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Materials Engineering

The Indian Institute of Metals


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(A Government of India Enterprise)
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VIZAG STEEL
Pride of Steel
Azadi Ka Amrit Mahotsav
आत्मनिर्भर भारत में
सहयोगी आर आई एन एल - वाइजाग स्टील
वाइजाग टी एम टी रीबार
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मजबूती
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बचत
अब आर आई एन एल - वाइजाग स्टील का
गुणवत्तापूर्ण उत्पाद
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C O N T E N T S

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THE INDIAN INSTITUTE OF METALS

Indigenous Technologies for Tungsten Metal Powder Production

Ch RVS Nagesh, T K Nandy, V V Satya Prasad and G Madhusudhan Reddy

Abstract

Tungsten metal is of special importance to defence sector. Different types of ammunition systems like anti tank penetrators are manufactured using tungsten based heavy alloys. The country's requirement of tungsten has been largely met by imports. It has been found essential to develop indigenous tungsten metal production technologies to avoid import dependency. This paper brings out details of various initiatives taken up by DMRL towards resource identification and efforts put in over the years for development of indigenous technologies for production of high purity tungsten metal both from primary and secondary resources.

Introduction

Tungsten metal is characterized by a unique set of properties such as very high melting point (3422C), very high density (19.3 g/cm^3), superior hardness, thermal & chemical stability, excellent electrical conductivity, very high radiation resistance etc. and is considered environmental friendly material. Industrial applications of tungsten metal include cemented carbide machine tools (drill bits, wear parts, cutting tools etc. in the manufacturing industry), automotive, oil & mineral exploration/mining, construction sector etc. Thin tungsten mill products are widely used in filaments, electrical & electronic applications and the like. Tungsten is also used in many steel additions, super alloys, medical equipment, inert electrodes in welding & arc melting furnaces, in different types of compounds for various chemical applications and so on.

Resources of tungsten consists of mainly the two important minerals of scheelite (calcium tungstate, $CaWO_4$) and wolframite (FeMn WO_4, a compound of oxides of iron, tungsten and manganese). Small quantities of tungsten minerals are found as associated minerals in the ores of cooper, nickel, tin, gold, manganese, molybdenum etc. The latest reports, suggest that the world resources of tungsten minerals are estimated to be around 3.7Mt [1]. Tungsten minerals are largely located in China, Austria, Bolivia, Russia, Rwanda, Portugal, Canada, USA and a few other countries. China alone accounts about 65% of the world mineral resources. There is a wide variety of industrial scraps/sludges that are generated in various manufacturing industries and chemical industries which are considered as secondary resources for production of tungsten and tungsten-based compounds. Various types of tungsten intermediates/commodities are widely marketed across the industry circles for various end applications (Table-1). Value of these materials are assessed based on W or WO_3 content. World consumption of tungsten is generally expressed in terms of WO_3 content and for the last 5 years the same is placed around 80-100 thousand tonnes[2].

Tungsten mineral resources in the country (DMRL-NMDC study)

Tungsten mineral resources are geographically widespread though the tenor (metal content of ore) of the ores is very less. Richest tungsten mineral in the world usually possesses not more than 1.0-1.1 wt% WO_3. In India, small pockets of tungsten mineral reserves are found in the states of Rajasthan, Maharashtra, AP, Karnataka, West Bengal etc. It is estimated that the country possesses about 1,42,094 Mt of tungsten in the

Defence Metallurgical Research Laboratory, Hyderabad

Table-1 : Different tungsten based compounds/materials				
S.No.	Compound/ material	Chemical formula/ trade name	W/WO_3 content (wt%)	Major applications
1.	Tungsten concentrate/pre-concentrate	impure WO_3	40-65% Pre-concentrates contain 1-10% WO_3	Raw material for production of tungsten and tungsten based compounds
2.	Tungsten scraps	–	40-90% W	Raw material for production of tungsten and tungsten based compounds
3.	Ammonium paratungstate	$(NH_4)10 [H_2W_{12}O_{42}] 4H_2O$	73%WO_3	Used for production of different tungsten based products like tungsten , WC, WO_3 etc.
4.	Tungsten trioxide	WO_3	>99%WO_3	Raw material for production tungsten metal, WC etc. and also used as catalysis reagent
5.	Yellow tungsten oxide, tungsten blue oxide	Sub-stiochiometric tungsten oxides, WO_{3-x}	About 99% WO_3	Used for production of tungsten metal, WC and also used in pigments, oil and water colours, chemical industries etc.
6.	Tungstic acid	$H_2WO_4.nH_2O$	>80% WO_3	Used for preparation of ultrafine tungsten and tungsten carbide powders, with highly active surface properties used in various chemical industries
7.	Tungsten carbide	WC	>90%W	Used for tool bits for cutting/ machining, various machine parts, drill bits, wear resistant tool applications in manufacturing industries, used for manufacture of cemented carbides
8.	Ferro-tungsten	Fe-W	(75-85% W)	Steel and other metallurgical additions

form of WO_3. [3]. Tailings dumps generated in the processing of gold ores at Kolar Gold Fields (which is not operational sincer 2000) and Hutti Gold Mines are also considered resources of tungsten as they contain 0.02-0.2 wt% WO_3.

In an attempt to assess the quality/quantity of the indigenous mineral resources of tungsten, DMRL, in collaboration with National Mineral Development Corporation (NMDC), Hyderabad, has carried out intensive study on tungsten mineral resources in the country so as to evolve methodologies for accomplishing indigenous mining. The study involved collection of available exploration data with the state geological departments and that available in the public domain and other reports. Based on the study of the data an expert opinion is obtained for identifying potential regions of tungsten mining. The findings of the study are compiled in a comprehensive report. Excerpts of the report [4] include the following:

i. The deposits in the country with significant resources of tungsten minerals include Degana and Balda deposits in Rajasthan; Bankura deposits in West Bengal; Tapasakonda & Burugubanda deposits in AP; Khuhi-Kobna deposits in Maharashtra These deposits are worth for further exploration/deep and wider sampling for establishing as viable deposits.

ii. However, the existing exploration information is not adequate to establish techno-economic feasibility of mining of the deposits in the country. More exploration involving large scale sampling and analysis is essential for assessing quantum of resources and feasibility. Also data on associated minerals which help improving economics of mining is inadequate.

iii. More explorations by GSI and other agencies are continuing in Rajasthan, Maharasthra, Karnataka, Bengal, Tamil Nadu, Jharkhand for locating tungsten mineral resources.

iv. Tailings dumps Kolar Gold Fields, Karnataka which are currently under the custody of MECL, Nagpur are considered potential tungsten resource as the material reportedly contain 0.18-0.20 wt% WO_3.

v. The tailings material that is generated in the gold ore processing at M/s Hutti Gold Mines, Karnataka also contains small quantities of WO_3.

Tungsten Extraction Metallurgy – Developments in India

Extraction metallurgy of tungsten is very cumbersome and highly complicated owing to very low WO_3 content in the ores and very high melting point of the metal. Historical developments in tungsten metal extraction from primary mineral resources of scheelite and wolframite are well compiled and is available in the literature [5]. Various types of techniques/ processes attempted for tungsten metal extraction mainly comprise (a) treatment of ore by processes such as alkali pressure leaching to recover tungsten metal values and discard the gangue material, (b) preparation of either tugnstic acid or ammonium paratungstate (APT) to further process the same for production of high purity WO_3 and (c) reduction of WO_3 by hydrogen, carbon etc. Thus the standardized practice of tungsten metal production has the principal process steps of (i) preparation of WO_3 enriched concentrate/pre-concentrate from minerals, (ii) preparation of APT through alkali roasting of the mineral concentrate, leaching to prepare sodium tungstate solution, solvent extraction to remove non-tungsten metallic species and precipitation by ammonia to produce APT, (iii) calcination of APT to produce high purity WO_3 and (iv) high temperature (800-950 ^{0}C) hydrogen reduction to produce W metal powder. Extensive and elaborate mineral beneficiation techniques are required to produce a mineral concentrate with enriched WO_3 content so as produce the metal powder economically. Recycling of various tungsten metal scraps has been relatively simple and a large number of industries use in-house developed techniques to process the scraps for preparation of tungsten metal powder. The process of scrap recycling generally include sorting/cleaning, high temperature oxidation/chemical processes to prepare either APT or tungstic acid which will be calcined to prepare high purity WO_3 from which the metal can be prepared by high temperature hydrogen reduction as already mentioned.

While tungsten metal extraction from the minerals is limited to a few countries, recycling of W based hard metal scraps are widely implemented in several counties for producing high purity tungsten metal powder. Globally 40-50% of tungsten metal powder supplies come from recycling of various types of tungsten scraps. The scrap recycling technologies are in practice from the last many decades. Individual companies develop their own processing technologies that suits the selected scraps.

In India, R& D on mineral beneficiation of tungsten minerals/ tailings from Kolar Gold Fields and Hutti Gold Mines to prepare enriched WO_3 concentrate/pre-concentrate, preparation of APT and tungsten metal extraction has been pursued decades back by several research organizations in the country; these include BARC, NML, AMD, IBM,TRDDC, NMDC, GSI, DMRL, MECL, IMMT etc. DMRL/DRDO also taken up initiatives for

(i) tungsten mining at Degana deposits, Rajasthan processing of wolframite to prepare enriched WO_3 concentrate was carried out in collaboration with NML

(ii) pilot scale studies on preparation of APT from wolframite concentrate and W metal powder production by hydrogen reduction of high purity WO_3.

A comprehensive summary of these indigenous efforts is well compiled and available in the literature [6]. These efforts however, could not be collated to realize sustainable technology due to dumping of cheaper tungsten commodities including W/WC powder from China. Over the years, country's tungsten metal powder requirement has been met through imports.

Subsequently however, a few private firms started scrap recycling plants of lower capacities with bought out technologies. Later NML developed innovative process technologies [7] for WC scrap recycling to prepare high purity W metal powder, the technology has been transferred to two small scale industries which are involved in producing high purity WO_3 and marketing. During 2008-2011, there was a severe shortage of tungsten supplies in the international market owing to changed Chinese policies. Since then uncertainty prevail over meeting the tungsten requirement for defence needs.

