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A STUDY OF THE PHYSICOCHEMICAL AND MINERALOGICAL PROPERTIES OF MARBLE ROCKS COLLECTED FROM THE SIHORA AND KATNI REGIONS OF MADHYA PRADESH

Chemistry

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ABSTRACT

Marble samples from the Sihora and Katni regions of Central India are characterized using X-ray Diffraction (XRD), X-ray Fluorescence (XRF), and Inductively Coupled Plasma–Mass Spectrometry (ICP–MS) to investigate their mineralogical and geochemical properties. The results revealed the presence of major elements Calcium (Ca), Magnesium (Mg), Silicon (Si), Iron (Fe), Titanium (Ti,) and Boron (B) and trace elements Phosphorus (P), Manganese (Mn), Barium (Ba), Chromium (Cr), Cobalt (Co), Nickel (Ni), Cadmium (Cd), Copper (Cu), Lead (Pb), Vanadium (V), and Zinc (Zn). The studied marbles are dominated by presence of CaO, and minor amounts of SiO_2, Al_2O_3, MgO, Fe_2O_3, K_2O, and Na_2O, indicating a carbonate-rich composition. The integrated mineralogical and geochemical data provides valuable insights into the physicochemical characteristics, quality, and industrial potential of the marble deposits. The findings suggest that these marble resources are suitable for construction, agriculture scope, agronomic scope ornamental, and other industrial applications.

KEYWORDS

Marble, XRD, XRF, ICP–MS, Sihora, Katni.

INTRODUCTION

Marble rock is a high-grade metamorphic carbonate rock formed through the recrystallization of calcitic and dolomitic limestones under conditions of elevated temperature and pressure. In India, major marble rock deposits are associated with the Aravalli Supergroup, Vindhyan Supergroup, and Dharwar Cratonic Belt. Rajasthan accounts for nearly 90% of the country's marble rock reserves, while significant deposits also occur in Gujarat, Madhya Pradesh, and Andhra Pradesh.

The marble rock deposits of Madhya Pradesh are of considerable geological and economic importance. They occur within the transitional zone between the Vindhyan Basin and the Archean Basement Complex and are primarily associated with calcitic ($CaCO_3$), and dolomitic [CaMg $(CO_3)_2$], metasedimentary sequences. The Katni and Sihora regions are selected for the present study because of their distinct geological, mineralogical, and geochemical characteristics. These areas have undergone complex tectono-metamorphic processes, including recrystallization, faulting, fracturing, and deformation, which have contributed to the development of diverse marble rock varieties.

Katni marble rock is predominantly dolomitic in nature and is characterized by fine to medium grained crystalline texture, high density, low porosity, and good polishing properties. Its mineralogical composition mainly includes Calcium carbonate ($CaCO_3$), dolomite [CaMg $(CO_3)_2$], quartz, mica, and minor iron-bearing minerals. In contrast, the Sihora region represents a structurally controlled carbonate zone where mineralization along fractures and shear zones has influenced the texture and crystallinity of the marble rock. Petrographic studies from these regions commonly reveal granoblastic textures, mosaic crystal fabrics, and recrystallized carbonate grains, indicating their metamorphic evolution. Marble rock is an important ornamental stone traded worldwide, and its value depends on both its natural characteristics, such as colour, purity, and texture, and the degree of technological processing (Kandil and Selim, 2007).

The present study aims to investigate the chemical characteristics of marble Sample from the Katni and Sihora regions of Madhya Pradesh. Representative samples are analysed using X-ray Diffraction (XRD), X-ray Fluorescence (XRF), and Inductively Coupled Plasma–Mass Spectrometry (ICP–MS) to determine their mineralogical composition and geochemical characteristics, thereby evaluating their geological significance and potential industrial applications.

