Citation analysis and research impact of National Metallurgical Laboratory, India during 1972-2007: a case study

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ABSTRACT
This paper provides an insight into the citation analysis of research publications of the National Metallurgical Laboratory (NML) during the period 1972-2007. It analysed 2830 most valuable citations spread over 561 publications made by the NML scientists and researchers indexed in Science Citation Index (SCI) retrieved through the Web of Science. It determines the research and citation impact using parameters such as extent of citation received in terms of number of citation per paper, year wise break up of citation, domain wise citation, self citations and citation by others, diachronous self citation rate, citing authors, citing institutions, highly cited papers and categories of citing documents, citing journals and impact factor. A Bradford plot constructed to determine the core-citing journals shows that the curve is a typical S shape which indicates subject maturity.

Keywords: Citation analysis; Bibliometric analysis; Institutional citation analysis; Productometric analysis; Bradford's Law; Lotka's Law

INTRODUCTION

This study highlights valuable research contribution made by the scientists of the National Metallurgical Laboratory (NML) in the area of minerals, metals, metallurgy, and materials science. It is one of the oldest research laboratories of the Council of Scientific and Industrial Research, New Delhi, inaugurated by the architect of modern India, the late Pandit Jawhwarlal Nehru on 26 November 1950 at Jamshedpur (Jharkhand) Erstwhile Bihar, India.

In order to trace out the productometric analysis of NML publications, it is essential to include citation analysis; otherwise, one cannot judge the quality and impact of papers and their worldwide recognition. Citation brings out the connection between two documents, the one, which cites and the other, which is cited. This act is an expression of the importance of the material cited, as authors often refer to previous material to support, illustrate, or collaborate on a particular point (Garfield 1972, 1980). A highly cited work naturally is the one that has been found to be useful by relatively large number of authors, required a relatively large number of experiments. Citation count,

therefore reassures the scientific activity, utility, and influence of scientific work. However, citation count does not say anything about the nature, utility of the same.

Citation analysis constitutes an important tool in quantitative studies of science and technology. To assess the quality of a given publications, the number of times it has been cited in the literature can be counted. The use of citation analysis in research on the history of science is based on a literary model of the scientific process. Bibliometrics in particular is primarily concerned with the extent to which one published research is cited by other published research, which can certainly be used as a means of assessing research quality. However, practicing librarians are well aware of the limitations of bibliometrics. If they were asked, they would probably have a lot of valuable advice to give to government departments in the use of bibliometrics tools, such as citation analysis, to assess the research quality and reward the best research with the most funding. Considering the importance of citation analysis, a number of studies have been conducted worldwide (Garfield 1972; Moravcsik et al. 1976; Moed 1989, 1980; Minor and Dostatni 1991; Mahajan 1993; Gupta et al. 1999; Koganuramath et al. 2002; Vinkler 2004). Kademani et al. (2007) conducted a pioneer work on the publication productivity of the Chemistry Division of Bhabha Atomic Research Centre, India. The study analysed the citations to 1933 publications published during 1970-1999. The present study is an attempt to highlight the institutional citation analysis by analysing the most valuable and scholarly communications of 36 years of India's premier research laboratory involved in Minerals Metals, Metallurgy & Materials Science available in the Science Citation Index (SCI) retrieved through the Web of Science (available at http://www.isiknowledge.com)

OBJECTIVES

The main objective of the study is to highlight the citation impact of publications contributed by the National Metallurgical Laboratory during 1972 – 2007 indexed in SCI retrieved through Web of Science. The specific objectives of the study are to:

a) Find out the growth of citations;
b) Find out the time lag between a publication of a paper and its first citation;
c) Identify domain wise distribution of citations;
d) Identify highly cited papers and their citation life cycle;
e) Examine the scattering of citations among journals;
f) Unfold the distribution of the citing journals according to their impact factors;
g) Find out the distribution of citing papers according to country of publications;
h) Find out the Cited Authorship Productivity and Lotka's Law;
i) Draw the Bradford-Zipf citograph;
j) Identify the institutions in the citing papers;
k) Determine sector wise followed by the global distribution of citations;
l) Identify the language wise distribution of citations; and
m) Find out the types of documents citing NML publications.