DMRL & CSIR labs Collaboration on Development of Process Technologies for Tungsten Metal Extraction & Scrap Recycling

Tungsten metal powder is required for defence applications such as manufacture of tungsten based heavy alloy anti tank penetrators, different types of pre-fragments, ballasts etc. High Energy Projectile Factory (HEPF), Trichy formerly known as HAPP (Heavy Alloy Penetrator Project) has been making these defence items with the technology developed by DMRL, since early '90s. The designed plant capacity requires over 300 Mt of high purity W metal powder though the actual requirement has been varying over the years. It is expected that 100 Mtpa may be consistently required in the next few years, which is subsequently expected to be much higher. Difficulty experienced by HEPF in sourcing W metal powder, especially since the crisis period of 2008-2010, prompted DMRL to work on indigenization of the complete tungsten supply chain.

DMRL took up the task of indigenous technology development for tungsten metal powder production with a view to work towards realizing indigenous tungsten metal production plant. Raw materials availability, flexibility of process flow sheets, energy & cost effectiveness, environmental friendliness, indigenous availability of necessary equipment & materials are the key factors in the technology development programme. HEPF has been accumulating heavy alloy scrap every year and has been looking for technological support for conversion of the scrap to high purity tungsten metal. M/s Hutti Gold Mines, Karnataka have been keen on recovery of valuable metals from the huge tailings material that is generated in the processing of gold ores. However, the tailings material is a very lean resource of tungsten metal as it constitutes of only 0.02 wt% as oxide. Ammonium paratungstate (APT) is a rich source of tungsten and can serve as the raw material for simple & quick conversion to tungsten metal.

In collaboration with two CSIR laboratories, viz. NML, Jamshedpur and IMMT, Bhubaneshwar DMRL developed the process technologies (Fig.1) for production of tungsten metal powder from the three different sources of (i) heavy alloy scrap (that is generated at HEPF), (ii) Hutti Gold Mines tailings material which is generated @ about 1,00,000 tpa and APT available in the market. The following is a brief description of the process technologies that are developed:

(i) Processing of heavy alloy scrap to produce high purity tungsten metal includes high temperature oxidation of cleaned scrap to convert all metals into metal oxides and selective leaching of tungsten oxide and filtration to prepare high purity yellow tungsten oxide which will be converted to high purity tungsten metal by high temperature hydrogen reduction

(ii) Preparation of tungsten metal from APT mainly involves two process steps of calcination at about 450C to prepare high purity WO_3 followed by high temperature (950C) hydrogen reduction of the oxide.

(iii) Processing of tailings material is very complex and involves elaborate physical beneficiation techniques like gravity separation (Falcon), magnetic separation and column flotation to prepare a pre-concentrate of 1-2 wt% WO_3. The pre-concentrate is subjected to hot alkaline pressure leaching to convert

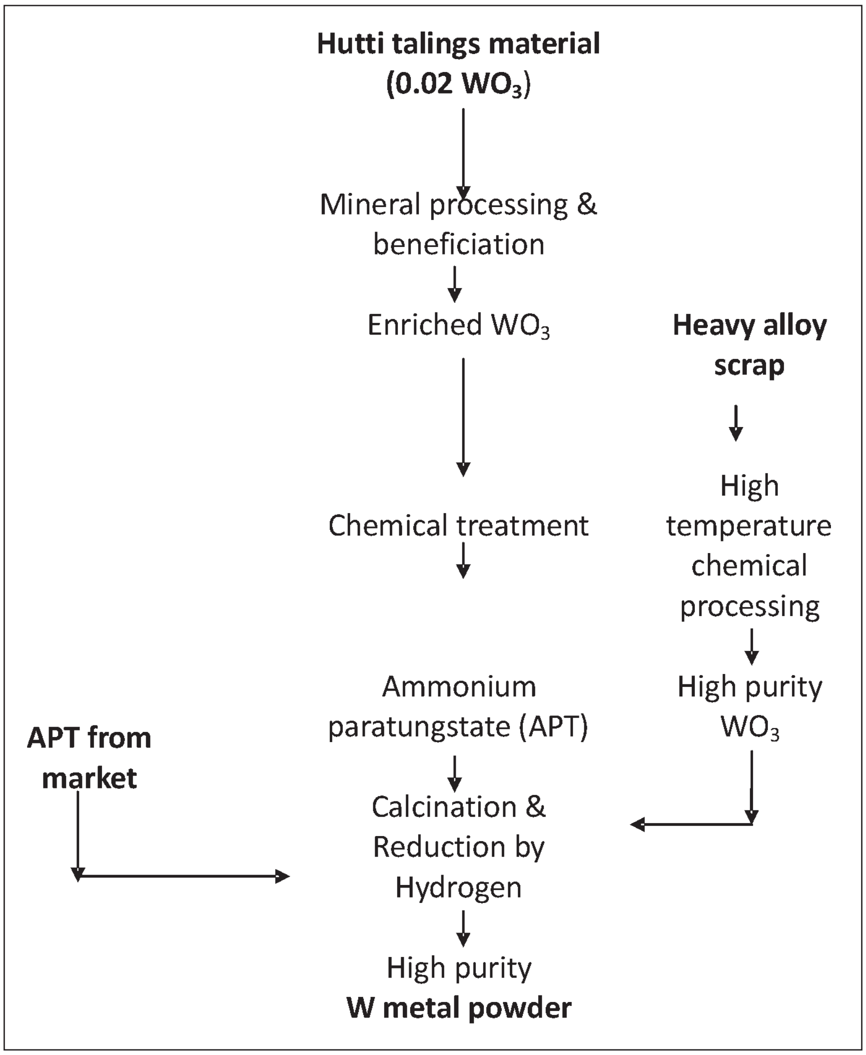


Fig.1 : DMRL –CSIR Process flow sheets for tungsten metal extraction and recycling

W values into sodium tungstate solution which is subjected to solvent extraction and stripping with ammonia followed by evaporation & crystallization to prepare high purity APT crystalline powder. Tungsten metal powder production from APT is as described above.

The process technologies were tested on a pilot scale to generate important process engineering data which will be useful for setting up for a commercial plant. The R & D program was successful and several samples of metal powder produced during the developmental works met all the technical/chemical specifications laid down (CQAM-58) for its use in defence applications. In Table-2 typical analysis of tungsten samples obtained from scrap recycling and from the tailings material are presented and is compared with the CQAM-58 standard. Further, using large quantities of tungsten metal powder samples, DMRL prepared a number of test samples of W based heavy alloy (92W-5Ni-3Co) and subjected to specific heat treatment cycle before testing their mechanical properties. The details of this investigation are presented elsewhere [8]. It is to be noted that the DMRL-CSIR process technologies for the tungsten metal production/recycling have the advantages of flexibility/adaptation to different types raw materials. Also the flow sheets are associated with the scope of recycling of major process wastes and can be implemented with minimum burden on the environment.

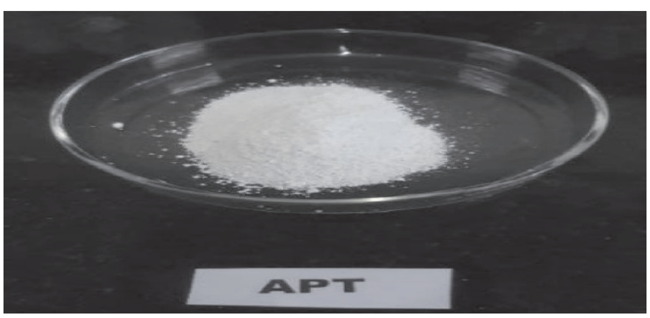
Table-2 : Typical analysis of tungsten metal powder samples			
Element	Content (ppm)		
	W metal powder from heavy alloy scrap recycling	W metal powder from Hutti tailings material	CQAM-58 (max.)
O	150	550	750
C	<20	<40	40
S	<10	<10	10
Co	<10	<10	20
Mn, Mo,Si,Cr	<10 each	<10 each	40
B, Cu,Al, Sn	<10 each	<10 each	20
Na	<10	<20	100
Ca, As,P	<10	<10	10

Prospects for Establishment of large capacity Indigenous Tungsten Metal Production Plant

Based on the successful development of process technologies for high purity tungsten metal production (from different resources), it has been decided to take forward the activity for the establishment of large capacity indigenous tungsten metal production plant. Recently, DMRL engaged M/s MECON, Ranchi for the preparation of a Detailed Project Report (DPR) to establish a 100 Mt/year tungsten metal production plant considering both raw materials of APT (to be procured from market) and heavy alloy scrap, huge quantity of which is already available at HEPF. The report shall cover complete details of engineering information such as material balance, raw materials requirement, list of equipment, effluents generation & their management, GA drawings, plant lay out and structural drawings of industrial plants etc. The report shall also provide complete details of economic viability study including estimation of project costs, cost of production of metal, IRR, break even etc. The report is expected to be ready in the next few months.

Currently, DMRL is seriously pursuing the task of establishment and operation of a technology demonstration plant (100 tpy) y employing the DRDO-CSIR technologies with participation/ collaboration of industry. Successful demonstration of the technologies is expected to pave way for realizing indigenous tungsten metal powder production plant. It is envisaged that after successful technology demonstration, the plant shall continue to operate for meeting the metal demand in India in the strategic sectors.

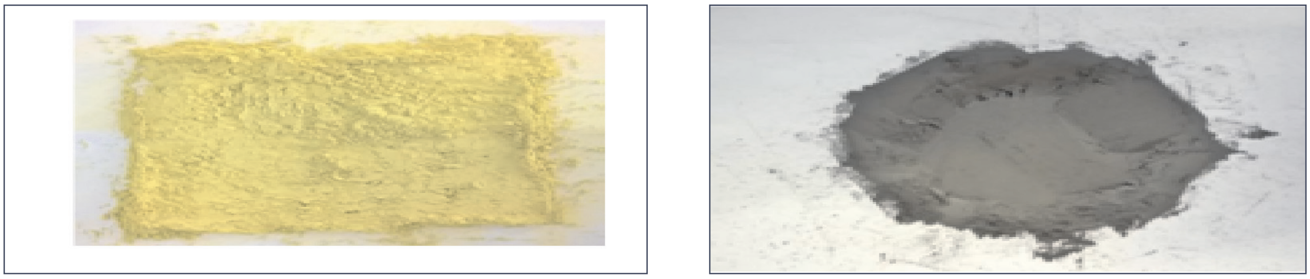
Fig.2 and Fig.3 show the photographs of samples of tungsten metal and tungsten intermediates produced as part of the technology development programme.



