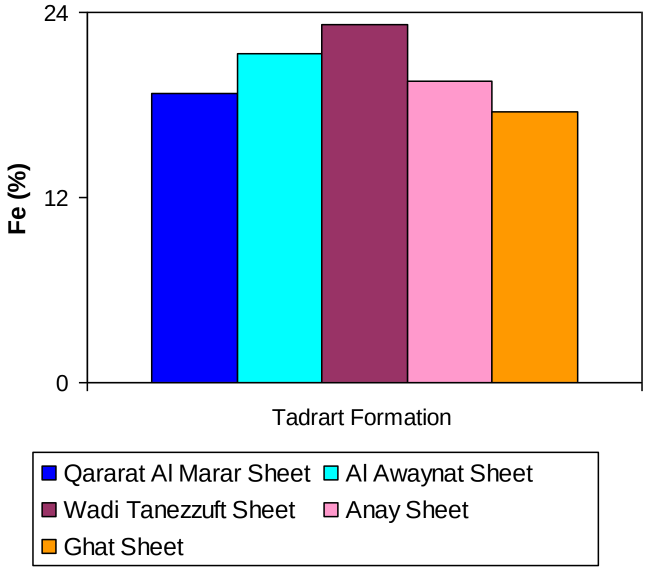

Figure 7. Fe concentration in the Tadrart Formation.

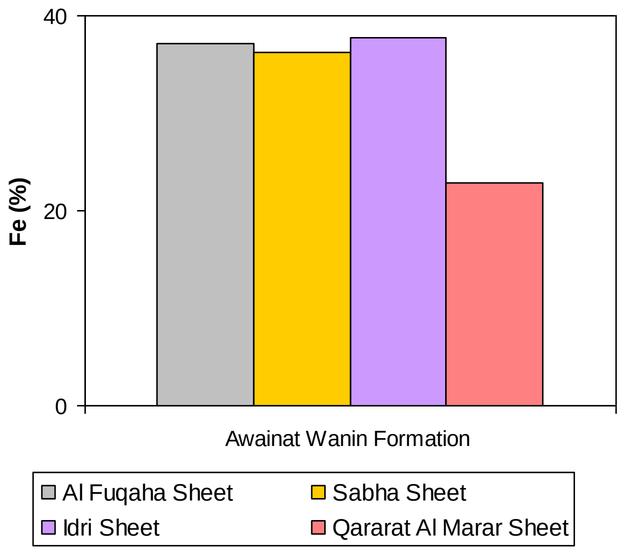

Figure 8. Fe concentration in the Awainat Wanin Formation.

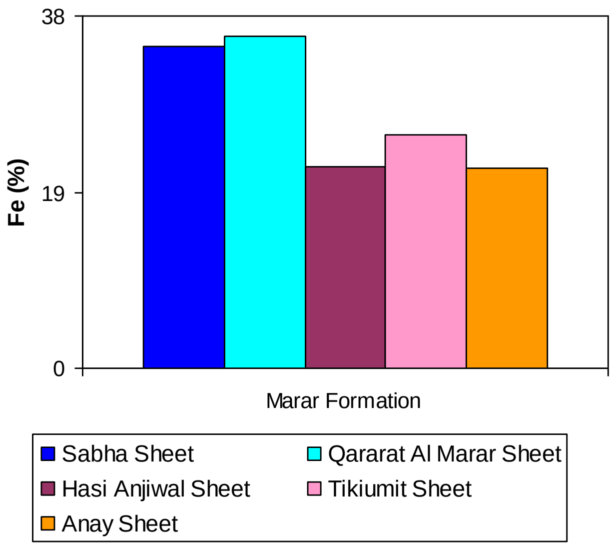

Figure 9. Fe concentration in the Marar Formation.