Field Survey & Sample Collection

A systematic field survey is conducted in the Sihora Block (Jabalpur District) and Katni block in Katni District of Madhya Pradesh to identify marble rock-bearing zones and collect representative samples for laboratory analysis. Both regions, forming part of the Central Indian marble rock belt, are characterized by extensive calcitic $Ca(CO_3)_2$, and dolomitic [CaMg $(CO_3)_2$], metamorphic marble rock deposits. The geographical extent of the regions is presented through their latitude and longitude coordinates in tabular form. Mineral resource maps prepared from published reports of the Geological Survey of India have also been included to illustrate the regional geology and distribution of marble rock resources. Representative samples are collected from different quarry sites for detailed investigations.

Table 1: - Geographical and climatic characteristics of the study areas

Parameter	Sihora, Block	Katni, Block
Latitude / Longitude	23.388 N / 80.104 E	23.834 N / 80.392 E
Elevation	~386 m	~304 m
Avg. annual temperature	~27–28 °C	~27 °C
Annual rainfall	1100–1200 mm	~1100 mm
Climate Classification	Tropical wet–dry (Aw)	Tropical wet–dry (Aw)

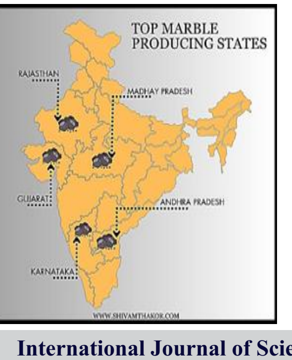

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Figure 1a: MR Producing map of India Source from GSI
Figure 1b: Sihora & Katni MR Resource map of M.P.

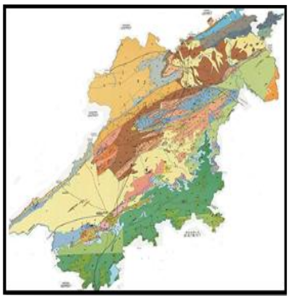

Figure 1c & 1d: DRM map of Sihora & Katni, Bolck, (Mudwara) of Jabalpur

Figure 1f: Marble Rocks Mine (Sihora) **Figure 1e: Marble Rocks Mine (Katni)**

Materials and methods:

Sample Preparation & Characterization:

Representative samples from selected quarry sites of Sihora & Katni are used for mineralogical and geochemical analyses. The collected marble are crushed, and grounded using a mortar to obtain fine powder.

Village- Ghutehi
Block Sihora
Distt. Jabalpur [M.P.]

Village- Kandra
Block Katni
Distt. Katni [M.P.

Figure 2a and 2b: Marble samples from the study area

The powdered samples are then sieved to obtain a particle size of <125 µm, and the sieved fractions are then characterised XRD, XRF, and ICP–MS analyses. In present study, the chemical characterization of marble samples from the Sihora and Katni regions of Madhya Pradesh is carried out at Indian Institute of Science Education and Research (IISER), Bhopal. For characterization of marble sample following instruments are used.

3.2 X-ray Diffraction (XRD): - Mineralogical and Crystallography characterization of marble samples are carried out using a Bruker D8 Advance X-ray diffractometer equipped with Cu Kα radiation (λ = 1.5406 Å), operating in Bragg–Brentano geometry with a graphite monochromator. The instrument is operated at 40 kV and 50 mA. Diffraction data are recorded over a 2θ range of 5°–90°, and mineral phases are identified using the ICDD-PDF 2004 database.

3.3 X-ray Fluorescence (XRF) Spectroscopy: - The major oxide composition of the marble samples is determined using X-ray Fluorescence (XRF) spectroscopy. Finely powdered samples (<125µm) are analyzed using a BRUKER S4 EXPLORER XRF spectrometer to quantify the major oxide constituents

Inductively Coupled Plasma–Mass Spectrometry (ICP–MS):
Trace element concentrations in the marble samples are determined using ICP–MS. Representative sample aliquots are digested using suitable acid mixtures to achieve complete dissolution of the mineral matrix. The resulting solutions are analyzed to quantify trace elements with high sensitivity, accuracy, and precision.

