Scientific article
UDC 667.6
DOI: 10.52957/2782-1900-2024-5-3-104-110

PRODUCTION OF IRON-OXIDE PIGMENTS USING METALLURGICAL WASTES

A. N. Kolosova[1], Y. V. Kudryavtsev[2], A. E. Tereshko[2]

Anastasia Nikolayevna Kolosova; **Yaroslav Vladimirovich Kudryavtsev; Anastasia Evgenyevna Tereshko,** Candidate of Chemical Sciences, Associate Professor
[1]OOO 'EcoCentre', Yaroslavl, Russia
[2]Yaroslavl State Technical University, Yaroslavl, Russia, *lyapisnuska@yandex.ru*

Keywords:
pigment, iron oxide, waste, pigment properties

Abstract. *To produce paints and varnish coatings, there is an opportunity to use a waste of metallurgical production of Yakovlevsky mining and processing complex, Cherepovets, Russia. This waste contains iron oxide as iron oxide pigment. It could be used as an analogue to iron oxide pigment already existing on the market. The authors studied the pigment properties of the waste and the opportunity of using it as a raw material for the synthesis of red iron oxide pigment. The article gives recommendations on the use of the obtained product and shows the opportunity of its application for paint and varnish coatings.*

For citation:
Kolosova A. N., Kudryavtsev Y. V., Tereshko A. E. Production of iron oxide pigments using metallurgical wastes, *From Chemistry Towards Technology Step-By-Step*, Vol. 5(3), pp. 104-110 [online]. Available at: https://chemintech.ru/ru/nauka/issue/5357/view

Introduction

Nowadays, mining-and-processing and metallurgical plants produce a large amount of waste containing iron. Such enterprises face the acute problem of their waste utilisation. One way to recycle iron-containing wastes is to produce iron oxide pigments [1]. They have good pigment properties, such as covering and oil capacity, light, and weather resistance.

Due to the shortage of metallic iron, it became necessary to search for alternative ways of obtaining raw materials for iron oxide pigments production. Waste of metallurgical production containing iron oxide as a source of raw materials can be recommended for pigments production. Many papers are interested in obtaining and developing of technological process for iron oxide pigment production of [2-17].

Therefore, the search of simple technological method of obtaining iron oxide pigments from industrial waste is very relevant one.

Objects of the research

To obtain iron-oxide pigments, we used red-coloured iron ore, a waste containing iron oxide, produced by the Yakovlevskiy mining and processing complex (Yakovlevsky GOK), Cherepovets, Russia as a raw material. We used red iron oxide pigment (TU2322-166-05011907-98) as a sample for comparison of pigment properties.

The authors investigated the elemental composition of iron-bearing ore by X-ray fluorescence analysis (see Table 1). Table 1 shows that the iron ore contains a fair amount of iron, which is most likely in oxide form. Consequently, such ore can be used to produce iron oxide pigments.

Table 1. The elemental composition of iron ore

Composition of elements, wt. %			
Fe	Al	P	V
41.376	0.022	0.156	0.022

Study results

We investigated the pigment properties of the ore and assessed its dispersibility to determine ore using as a pigment. Table 2 presents the results of ore pigment properties studies.

Table 2. Studies on the properties of red-coloured iron ore

Indicator	Value
Particle size, μm	2.0
Iron content, %	75.55
Oil capacity, g/100g	10.3
Coverage, g/m^2	55.5
Water-soluble salt content, %	1.30
pH of the aqueous suspension	7.46
Colouring capacity, %	0.06
Colour characteristics (colour coordinates in the CIEL*a*b* system)	L*=14.60 a*=21.28 b*=46.88

Indeed, red coloured iron ore has a very good oil capacity value. It can provide a high critical volume concentration of pigment in a composite material or coating. The covering values correspond to iron oxide pigments of low-quality level. The water-soluble salt content and pH of the iron ore aqueous extract meet the requirements for pigments. However, the water-soluble salt content should be reduced by washing. Moreover, colouring power is very low – 0.06 %. The unsatisfactory value of colouring power for (Yakovlevsky GOK), Cherepovets, Russia ore is due to both insufficient dispersibility and lower purity of tone. According to defined colour coordinates, its iron oxide ore does not meet the colour requirements of red iron oxide pigment.

