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(Part- II : Metals & Alloys)

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PLATINUM AND PALLADIUM

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GOVERNMENT OF INDIA
MINISTRY OF MINES
INDIAN BUREAU OF MINES

Indira Bhavan, Civil Lines,
NAGPUR – 440 001

PHONE/FAX NO. (0712) 2565471
PBX : (0712) 2562649, 2560544, 2560648
E-MAIL :cme@ibm.gov.in
Website: www.ibm.gov.in

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13 Platinum and Palladium

Platinum Group of Metals (PGM) is a family comprised of 6 metals - platinum, palladium, rhodium, iridium, osmium and ruthenium. They have similar physical and chemical properties and tend to occur together in the same mineral deposits. These six elements are classified into two groups with reference to the specific gravity of gold (19.2). The elements, Ru, Rh, Pd (sp. gr. 12- 12.4) are lighter, while the other three elements, Os, Ir and Pt are heavier than gold with sp. gr. in the range of 21.0-21.5. Platinum is an extremely rare metal occurring at a concentration of only 0.005 ppm in earth's crust. Major applications of platinum and palladium are in automotive sector for emission control and in chemical and petroleum refining.

RESERVES/RESOURCES

Reserves/Resources of PGM in the country as on 1.4.2015 as per NMI Database, based on UNFC System are placed at 15.71 tonnes of metal content. Reserves/ Resources are grouped under remaining resources category. By state, Odisha alone accounts for 90% of country's reserves/resources of PGE followed by Karnataka (10%) & negligible amount by Uttar Pradesh (Table-1).

Boula - Nausahi, a 3 km - long belt, 170 km NE of Bhubaneswar, Odisha is the only proven Platinum Group of Metals (PGM) deposit in the country. Preliminary assessment of PGMs in Sukinda ultramafic field indicated isolated anomalous values in chromite. Platinum values of 2 to 400 ppb and palladium values of 1 to 500 ppb were established on analysis. The limonite cappings over ultramafic rocks showed combined platinum and palladium values between 40 and 290 ppb. In Boula-Nuasahi ultramafic complex, the easternmost chromite band known as Shankar-Ganga load, investigations revealed potential PGM mineralisation. In Sittampudi Complex, Salem district, Tamil Nadu, analysis of chromite bands showed 0.03 to 0.75 ppm Pt and 0.1 to 1.0 ppm Pd, whereas amphibolite samples showed 0.03 to 0.05 ppm Pt and 0.03 to 0.5 ppm Pd. A platinum-rich chromite-ferro-chromite breccia zone stretching to about hundred metres in gabbroic matrix was identified in the southern extension of the already known Boula-Nuasahi area in Kendujhar district, Odisha. In Usgaon area, Southern Goa, PGM samples analysed up to 0.03 ppm Pt and 0.03 to 0.15 ppm Pd. In recent past, occurrences of PGE mineralisation were reported in mafic-ultramafic complex of Shivamogga schist belt in Davanagere district of Karnataka. Three zones having 10 to 830 ppb of platinum and 50 to 1500 ppb of palladium were established.

The major part of 15.7 tonnes of metal content UNFC reserves/resources of PGM estimated so far about 14.2 tonnes of metal content of PGM are located in Niligiri, Boula-Nuasahi and Sukinda areas in Odisha and remaining 1.5 tonnes of metal content of PGM in Hanumalpura area in Shivamogga schist belt of Karnataka. About 49% resources are under Indicated category and the remaining under Inferred and Reconnaissance categories. The reserves/resources of PGM in Uttar Pradesh reported here as first time in NMI as on 1.4.2015 are furnished in Table-1.

EXPLORATION & DEVELOPMENT

The exploration and development details, if any, are given in the review on Exploration & Development in "General Reviews"

USES

China and India are moving forward with large scale plans to reduce the amount of carbon emission in their respective countries. Currently, more than half of platinum and palladium mineral goes into making catalytic converters in automobiles. Automobiles that run on diesel predominantly use platinum for catalytic conversion. Platinum-cured silicones are used to coat and protect automotive air bags from their explosive system. The air bags contain an initiator senser, which uses a fine platinum wire coated with explosive material to facilitate release of the air bag. The chemical inertness and refractory properties of these metals are conducive for their applications in electrical, electronics, dental, medical fields and glass industry. These metals are also used as catalyst in various chemical processes, viz, in organic synthesis in hydrogenation, de-hydrogenation and isomerisation, production of nitric acid, the raw material for the manufacture of fertilizers, explosives & polymers and fabrication of laboratory equipment.