METHODOLOGY

To determine the research impact through citation analysis of NML publications, the authors used SCI as the major source of data. The study covered a period of 36 years (1972-2007). It was initially planned to cover the period 1950-2007, however data was not available. During 1950-2007, a total of 4397 papers were published by NML. However, the

present study covers 1972-2007 as per the availability of data through SCI. Hence, the available data for 36 years was scanned, downloaded, analysed and further derived for interpretation. Domain wise classification of citations was done based on the Universal Decimal Classification (UDC) Scheme (BS: 1000 M-2005). Similarly, to determine the world wide visibility of NML's research and publication productivity, institution wise citations were highlighted with countries which were further categorised into sector wise distribution with the help of reference tools such as the World of Learning and the university handbook. Peer suggestions from NML scientists and technical personnel were also incorporated in the study.

RESULTS AND DISCUSSION

The search resulted in a total of 2830 citations spread over 561 research papers of NML were worked out over a spreadsheet data and further analysed as per the objectives of the study. The results are detailed and discussed as follows.

Growth of Citations

The stature and credibility of any scientific or research institution depends substantially on the number of citations which the contribution of its scientists and researchers receive. During 1972-2007, NML received a total of 2830 citations. The average number of citations per year was 78. The highest number of citations received was 572 in 2007. A continuous growth of citations was found throughout. The number of papers published and citation rate peaked during 2004 – 2007 as an inflow of the earlier papers have continued to receive citations. This indicates that the quality and quantity analysis go hand in hand. The citation rate increased more qualitative paper published earlier. Table 1 presents the growth of citations received by NML over the period of 36 years. Figure 1 presents the publication growth and trends of citations to make the same information (in Table 1) more crystal clear.

Table 1: Growth of Citations Received by NML during 1972-2007 as per SCI database

Years	Papers Published	Citations Received	Percentage	Cumulative Citations
1972-75	41	3	0.10	3
1976-79	40	16	0.56	19
1980-83	51	39	1.37	58
1984-87	42	28	0.98	86
1988-91	68	58	2.04	144
1992-95	160	212	7.49	356
1996-99	175	345	12.19	701
2000-03	214	541	19.11	1245
2004-07	396	1588	56.1	2830

Source: www.isiknowledge.com (Accessed on 28th December 2007)

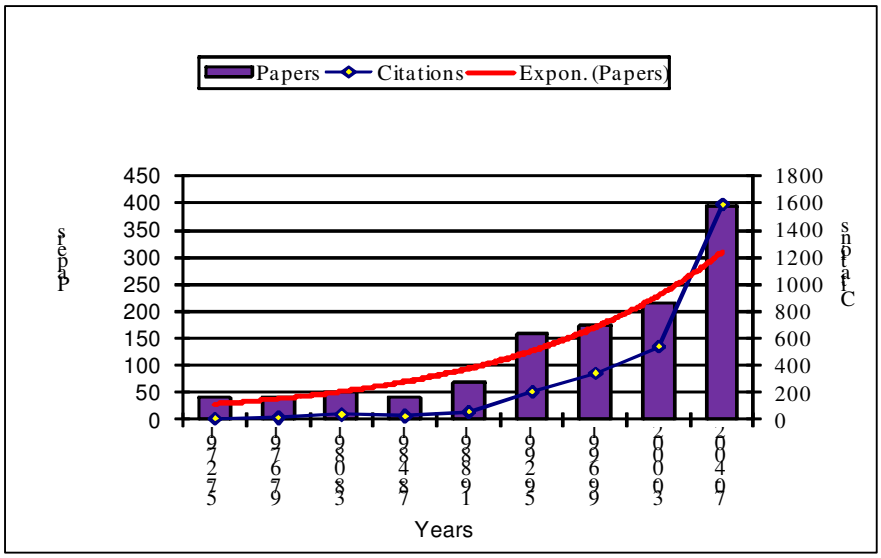

Figure 1: Trend of Papers Published and Citations Received during 1972-2007 as per SCI Database