Received: *27-03-2025* - **Accepted**: *22-05-2025* - **Published**: *30-05-2025*

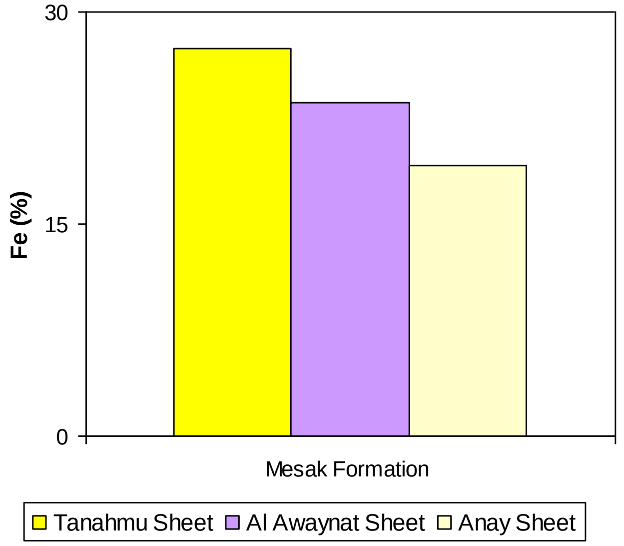

Figure 10. Fe concentration in the Mesak Formation.

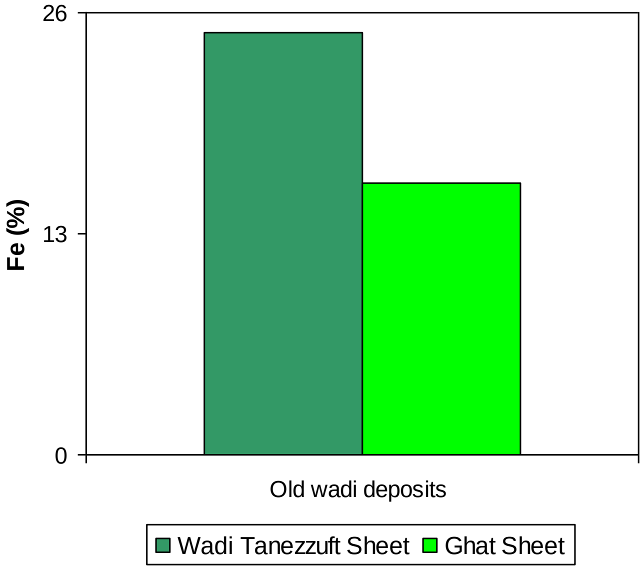

Figure 11. Fe concentration in the Old wadi deposits.

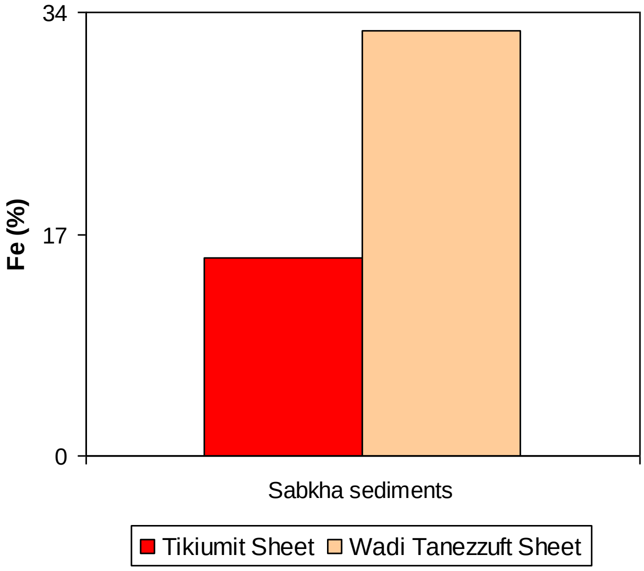

Figure 12. Fe concentration in the sabkha sediments.