Fig. 1 shows a micrograph of an iron ore. Microscopy results show the presence of white flecks. They can severely limit the use of this product as a pigment, as such impurities are most often due to the presence of difficult-to-disperse quartz.

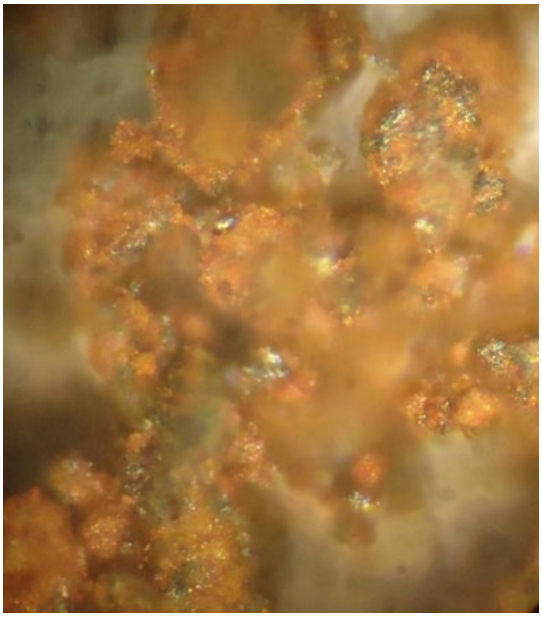

Fig. 1. Microphotograph of Yakovlevsky GOK), Cherepovets, Russia iron ore (reflected polarised light, coaxial illumination, magnification 800x).

Therefore, due to low intensity and unsatisfactory pigment properties, iron-oxide ore of Yakovlevsky GOK), Cherepovets, Russia production cannot be used for iron-oxide pigments production.

One way to utilise iron oxide waste is to obtain it by processing a product containing an iron oxide pigment with transparent properties. The most common method of obtaining iron oxide pigments is the calcination of iron-containing raw materials. Therefore, we investigated the possibility of obtaining products with pigment properties by calcination of ore samples.

We synthesised pigments of iron ore of red colour by calcination in a muffle furnace at temperatures 300-1000 °C. Table 3 shows the temperature dependence of calcination products properties. Full colour and split colour plots of the synthesis products are shown on Figures 2-7.

Table 3. Studies of pigment properties of synthesis products

Indicator	300 °C	400 °C	500 °C	600 °C	800 °C	1000 °C
Average particle size, μm	2.9	3.80	2.8	4.40	4.1	7.1
Most probable particle size, μm	1.47	1.88	1.38	2.20	2.04	3.54
Iron content, %	59.83	66.11	33.0	64.35	36.0	25.0
Oil capacity, g/100g	51	16.5	12	11.5	12	11
Coverage, g/m^2	15.66	23.33	30	26.07	30	28
Water-soluble salt content, %	0.017	2.5	2.4	2.35	2.08	2.56
pH of the aqueous suspension	7.50	6.89	6.85	6.728	6.92	7.23
Colour characteristics (colour coordinates in the CIEL*a*b* system)	L*=34.07 a*=13.08 b*=6.98 c=14.83 H=61.91^0	L*=30.56 a*=10.31 b*=6.40 c=12.13 H=58.17^0	L*=29.48 a*=10.81 b*= 5.37 c=12.07 H= 63.58^0	L*=31.42 a*=10.54 b*=7.05 c=12.68 H=56.22^0	L*=32.33 a*= 14.79 b*=6.44 c= 15.86 H=66.47^0	L*=27.2 a*=11.27 b*=4.12 c=11.99 H=69.92^0
Colouring capacity, %	20	76	72	68	56	24

The synthesis products have more saturated red and brown colours and good intensity as can be seen in Figs. 2-7 and in Table 3.