Citedness of NML Publications during 1972-2007

The credibility of any scientific and research institution substantially depends upon its research output and intellectual publications. However, such publications become redundant and futile if they go unnoticed and are not referred to or cited by any scientists. Citedness reflects the frequency of citations. Citations frequency is a function of many variables besides scientific merit. Some of them are known and can be reusable assuming an author's reputation, comprehensiveness of the subject matter, circulation, availability and extent to library holdings, reprint dissemination, coverage by secondary services, priority in allocation of research funds, and clarification of their impact on citation frequency. One such variable is, however, obvious. If every article has an equal likelihood of being cited, it should follow that the more articles a journal publishes, the more frequently the journal will be cited. For the most part, the data show that such is indeed the case, although many articles are never cited. Considering the importance and its significance, citedness of NML publications was identified out and presented in Table 2.

Out of 1187 papers, 561 papers have received citation while the remaining 626 papers did not receive any citation. Out of 561 papers, one paper, published during 1990 – 1991 received 51 citations in Materials Science & Technology, followed by 44 citations during 1978 – 1979 in Applied Chemistry and Corrosion Science, and was 41 times cited during 2002 –2003 in the same research area. It clearly reflects that the research on Materials Science & Technology conducted by NML has acclaimed global recognition. Figure 2 reflects the citedness of NML publications.

There is always some percentages of papers remain uncited for a variety of reasons. The contents of the paper may be ahead of time and beyond the grasp of contemporary scientists, in contrast, same papers were published in an obscure journal. Ghosh and Neufeld (1974) who studied the uncitedness of articles in the *Journal of American Chemical Society* found that only 14.7% papers were not cited during any given year. Ghosh (1975) also studied the uncitedness of articles in the multidisciplinary scientific journal *Nature* and

found that an average of 48% of the test papers from *Nature* were uncited. Sharma and Sen (2005) stated that it is very difficult to find out the reasons for uncitedness for significant contributions as there is an easy mechanism, currently available other than through citation to ascertain the same.

Table 2: Citedness of NML Publications during 1972-2007

No. of Times Cited (A)	No. of Papers (B)	No. of Citations (AXB)	Cumulative	No. of Times Cited (A)	No. of Papers (B)	No. of Citations (AXB)	Cumulative
1	161	161	161	17	2	34	2281
2	114	228	389	18	4	72	2353
3	63	189	578	19	2	38	2391
4	51	204	782	20	1	20	2411
5	44	220	1002	21	1	21	2432
6	33	198	1200	22	2	44	2476
7	26	182	1382	23	3	69	2545
8	16	128	1510	24	1	24	2569
9	14	126	1636	29	1	29	2598
10	8	80	1716	30	1	30	2628
11	16	176	1892	32	1	32	2660
12	10	120	2012	34	1	34	2694
13	3	39	2051	41	1	41	2735
14	4	56	2107	44	1	44	2779
15	4	60	2167	51	1	51	2830
16	5	80	2247	-	-	-	-