Received*: 27-03-2025 -* ***Accepted****: 22-05-2025 -* ***Published****: 30-05-2025*

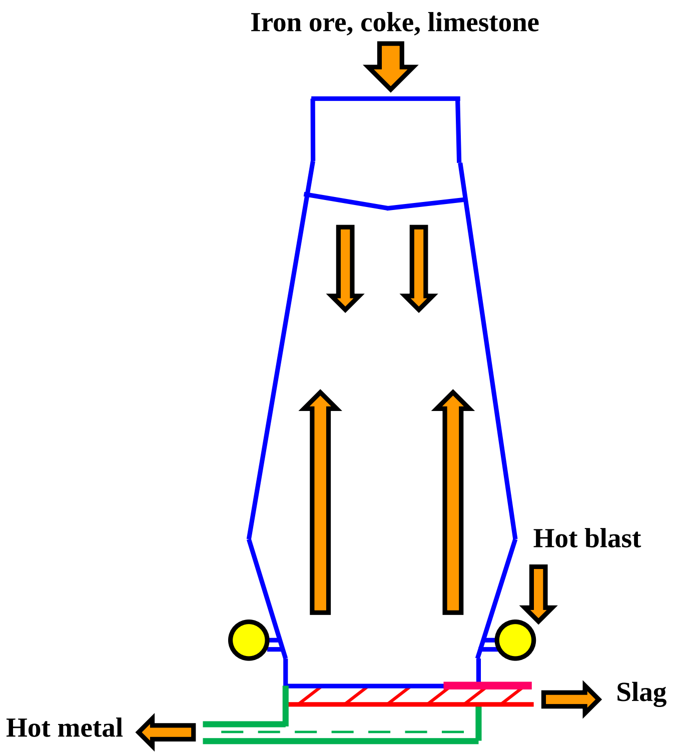

Figure 13. Simplified representation of a blast furnace [after 4].

Conclusion

An indication of industrialization and advancement is the amount of steel consumed per person in the population, with the iron and steel industry being arguably the most significant component of a country's industrial economic infrastructure. Ferrous metals are extracted using two processes: the reduction process used in ironmaking and the oxidation process used in steelmaking. The goal of this study is to recommend applications for Libyan iron ores in the steel and iron industry. The study encompassed thirteen areas (Sabkhat Ghuzayil, Al Fuqaha, Sabha, Tanahmu, Idri, Qararat Al Marar, Hasi Anjiwal, Bir Anzawa, Tikiumit, Al Awaynat, Wadi Tanezzuft, Anay, and Ghat sheets). Due to the lack of prior study on the raw materials utilized in Libya's iron and steel industry, this work can be considered the first on this topic. Iron ore has been discovered in a number of formations (Hasawnah Formation, Melaz Suqran Formation, Tanezzuft Formation, Akakus Formation, Tadrart Formation, Wan Kasa Formation, Awainat Wanin Formation, Marar Formation, Zarzaitine Formation, Taouratine Formation, Mesak Formation, Al Hishah Formation, Old wadi deposits, and sabkha sediments). The Fe concentration in the studied sediments indicates that iron and steel production may be possible from these sediments.

Conflict of interest. Nil

References

1. IEA ETSAP (International Energy Agency-Energy Technology Systems Analysis Program, 2010): Iron and steel. Technology Brief 102; 6p.
2. IEA (International Energy Agency, 2020): Iron and steel technology roadmap: Towards more sustainable steelmaking. Part of the Energy Technology Perspectives series; 187p.
3. Anbar, A.D. and Weis, D. (2024): Treatise on geochemistry. 3rd edition, Elsevier Science; 10500p.
4. Dutta, S.K. and Chokshi, Y.B. (2020): Basic concepts of iron and steel making. 1st edition, Springer Singapore; 645p.
5. Jakovljevic, Z. (1984): Geological Map of Libya, 1:250000, Sheet: Al Awaynat, NG 32-12, Explanatory Booklet. Industrial Research Centre (IRC), Tripoli, Libya; 140p.
6. Galecic, M. (1984): Geological Map of Libya, 1:250000, Sheet: Anay, NG 32-16, Explanatory Booklet. Industrial Research Centre (IRC), Tripoli, Libya; 98p.
7. Mrazek, P. (1984): Geological Map of Libya, 1:250000. Sheet: Tanahmu, NG 33-6, Explanatory Booklet. Industrial Research Centre (IRC), Tripoli, Libya; 72p.
8. Parizek, A., Klen, L. and Rohlich, P. (1984): Geological Map of Libya, 1:250000, Sheet: Idri, NG 33-1, Explanatory Booklet, Industrial Research Center (IRC) Tripoli, Libya; 108p.
9. Protic, D. (1984a): Geological Map of Libya, 1:250000, Sheet: Bir Anzawa, NG 32-3, Explanatory Booklet. Industrial Research Centre (IRC), Tripoli, Libya; 73p.