(a) APT

(b) W metal powder

Fig. 2 : Photographs of samples of ammonium paratungstate and tungsten metal powder produced from Hutti tailings



(a) (b)

Fig. 3 : Photographs of samples of (a) yellow tungsten oxide and (b) tungsten metal powder produced in the scrap recycling process

Acknowledgement

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A Composite Event on August 5th, 2022 (Friday)

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TECHNICAL PROGRAMME

10:00 hrs. **Inauguration of the Product Exhibition by Lt. Gen. J. K. Sharma (Retd.)**
Declaration of Product Exhibition Open to Students (Coordinator: Shri J. N. Srivastava, DMSRDE)

Technical Session - I : Advanced Functional Materials
Chairman: Prof. L. M. Manocha; Co-Chairman: Dr. Ashish Dubey
Venue: Director's Conference Hall, DMSRDE, DRDO, Kanpur
Please Join us using the weblink: https://meet.google.com/wwy-obtp-ytw

10:15 hrs.	Welcome by Dr. S. M. Abbas, Additional Director, DMSRDE, Kanpur, India
10:20 hrs.	Address by Guest of Honour Dr. Kamachi U. Mudali, Trustee, ASM International, India
10:30 hrs.	Address by Chief Guest Dr. Samir V. Kamat, DS & DG (NS&M), DRDO, Visakhapatnam, India
10:45 hrs.	Introduction of Chairman and Speakers by Dr. Kingsuk Mokhopadhyay
11:00 hrs.	Invited Lecture: Ultra High Temperature Ceramics for Re-entry Space Vehicles by Prof. Kantesh Balani,IIT/K, Kanpur, India
11:30 hrs.	Invited Lecture: Refractory multicomponent alloys for next generation applications by Prof. Koteshwararao V. Rajulapati, University of Hyderabad, Hyderabad, India
12:00 hrs.	Invited Lecture: Polymer composites of advanced functional materials for organic electronic applications by Prof. Rajiv Prakash, IIT(BHU), Varanasi, India
12:30 hrs.	Invited Lecture: Carbon Nanotubes Based Stretchable and Printable Conductive Materials by Dr. Debmalya Roy, DMSRDE, Kanpur, India
13:00 hrs.	Chairman Remarks
13:10 hrs.	Vote of Thanks by Dr. Ashish Dubey, DMSRDE, Kanpur, India
13:15 hrs.	Lunch

Technical Session - II : Product Exhibition
Chairman: Shri Hari Babu Sriavastava; Co-Chairman: Dr. N. Eswara Prasad
Venue: DMSRDE Exhibition Hall, DMSRDE, DRDO, Kanpur
(Coordinator: Shri J. N. Srivastava, DMSRDE)

14:30 hrs.	Welcome by Shri Amit Saraiya, DMSRDE, Kanpur, India
14:35 hrs.	Address by Guest of Honour Prof. P. Venkitanarayanan, IIT/K, Kanpur, India
14:45 hrs.	Address and Release of Souvenir by Chief Guest, Lt. Gen. J. K. Sharma (Retd.)
15:00 hrs.	Invited Lecture: Defence Products & ToT Road Map for DMSRDE by Shri J. N. Srivastava, DMSRDE, Kanpur, India
15:30 hrs.	High Tea
16:00 hrs.	Visit to Product Exhibition

Technical Session - III : Advanced Engineering Materials
Chairman: Shri Pradeep Goyal; Co-Chairman: Dr. Shantanu Chakraborty
Venue : Director's Camp Office, DMSRDE Transit Facility, G.T. Road, Kanpur
Please Join us using the webLink: https://meet.google.com/fgb-fjmy-dnp

17:00 hrs.	Welcome by Dr. Ashok Kr. Tiwari, Chairman, ASM International India National Council
17:10 hrs.	Address by Chief Guest Shri Pradeep Goyal, President (Elect), ASM International [2023-'24]
17:20 hrs.	Introduction of the Speakers by Dr. Kingsuk Mukhopadhyay, DMSRDE, Kanpur, India
17:30 hrs.	Invited Lecture: Quantitative Fractography (QF) for Fatigue Crack Growth Analyses of Metallic Aircraft Components by Dr. R. J. H. Wanhill, Emmeloord, Flevoland, the Netherlands
18:00 hrs.	Invited Lecture: Additive manufacturing in Electrical Machines - The Road to Electrification by Dr. Priya Munagala, University of Bristol, Bristol, UK
18:30 hrs.	Invited Lecture: Materials Design through Nano Engineering by Prof. P. M. Ajayan, Rice University, Houston, USA
19:10 hrs.	Invited Lecture: On the Prediction of Long-term High Temperature Creep Life of Materials using Short-term High Temperature Creep Test Results by Prof. K. A. Padmanabhan, Anna University, Chennai, India
19:40 hrs.	Invited Lecture: NEP of Light Metals by Prof. C. Suryanarayana, University of Central Florida, Orlando, USA
20:10 hrs.	Invited Lecture: Acoustophoretic Self-assembly of Colloidal Composites for Additive Manufacturing by Dr. Meghana Akella, Boston Science Corporation, Boston, MN, USA
20:40 hrs.	Special Lecture: Aerospace Materials - A journey of 4 Decades by Dr. N. Eswara Prasad, DMSRDE, Kanpur, India
21:20 hrs.	Vote of Thanks by Dr. Debmalya Roy, DMSRDE, Kanpur, India
21:45 hrs.	Dinner

Dr. N. ESWARA PRASAD, a B.Tech. (1985) and Doctorate (1993) from IIT(BHU) Metallurgical Engineering Department, is an Outstanding Scientist of DRDO and Director of DMSRDE, DRDO, Kanpur. His contributions to DRDO and Indian Defence are numerous. Dr. Prasad's wide range of S&T and R&D contributions on the extensive fundamental scientific research on aerospace materials have led to more than 700 publications and Rs. 1650 Cr. worth Defence Materials / Store. For these accomplishments, Dr. Prasad received 15 major awards and more than 60 honours and recognitions including FIIM, FAeSI, FInSIS, FAPAM. He will be felicitated in this symposium, on the occasion of his superannuation.


Lt. Gen. J. K. Sharma (Retd.)

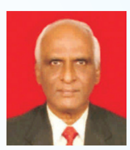

Hari Babu Srivastava


Dr. Samir V. Kamat


Dr. G. Satheesh Reddy


Dr. V. K. Saraswat


Dr. P. Rama Rao


Prof. V. V. Kutumbarao


Shri Pradeep Goyal


Dr. Kamachi U. Mudali


Dr. A. K. Tiwari

The Unexpected Happens: Challenges & Risks of Using Nanomaterials

Avnika S Anand and Ekta Kohli

Abstract

Nanotechnology is the science of studying matter at a very small scale, that is, 1–100 nm. Because of the small size the surface to mass ratio increases, resulting in novel properties of the same material in comparison to those at the bulk form. At different nanometer size scales, the properties can be tuned to suit the requirements, a process known as tuning of nanoparticles. With the global increase in the acceptance of this technology, it is crucial to regulate its safe use. In the biological system, these nanoparticles result in increased reactive oxidative species (ROS) via release of metal ions, interact with vital proteins, leading to the formation of protein corona, and even result in damage to the genetic machinery. Various regulatory agencies worldwide, like the Food and Drug Administration (FDA), EURO-NanoTox, and European Union (EU) nanosafety, regulate the safe use of these particles. In India, the guidelines for the safe use of nanoparticles are implemented by regulatory bodies at state and central levels in line with the research by CSIR and ICMR. DIPAS is the nodal laboratory under DRDO, providing a platform for toxicological testing of nanomaterials used in defence and military applications. The organisation aims to study the toxicity of various nanoparticles like zinc oxide, aluminum oxide, titanium oxide, cobalt oxide, and tungsten oxide through in vitro (cell lines) and in vivo exposure (Drosophila melanogaster). The need of the hour is to develop and improve the current strategies for nanotoxicology studies and the implementation of modern computational approaches for the safe use of nanotechnology on a wide scale.

Keywords : Nanotechnology, Nano-bio interface, Nanotoxicology, Regulations.

1. Nanotechnology: what, when and how?

To get an idea about the scale, the dot of an 'i' alone can hold one million nanoparticles. Nanotechnology refers to the manipulation of matter at a subatomic scale, i.e. 1 to 100 nanometers, and the tuning of its physical, chemical, and biological properties as needed [1]. A lot of natural nanomaterials are also present in the mineral, vegetal, and animal worlds. What distinguishes nano-scale materials from larger-scale materials is that, due to their larger surface-area-to-mass ratio, they become chemically more reactive, which changes their strength and other properties [2]. Furthermore, below 50 nm, classical physics laws give way to quantum effects.

Although nanotechnologies appear to be a new idea that evolved at the end of the twentieth century, nanoparticles have been used since antiquity, specifically as colorants in glass and ceramics in Roman and Egyptian civilizations. Nanoscale materials science and technology have age-old roots, dating back to the formulation of precious metal colloids for mediaeval stained glass to the Roman use of cement [3]. The oldest known manmade nanomaterials have been discovered in the 'unique black coatings' of ancient pottery rubbles unearthed at an archaeological site in Keeladi, Tamil Nadu, India, dating back to 600 BC [4]. *Bhasma*, which is an ayurvedic metallic and mineral preparation used in India from ancient times as therapeutics, is nothing but biologically synthesized nanoparticles [5].