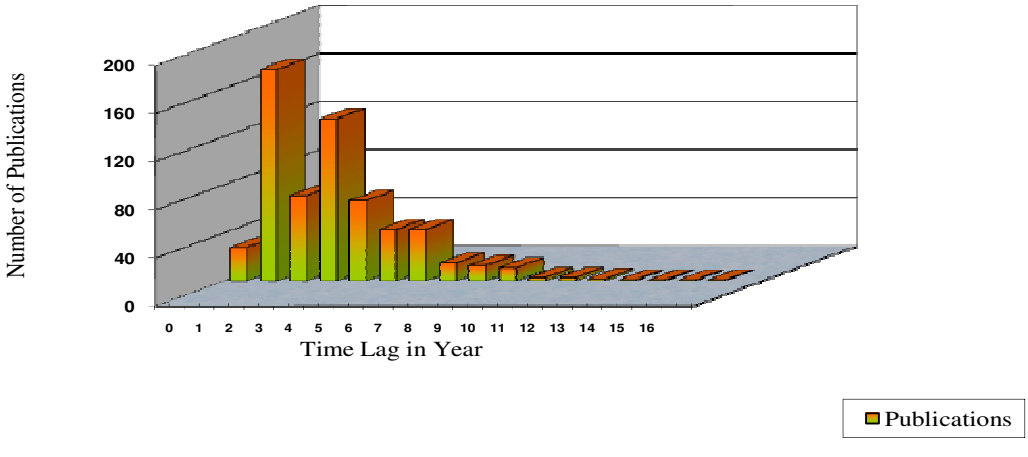

Figure 2: Citation Time Lag of NML Papers during 1972-2007 as per SCI database

Domainwise Distributions of Citations

The basic objective of Table 3 is to unmask the different subject areas in which the learned papers of NML scientists were cited during 1972-2007. The paper contributed by the scientists of NML have been cited in 46 broad subject areas, ranging from Materials Science to Physics, and from Fluid to Plasmas. These subjects along with the number of citations received in each are enumerated in descending order in Table 3.

To judge the quality of NML citations according to the subject areas, the data and broad key words were downloaded from SCI database and further analysed and categorised as per UDC classification scheme. The findings indicate that Materials Science (620.1) was highly cited and received the maximum of 1123 citations (28.30%) ; followed by Metallurgy & Metallurgical Engineering (669) with 521 citations (13.13%) and Physics, Multidisciplinary (52/539.839) obtained 182 citations (4.58%). Other subject areas appear to be quite insignificant in terms of citations received. The distribution of citations are further classified and condensed under 6 broad subject areas as depicted in Figure 3.

Table 3: NML Papers Cited in different Subject Area During1972-2007 as per SCI database

Subject	Classification Number (UDC)*	Citations	Percentage	Cumulative Citations
Materials Science	620.1	1123	28.30	1123
Metallurgy & Metallurgical Engineering	669	521	13.13	1644
Physics, Multidisciplinary	52/539.893	182	4.58	1826
Chemical Engineering	66	181	4.56	2007
Physics, Applied	53	180	4.53	2187
Nanoscience & Nanotechnology	620.3	166	4.18	2353
Chemistry and Chemical Technology	54:66	163	4.10	2516
Mining & Mineral Processing	622.7	155	3.90	2671
Chemistry, Analytical	543	138	3.47	2809
Physics, Condensed Matter	538.9	135	3.40	2944
Electrochemistry	544.6	123	3.10	3067
Environmental Sciences	504	115	2.89	3182
Ceramics	666	101	2.54	3283
Mineralogy	549	80	2.01	3363
Environmental Engineering,	504	77	1.94	3440
Mechanical Engineering,	621	70	1.76	3510
Civil Engineering	624	58	1.46	3568
Manufacturing Engineering	67.02	52	1.31	3620
Sciences &Technology Multidisciplinary	6	33	0.83	3653
Mechanics	531	32	0.80	3685
Water Resources	551.444	31	0.78	3716
Biotechnology & Applied Microbiology	60	29	0.73	3745
Spectroscopy	543.42	25	0.63	3770
Computer Science, Applications	004	25	0.63	3795
Energy & Fuels	620.9	24	0.60	3819
Chemistry, Inorganic & Nuclear	546	20	0.50	3839
Crystallography	548	16	0.40	3855
Electrical & Electronic Engineering	621.3/.38	14	0.35	3869
Thermodynamics	536.7	13	0.32	3882

Instruments & Instrumentation	681.2	12	0.30	3894
Soil Science	631.4	12	0.30	3906
Biochemistry & Molecular Biology	577	10	0.25	3916
Nuclear Science & Technology	621.039	10	0.25	3926
Geochemistry & Geophysics	550.3/.8	6	0.15	3932
Optics	535	5	0.12	3937
Geosciences, Multidisciplinary	550	4	0.10	3941
Microbiology	579	4	0.10	3945
Microscopy	543.456	3	0.07	3948
Plant Sciences	581	3	0.07	3951
Public , Occupational Health & Safety	614.87	3	0.07	3954
Toxicology	615.9	3	0.07	3957
Acoustics	534.8	2	0.05	3959
Biophysics	577.3	2	0.05	3961
Engineering, Aerospace	629.73	2	0.05	39663
Mathematics, Applied	519.677	2	0.05	3965
Physics, Fluids & Plasmas	532:533.92	2	0.05	3967