In addition, platinum, palladium and a variety of complex gold-silver-copper alloys are used as dental restorative materials. The non-corrosive and non-allergic properties of platinum find varied applications in the medical field. Platinum's excellent compatibility with living tissue unaffected by the oxidising reaction of blood, enables its utility in pacemakers.

Table – 1: Reserves/Resources of PGM as on 1.4.2015

(In tonnes of metal content)

State	Reserves Total (A)	Remaining resources				Total Resources
		Indicated STD 332	Inferred STD 333	Reconnaissance STD 334	Total (B)	Total (A+B)
India	**-**	**7.71**	**6.5**	**1.5**	**15.71**	**15.71**
Karnataka	-	-	-	1.5	1.5	1.5
Odisha	-	7.7	6.5	-	14.2	14.2
Uttar Pradesh	-	0.01	-	-	0.01	0.01

The primary usage of PGM is in chemotherapy for treatment of cancer. It has the ability to prevent division of certain living cells, a remarkable characteristic which finds profound application in treatment of cancer. Besides, platinum-iridium alloys are extensively used in prosthetics and biomedical devices.

Platinum's excellent conductivity lends itself for use in the electrodes of phosphoric acid fuel cells for generating electricity. Another significant use of platinum and its alloys, in cast or wrought form is in jewellery. Platinum-iridium alloys find major application in making crucibles for growing crystals. Glass made with platinum and rhodium is used in housing construction, flat screen televisions, computer monitors, display panels, automobile displays, factory monitoring equipment, etc. Recently, a new metallic glass featuring micro-alloys of palladium with silicon, germanium, silver, etc. was reportedly developed at University of California. The glass is characterised by strength and toughness. Platinum is used to enhance storage capacity of devices, such as computer hard discs, cell phones, digital cameras and personal music players. Recently, palladium-silver resistors have been used in secondary lightning surge protection devices. In Electronic Industry, palladium's use is for Multi-Layer Ceramic Capacitors (MLCC). The effect of miniaturisation of MLCC has not reduced the quantum of palladium used as more number of MLCC are required for the same electronic device. Platinum based fuel cells are proving to be more cost effective, cleaner and more reliable than alternatives such as diesel generators.

Rhodium usage is also on the rise in the Automotive Industry apart from fibre glass. Platinum is the catalyst used by fuel cells to convert hydrogen and oxygen to electricity.

Palladium is also likely to play a role in fuel cells. Platinum acts as an effective and durable catalyst in hydrogen-powered Fuel Cell Electric Vehicles (FCEVs).

SUBSTITUTES

Platinum and palladium are two of the most expensive metals on the planet. Platinum is currently about 30% more expensive than gold while palladium is about half the cost of gold. It is usually easier to substitute metals of the platinum group for one another, especially in alloys, than to use alternative materials, which is evident from the total dominance of ruthenium-based resistors over the palladium-silver resistors for high-powered applications. Substitutes in electrical use include tungsten, nickel, silver, gold and silicon carbide. Alternative catalysts include nickel, molybdenum, tungsten, chromium, cobalt, vanadium, silver and rare earths. Rhenium, however, has been used most satisfactorily as substitute for platinum as a catalyst in petroleum refining. Stainless steel and ceramics can be substituted where resistance to corrosion is the primary concern. Some motor vehicle manufacturers have substituted platinum by palladium in catalytic converters, especially for petrol engines. Particulate matter and residual sulphur contaminate palladium and hence, it was excluded from catalysts used in diesel vehicles. A new technology now allows up to 25% substitution of platinum in diesel catalytic converters with palladium.