Results and discussion:

X-ray diffraction (XRD): - X-ray diffraction (XRD) analysis is employed to identify the mineralogical phases present in the marble samples collected from the Sihora and Katni regions of Madhya Pradesh, India. The XRD patterns of the marble samples from Sihora and Katni are presented in Figures 3 and 4, respectively. The diffraction peaks observed in the diffractograms provide information regarding the crystalline phases, chemical composition, and crystal structure of the constituent minerals. Phase identification based on standard mineral diffraction databases revealed that calcite ($CaCO_3$) is the dominant mineral phase in marble samples from Sihora. In contrast, the marble samples from Katni contain calcite as the major phase along with a significant proportion of dolomite [$CaMg(CO_3)_2$]. Calcite ($CaCO_3$) is the principle mineral constituent of marble and limestone and is typically associated with white to pale-colored marble varieties.

The high calcite ($CaCO_3$) content in the marble samples from Sihora is consistent with their characteristic white appearance. Conversely, the grey coloration of the marble samples from Katni can be attributed to the presence of dolomite and other minor mineral impurities. In general, impurities such as oxides, silicates, quartz, and graphite influence the texture, color, and physicochemical properties of marble, leading to the development of grey, yellow, or other color variations (Lindaawati et al., 2019). The XRD results indicate that marble samples from Sihora is predominantly calcitic ($CaCO_3$) in nature, whereas marble samples from Katni exhibits a mixed calcite–dolomite mineralogy, reflecting compositional variations that may significantly affect its industrial and decorative applications. Marble sample that is rich in calcites typically has a white color. Marble rock's texture and color may be affected in this area by the presence of impurities like oxide, silicate, quartz, and graphite (Lindaawati et al., 2019).

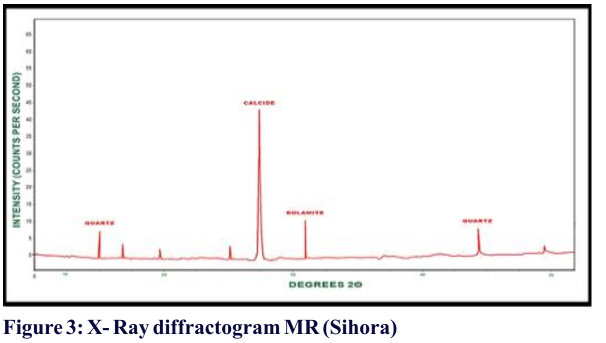

Figure 3: X- Ray diffractogram MR (Sihora)

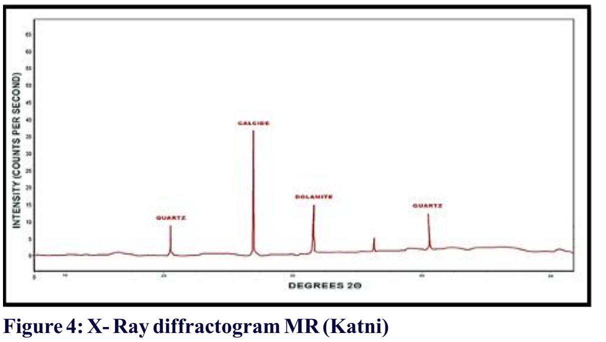

Figure 4: X- Ray diffractogram MR (Katni)

Table 2: Chemical composition of Marble samples from Sihora & Katni

S. No.	Contents	Sihora, MR Content %	Katni, MR Content%
1.	Dolomite	12	20
2.	Calcite	70	75
3.	Quartz	18	5

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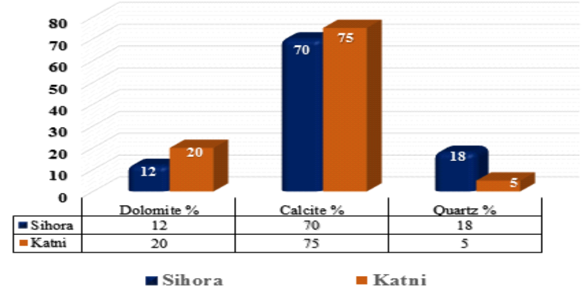

Figure 5: Percentage composition of MR sample from Sihora and Katni based on XRD analysis