The current idea of nanotechnology was given by the Nobel laureate Richard Feynman, who explained the potential of nanomaterials in a visionary talk in 1959, "There is plenty of space at the bottom [6]." Fifteen years later,

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the word nanotechnology was coined by Norio Taniguchi, who defined nanotechnology as a production technology for the fabrication of ultra-small materials with ultra-high precision [7]. Nanotechnology is thus used in almost every field, from agriculture to electronics, automobiles, health and medicine, and everyday consumer products [8–12]. A brief timeline of the growth of nanotechnology is shown in Figure 1.

2. Nanotoxicology

The nano size opens the door to many novel properties of materials which are not seen in the bulk form. However, 'novelty' may probably be associated with some risks [13]. Novel properties that make nanomaterials promising can lead to unforeseen risks. With the increasing application of nanomaterials, unplanned release into the environment cannot be ruled out. Humans can come into contact with these nanoparticles (NPs) through various routes of exposure, i.e., inhalation, dermal absorption, ingestion, and olfactory routes [14]. In order to comprehend nanomaterials' effects on biological systems and the associated risks to human health and the environment, we must first learn more about the nano-bio interface. Humans have been exposed to nano-sized particles throughout the evolutionary stages, but there was a drastic increase after the industrial revolution. In 1990, researchers highlighted and questioned whether inhaled particles of nano-size caused a greater than expected pulmonary response [15, 16]. On the basis of mass to mass ratio, aluminum oxide and titanium oxide cause significantly greater inflammatory responses in the lungs of rats in comparison to that caused by the bulk form of the same materials. These two research articles challenged the safer use of NPs and highlighted the unusual biological response linked to the nanometer size of the materials. To better understand how the presence of these NPs in the biological system will affect cellular machinery, the term 'nanotoxicity' was defined fourteen years later [17]. Metal and metal oxide NPs, which mainly include silver oxide, gold, titanium dioxide, cesium dioxide, iron oxide, aluminium oxide, zinc oxide, carbon black, and diesel exhaust NPs, are examples of NPs that have been extensively studied in various toxicological studies [18, 19].

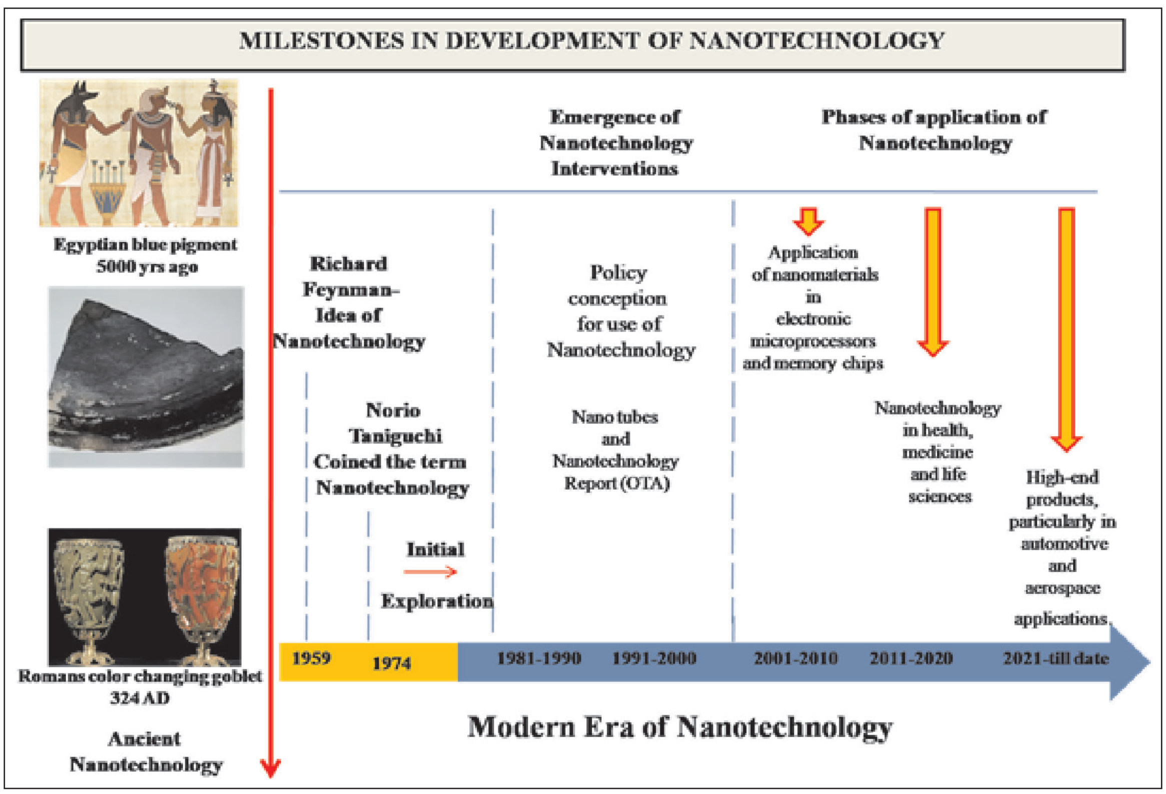

Fig. 1 : A Brief Timeline of the Ancient and Modern Eras of Nanotechnology

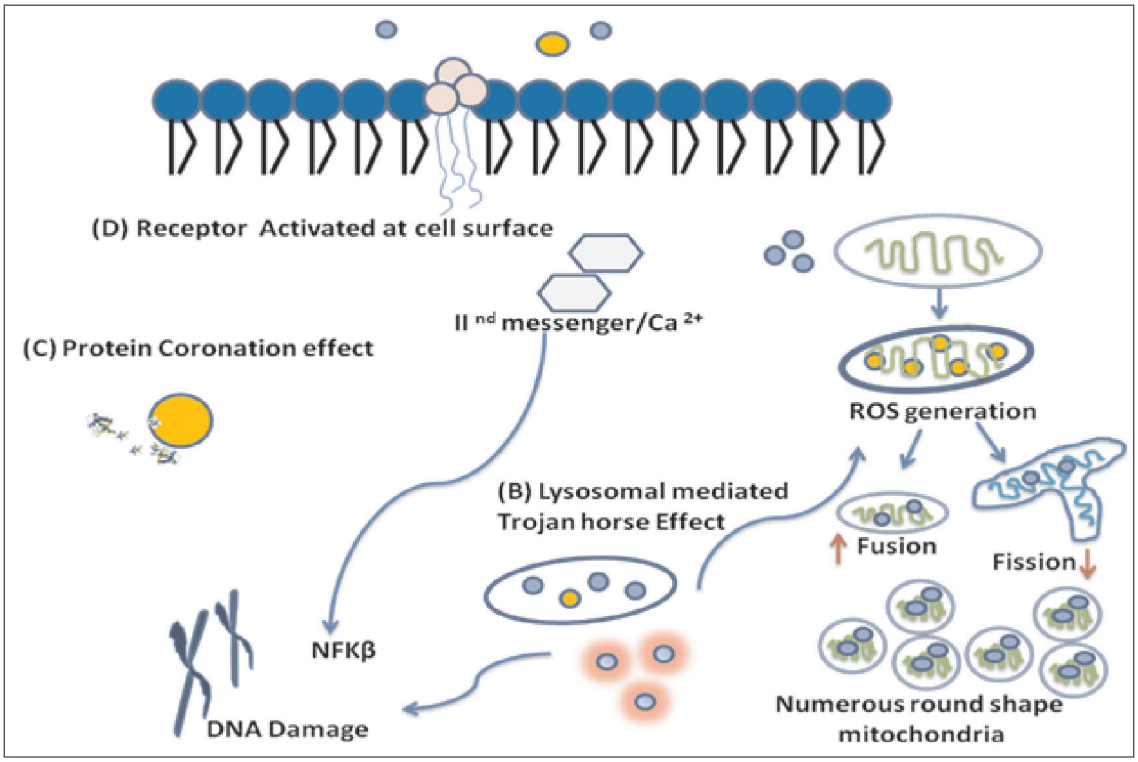

Fig. 2 : Nano-bio interference and Nanotoxicity (A) Mitochondrial damage and ROS generation, (B) Lysosomal mediated Trojan Horse effect, (C) Protein coronation formation, (D) Cell surface receptor activation

3. Mechanism of nanotoxicity

NPs by interacting with cellular components such as the lysosome, mitochondria, proteins, and nucleus can cause a cascade of reactions such as ROS generation leading to mitochondrial damage, lysomal-mediated Trojan horse effect, protein coronation formation, and cell surface receptor activation, as shown in Figure 2. NPs are reported to generate free radicals, mitochondrial dysfunction, membrane potential dissipation, caspase3 activation, and apoptosis in cells. However, mitochondria have an effective repair mechanism to overcome this damage via fusion and fission dynamics, as mitochondria use this machinery to overcome the damage. Fission takes over the fusion reaction, resulting in numerous round small mitochondria. The toxicity generated by the NPs not only results in increased ROS in the mitochondria but also a faulty repair mechanism, resulting in very small mitochondrial generation [20].

One of the recent factors in understanding nanotoxicity is lysosomal damage. Most of the NPs (metal oxide, metals, and semiconductors), which enter the cell through the energy-dependent process, are engulfed into vessels like endosomes and are eventually processed in the acidic surroundings of the lysosome. NPs are actively taken up by the cells and internalized into cellular vesicles, so called the Trojan horse effect. Further, they release this cargo into the cell, in the form of toxic ions ($Fe^{2+/3+}$, Ag^{+}, Cd^{2+}). As the lysosome is the organelle of target, this effect is known as the 'lysosome-enhanced Trojan horse effect' (LETH mechanism) [21]. The toxic ions generated from this cargo lysosome add on to ROS generation, leading to DNA damage. However, safer NPs can be designed to overcome this effect, e.g., if the particles escape the endocytic entry into the cell, coating resistance to this acidic environment of the lysosome, there is no further leaching of the metal ions.