Similarly, manufacturers of electronic parts are also reducing the average palladium content of the conductive pastes used to form the electrodes of multi-layer ceramic capacitors, substituting base metals or silver-palladium pastes which contain significantly less palladium.

Rhenium, tungsten and molybdenum as substitute for platinum in aeromatics hydrogenation catalysts have been investigated. Recently, a new type of iron and carbon-based catalysts has been discovered which is stable and active in both acidic and alkaline media and may even eliminate the need of platinum in catalysts and thus revolutionise the Proton Exchange Membrane Fuel Cell (PEFC) Industry.

TECHNICAL POSSIBILITIES

The spent converters contain platinum and palladium in 3:1 ratio, but heavy shift towards use of palladium to meet stringent emission controls will change this proportion of recovery.

The emergence of Polymer Electrolytic Membrane (PEM) fuel cells developed for passenger cars and trucks will boost prospects of platinum in near future by replacing the high energy battery-operated options for emission controls. The costs of higher range of driving and quick refuelling of fuel cells are, however, 10 times more than the cost of petrol engine.

The development of Solid Oxide Fuel Cell (SOFC) in Japan will eliminate the use of platinum converter as it is compact and gives consistent performance as conversion of conventional fuels into hydrogen is avoided.

Recycling, a significant factor in the supply of many of the metals used in our society. It plays an important role in lowering the environmental foot print of global PGM production. Over 95% of the PGM content of spent automotive catalysts can be repeatedly recovered. Cell phones are one of the major sources of secondary metals. Falconbridge Ltd estimated that in 1 tonne of obsolete cell phones (excluding batteries) the average palladium and platinum was about 130 g and 8 g respectively.

RESEARCH & DEVELOPMENT

The mineral processing department of the Institute of Minerals & Material Technology (IMMT), Bhubaneswar (CSIR) had envisaged projects to pursue research focused on recovery of PGE values from the low tenor hosts like Boula-Nuasahi igneous complex by adopting suitable beneficiation tests and development of process flow sheet for recovery of PGE from Indian ores. The methods adopted elsewhere in the world perhaps may not suit in India because the PGE occurs in oxide of chromium and sulphide facies in very fine inclusions & exsolution form.

Bench scale beneficiation of low grade PGM samples from T2 sector, Tasampalayam block in Sitampundi Anorthosite complex in Tamil Nadu for GSI was carried out at the Modern Mineral Processing Laboratory and Pilot Plant, IBM with the objective of enriching platinum group metal present in the sample and to envolve a suitable process flow sheet for recovery of PGM concentrate and chromite. The study indicates that the samples are amenable to beneficiation to produce a platinum group of minerals.

WORLD REVIEW

The world reserves of PGM are estimated at 69,000 tonnes concentrated mostly in South Africa (91%) followed by Russia (6%), Zimbabwe (2%) and USA (1%) (Table - 2).

In 2017, world mine production of PGMs decreased slightly by 3% to 446 tonnes of metal content from 462 tonnes of metal content in the preceding year (Table-3). South Africa, which accounted for 58% of the total PGM mine production in 2017 followed by Russia (23%), Zimbabwe (7%), Canada (6%), USA (4%) and other countries 1%. In 2017, world platinum mine production decreased by only 1% to 181.71 tonnes of metal content as against 188.35 tonnes of metal content in the preceding year. South Africa which accounted for 71% of world platinum production total at 131 tonnes of metal content, about 4% decreased from that in 2016. Global mine production of palladium in 2017 decreased by 3% to 205.89 tonnes of metal content. Russia accounting for 41% followed by South Africa (37%),Canada (9%), USA & Zimbabwe (6% each). World mine production of other PGMs (iridium, osmium, rhodium and rethenium) increased by 2% in 2017 as compared to that of 2016. South Africa, which accounted for 83% of global production, accounted for most of the increase of other PGMs, Zimbabwe (5%), was the second leading producer.

To give a generalised view of the development in various countries the country-wise description as sourced from the latest available publication of Minerals Yearbook 'USGS' 2016 is furnished below:

Canada

North American Palladium Ltd produced 4,650 kg of palladium and 318 kg of platinum from its Lac des Isles Mine in Ontario registered a decrease of 10% and 17%, respectively as compared to that of the production in 2015. The decreases were a result of unfavourable ground conditions as the mine transitioned to be sublevel shrinkage mining method.

