

IRON OXIDE PIGMENTS

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Natural iron oxides are derived from hematite, which is a red iron oxide mineral; limonites, which vary from yellow to brown, such as ochers, siennas, and umbers; and magnetite, which is black iron oxide. Synthetic iron oxide pigments are produced from basic chemicals. The three major methods for the manufacture of synthetic iron oxides are thermal decomposition of iron salts or iron compounds, precipitation of iron salts usually accompanied by oxidation, and reduction of organic compounds by iron (Podolsky and Keller, 1994, p. 765, 772).

Production

U.S. output of finished natural (mined) iron oxide pigments (IOPs) sold by processors in 2001 was 69,900 metric tons (t), 20% less than in 2000; this category accounted for 52% of the tonnage and 17% of the value of total IOP output. Finished synthetic IOPs were 64,700 t, a decrease of 2% from the revised tonnage in 2000, and accounted for 48% of the tonnage and 82% of the value of total IOP output. Total finished natural and synthetic IOPs were 135,000 t, 12% less than the revised output for 2000 (table 2).

Production data for crude IOPs sold or used were developed from a voluntary survey. Of five known companies, data were obtained from three. By tonnage, the three companies represented 76% of the output. In a second voluntary survey, data were received from 9 of 13 known operations that produced finished IOPs, for a response rate of 69%. By tonnage, the nine operations represented 80% of the output.

Data were obtained from two of three producers of regenerated iron oxide, which is obtained when spent pickle liquor from steelmaking is treated (table 3). A major end use for this material was ferrites, which are magnetic ceramic oxides. Two types of ferrites are soft ferrites, which do not retain permanent magnetism, and hard ferrites, which retain permanent magnetism (Govila, 1991). Hard ferrites are used in loudspeakers, motors, generators, and flexible magnets. Regenerator iron oxide data are not included in tables 1, 2, and 4.

Iron Oxide Recovery, Inc., of Pittsburgh, PA, which was formed in 2001, delivered 500 t of semifinished goethite to a U.S. pigment producer. The material was obtained from passively precipitated iron sludge from an abandoned coal mine in Pennsylvania. Drainage containing dissolved iron often results from coal and metal mining. Passive treatment of the drainage from the Pennsylvania mine with bicarbonate as a neutralizing agent produced a sludge containing 80% to 95% goethite (Hedin, 2002).

Consumption

The largest end-use categories for total U.S. IOP output (natural and synthetic) in 2001 continued to be construction,

with 35%, and coatings, with 20% (table 4).

In brick coloring, the main ingredients in a brick body that determine the color of the product are iron compounds including hematite, limonite, and pyrite. The iron oxide content of red brick ranges between 4% to 8%. However, the use of iron oxide in the brick body is more expensive than it is in surface coatings on bricks. Approximately 75% of the 9 billion bricks in 2001 was made with some sort of surface coating. Engobes are one type of surface coating and consist of a mixture of clays, fluxes, and nonplastics. Engobes could be described as a ceramic paint that is applied to a ceramic body in the green state prior to drying and firing (Newman, 2002).

Another method for coloring brick results from firing in a reducing atmosphere in a kiln. The typical red color can be changed to gold, brown, and black depending on the degree of reduction (Newman, 2002).

Mach I, Inc., of King of Prussia, PA, was producing a very fine particle size form of high-purity ferric oxide. The company has also produced magnetic iron oxide by reducing its ferric oxide. The material is referred to as nano iron oxide and has a particle size of 3 nanometers. End uses include as a catalyst in solid rocket propellants, as a catalyst in automobile air bag restraint systems, and in cosmetics for color and ultraviolet absorbance. The cost of nano iron oxide was currently [2001] higher than for other commercial forms of iron oxide (Kosowski, 2002).

According to an industry source, markets for regenerated iron oxide included magnetic applications, paints, brick and ceramic tile, and construction markets. Emerging markets could include use in iron oxide dispersions, environmental remediation, building materials and construction applications, chemical process applications, and hard and soft ferrite magnets (Will, James, 2002).

Prices

Yearend 2001 IOP published prices, meant to serve as a general guideline only, converted to dollars per kilogram, in bags, per truckload, free on board (f.o.b.) warehouse, were black, synthetic, \$2.07; yellow, synthetic, \$2.25 to \$2.34; and buff, natural, domestic, including dark and light, ranging from \$1.16 to \$2.14 (Chemical Market Reporter, 2001). The average annual producer price index (PPI) for IOPs for 2001 was 167.4 compared with 174.9 in 2000. The PPI measures the average change over time in the selling prices received by domestic producers of IOPs. The base year for the IOP PPI is June 1983 (U.S. Bureau of Labor Statistics, 2002¹).