X-Ray Fluorescence (XRF): - X-Ray Fluorescence (XRF) Analysis The chemical composition of the marble samples obtained using XRF analysis is presented in Table 3. The XRF results reveal that Calcium Oxide (**CaO**) is the dominant oxide in both samples, whereas other oxides i.e. Magnesium Oxide (**MgO**), Silica (**SiO_2**)**, Alumina (Al_2O_3), Hematite Fe_2O_3, Potassium Oxide (K_2O),** and Sodium Oxide (**Na_2O**) occur in relatively minor concentrations. These oxides constitute the principal chemical components that govern the mineralogical and physicochemical characteristics of the marble rocks.

The high Calcium Oxide (**CaO**) content observed in analyzed samples is consistent with the XRD results, confirming the predominance of Calcite ($CaCO_3$) as the major mineral phase. The marble sample from Sihora contains 56.26 wt.% Calcium Oxide **CaO,** while the marble sample Katni contains 54.80 wt.% Calcium Oxide **CaO.** In contrast, Magnesium Oxide (**MgO**) concentrations are relatively low, with values of 0.18 wt.% and 0.53 wt.% for the marble sample from Sihora and Katni, respectively. The combination of high Calcium Oxide **(CaO)** and low Magnesium Oxide **MgO** contents indicates that both marble deposits are predominantly calcitic in nature. The presence of Silica (**SiO_2**) and Alumina (**Al_2O_3**) suggests minor contributions of quartz and aluminosilicate phases. Alkali oxides such as Potassium Oxide (**K_2O**) and Sodium Oxide (**Na_2O**)**,** although present in small amounts, may influence the physicochemical behavior of the rock, particularly under high-temperature conditions where they can form eutectic phases with Silica (**SiO_2**) and Alumina (**Al_2O_3**)**.** Hematite **(Fe_2O_3)** is present in low concentrations in both samples, with a comparatively higher value in the marble sample from Katni. The occurrence of Iron (**Fe**)**-**bearing impurities may contribute to variations in color and texture, particularly the grayish appearance observed in some marble varieties. Similarly, the low Magnesium Oxide (**MgO**) content may be attributed to minor dolomitic or aluminosilicate impurities within the rock matrix. The results obtained in agreement with previous studies, According to Khan et al. (2017), marble rocks containing more than 49 wt.% Calcium Oxide (**CaO**) and less than 2.6 wt.% Magnesium Oxide (**MgO**) are classified as calcite ($CaCO_3$) marble. Likewise, Amin et al. (2020) reported that marble rocks are primarily composed of calcium oxide, silica, alumina, and minor accessory oxides. Furthermore, Benjeddou and Alwetaishi (2021) demonstrated that a significantly higher Calcium Oxide (**CaO**) concentration relative to Magnesium Oxide (**MgO**) is a characteristic feature of calcite-rich marble.

Overall, the geochemical composition of the marble samples from Sihora and Katni confirms their calcitic nature, characterized by high Calcium Oxide (**CaO**) content and comparatively low concentrations of Magnesium Oxide (**MgO**) and other accessory oxides. These findings strongly support the mineralogical interpretations derived from the XRD analysis and provide valuable insights into the compositional characteristics of the studied marble deposits.

Table 3: Oxides percentage of marble samples from Sihora & Katni, Block

S. No.	**Oxides**	**Sihora, Block (%)**	**Katni, Block (%)**
1.	Calcium Oxide (CaO)	56.26	54.80
2.	Magnesium Oxide (MgO)	0.18	0.53
3.	Silica (SiO_2)	0.15	0.23
4.	Alumina (Al_2O_3)	0.08	0.14
5.	Hematite (Fe_2O_3)	0.18	0.84
6.	Potasium Oxide (K_2O)	0.27	0.30
7.	Sodium Oxide (Na_2O)	0.05	0.08

Figures 6 and 7 effectively depicted in oxide distribution, conforms the dominance of Calcium Oxide (**CaO**) and supporting the mineralogical purity of the marble sample. These results validate the potential use of calcium-rich marble sample from Sihora and Katni as mineral inputs in agronomic or environmental applications.