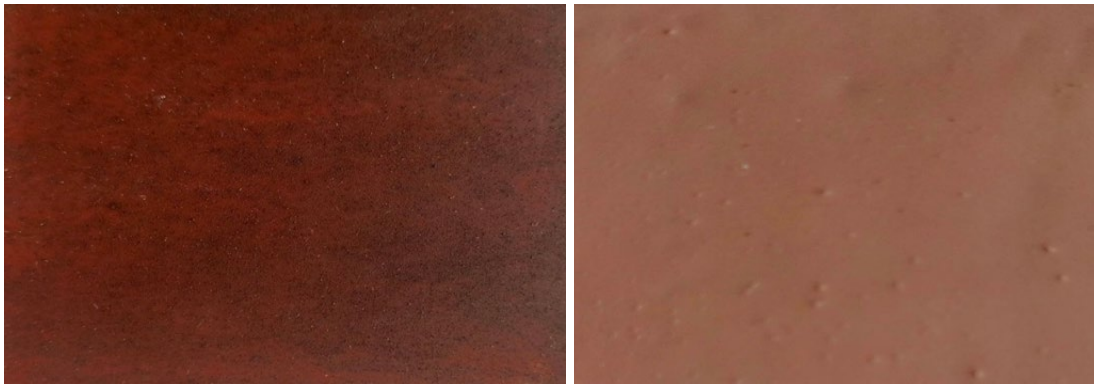

Fig. 2. Paintings of the synthesis product at 300 °C in full colour (left) and in brightening (right).

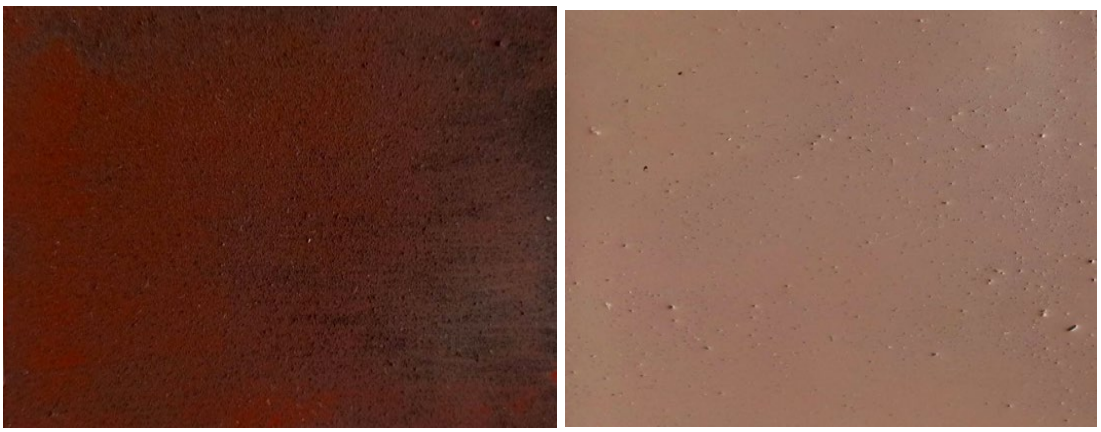

Fig. 3. Paintings of the synthesis product at 400 °C in full colour (left) and in brightening (right).

Fig. 4. Paintings of the synthesis product at 500 °C in full colour (left) and in brightening (right).

Fig. 5. Paintings of the synthesis product at 600 °C in full colour (left) and in brightening (right).

Fig. 6. Paintings of the synthesis product at 800 °C in full colour (left) and in brightening (right).

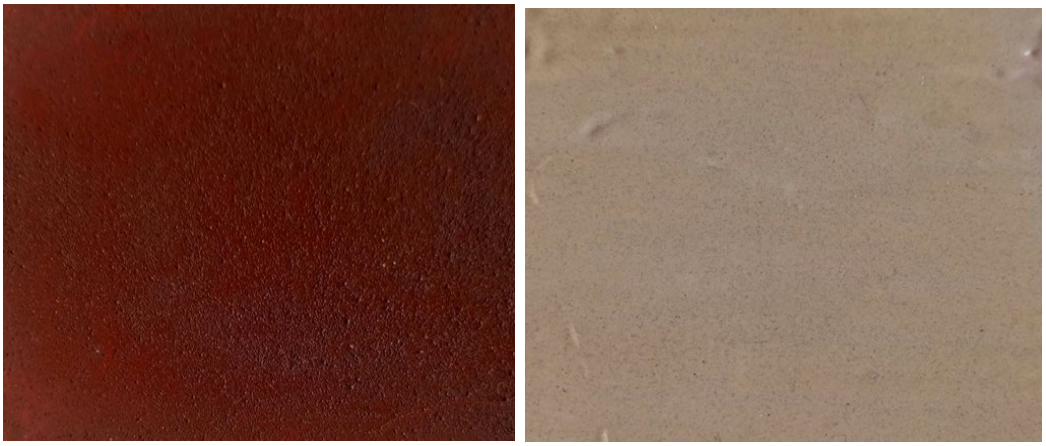

Fig. 7. Paintings of the synthesis product at 1000 °C in full colour (left) and in brightening (right).