Russia

PJSC MMC Norilsk Nickel produced 79,400 kg of palladium and 19,300 kg of platinum in 2016, slightly less in case of platinum and essentially unchanged for palladium from the production of 2015.

Zimbabwe

Production of both palladium and platinum increased by 19% in 2016 as compared to 2015. Zimplats Holdings Ltd. continued to redevelop the Bimha Mine following its collapse in 2014. Full production was on schedule and expected to take place in April 2018. Zimplats was also finalizing plans to develop a new shaft to replace production from the oldest mines, with first production expected in 2021.

South Africa

Production of Palladium and Platinum decreased by 8% and 4% respectively in 2016 as compared to 2015. The world leading PGM producer, Anglo American Platinum Ltd reported primary equivalent refined platinum production from its mining operations of 52,500 kg in 2016, an 8% decrease compared with that in 2015.

Table – 2 : World Reserves of PGMs (By Principal Countries)

(In tonnes of metal content)

Country	Reserves
World: Total (*rounded off*)	**69000**
Canada	310
Russia	3900
South Africa	63000
USA	900
Zimbabwe	1200

Source: *Mineral Commodity Summaries, 2019 USGS.*

Table – 3 : World Mine Production of PGMs (By Principal Countries)

(In tonnes of metal content)

Country	2015	2016	2017
World:Total	**457**	**462**	**446**
Botswana			
Platinum	0.03	-	-
Palladium	0.16	-	-
Canada[e]			
Platinum	11.90	11.30	9.80
Palladium	20.80	19.70	17.10
Other platinum metals	1.40	1.30	1.10
China			
Platinum	2.3	2.3	2.3
Palladium	1.2	1.2	1.2
Russia			
Platinum [a]	20.80	22.50	20.20
Palladium[a]	75.50	86.30	82.50
Other platinum metals[a]	2.50	2.60	2.0
South Africa			
Platinum	139.12	133.24	131.25
Palladium	82.69	76.27	80.13
Other platinum metals	53.70	54.14	48.89
USA			
Platinum	3.67	3.90	3.90
Palladium	12.50	13.10	13.00
Zimbabwe			
Platinum	12.56	15.11	14.26
Palladium	10.6	12.22	11.82
Other platinum metals	2.61	3.09	3.00
Other countries (Platinum Group Metals)	2.96	3.73	3.55

Source: *World Mineral Production, 2013-2017, BGS.*
(a) Sales from mine production and stocks

FOREIGN TRADE

Exports

Exports of platinum alloys and related metals jumped drastically by about 112% to 758 kg valued at ` 126.18 crore in 2017-18 from 344 kg valued at ` 40.40 crore in the previous year. Exports were mainly to UK (72%), Germany (15%) and Mexico (6%). Exports in 2017-18 comprised of platinum unwrought at 576 kg & platinum others at 67 kg. During 2017-18 export of other metals of platinum group was 115 kg as compared to 6 kg during the preceding year. During 2017-18 export of platinum-clad base/precious metal was at 13 kg as compared to 5 kg in the previous year. Exports were mainly to Italy (77%), Israel, Mauritius and New Zealand (8% each) (Tables- 4 to 9).

Imports

Imports of platinum alloys and related metal during 2017-18 increased by 17% to 12,099 kg valued at ` 2,271 crore as compared to 7,072 kg valued at ` 1,258 crore in the previous year. Imports in 2017-18 comprised of platinum (powder, unwrought & others) 6,808 kg, platinum (others) 1,496 kg and other metals of platinum group 3,795 kg. Imports of other metals of platinum group were mainly from UK (23%), South Africa (22%), Russia (21%), Germany (15%) and Switzerland (8%), USA (6%) and Japan (5%). During 2017-18 imports of platinum-clad (rolled etc) were at 25 kg as compared to 21 kg in the previous year. Exports were mainly to Germany (76%) and USA (16%) (Tables- 10 to 17).