¹References that include a section twist (§) are found in the Internet References Cited section.

Foreign Trade

U.S. exports of pigment grade IOPs in 2001 were 9,100 t, 6% less than in 2000 (table 5). The largest recipients were Mexico (25%), Japan (20%), Russia (14%), and the Republic of Korea (13%).

In 2001, U.S. imports of natural IOPs were 5,280 t (tables 6, 7). The 596 t of micaceous iron oxide from the Netherlands appears to be misclassified because of its relatively low value of \$0.41 per kilogram. Imports of synthetic IOPs were 84,700 t, about the same as in 2000. The largest amounts of material were supplied by China (61%), Germany (19%), and Brazil and India (4% each). The total value of synthetic IOP imports was \$74.4 million, which was an increase of 2% compared with imports in 2000.

Total U.S. imports of IOPs (natural and synthetic) were 89,900 t, 2% less than in 2000. The total value of the imports was \$76.9 million, about the same as in 2000 (tables 6, 7).

World Review

According to SRI Consulting, world production of natural and synthetic IOPs in 2000 was 912,000 t. The largest sources were Western Europe with 42%, Japan 25%, and China 12%. Another reference source put Chinese output much higher at 354,000 t, in 2001 (Gao, 2002).

Total world consumption of IOPs in 2000 was put at 50% in construction materials, 28% in coatings, 6% in plastic, rubber, paper, glass, and ceramics, and 16% in other, according to SRI. Consumption was 363,000 t in the European Union; 311,000 t in North America; 49,000 t in Japan; and 190,000 t in the rest of the world (Will, Raymond, 2002).

Current Research and Technology

PEL Technologies LLC, headquartered in Canton, OH, completed construction and preliminary trials of its demonstration-scale plant for producing engineered iron oxides such as magnetite, magnesium ferrite, manganese ferrite, and nickel ferrite. Actual production was to begin in January 2002. The process uses a source of iron, such as mill scale. Applications include pigments, abrasives, reprographic substrates, ferrite raw materials, and other uses (Srivastava, 2002).

A process was described that uses biotechnology to make transparent yellow and red IOPs. An initial raw material is iron waste or iron filings containing 40% to 100% elementary iron. *Thiobacillus ferrooxidans* bacteria are used to convert ferrous sulfate into ferric sulfate. The pigment that is obtained is alpha-goethite that contains spherical particles instead of traditional needle or prismatic particles. Calcining the yellow pigment produces red transparent IOPs (Boiko, 2002).

Outlook

Construction materials continued to be the largest market for IOPs. Concrete block was said to be the leading application for both natural and synthetic IOPs, according to SRI. Other construction applications are roofing tiles and paving stones (Brown, 2001).

The paint and coatings market, the second largest end use of

IOPs, decreased by 1% in volume in 2001 compared with that of 2000 (U.S. Census Bureau, 2002§). Architectural paint sales, which represent about 50% of the coatings in the United States, decreased by 4% from those of 2000. The other major segment of the U.S. coatings market—product coatings or original equipment manufacture (OEM)—made up 39% of the market in 2001; this category showed an 8% increase compared with that of 2000, according to U.S. Census Bureau data. OEM and corresponding use of IOPs depend on the cyclical nature of manufactured products, such as automobiles, home appliances, wood and metal furniture, and machinery and equipment (Sauer, 2001).

Consolidation, emerging markets, and technological advances are engines for growth in coatings, according to a nongovernment source. Mergers and acquisitions have been the standard path to increasing market share in the coatings industry. For example, the merger of Dow Chemical Co. and Union Carbide Corp. in early 2001 was said to have enhanced Dow's position as a raw materials supplier to the coatings industry (Sauer, 2001).

Global market share of the coatings industry is approximately 25% in each of Asia, North America, and Western Europe, according to another nongovernment source. Asia may hold a higher market potential compared with other more mature geographic market areas (Sauer, 2001).

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TABLE 1
SALIENT U.S. IRON OXIDE PIGMENTS STATISTICS 1/

(Metric tons, unless otherwise noted)

	1997	1998	1999	2000	2001
Crude pigments sold or used 2/					
Quantity	46,900	46,100	44,100	57,100	61,500
Value thousands	\$7,580	\$7,290	\$7,740	\$4,470	\$3,460
Finished pigments sold 3/					
Quantity	176,000	180,000	183,000	154,000 r/	135,000
Value thousands	\$193,000	\$193,000	\$187,000	\$142,000 r/	\$130,000
Exports					
Quantity	16,600	14,600	13,800	9,640	9,100
Value thousands	\$20,600	\$18,200	\$15,200	\$17,200	\$16,800
Imports for consumption					
Quantity	66,700 r/	63,800 r/	80,800 r/	91,300	89,900
Value thousands	\$75,400	\$62,900 r/	\$71,400 r/	\$76,700	\$76,900

r/ Revised.