ICP–MS Analysis: - The ICP–MS results reveal negligible variations in the trace-element composition of the marble sample from Katni and marble sample from Sihora, with Iron (**Fe**) being the most abundant element, followed by Titanium (**Ti**), Boron (B), and Silicon (**Si**)**.** Katni marble exhibits a higher Iron (**Fe**) concentration (5726 ppm) than Sihora marble (5258 ppm), indicating a greater enrichment of iron-bearing phases. Since Iron-containing minerals are known to facilitate redox reactions and electron-transfer processes, the higher Iron (**Fe**) content in the marble sample from Katni may enhance its potential for catalytic and environmental applications (Wang et al., 2020). Iron-rich materials have been widely utilized in oxidation reactions, wastewater treatment, and advanced oxidation processes due to their catalytic efficiency. Concentrations of Titanium (Ti) in both marble samples from Sihora and Katni, containing higher Titanium **(Ti)** levels (351 ppm) compared to Sihora marble (286 ppm). Titanium-bearing minerals are well known for their photocatalytic properties and their ability to promote pollutant degradation under light irradiation (Fujishima and Zhang, 2006; Chen and Mao, 2007). Therefore, the relatively higher Titanium **(Ti)** concentration in the marble sample from Katni suggests that greater potential for photocatalytic applications. A similar trend is observed for Boron (B), which occurs at 15 ppm in marble sample from Katni and 13 ppm in marble sample from Sihora. Although present in lower concentrations than Iron (**Fe**) and Titanium (**Ti**), its plays an important role in modifying surface acidity and improving catalytic selectivity and stability (Liu et al., 2019). Boron (**B**)(13–15 ppm) is an essential micronutrient that supports cell wall formation, pollen viability, reproductive development, and carbohydrate transport in plants. Its adequate supply improves root growth, flowering, and crop yield, while deficiency leads to poor productivity (Marschner, 2012; Shorrocks, 1997). Thus, the presence of boron in the studied marble deposits suggests its potential applicability in agronomic beneficiation as natural soil micronutrient source. Silicon (**Si**) is present in both marble samples and is associated with quartz-bearing phases within the carbonate matrix. Marble sample from Katni contains higher (**Si**) concentration (3.110 ppm) than marble sample from Sihora (1.769 ppm), indicating a relatively greater contribution from siliceous minerals. As mentioned in literature that Silica-bearing phases are important in catalytic systems due to structural stability, thermal resistance, and support for active catalytic components (Corma, 1997). Consequently, the higher silicon content presence in marble sample from Katni, may enhance its suitability as catalyst-support material. Geochemical Interpretation of trace elements composition of results marble samples obtained using Inductively Coupled Plasma–Mass Spectrometry (ICP–MS), demonstrated that marble sample from Sihora and Katni, contain only trace amounts (<1 ppm) of potentially toxic elements, including Cadmium (**Cd**)**,** Cobalt **(Co),** Chromium **(Cr),** Nickel **(Ni),** Lead **(Pb)**, and Vanadium (**V**). Such low concentrations suggest a negligible risk of heavy-metal accumulation in soils and crops following application. This characteristic enhances the agricultural suitability of these marble deposits, supporting their potential use as environmentally safe mineral amendments for improving soil fertility and crop productivity without significant concerns regarding heavy-metal toxicity. Ionic form of elements capable of substituting calcium in the crystal lattice of Calcium Carbonate (**$CaCO_3$**) are particularly useful for understanding the geochemical evolution and provenance of marble rocks. Due to similarities in ionic radius, elements such as Iron (**Fe**)**,** Stronsium **(Sr),** Mangnese **(Mn)**, and Magnesium (**Mg**) can readily replace Calcium ion (**Ca^{++}**) within the **CO_3^{2-}** structure (Yavuz Çelik, 2022). In the present study, the elevated Iron (Fe) content and measurable Manganese **(Mn)** concentrations suggest partial ionic substitution and incorporation during marble formation and metamorphic processes.