Products treated at temperature 300-1000 °C have similar pigment characteristics. They have a lower covering power and higher oil content at the maximum calcination temperature compared to the sample without calcination. This can be explained by the larger particle size. The sample obtained at 400 °C is the closest to the standard and LRC without calcination. Indeed, calcination can increase pigments colouring and covering power and reduce their oil content. The product obtained by calcination at 400 °C shows better pigment properties. Increasing the calcination temperature above 600 °C is not effective; the products obtained at a higher temperature do not improve their pigment properties.

Conclusion

The research has shown the opportunity of using iron-containing waste containing metallurgical waste as a raw material for the synthesis of iron oxide pigments by calcination.

We have studied the properties of ore calcination products at different temperatures. According to the study, the obtained pigments have good colouring ability and pigment covering, low oil content. The best pigment properties are obtained by calcination at 400 °C. Further increase of calcination temperature is not effective and does not cause the improvement of pigment properties.

The iron oxide pigments obtained during the studies can be recommended for approbation as pigments for colouring cement, paving tiles, paint and varnish materials, colouring paper, etc.

References

1. **Ermilov, P. I.** Pigmenty i pigmentirovannye lakokrasochnye materialy : [uchebnoe posobie dlya vuzov po special'nosti «Himicheskaya tekhnologiya lakov, krasok i lakokrasochnyh pokrytij»] [Pigments and pigmented paint and varnish materials : [textbook for universities in the speciality 'Chemical technology of varnishes, paints and paint and varnish coatings'] / P.I. Ermilov, E.A. Indeikin, I.A. Tolmachev. - Leningrad : Khimiya [Chemistry] : Leningrad department, 1987. - 198 p. (In Russian).
2. **Guixiang, P., Jinhua, L., Hui, S., Feng, C., Zenglin, Z., Jianmin, Z., Minhong X., Yuhua G.** (2017) Synthesis method of zinc phosphate-coated heat-resistant iron oxide yellow pigment, 107011702 CN.
3. **Shuilong, Z.** (2020) Preparation method of iron oxide red-bentonite composite pigment with high covering power. 111909542 CN.
4. **Jinhua, L. Zenglin, Z. Hui, S., Yajuan, N.** (2015) Method for preparing high-purity gamma-Fe_2O_3 iron oxide red pigment. 105110382 CN.
5. **Czaplik, W., Kiszkiewitz, J., Spiegelhauer, S.** (2018) Red iron oxide pigments with improved color parameters, 2701032 RU (in Russian).
6. **Dobrovolsky, I. P., Kapkaev, Y. Sh., Barkhatov, V. I., Kostyunin, S. V., Kostyunina, I. L., Abyzov, V. A.** (2017) Method for obtaining magnesium sulfate and iron oxide pigments using industrial waste 2634017 RU.
7. **Larin, V. K., Bikbaev, L. Sh., Bibik, E.** (2018) Method for obtaining iron oxide pigments, 2656047 RU (in Russian).
8. **Chichvarin, A. V., Smirnov, V. P., Kantarchan, M. V.** (2019) Method of obtaining mineral iron-containing pigments and fillers 2683100. (in Russian).
9. **Czaplik,V., Ketteler, G., Kiszkiewitz, J.** (2019) Preparation of red iron oxide pigment. 2697459 RU (in Russian).
10. **Kapkaev Yu. Sh., Dobrovolsky I. P., Barkhatov V. I., Golovachev I. V.** (2021) Method for obtaining iron- and manganese-containing pigments produced by industrial waste. 2756464 RU (in Russian).
11. **Lukashevich O. D., Usova N. T., Kutugin V. A., Toporkov N. E.** (2012) Installation for obtaining iron oxide pigment using sludge of water treatment station. 114683 RU (in Russian).