1/ Data are rounded to no more than three significant digits.

2/ Mined.

3/ Natural (mined) and synthetic.

TABLE 2
FINISHED IRON OXIDE PIGMENTS SOLD BY PROCESSORS IN THE UNITED STATES, BY KIND 1/

Kind	2000		2001	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Natural:				
Black, magnetite	19,400	\$3,190	16,000	\$2,630
Umbers:				
Burnt	2,100	2,880	2,010	3,180
Raw	W	W	W	W
Red, iron oxide 2/	52,700	10,600	38,900	8,020
Undistributed and other 3/	13,600	8,550	13,000	8,680
Total	87,800	25,200	69,900	22,500
Synthetic:				
Black, iron oxide	18,200 r/	29,600 r/	18,500	36,800 4/
Brown, iron oxide 5/	7,400 r/	13,500 r/	5,420	(6/)
Red, iron oxide 7/	40,700 r/	73,600 r/	40,700	70,400
Yellow, iron oxide	(8/)	(8/)	(8/)	(8/)
Mixtures of natural and synthetic iron oxides	(9/)	(9/)	(9/)	(9/)
Total	66,300 r/	117,000 r/	64,700	107,000
Grand total	154,000 r/	142,000 r/	135,000	130,000

r/ Revised. W Withheld to avoid disclosing company proprietary data; included with "Undistributed and other."

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

2/ Includes pyrite cinder.

3/ Includes raw umber, burnt sienna, ochre, and raw sienna.

4/ Includes synthetic brown iron oxide and mixtures of natural and synthetic iron oxides.

5/ Includes mixtures of natural and synthetic iron oxides.

6/ Included with "Black, iron oxide" to avoid disclosing company proprietary data.

7/ Includes synthetic yellow iron oxide.

8/ Included with "Red, iron oxide" to avoid disclosing company proprietary data.

9/ Included with "Brown, iron oxide" to avoid disclosing company proprietary data.

TABLE 3
PRODUCERS OF IRON OXIDE PIGMENTS AND REGENERATOR IRON OXIDES
IN THE UNITED STATES IN 2001

Producers	Plant location
Finished pigments:	
Alabama Pigments Co.	Green Pond, AL.
Bayer Corp.	New Martinsville, WV.
Dynamic Color Solutions, Inc.	Milwaukee, WI.
Elementis Pigments Inc.	East St. Louis, IL; Easton, PA.
Hoover Color Corp.	Hiwassee, VA.
New Riverside Ochre Co., Inc.	Cartersville, GA.
Pea Ridge Iron Ore Co.	Sullivan, MO.
Prince Manufacturing Co., Inc.	Quincy, IL; Bowmanstown, PA.
Rockwood Pigments Inc.	Beltsville, MD; St. Louis, MO.
Solomon Grind-Chem Services Inc.	Springfield, IL.
Crude pigments:	
Alabama Pigments Co.	Green Pond, AL.
Cleveland-Cliffs Iron Co., Mather mine and Pioneer plant (closed July 31, 1979; shipping from stockpile)	Negaunee, MI.
Hoover Color Corp.	Hiwassee, VA.
New Riverside Ochre Co., Inc.	Cartersville, GA.
Pea Ridge Iron Ore Co.	Sullivan, MO.
Regenerator iron oxides:	
Bailey-PVS Oxides, L.L.C.	Decatur, AL; Fairfield, AL; Delta, OH.
International Steel Services, Inc.	Allenport, PA.
Weirton Steel Corp.	Weirton, WV.

TABLE 4
ESTIMATED IRON OXIDE PIGMENT CONSUMPTION, BY END USE, AS A PERCENTAGE OF REPORTED SHIPMENTS

End use	All iron oxides		Natural iron oxides		Synthetic iron oxides	
	2000	2001	2000	2001	2000	2001
Coatings (industrial finishes and trade sales coatings: lacquers, paints, varnishes)	19 r/	20	12	12	28 r/	29
Construction materials (cement, mortar, preformed concrete, roofing granules)	33 r/	35	23	22	W	W
Colorants for ceramics, glass, paper, plastics, rubber, textiles	10	9	W	W	10	8
Foundry sands	W	W	W	W	--	--
Industrial chemicals (such as catalysts)	8	7	W	W	W	W
Other 1/	26 r/	29	65	66	62 r/	63
Total	100	100	100	100	100	100

r/ Revised. W Withheld to avoid disclosing company proprietary data; included with "Other." -- Zero.