Table 4: Elemental investigation of samples from Sihora & Katni

S. No.	**Elements**	**MR, Sihora, Block (ppm)**	**MR, Katni, Block (ppm)**

1.	Boron (Bo)	13.040	14.740
2.	Iron (Fe)	5726.000	5258.000
3.	Titanium (Ti)	350.500	285.600
4.	Barium (Ba)	1.476	1.034
5.	Cadmium (Ca)	0.002	0.002
6.	Cobalt (Co)	0.019	0.013
7.	Chromium (Cr)	0.133	0.114
10.	Lanthanum (La)	0.052	0.046
11.	Magnesium (Mg)	0.000	0.000
12.	Manganese (Mg)	3.046	2.999
13.	Nickel (Ni)	0.019	0.004
14.	Phosphorus (P)	0.835	1.014
15.	Lead (Pb)	0.060	0.063
16.	Silicon (Si)	3.110	1.769
17.	Vanadium (V)	0.076	0.054
18.	Zinc (Zn)	0.127	0.063

Overall, the ICP–MS results indicate that the marble Sample from both regions are characterized by iron-rich geochemical signatures. These findings provide valuable insights into the provenance, compositional characteristics, and potential industrial significance of the marble deposits from the Sihora and Katni regions of Madhya Pradesh, India.

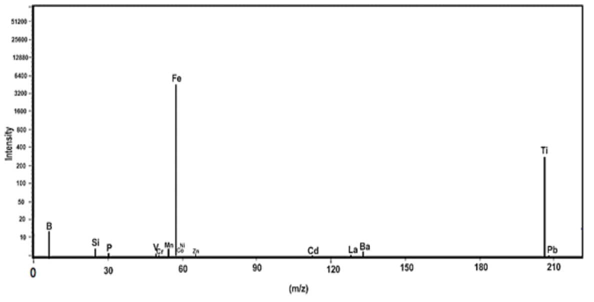

Figure 4: Elemental analysis of marble rock samples of Sihora region via ICP-MS

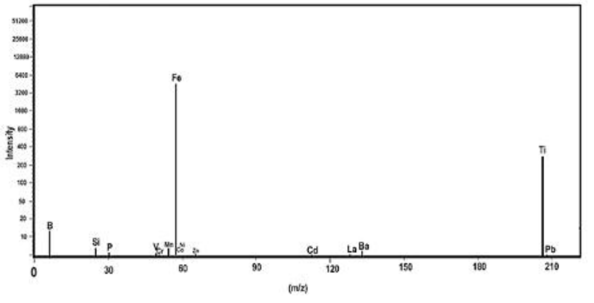

Figure 5: Elemental analysis of marble rock samples from Katni region via ICP-MS

CONCLUSION:

The present study demonstrates that the dominance of Calcium (**Ca**) content in marble samples from Sihora and Katni have strong potential for soil pH regulation, improved nutrient availability, and enhanced crop & tubers crop growth, and also indicating that these marble resources can also be useful in sustainable agriculture application. The presence of Boron (**B**), Manganese (**Mn**), and **Zinc (Zn)** further supports improved enzymatic activity, photosynthetic efficiency, and secondary metabolite production in plants, particularly in medicinal and aromatic crops. Furthermore, the detectable level of Lanthanum **(La)** within biologically active ranges suggests potential stimulation of root development and metabolic activity, aligning with recent findings on Rare Earth Elements (**REEs)** for enhance plant growth. Further is indicated that marble sample from katni exhibits a more favorable elemental profile than marble sample from Sihora, particularly in terms of Calcium Oxide (**CaO)** and key micronutrients, making its utility preferred than the other sample. While the presence of Iron (**Fe)** and Titanium (**Ti)** in suggests possible catalytic and photocatalytic applications in degradation of organic pollutants and redox-driven reactions. In addition, Iron (**Fe),** Titanium **(Ti),** and Silicon (**Si)** bearing phases are widely recognized for their roles in heterogeneous catalysis and catalyst-support systems

Overall, the geochemical composition of these marbles supports their dual potential as natural soil remineralizers for sustainable agriculture and as mineral-based precursors for catalytic and photocatalytic applications. However, detailed field trials and catalytic performance studies are suggested to validate their practical effectiveness and optimize their future applications.