12. **Bashlykova T. V., Ashirbaeva E. A.** (2017) Method of deep utilisation of iron-containing waste. 2623928 RU (in Russian).
13. **Kudryavtsev, Y. V., Kolosova, A. N., Tereshko, A. E.** Poluchenie zhelezooksidnyh pigmentov iz othodov metallurgicheskogo proizvodstva [Obtaining iron oxide pigments of waste metallurgical production] // Sem'desyat chetvertaya vserossijskaya nauchno-tekhnicheskaya konferenciya studentov, magistrantov i aspirantov vysshih uchebnyh zavedenij s mezhdunarodnym uchastiem : sbornik materialov konferencii [Seventy-fourth All-Russian Scientific and Technical Conference of students, undergraduates and graduate students of higher educational institutions with international participation : conference proceedings], Yaroslavl, 21 April 2021. Vol. 74. Part 1. - Yaroslavl: Yaroslavl State Technical University, 2021. - Pp. 181-182 (in Russian).
14. **Kolosova, A. N., Tereshko, A. E.** Novye vidy syr'ya dlya sinteza zhelezooksidnyh pigmentov [New types of raw materials for the synthesis of iron oxide pigments] // Sem'desyat pyataya vserossijskaya nauchno-tekhnicheskaya konferenciya studentov, magistrantov i aspirantov s mezhdunarodnym uchastiem : Sbornik materialov konferencii [Seventy-fifth All-Russian Scientific and Technical Conference of students, undergraduates and postgraduates with international participation : Proceedings of the conference]. In 3 parts, Yaroslavl, 20-21 April 2022. Vol. 75. - Yaroslavl: Yaroslavl State Technical University, 2022. - Pp. 180-182 (in Russian).
15. **Kolosova, A. N., Kudryavtsev, Ya. V., Tereshko, A. E.** Pokrytie na osnove krasnogo zhelezooksidnogo pigmenta, sintezirovannogo iz othodov metallurgicheskogo proizvodstva [Coating based on red iron oxide pigment synthesised using metallurgical waste] // Sem'desyat shestaya Vserossijskaya nauchno-tekhnicheskaya konferenciya studentov, magistrantov i aspirantov s mezhdunarodnym uchastiem : Sbornik materialov konferencii [Seventy-sixth All-Russian Scientific and Technical Conference of students, undergraduates and postgraduates with international participation : Proceedings of the conference]. In 3 parts, Yaroslavl, 19-20 April 2023. Vol. 76. - Yaroslavl: Yaroslavl State Technical University, 2023. - Pp. 183-185 (in Russian).
16. **Kolosova, A. N., Tereshko, A. E.** Poluchenie zhelezoooksidnyh pigmentov prokalochnym sposobom iz othodov metallurgicheskoj promyshlennosti [Preparation of iron oxide pigments by rolling method using

metallurgical industry wastes]. // Sem'desyat sed'maya nauchno-tekhnicheskaya konferenciya studentov, magistrov i aspirantov s mezhdunarodnym uchastiem : Sbornik materialov konferencii [Seventy-seventh scientific and technical conference of students, masters and postgraduates with international participation : Proceedings of the conference]. In 3 parts, Yaroslavl, 17-18 April 2024, Vol. 77. - Yaroslavl: Izd-vo YSTU, 2024. - Pp. 231-233 (in Russian).

17. **Kudryavtsev, Y. V., Kolosova, A. N., Tereshko, A. E.** Ispol'zovanie zhelezosoderzhashchshchih othodov metallurgicheskih proizvodstv dlya polucheniya zhelezooksidnyh pigmentov [Use of iron-containing wastes of metallurgical industries for the production of iron oxide pigments] // Problemy nauki. Himiya, himicheskaya tekhnologiya i ekologiya : Sbornik materialov Vserossijskoj nauchno-tekhnicheskoj konferencii [Problems of Science. Chemistry, Chemical Technology and Ecology : Proceedings of the All-Russian Scientific and Technical Conference], Novomoskovsk, 31 October - 02 November 2022. - Tula: Aquarius, 2022. - Pp. 285-289 (in Russian).

Received 28.05.2024
Approved 19.06.2024
Accepted 02.07.2024