1/ Includes animal feed, cosmetics, ferrites, fertilizers, magnetic ink and toner, polishing agents and data indicated by the symbol W.

TABLE 5
U.S. EXPORTS OF IRON OXIDES AND HYDROXIDES, BY COUNTRY 1/

Country	2000				2001			
	Pigment grade		Other grade		Pigment grade		Other grade	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Argentina	4	\$14	79	\$21	3	\$7	74	\$31
Australia	153	301	305	732	107	247	322	586
Belgium	5	29	33	128	83	237	567	2,170
Brazil	48	28	255	465	36	85	415	423
Canada	38	42	10,600	12,100	75	61	11,200	12,000
China	84	156	452	143	261	422	2,440	716
Colombia	51	205	89	103	73	334	86	70
France	9	29	210	679	11	37	85	230
Germany	1,450	1,920	2,280	4,510	280	369	1,930	4,270
Hong Kong	529	288	1,310	3,290	172	345	1,970	3,850
India	281	382	491	622	405	536	724	615
Indonesia	15	32	219	291	1	11	27	45
Italy	--	--	909	808	16	57	1,450	1,860
Japan	2,160	3,860	3,610	7,160	1,800	3,120	3,740	5,480
Korea, Republic of	467	727	1,210	3,480	1,190	1,880	3,380	3,320
Malaysia	--	--	338	1,060	--	--	146	436
Mexico	2,100	2,060	2,560	2,340	2,280	2,230	1,170	1,410
Netherlands	--	--	792	1,290	18	25	1,000	1,800
Russia	508	755	16	44	1,270	3,580	--	--
Singapore	38	224	160	294	--	--	365	223
South Africa	1	3	3	5	--	--	--	--
Taiwan	204	1,070	1,340	1,320	171	362	2,300	1,590
Thailand	127	121	292	266	114	74	130	204
Turkey	3	16	--	--	2	17	18	26
United Kingdom	1,150	4,520	2,800	4,620	289	1,280	3,360	5,940
Venezuela	3	13	105	35	67	63	102	26
Other	221	421	435	758	372	1,360	1,050	1,690
Total	9,640	17,200	30,900	46,500	9,100	16,800	38,100	49,000

-- Zero.

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

TABLE 6
U.S. IMPORTS FOR CONSUMPTION OF SELECTED IRON OXIDE PIGMENTS, BY TYPE 1/

Type	2000		2001		Principal sources, 2001 (metric tons)
	Quantity (metric tons)	Value 2/ (thousands)	Quantity (metric tons)	Value 2/ (thousands)	
Natural:					
Earth colors 3/	5,120	\$2,240	4,200	\$1,910	Cyprus, 2,830; Spain, 680; Germany, 353; India, 105; South Africa, 101; Canada, 53; Italy, 33; Sweden, 20; China, 16; Taiwan, 5; United Kingdom 4; Japan (4/).
Micaceous	2,220	1,170	1,080	599	Netherlands, 596; Austria, 206; France, 135; Australia, 61; Belgium, 20; Morocco, 20; Spain, 18; United Kingdom, 12; Japan, 6; Singapore, 1.
Total	7,340	3,410	5,280	2,510	
Synthetic:					
Black	16,000	22,500	17,000	25,900	Germany, 5,780; China, 5,290; India, 3,300; Japan, 1,350; Mexico, 533; Italy, 246; Hong Kong, 198; Canada, 177; Thailand, 60; Netherlands, 57; South Africa, 25; Republic of Korea, 9; United Kingdom, 8.
Red	36,300	25,500	33,900	22,400	China, 25,000; Germany, 5,450; Italy, 580; Hong Kong, 494; Mexico, 478; Canada, 324; Sweden, 324; India, 290; United Kingdom, 242; Spain, 227; Japan, 128; Brazil, 120; Colombia, 65; Czech Republic, 94; Belgium, 27; France, 13; Netherlands, 3.
Yellow	30,000	22,600	31,500	23,100	China, 20,400; Germany, 4,660; Brazil, 2,970; Mexico, 1,130; Italy, 765; Hong Kong, 701; Spain, 243; United Kingdom, 129; Canada, 128; Republic of Korea, 126; Colombia, 77; Hungary, 51; Belgium, 43; France, 13; India, 10; Japan, 24.
Other 5/	1,780	2,630	2,270	2,980	China, 700; Japan, 574; Germany, 517; Cyprus, 237; Canada, 73; Italy, 60; Hong Kong, 57; Colombia, 31; Mexico, 20; Spain, 3; France, 1.
Total	84,000	73,300	84,700	74,400	
Grand total	91,300	76,700	89,900	76,900	

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

2/ Customs value.