This process of protein being adsorbed at the nano interface is defined as 'Nanoparticles-protein coronation (NP-PC).' The overall process of NP-PC is determined by three major factors: (i) particle characteristics, (ii) interacting protein, and (iii) surrounding medium. NP-protein interaction is a flexible mechanism which results in "hard-corona" of protein on the particle surface, which is an irreversible process, or ‘soft-corona’, which is a quick and reversible process [22]. The NP-PC can impair various functions regulated by the protein, as these particles make the protein unstable and deformed. Another outcome of this NP-protein interaction is in the form of fibril formation. NPs can also easily pass through the blood-brain barrier and result in fibrillation of proteins present in the brain, which could be the major cause of neurological disorders like Parkinson's or Alzheimer’s.

Cell-surface receptors are well designed to bind to specific ligand molecules and this triggers an intracellular process. This binding is the key step to determining the strength and extent of downstream events. The upcoming engineered NPs have the potential to bind to these receptors and start their expression, which gives access to further signaling processes and cellular systems. This NP-PC effect also contributes to this mechanism; protein once bound to the NPs makes these particles effectively bind to various cell surface receptors, which gives access to these particles to the cell and affects various signaling pathways and immunogenic responses.

4. International Scenario of Nanotoxicology

Over the past few years, the use of products with nano-based applications has increased drastically, as estimated in the year 2019 the market worth 8.5 billion US dollar and anticipated to grow with a rate of 13.1% from 2020 to the year 2027. [23] This tremendous growth of nanotechnology has raised concerns about the adverse effects of nanotechnology on humans and the environment [24]. As nanotechnology gained ground, concerns about the potential health and environmental consequences of nanotechnology quickly arose. Bill Joy's article "Why the Future Doesn't Need Us" in wired magazine raised concerns about modern technology including nanotechnology [25]. The Paracelsus adage "sola dosis facit venenum," which means that dose causes poison, makes *dosimetry* a powerful force in nanotoxicology [26]. The chemical properties, dose and physical conditions in which these particles react regulate toxicity. Global research is trying to better understand the classification of nanomaterials based on the characteristics and conditions that lead to toxicity. A summary of research articles over the last ten years in the Pubmed research database with ’Nanotoxicology’ as a keyword is shown in Figure 3.

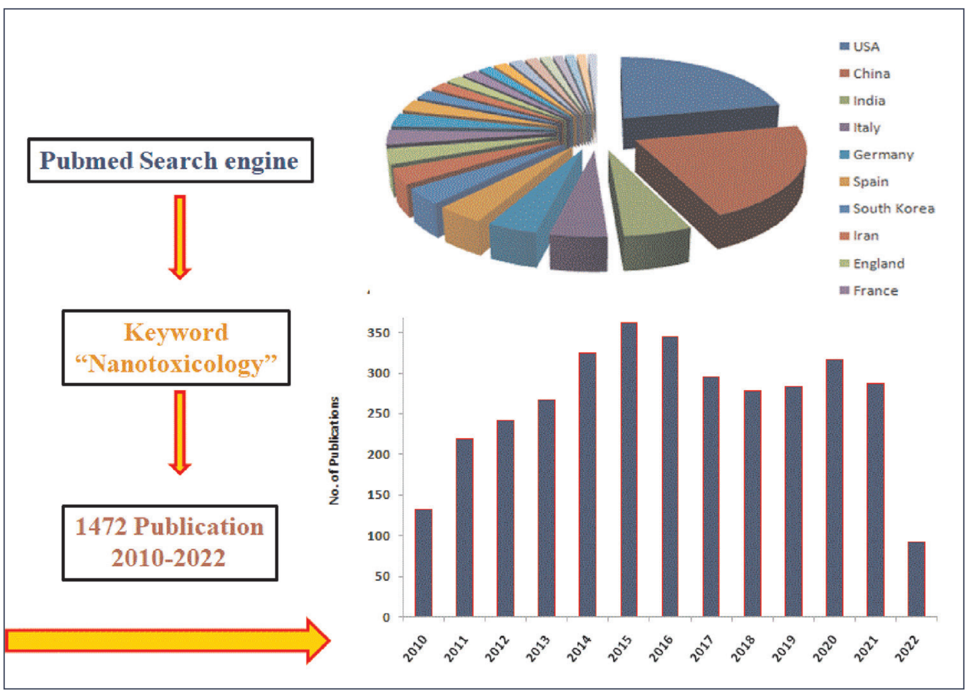

Fig. 3 : Number of Nanotoxicology publications worldwide

In 2004, the Civil Society group then called for a research memorandum from Swiss Re, the UK Royal Society, and the Royal Academy of Engineering, raised concern about the uncertainties of nanotechnology. Concerns that nanomaterial with novel functionalities may result in unpredictable exposure routes as these particles are capable of crossing various biological barriers, resulting in unusual biological behavior; thus this emphasizes the importance of studying nanotoxicity. The primary regulatory bodies in charge of nano-safety issues in the United States are the US Food and Drug Administration (FDA) and the Environmental Protection Agency (EPA), both of which are part of the Department of Health and Human Services [27]. The European Union (EU), which includes ERC and EURO-NanoTox, an EU nano-safety cluster, regulates the safer use of nanotechnology in Europe [28]. The use of nanomaterials in agriculture, food, and feed is allowed by the EC and EU member states. For cosmetic applications, toxicological data for those particular nanomaterials are required by the European regulation (EC 2009). The release of free NPs in everyday life scenarios is regarded as a potential threat to human health.

5. India's contribution to Nanoscience and Nanotoxicology

According to a recent Assocham-TechSci study, nearly one in every four nanotechnology professionals in the world will be Indian by 2025. According to the report, India's contribution to the development and application of nanotechnology is expected to increase significantly due to increased investments, strong funding and extended government policies. The key weaknesses of India's nanotechnology market are a lack of appropriate infrastructure and a significant brain drain. However, the nanotechnology market in India is expected to grow rapidly due to the government's increased emphasis on developing and improving this stream of technology [29].

India is also in collaboration programs for development of nanotechnology and Nanotoxicology. The Nanotoxicology Link between India and European Nations, (NanoLINEN) is a collaboration of seven European laboratories and the Indian Institute of Toxicology Research (CSIR Laboratory) to strengthen research ties in the field of nanomaterial toxicology. The project's goal is to create robust risk-assessment methodologies that will be useful for the community manufacturing and using nano-products. Different regulatory organizations ensuring the safer use of nanomaterials are described in Figure 4.

6. Role of DRDO

DIPAS is the DRDO's nodal lab for nanotoxicological evaluation. The nanomaterials(NMs)

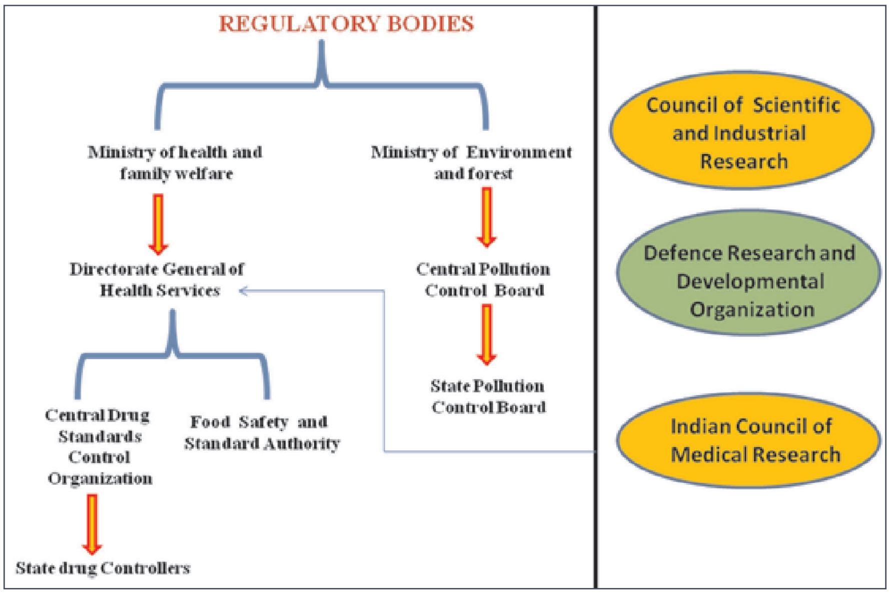

Fig. 4 : Regulatory bodies in India for Nanotoxicology

used in military applications must be characterized on the basis of toxicity in order to protect the health of army personnel as well as civilians. DIPAS has been conducting research to determine the nature of NM-toxicity based on the circulation half-life and interaction of engineered NMs with biomolecules. The lab is also uncovering cellular toxic mechanisms that disrupt normal intracellular processing.

At DIPAS, we aim to understand the primary toxicity in cells upon exposure to NPs. So far, we have screened and characterized various NPs on the basis of cytotoxicity. The main objective was to study toxicity of metal oxides nanoparticles used in the military applications. For this, Zinc oxide NPs, Tungsten oxide, Titanium Oxide, Cobalt oxide, and Aluminum oxide were screened for cytotoxicity in different cell lines like mammalian lung, macrophages, skin, and liver cell lines. In this study, Zinc oxide NPs were reported to be the most toxic [30]. Furthermore, we analyzed the mechanism behind this cytotoxicity, inflammatory molecules and genotoxicity.

ZnO-NPs accumulate inside the mitochondrial matrix after internalization in the cell and damage this organelle. Mitochondrial dysfunction and imbalance in its dynamics by ZnO-NPs were studied. Electron microscopy studies conducted to observe the mitochondrial morphology revealed that mitochondria are significantly shorter, donut shaped, with damaged cristae, non-functional with a decrease in length in A549 cells exposed to ZnO-NPs. These findings suggest that the balance of mitochondrial fission and fusion, a process that controls mitochondrial morphology, is tipped towards less fusion. We have found that mitochondrial dysfunction is a crucial step in toxicity induced by ZnO-NPs. We also tested its functional significance in the setting of an advanced tier of toxicity, and showed that mitochondrial fragmentation led to increased necrotic core formation and apoptotic cell accumulation. A quantitative proteomic profiling of control and ZnO-NPs treated A549 cells was done using MALDI-TOF/TOF and MS/MS to identify differential protein expression on exposure to NPs among non-exposed and exposed cells. This study was a systematic analysis of protein modulation of the A549 cells exposed to ZnO NPs, indicating alterations in the cytoskeleton [31].