***Received**: 27-03-2025 - **Accepted**: 22-05-2025 - **Published**: 30-05-2025*

https://doi.org/10.54361/ajmas.258268

10. Protic, D. (1984b): Geological Map of Libya, 1:250000, Sheet: Tikiumit, NG 32-7, Explanatory Booklet. Industrial Research Centre (IRC), Tripoli, Libya; 120p.
11. Radulovic, P. (1984a): Geological Map of Libya, 1:250000, Sheet: Wadi Tanezzuft, NG 32-11, Explanatory Booklet, Industrial Research Center (IRC) Tripoli, Libya; 114p.
12. Radulovic, P. (1984b): Geological Map of Libya, 1:250000, Sheet: Ghat, NG 32-15, Explanatory Booklet, Industrial Research Center (IRC) Tripoli, Libya; 86p.
13. Roncevic, G. (1984): Geological Map of Libya, 1:250000, Sheet: Hasi Anjiwal, NG 33-4, Explanatory Booklet, Industrial Research Center (IRC) Tripoli, Libya; 92p.
14. Seidl, K. and Rohlich, P. (1984): Geological Map of Libya, 1:250000, Sheet: Sabha, NG 33-2, Explanatory Booklet. Industrial Research Centre (IRC), Tripoli, Libya; 149p.
15. Woller, F. (1984): Geological Map of Libya, 1:250000. Sheet: Al Fuqaha, NG 33-3, Explanatory Booklet. Industrial Research Centre (IRC), Tripoli, Libya; 123p.
16. Gundobin, V.M. (1985): Geological Map of Libya, 1:250000, Sheet: Qararat Al Marar, NH 33-13, Explanatory Booklet. Industrial Research Centre (IRC), Tripoli, Libya; 176p.
17. Kodym, O. (1985): Geological Map of Libya, 1:250000. Sheet: Sabkhat Ghuzayil, NH 34-10, Explanatory Booklet. Industrial Research Centre (IRC), Tripoli, Libya; 104p.
18. Kridan, F.A.M. (2008): A study on the quality of material in Libyan iron and steel industry. Unpublished MSc Thesis, University Sains Malaysia, Malaysia.
19. Elamin, F., Altaweel, A. and Abugeddida, R. (2022): An exploration of the extent of total productive maintenance implementation in the iron and steel industry in Libya. Tobruk University Journal of Engineering Sciences (TUJES); 3(2); 9p.
20. Abugeddida, R. and Elamin, F. (2022): An analytical study of work-related injuries in heavy industries. 2nd International Conference on Applied Engineering and Natural Sciences, Konya, Turkey; pp. 188-192.
21. Elshahoubi, I.S., Masli, A.M. and Sidoun, M.W. (2023): The availability of the components of applying the balanced scorecard model: The case study of Libyan Iron and Steel Company. Journal of Economics and Business Studies; 24p.
22. Badi, I. and Abdulshahed, A. (2021): Sustainability performance measurement for Libyan Iron and Steel Company using Rough AHP. Journal of Decision Analytics and Intelligent Computing; 1(1): 22-34.
23. Elsaghier, E.H., Zaghinin, M.S. and Elderrat, H.I. (2019): Investigation model for environmental impacts of the steel industry in Libya. International Conference on Technical Sciences (ICST2019); pp. 1223-1228.
24. Mucke, A. and Farshad, F. (2005): Whole-rock and mineralogical composition of Phanerozoic ooidal ironstones: Comparison and differentiation of types and subtypes. Ore Geology Reviews; 26: 227-262.
25. World Atlas (2019): What are the major natural resources of Libya (available at https://www.worldatlas.com/articles/what-are-the-major-natural-resources-of-libya.html).

Received*: 27-03-2025 -* ***Accepted****: 22-05-2025 -* ***Published****: 30-05-2025*