3/ Includes those earth colors not elsewhere specified or included.

4/ Less than 1/2 unit.

5/ Includes synthetic brown oxides, transparent oxides, and magnetic and precursor oxides.

Source: U.S. Census Bureau.

TABLE 7
U.S. IMPORTS FOR CONSUMPTION OF IRON OXIDE AND IRON HYDROXIDE PIGMENTS, BY COUNTRY 1/

Country	Natural				Synthetic			
	2000		2001		2000		2001	
	Quantity (metric tons)	Value 2/ (thousands)	Quantity (metric tons)	Value 2/ (thousands)	Quantity (metric tons)	Value 2/ (thousands)	Quantity (metric tons)	Value 2/ (thousands)
Austria	151	\$146	206	\$195	--	--	--	--
Belgium	718	303	20	6	86	\$396	70	\$425
Brazil	--	--	--	--	3,020	2,890	3,090	2,920
Canada	--	--	53	44	2,210	1,750	702	925
China	80	36	16	5	48,000	25,500	51,400	26,600
Colombia	--	--	--	--	172	228	174	262
Cyprus	3,850	1,510	2,830	1,160	--	--	237	82
France	91	73	135	75	51	516	38	357
Germany	345	474	353	378	16,100	18,700	16,400	18,200
Hong Kong	--	--	--	--	1,850	1,320	1,450	997
India	125	29	105	28	4,520	3,180	3,600	2,530
Italy	2	12	33	32	1,680	2,030	1,650	2,020
Japan	(3/)	3	6	14	1,190	11,200	2,080	13,800
Mexico	20	3	--	--	2,790	2,470	2,180	1,950
Netherlands	913	407	596	244	938	346	60	29
Spain	781	180	698	161	476	304	474	385
Sweden	--	--	20	9	72	22	324	97
United Kingdom	3	22	16	35	509	2,160	379	2,270
Other	265	217	188	130	247	252	365	481
Total	7,340	3,410	5,280	2,510	84,000	73,300	84,700	74,400

-- Zero.

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

2/ Customs value.

3/ Less than 1/2 unit.

Source: U.S. Census Bureau.

TABLE 8
ESTIMATED WORLD PRODUCTION OF NATURAL IRON OXIDE PIGMENTS, BY COUNTRY 1/ 2/

(Metric tons)

Country 3/	1997	1998	1999	2000	2001
Austria	7,500	7,000	6,000 r/	6,000 r/	5,000
Brazil	2,000 r/	2,000 r/	2,000 r/	2,000 r/	2,000
Chile	10,678 4/	10,449 4/	9,992 r/ 4/	10,000 r/	10,000
Cyprus (umber)	7,120 4/	6,056 4/	9,169 4/	12,258 4/	12,000
France	2,200 r/	2,000 r/	1,500 r/	1,500 r/	1,000
Germany 5/	4,176 4/	4,000	4,000	4,000	4,000
India (ocher)	347,429 4/	351,704 4/	360,000	365,000	370,000
Iran	10,000	13,300	13,300	13,500	13,500
Italy	500	500	500	500	500
Pakistan (ocher)	2,600	3,180 4/	3,200	4,747 r/ 4/	4,800
Paraguay (ocher)	300	300	300	300	300
South Africa	1,397 r/ 4/	1,352 r/ 4/	216 4/	568 r/ 4/	852 4/
Spain:					
Ocher	8,000 r/	7,000	7,000	7,000	7,000
Red iron oxide	15,000	15,000	15,000	15,000	15,000
United States	46,900 4/	46,100 4/	44,100 4/	57,100 4/	61,500 4/

r/ Revised.

1/ Estimated data are rounded to no more than three significant digits.

2/ Table includes data available through June 4, 2002.

3/ In addition to the countries listed, a number of others undoubtedly produce iron oxide pigments, but output is not reported and no basis is available for formulating estimates of output levels. Such countries include, but are not limited to, Azerbaijan, China, Kazakhstan, Russia, and Ukraine. Unreported output is probably substantial.

4/ Reported figure.

5/ Includes Vandyke brown.