The long-term goal is to assess the key biological effects of NMs upon contact with biological systems, such as bio-distribution, circulatory half-life, phenotypic and genotypic toxicity mechanisms, and transmission to subsequent generations. To conduct additional research, DIPAS has established experimental facility with fly (Drosophila). The laboratory has also successfully established a transgenic fly clone (GFP-expressing) to collect real-time physiological, neuronal, and molecular data in vivo under environmental challenges. *Drosophila melanogaster* (fruit fly) has been a sought-after model organism for over a century in biology, genetics, neurobiology, and toxicology. There are numerous advantages of studying nanotoxicity using *Drosophila melanogaster* as the experimental model. More than 65–70% of human disease genes are found in Drosophila. Flies have a short life span and a large progeny population. It is inexpensive to study NPs-mediated toxicity in Drosophila (Figure 5). The in vivo studies include chronic exposure of ZnO NPs and Al_2O_3 NPs using *Drosophila melanogaster* as a model organism. The main objective of this study was to evaluate the lethal effect on biological forms of exposure to ZnO NPs. Drosophila melanogaster fruit flies were exposed to ZnO NPs through an ingestion method. To further evaluate the chronic effects of NPs in the subsequent generation, F1, F2, F3 and F4 flies were screened for phenotypic changes. Most of the fly offspring showed wing deformation (mild phenotypic change). However, distinctive phenotypic alterations were observed in a few. Moderate phenotypic changes, which include deformed wings, were observed. A severe phenotype of deformed thorax, duplication of notum, and single wing were observed in 3 ± 0.4% of the population. The aberrant phenotype becomes more severe in the offspring if the offsprings are also exposed to the NPs. The thorax appeared to be pigmented and deformed at the notum, and the right wing failed to develop; a similar phenotype was observed where the left wing failed to develop. The ventral nerve cord failed to develop, the thorax was completely deformed, and the left wing failed to develop. The genotoxic effects of ZnO NPs were demonstrated by the distinct severe mutagenic phenotypes observed, namely the absence of wing, segmented thorax, and completely distorted thorax [32]. Toxicoproteomics tools were further used to understand the mechanism behind this abnormal phenotype. In particular, we also studied the expression of wingless protein, which is a segment polarity protein. Our research findings clearly show the role of the WNT pathway behind the abnormal phenotype of drosophila progeny.

In order to study the nano-bio interaction of Al_2O_3 NPs, *Drosophila melanogaster* flies were exposed to Al_2O_3 NPs at concentrations of 0.1 and 1 mM via ingestion throughout their lifespan and next generation flies were screened for behavioral and phenotypic abnormalities. Behavioral abnormalities in flies were recorded through larval crawling, climbing, and two taste tests. Loss of appendages was observed in flies exposed to Al_2O_3 NPs resulting in five-legged flies, four-legged flies, and no haltere. Renal failure was also observed in flies exposed to Al_2O_3 NPs resulting in swollen abdomen.

Our studies focused on the health ailments due to exposure of Al_2O_3 NPs which could be in human bodies, like birth deformities and kidney failure. Further, damage at the cellular level was studied through proteomic profiling. Differentially expressed protein-enrichment analysis revealed significant changes in striated muscle cell differentiation, digestive tract morphogenesis, photo-transduction, chromatin organization regulation, and DNA duplex unwinding [33].

7. Conclusion

The importance of nanotechnologies for our well-being is undeniable, but their potential negative consequences must be thoroughly investigated. A better understanding of the risk factors associated with nanomaterials in the human body and the ecosystem will aid in the development and exploitation of a wide range of nanomaterials in the future. Concerns about the release of new NPs into the environment are making headlines. Though we have always been surrounded by sub-micron particles, the introduction of synthetic versions has only highlighted how little we know about their toxicity. The need for developing an infrastructure for characterization and measuring nanomaterials in complex matrices,

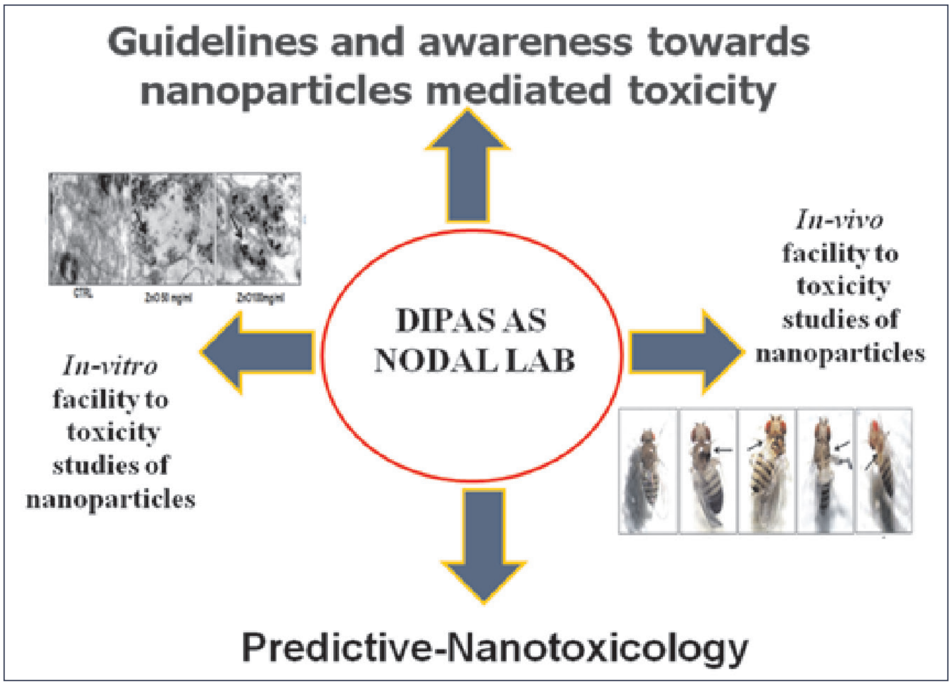

Fig. 5 : DIPAS as a nodal centre for nanotoxicological studies in India

as well as developing reference materials, is becoming more apparent, both for calibrating instruments used for assessing exposure and dosimetry, and for benchmarking toxicity tests. The public in general expects new or emerging technologies to meet higher safety standards than tried and tested technologies. Failure to meet these requirements may cause public fear or even rejection of products based on nanotechnology, which normally improve our quality of life.

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IIT-M researchers develop zinc-air batteries

It is an alternative to lithium-ion batteries for electric vehicles

Researchers at the Indian Institute of Technology Madras are developing mechanically rechargeable zinc-air batteries as an alternative to lithium-ion batteries to power electric vehicles (EV). They have filed for patents for their technology and are collaborating with major industries to develop the batteries.

As zinc-air batteries are economical and have longer shelf-life, they can be used in two and three-wheel EVs, the researchers say.

Aravind Kumar Chandiran, assistant professor in the Chemical Engineering Department at the Institute, and his team is working on zinc-air batteries as zinc is a widely available resource in the country. Currently India imports lithium-ion batteries from China. “Our research team is developing a futuristic model for zinc-air batteries for EVs. The team has developed zinc-air cells and is working to develop zinc-air packs for EVs,” he said.

The researchers are mooting separate zinc recharge stations similar to petrol stations. Zinc-air battery users can swap their empty batteries for charged ones. “This is a major advantage of the zinc-air batteries as currently the only option available with the lithium-ion batteries is that the entire used battery pack has to be removed and be swapped with a complete lithium-ion battery pack. This results in double the capital investment in the case of lithium-ion batteries,” he added. The researchers are also mooting recharge of used ‘zinc cassettes’ through solar panels.

Not only will it take just a few minutes to recharge batteries but they are also safe as the batteries use aqueous electrolyte that does not catch fire. While lithium-ion batteries costs $200-250 per KW hour zinc-air batteries cost $150/Kwhr. The cost would reduce with wider usage, the researchers say.

Source: The Hindu

Outokumpu launches stainless steel product with 92% lower carbon footprint than industry average

Outokumpu has launched, Circle Green Core, which it says has the smallest emission intensity in the world, with a 92% lower carbon footprint than the global average.

The company says improvements were made throughout the whole production chain with reductions in upstream raw material emissions.

Biogas, biodiesel, bio coke, and low-carbon electricity were used in production to eliminate 95% of all scope 1 and 2 CO_2 emissions. While these bio-based materials have all been tested previously in production, they were used together for the first time in this process.

It reviewed and optimised the emissions from each production step from the stainless steel melt process and energy production to transportation and raw material production. The emission reduction calculation includes all emission scopes according to the Greenhouse Gas Protocol method.

Niklas Wass, Outokumpu’s Executive Vice President of Operations, outlines future plans, “In this first phase, we will concentrate our efforts to serve a few strategic customers, but we are already looking at ways to scale up the production,” he says.

Source : iom3

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B E College Chapter

An online lecture was organised by IIM B E College Chapter and Society of Student Metallurgists on 30th April 2022 at 6:30 pm. The lecture was delivered by Prof. Narayan Kar from University of Windsor, Canada. Prof. Kar is associated as Professor in Tier 1 Canada Research Chair in Electrified Vehicles. The talk was thoroughly well accepted by the audience and was concluded with an interaction session between the speaker and the viewers.

Delhi Chapter

1. The IIM Delhi Chapter organised a meeting of the "Resource Mobilization & Technical Exhibition", "Technical", and "Conference Secretariat & Registration" committees of MMMM 2022 Conference which was held on May 12, 2022. The progress of various activities of the Conference was discussed.

2. A meeting of the Executive Committees was held on google meet platform on 28th May 2022. After the EC meeting, a Technical Talk on "Stainless Steel: Process, Products & Applications" was delivered by Shri Ranit Rana, General Manager (Sales and Distribution), Jindal Stainless Ltd. There was a lively interaction amongst the participants at the end of the talk.