Table – 4: Exports of Platinum Alloys & Related Metals: Total (By Countries)

Country	2016-17		2017-18	
	Qty (t)	Value (``'000)	Qty (t)	Value (``'000)
All Countries	**344**	**404007**	**758**	**1261759**
UK	133	94647	545	927156
Germany	1	39	112	230479
Singapore	2	149	27	59637
USA	22	25332	14	18983
Mexico	-	-	44	15580
Italy	121	189797	5	8097
UAE	-	-	3	593
Bulgaria	-	-	1	555
Iran	2	2536	1	318
Israel	2	956	1	281
Other countries	61	90551	5	80

Table – 5 : Exports of Platinum (Unwrought) (By Countries)

Country	2016-17		2017-18	
	Qty (kg)	Value (`'000)	Qty (kg)	Value (`'000)
All Countries	**61**	**14185**	**576**	**988411**
UK	52	8307	543	926997
Singapore	1	99	26	59620
Bulgaria	-	-	1	555
USA	2	4354	1	388
Iran	-	-	1	318
Israel	2	956	1	281
UAE	-	-	1	248
Hong Kong	-	-	1	3
Peru	-	-	1	1
Saudi Arabia	2	384	-	-
Other countries	2	85	-	-

Table – 6 : Exports of Platinum (Others) (By Countries)

Country	2016-17		2017-18	
	Qty (kg)	Value (`'000)	Qty (kg)	Value (`'000)
All Countries	**275**	**384725**	**67**	**42774**
USA	16	18467	12	18579
Mexico	-	-	44	15580
Italy	121	189797	5	8097
UAE	-	-	2	345
UK	81	86340	1	155
Kenya	1	26	1	12
Egypt	-	-	1	6
Germany	-	-	1	-
Japan	56	90095	-	-

Table – 7 : Exports of Platinum (Powder) (By Countries)

Country	2016-17		2017-18	
	Qty (kg)	Value (`'000)	Qty (kg)	Value (`'000)
All Countries	**2**	**50**	-	-
Singapore	1	50	-	-
Sri Lanka	1	-	-	-

Table –8 : Exports of Other Metals of Platinum Group (By Countries)

Country	2016-17		2017-18	
	Qty (kg)	Value (`'000)	Qty (kg)	Value (`'000)
All Countries	**6**	**5047**	**115**	**230574**
Germany	-	-	111	230479
Ethiopia	-	-	1	58
Singapore	-	-	1	17
USA	4	2511	1	16
UK	-	-	1	4
Iran	2	2536	-	-

Table – 9 : Exports of Platinum-Clad Base/Precious Metal (By Countries)

Country	2016-17		2017-18	
	Qty (kg)	Value (`'000)	Qty (kg)	Value (`'000)
All Countries	**5**	**414**	**13**	**681**
Italy	-	-	10	403
Israel	-	-	1	149
Mauritius	2	250	1	72
New Zealand	-	-	1	57
Gabon	1	77	-	-
UK	1	54	-	-
Sierra Leone	1	33	-	-

Table – 10 : Imports of Platinum Alloys and Related Metals (By Countries)

Country	2016-17		2017-18	
	Qty (t)	Value (`'000)	Qty (t)	Value (`'000)
All Countries	**7072**	**12581542**	**12099**	**22710833**
South Africa	3404	6476272	3597	7009793
UK	1056	1876023	2511	4999893
Germany	458	856949	1453	3117556
Russia	204	367732	1231	2305588
Belgium	236	536766	540	1095610
USA	792	1173298	708	1025125
Italy	210	221480	497	701358
Singapore	1	693	351	693702
Switzerland	441	766437	304	535506
Japan	107	187519	195	311893
Other countries	163	118373	712	914809

Table – 11 : Imports of Platinum (Powder, Unwrought & Others) (By Countries)