REFERENCES:

1. Amin, S. K., Allam, M. E., & Garas, G. L. (2020). "A study of the chemical effect of marble rock and granite slurry on green mortar compressive strength", *Bulletin of the National Research Centre, 44.*
2. Barron, A. J. M. (2018). "Carrara marble rock". *Mercian Geologist, 19(3),* 188–194.
3. Benjeddou, O., & Alwetaishi, M. (2021). "Valorization of powder obtained from marble rock sludge waste and its suitability as a mineral filler". *Crystals, 11(6),* 619.
4. Careddu, N., & Marras, G. (2015). "Marble processing for future uses of $CaCO_3$-Microfine dust: A study on wearing out of tools and consumable materials in stone working factories"s. *Mineral Processing and Extractive Metallurgy Review, 36(3),* 183–191.
5. Celik, M. Y. (2022). "The characterization of Docimian white marble rock (Dokimeion-Phrygia/İscehisar-Turkey) and its significance for architectural materials in ancient times". *Research Square*. Advance online publication.
6. Chen, X., & Mao, S. S. (2007). (Titanium dioxide nanomaterials: Synthesis, properties, modifications, and applications". *Chemical Reviews, 107(7),* 2891–2959.
7. Chouhan, S. (2022). "A study on marble rock industry with special reference to Rajasthan". *Inspira-Journal of Commerce, Economics & Computer Science, 8*(1), 76–81.
8. Conti, P. (2013). "Microstructures, textures and material properties of marble rock rocks: An introduction". In *Geological setting, mineral resources and ancient works of Samos and adjacent islands of the Aegean Sea* Karlovassi, Samos Island, Greece. 26–30.
9. Conyers, M. K., Heenan, D. P., McGhie, W. J., & Poile, G. P. (2003). "Amelioration of acidity with time by limestone under contrasting tillage". *Soil and Tillage Research, 72(1),* 85–94.
10. Corma, A. (1997). "From microporous to mesoporous molecular sieve materials and their use in catalysis". *Chemical Reviews, 97*(6), 2373–2419.
11. El-Gammal, M., Ibrahim, M., Badr, E., Asker, S. A., & El-Galad, N. M. (2011). "Health risk assessment of marble rock dust at marble rock workshops". *Natural Science, 3*(2), 144–154.
12. Fujishima, A., & Zhang, X. (2006). "Titanium dioxide photocatalysis: Present situation and future approaches". *Comptes Rendus Chimie, 9(5–6)*, 750–760.
13. Garg, S., Kaur, P., Pandit, M., Fareeduddin, Kaur, G., Kamboj, A., & Thakur, S. N. (2019). "Makrana marble rock: A popular heritage stone resource from NW India". *Geoheritage, 11*, 909–925.
14. Geological Survey of India. (2015). "*Geological and mineral map of Madhya Pradesh".* Geological Survey of India Publication Division.
15. Kandil, A. I., & Selim, T. H. (2007). "*Characteristics of the marble rock industry in Egypt".*
16. Khan, Z., Umar, M., Khan, S., & Ali, A. (2017). "Utilization of marble rock dust in fired clay bricks". *The Environmental Monitor, 17, 4–5.*
17. Lindawati, L., Mursal, M., & Afdhal, A. (2019). "Determination of mineral contents in Meukek marble rock using XRD and SEM-EDS analysis". In *IOP Conference Series: Materials Science and Engineering* (Vol. 506, Article 012023).
18. Liu, Y., et al. (2019). "Boron-containing catalysts and their catalytic applications".
19. Moghaddam, H. K., Rajaei, A., & Moghaddam, H. K. (2018). "Marble rock slabs classification system based on image processing (Ark Marble rock Mine in Birjand)". *Civil Engineering Journal, 4*(1), 107–116.
20. Wang, X., et al. (2020). "Iron-based catalysts for environmental remediation and advanced oxidation processes".