Coimbatore Chapter

The AGM of IIM Coimbatore Chapter was held on 23rd May, 2022. The Chapter Secretary presented the annual report on the activities organized by them during 2021-22, as follows:

(i) AGM meeting & three EC meetings; (ii) Five guest lectures; (iii) Wootz'13, a students' technical symposium.

The new office bearers for the FY 2022-23 and 2023-24 are :

Chairman	Dr. J Krishnamoorthi
Secretary	Mr. N Kannapiran
Treasurer	Mr. K Krishna Kumar

Vijaynagar Chapter

IIM Vijaynagar Chapter organised a programme on 24th May, 2022 at Experience Centre (FORUM auditorium) to felicitate Dr. G. Balachandran, Sr. Vice President, R&D Dept. JSW who has been conferred with prestigious "Award for Research & Development in Iron & Steel Sector" by Hon'ble Union Minister of Steel, Shri Ram Chandra Prasad Singh at National Metallurgist Award-2021 Ceremony on 20th April, 2022 in New Delhi. Dr. Balachandran donated the award money of Rs. 1 Lakh to the IIM Vijaynagar Chapter.

Felicitation to Dr. Balachandran by Shri P. K. Murugan, President, JSW Steel, Vijaynagar Works and Vice Chairman, IIM Vijaynagar Chapter

On this occasion, Shri L.R. Singh, COO, JSW Steel, Vijayanagar Works and Secretary, IIM Vijaynagar Chapter announced the constitution of "JSW-INNOVATOR of the Year Award" for JSW Employee, carrying a cash prize of Rs. 10,000/- and a Scroll of Honour. The award will be given to an outstanding practising Engineer in recognition

of BREAKTHROUGH INNOVATION in the fields of Metallurgical & Industrial Process, Design and Maintenance resulting in Cost control & Cost reduction, Industrial Productivity, Resources & Capacity Utilisation, Product quality improvement or reducing Energy & Waste and Impacting Environment made in last 5 years at JSW. A lecture series was also organised on the topic "BOF slag - From a solid waste to a medium for water purification". Dr. Somnath Basu, Professor, Met. Engg. & Material Science Dept., IIT Bombay was the guest lecturer.

Kolkata Chapter

As a part of the yearlong programme on "Demystifying Industry 4.0", being organized by the IIM Kolkata Chapter along-with the IIChE Calcutta Regional Centre and the Jadavpur University, a series of Webinars on Industry 4.0 is being organised and the same shall continue till December, 2022.

The Seventh Lecture of the Webinar Series 2022 was delivered by Mr. Prith Banerjee, Chief Technology Officer at ANSYS, a leader in Engineering Simulation, on "Future of Simulation Based Product Innovation in the 21st Century", at 8.00 pm on 26th May, 2022.

Mumbai Chapter

On May 27, 2022 IIM Mumbai Chapter organised a technical talk on "Sodium-ion batteries: Hype, Hope or Reality?" at Seminar Room, MEMS, IIT Bombay. It was mainly organised for the student affiliate chapter of IIM Mumbai Chapter. Shri Parth Desai, a former DD student of IITB, and currently a PhD candidate at Solid State Chemistry and Energy (CSE) Lab at College de France, Paris has delivered the talk. The duration of the talk was ~45 minutes, followed by ~20 minutes of discussion and interactions. The total number of attendees was ~60, which included primarily graduate students, post-doctoral researchers and a few faculty and staff members, for this student chapter event.

Keonjhar Chapter

The AGM of IIM Keonjhar Chapter was held on 10th June, 2022 at hotel "The World" at Barbil. The Executive Committee of the chapter for FY 2022-23 is as follows :

Chairman	Mr. Manikanta Naik
Vice-Chairman	Mr. Suresh Chandra Khattoi
Secretary	Mr. Pratyusha Kumar Nanda
Treasurer	Mr. Pratyush Kumar Pattnaik

Raigarh Chapter

The AGM of IIM Raigarh Chapter was held on June 28, 2022 on virtual mode. The Executive Committee of the chapter for FY 2022-23 is as follows :

Chairman	Mr. R K Ajmeria
Vice-Chairmen	Mr. Satyendra Singh Mr. A K Bhagat
Secretary	Mr. Moreshwar Borkar
Treasurer	Mr. Joy Dutta

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*Dow Jones Sustainable Indices 2020 & 2021

Mr. Satish Pai
Managing Director, Hindalco Industries Ltd
Vice President, The Indian Institute of Metals

The only body representing the global primary aluminium industry, International Aluminium Institute (IAI), has publicised the appointment of **Mr. Satish Pai** as its new Chairman. Mr. Satish Pai is the Managing Director of Hindalco Industries Ltd., one of the world's largest integrated aluminium producers. He is also the Vice President of The Indian Institute of Metals. Previously he was serving as the Vice-Chairman of IAI and he succeeds Ben Kahrs, Alcoa Corp's Chief Innovation Officer.

The Secretary-General of IAI, Miles Prosser said "Satish is an exceptional leader who is as familiar with boots-on-ground issues as he is with geo-economic perspectives. He is well able to convert industry challenges into opportunities – strategic R&D led to Hindalco becoming the first aluminium company to achieve 100% utilisation of bauxite residue in three of the refineries."

The newly appointed Chairman stated, "I'm excited to work even closer with my industry colleagues and to test the limits of what we can achieve together. Aluminium is the material of choice of the 21st century and being endlessly recyclable, an integral part of the circular economy. I believe this positioning need to be amplified so that as a sector, we can contribute to the world's climate action goals. ESG and the sustainability agenda will be key to our future growth path. I'm looking forward to working through the IAI forum to engage with colleagues to take the aluminium story to a new peak."

Mr. Pai, an engineer by education and profession earlier worked with Schlumberger, based out of Paris, where he was responsible for Schlumberger's global operations.

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INDIAN STEEL MARKET ROUND-UP

The following is a status report on the performance of Indian steel industry during April 2022, based on provisional data released by Joint Plant Committee (JPC) in its MIS Report for April 2022. It is to be noted that total finished steel includes both non-alloy and alloy (including stainless steel) and all comparisons are made with regard to same period of last year.

Item	Performance of Indian steel industry		
	April 2022*(Mt)	**April 2021 (Mt)**	**% change***
Crude Steel Production	10.144	9.551	6.2
Hot Metal Production	6.669	6.327	5.4
Pig Iron Production	0.597	0.545	9.5
Sponge Iron Production	3.526	3.324	6.1
Total Finished Steel (alloy/stainless + non-alloy)			
Production	9.382	9.266	1.3
Import	0.327	0.364	-10.1
Export	0.743	0.951	-21.9
Consumption	9.072	8.962	1.2
Source: JPC; *provisional; Mt=million tonnes			

Overall Production

- ***Crude Steel :*** Production at 10.144 million tonnes (Mt), up by 6.2%.
- ***Hot Metal :*** Production at 6.669 Mt, up by 5.4%.
- ***Pig Iron :*** Production at 0.597 Mt, up by 9.5%.
- ***Sponge Iron :*** Production at 3.526 Mt, up by 6.1%, led by coal-based route (80% share).
- ***Total Finished Steel :*** Production at 9.382 Mt, up by 1.3%.

Contribution of Other Producers

- ***Crude Steel :*** SAIL, RINL, TSL Group, AM/NS, JSWL & JSPL together produced 6.103 Mt (60% share) during this period, up by 5.2%. The rest (4.041 Mt) came from the Other Producers, up by 7.7%.
- ***Hot Metal :*** SAIL, RINL, TSL Group, AM/NS, JSWL & JSPL together produced 5.967 Mt (89% share) up by 5.8%. The rest (0.703 Mt) came from the Other Producers, up by 2.3%.
- ***Pig Iron :*** SAIL, RINL, TSL Group, AM/NS, JSWL & JSPL together produced 0.176 Mt (30% share) down by 6.3%. The rest (0.421 Mt) came from the Other Producers, up by 17.9%.
- ***Total Finished Steel :*** SAIL, RINL, TSL Group, AM/NS, JSWL & JSPL together produced 5.32 Mt (57% share) up by 1.9%. The rest (4.062 Mt) came from the Other Producers, up by 0.4%.

Contribution of Public Sector Units (PSU)

- ***Crude Steel :*** With 83% share, the Private Sector (8.407 Mt, up by 7.1%) led crude steel production compared to the 17% contribution of the PSUs.
- ***Hot Metal :*** With 71% share, the Private Sector (4.737 Mt, up by 7.3%) led hot metal production, compared to the 29% contribution of the PSUs.
- ***Pig Iron :*** With 85% share, the Private Sector (0.506 Mt, up by 12.8%) led pig iron production, compared to the 15% contribution of the PSUs.
- ***Total Finished Steel :*** With 86% share, the Private Sector (8.061 Mt, up by 1.2%) led production of total finished steel, compared to the 14% contribution of the PSUs.

Contribution of Flat /Non-Flat in Finished Steel

- ***Production :*** Non-flat products accounted for 51% share (down by 0.5%), the rest 49% was the share of flats (up by 3.2%).
- ***Import :*** Flat products accounted for 94% share (down by 4.8%), the rest 6% was the share of non-flats (down by 53.0%).
- ***Export :*** Flat products accounted for 85% share (down by 16.4%), the rest 15% was the share of non-flats (down by 16.4%).
- ***Consumption :*** Led by Non-flat steel (53% share; down by 3.8%) while the rest 47% was the share of flat steel (up by 7.5%).

Finished Steel Production Trends

- At 9.382 Mt, production of total finished steel was up by 1.3% in April 2022.
- Contribution of the non-alloy steel segment stood at 8.806 Mt (94% share, up by 1.5%), while the rest was the contribution of the alloy steel segment (including stainless steel).
- In the non-alloy, non-flat segment, in volume terms, major contributor to production of total finished steel was Bars & Rods (3.768 Mt, down by 1.1%) while growth in the non-alloy, flat segment was led by HRC (3.938 Mt, up by 2.7%) during this period.

Finished Steel Export Trends

- Overall exports of total finished steel at 0.743 Mt, down by 21.9%.
- Volume wise, Non-alloy HR Coil/Strip (0.373 Mt, down by 14.1%) was the item most exported (55% share in total non-alloy).
- Vietnam (0.130 Mt) was the largest export market for India.