Country	2016-17		2017-18	
	Qty (kg)	Value (`'000)	Qty (kg)	Value (`'000)
All Countries	**3861**	**8411508**	**6808**	**5362454**
South Africa	2262	4940334	2649	5362454
UK	335	788192	1218	2409591
Germany	242	532131	707	1416952
Belgium	235	535493	540	1095610
Russia	91	210072	389	763104
Singapore	-	-	321	628991
USA	379	728731	317	625034
Italy	60	127159	243	463945
Norway	-	-	135	256777
Unspecified	-	-	112	229178
Other countries	257	549396	177	91226

Table – 12: Imports of Other Metals of Platinum Group (By Countries)

Country	2016-17		2017-18	
	Qty (kg)	Value (`'000)	Qty (kg)	Value (`'000)
All Countries	**2293**	**3165536**	**3795**	**7040352**
UK	433	623213	862	1782969
Russia	113	157660	786	1435645
South Africa	989	1303958	830	1432128
Germany	199	322327	570	1289388
Switzerland	276	413327	300	531271
Japan	57	79914	180	281362
USA	223	264152	219	199673
Italy	-	-	18	46721
Norway	-	-	20	40091
China	1	103	8	991
Other countries	2	882	2	113

Table – 13: Imports of Platinum (Others) (By Countries)

Country	2016-17		2017-18	
	Qty (kg)	Value (`'000)	Qty (kg)	Value (`'000)
All Countries	**918**	**1004498**	**1496**	**2327619**
UK	288	464618	431	807333
Germany	17	2491	176	411216
South Africa	153	231980	118	215211
USA	190	180415	172	200418
Italy	150	94321	236	190692
Tunisia	-	-	73	141709
Iran	-	-	72	139473
Russia	-	-	56	106839
Singapore	1	693	30	64711
Spain	51	25040	42	27481
Other countries	68	4940	90	22536

Table – 14 : Imports of Platinum-Clad (Rolled etc.) (By Countries)

Country	2016-17		2017-18	
	Qty (kg)	Value (`'000)	Qty (kg)	Value (`'000)
All Countries	**21**	**15916**	**25**	**5375**
UK	-	-	1	2735
USA	3	6352	4	2343
Italy	1	717	1	214
Germany	16	8734	19	83
Russia	1	113	-	-

Table – 15 : Imports of Platinum -Unwrought (By Countries)

Country	2016-17		2017-18	
	Qty (kg)	Value (`'000)	Qty (kg)	Value (`'000)
All Countries	**3499**	**7623724**	**5890**	**11488485**
South Africa	2127	4646568	2173	4396191
UK	316	744889	1214	2402521
Belgium	235	535493	540	1095610
Russia	91	210072	389	763104
Germany	55	128343	315	630417
Singapore	-	-	321	628991
USA	358	681804	303	594111
Italy	60	127159	212	400735
Norway	-	-	135	256777
Unspecified	-	-	112	229178
Other countries	257	549396	176	90850

Table – 16: Imports of Platinum-Powder (By Countries)

Country	2016-17		2017-18	
	Qty (kg)	Value (`'000)	Qty (kg)	Value (`'000)
All Countries	**362**	**787784**	**918**	**1854377**
South Africa	135	293766	476	966263
Germany	187	403788	392	786535
Italy	-	-	31	63210
USA	21	46927	14	30923
UK	19	43303	4	7070
Australia	-	-	1	376

Table – 17 : Imports of Platinum-Clad Base/Precious Metal (By Countries)

Country	2016-17		2017-18	
	Qty (kg)	Value (`'000)	Qty (kg)	Value (`'000)
All Countries	**21**	**15916**	**25**	**5375**
U K	-	-	1	2735
USA	3	6352	4	2343
Italy	1	717	1	214
Germany	16	8734	19	83
Russia	1	113	-	-

FUTURE OUTLOOK

India is meeting its demand entirely by imports. The demand for PGEs is expected to touch 120 tonnes by 2025, as per the Report of the Sub-group for 12th Plan period.

As per PGM Market Report, May, 2018 of "Johnson Matthey Platinum Group Metals Service" there has been a decline in demand in 2017 due to sharp falls in Japanese investment buying and Chinese jewellery fabrications. Indian platinum jewellery demand may likely to expand following successful industry marketing campaining to promote the purchase of platinum jewellery sets as a wedding gift.