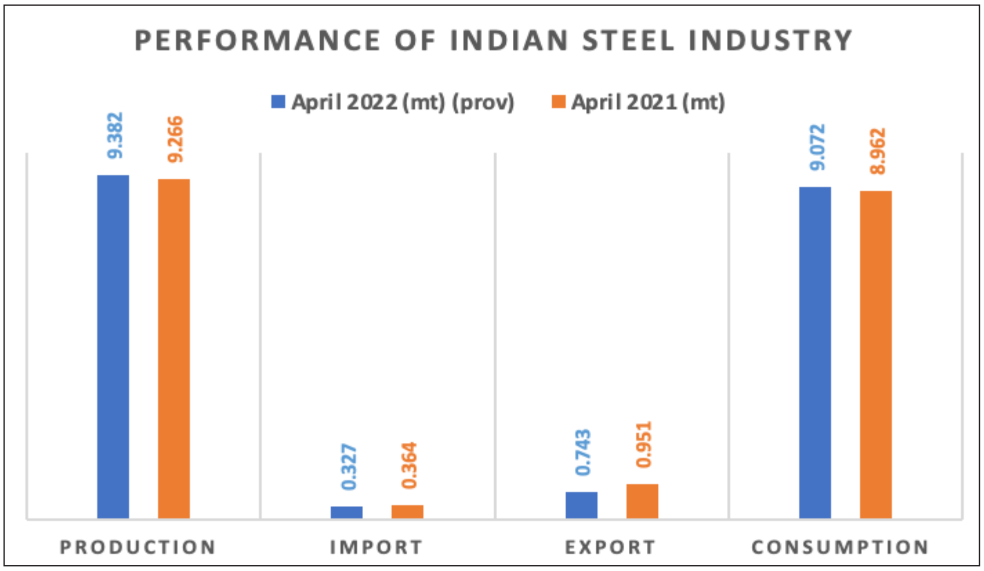
Finished Steel Import Trends

- Overall imports of total finished steel at 0.327 Mt, down by 10.1%.
- India was a net exporter of total finished steel in April 2022.
- Volume wise, HR Coil/ Strip (0.07 Mt, up by 14.7%) was the item most imported (36% share in total non-alloy).
- Korea (0.178 Mt) was the largest import market for India (43% share in total).

Finished Steel Consumption Trends

- At 9.072 Mt, consumption of total finished steel was up by 1.2% in April 2022.

- Contribution of the non-alloy steel segment stood at 8.436 Mt (93% share, up by 0.9%), while the rest was the contribution of the alloy steel segment (including stainless steel).
- In the non-alloy, non-flat segment, in volume terms, major contributor to consumption of total finished steel was Bars & Rods (3.801 Mt, down by 5.5%) while growth in the non-alloy, flat segment was led by HRC (3.598 Mt, up by 4.8%) during this period.



Source : http://jpcindiansteel.nic.in/

Crude Steel production by region				
	May 2022 (Mt)	% change May 22/21	Jan-May 2022 (Mt)	% change Jan-May 22/21
Africa	1.1	-18.9	6.1	-7.0
Asia and Oceania	126.8	-1.7	582.0	-6.5
EU (27)	12.9	-6.8	62.3	-4.3
Europe, Other	4.1	-1.7	20.2	-3.5
Middle East	3.5	-10.0	17.0	-6.1
North America	9.9	-4.0	47.5	-2.3
Russia & other CIS + Ukraine	7.4	-19.1	38.4	-13.1
South America	3.8	-2.8	18.1	-2.4
Total 64 countries	**169.5**	**-3.5**	**791.8**	**-6.3**

The 64 countries included in this table accounted for approximately 98% of total world crude steel production in 2021. Regions and countries covered by the table:

- **Africa :** Egypt, Libya, South Africa
- **Asia and Oceania :** Australia, China, India, Japan, New Zealand, Pakistan, South Korea, Taiwan (China), Vietnam

- **European Union (27)**
- **Europe, Other :** Bosnia-Herzegovina, Macedonia, Norway, Serbia, Turkey, United Kingdom
- **Middle East :** Iran, Qatar, Saudi Arabia, United Arab Emirates
- **North America :** Canada, Cuba, El Salvador, Guatemala, Mexico, United States
- **Russia & other CIS + Ukraine :** Belarus, Kazakhstan, Moldova, Russia, Ukraine, Uzbekistan
- **South America :** Argentina, Brazil, Chile, Colombia, Ecuador, Paraguay, Peru, Uruguay, Venezuela

Top 10 steel-producing countries

	May 2022 (Mt)	% change May 22/21	Jan-May 2022 (Mt)	% change Jan-May 22/21
China	96.6	-3.5	435.0	-8.7
India	10.6	17.3	53.2	6.5
Japan	8.1	-4.2	38.5	-3.5
United States	7.2	-2.6	34.3	-1.6
Russia	6.4 e	-1.4	31.0	-2.3
South Korea	5.8	-1.4	28.2	-3.4
Germany	3.2	-11.5	16.4	-4.8
Turkey	3.2	-1.4	16.0	-2.8
Brazil	3.0	-4.9	14.5	-2.2
Iran	2.3 e	-17.6	11.4	-10.8

e - estimated. Ranking of top 10 producing countries is based on year-to-date aggregate

Source : worldsteel.org

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NEWS UPDATES

Combating Inflation: Domestic industry to get cheaper steel at the cost of export as govt levies new duties

The Finance Ministry's move to levy export duty on iron ore and steel while reducing the import duty on coal, ferronickel a key input for steelmakers, is expected to rein in the galloping steel prices in the domestic market and the resultant inflation.

The move will bring some respite to manufacturing industries like automotive, consumer electronics and construction, where high steel prices have squeezed corporate margins and hurt consumer demand due to price hikes. However, the move may not enthuse steelmakers who tend to make higher margins on exported steel.

"This (export) duty will impact steel exports," said a senior steel industry. About 15% of the flat steel made in India is exported. A 15% export duty on flat steel will make Indian steel pricier abroad, thus forcing steelmakers to sell more locally.

The government has levied a 15% export duty on several steel intermediates like flat-rolled steel and bars and rods, which are consumed by the manufacturing industry. Iron ore will attract a 50% export duty. Meanwhile, import duty on inputs for the steel industry like coke, coal and ferronickel has been reduced to nil.

The Economic Times

Tata Steel to spend Rs 1,200 crore on new technology development over 4 years, non-steel materials in focus

Tata Steel Ltd is betting big on new technology development over the next three to four years and has firmed up plans to pump in around Rs 1,200 crore as a part of its endeavour to "enter materials beyond steel", a top company official said.

In the new materials business, the steel giant has been focusing on graphene, which can be mixed with plastic and recycled like brand-new products, among other attributes, he said.

Tata Steel is a leading global producer of graphene-enriched products - the biggest in the country and among the top 10 in the world. As compared to "asset heavy" steel - the core of Tata Steel, these new materials are asset light, he said.

The Economic Times

Steel prices ease over 10%, coal crisis playing havoc on secondary steelmakers

Steel sector players are facing some heat owing to high input commodity prices as finished steel products have begun to decline since April after the Russia-Ukraine war broke out. Prices in the long products segment have declined on an average of 10-15 per cent to Rs 57,000 per tonne in Kolkata market from a high of Rs 65,000 a tonne. Coal which is a key raw material for the secondary steel producers has turned out to be the major pain point, officials said.

Steel prices from leading players were higher at Rs 75,000-76,000 per tonne at its peak.

"Steel products, be it construction like TMT bars and structurals have come down between 10 and 15 per cent due to sluggish demand and are expected to ease a little more before it settles. While our costs have soared," Steel Rolling Mills Association chairman Vivek Adukia told PTI.

"Our costs have increased by 50 per cent despite a compromise on quality of inputs, secondary steel producers using Direct Reduced Iron (DRI) require high quality thermal coal to make sponge iron. The imported coal price which was USD 120 per tonne had shot up to USD 300 per tonne after the war broke out. The price is not sustainable unless passed through," he said.

The Economic Times

JSW Steel crude steel output rises 22% in April

JSW Steel said its crude steel production increased 22 per cent to 16.67 lakh tonne in April 2022. Crude steel production in April 2021 stood at 13.71 lakh tonne, JSW Steel said in a statement.

"JSW Steel reported crude steel production for the month of April 2022 at 16.67 lakh tonne, that grew 22 per cent Y-o-Y on standalone basis," it said.

Production of flat-rolled products rose 25 per cent to 12 lakh tonne over 9.57 lakh tonne in the year-ago period. Output of long-rolled products also increased 5 per cent to 3.54 lakh tonne, over 3.37 lakh tonne in the year-ago period.

The Economic Times

Vedanta outbids JPL for Athena

Anil Agarwal-promoted Vedanta has emerged as the highest bidder for bankrupt Athena Chhattisgarh Power Ltd, outbidding Naveen Jindal controlled Jindal Power Ltd (JPL) in an auction process that ran for 28 hours, two people aware of the development told ET.

Resources conglomerate Vedanta's final offer of Rs 565 crore was much higher than the staggered payment of Rs 400 crore it had offered under the corporate insolvency and resolution process (CIRP). The auction process, which started on the morning of May 6, ended the next day, the people said.

The Hyderabad National Company Law Tribunal ordered the liquidation of the thermal power project in May 2021 after the requisite majority of lenders rejected a plan submitted by Vedanta Ltd offering staggered payment of Rs 400 crore over a period of five years. The tribunal has ordered the sale of the thermal company as an ongoing process.

Vedanta's bid of Rs 565 crore is 16% higher than the Rs 485.3 crore reserve price set for the auction. The auction process of the Athena Chhattisgarh Power started in December 2021 with a reserve price of Rs 1,503 crore, as per the first auction notice. However, since the liquidator did not receive any bids in the initial rounds, it was lowered with every successive auction.

The Economic Times

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FUTURE-READY SOLUTIONS IN COMPOSITES
FOR NEW-GENERATION INDUSTRIES
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