*Citation classified as per UDC Scheme (BS 1000M: 1993)

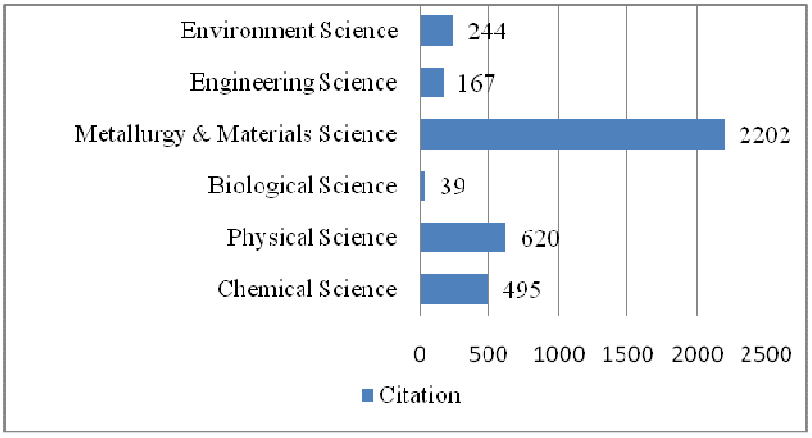

Figure 3: Broad Subject Wise Distribution of Citation (1972-2007)

Highly Cited Papers of NML during 1972-2007

The potentiality and credibility of a researcher and his/her research findings are often judged by the number of times the papers have been cited. The more a paper is cited, the greater would be its research value and impact as often assumed. Adopting Kademani et al.'s (2007) model on the presentation of highly cited papers, a total of 25 highly cited papers authored by NML scientists with the bibliographical details is presented in Table 4.

The paper P1 received a total of 51 citations during 1991 –2007, out of which six were self-citations. This paper has received citations after one year of its publication with average citations of 2.68 per year. There were 25 journals citing this papers and the diachronous self-citation rate was 11.76.

The paper P2 received 44 Citations during 1978 – 2007, out of which, four were self-citation. This paper has received citations after one year of its publications and continues

to receive citations until the period under study. There is however, a declining trend noticed last year. This paper was four times self-cited by the author. The average citation per year was 1.24. There were 14 journals in total citing this paper. The diachronous self-citation rate was 9.09.

The paper P3 received 41 Citations during 2002 to 2007, out of which 2 were self- citations. This paper received citations in the same year of its publication and continues to receive citations until the period under study. This paper has been cited in 21 journals and the average rate of citation per year was 5.86. The diachronous self-citation rate was 4.87.

The paper P4 received 34 citations during 1993-2007. There is no self-citation at all. This paper has received citations after one year of its publication and continues to be cited until the period under study. The average rate citation per year was 2.12.

Table 4: Highly Cited Papers of NML

Paper	Bibliographic details of Highly Cited papers	SC	CO	TC	CTY	DR	Average Citation
P1	**Ghosh RN**, Curtis RV, Mclean M. Creep deformation of Single- Crystal Superalloys Modeling - the Crystallographic Anisotrophy. *Acta Metallurgica Et Materialia,* **V**.38 (10), pp 1977-1992 (1990).	6	45	51	1	11.76	2.68
P2	**Pillai KC, Narayan R.** Inhibition of Corrosion of Iron in Acids by Thiourea and Derivatives. *Journal of the Electrochemical Society,* **V.**125 (9), pp 1393-1397 (1978).	4	4	44	1	9.09	1.24
P3	**Chakravarty S, Dureja V, Bhattacharyya G, Maity S, Bhattacharjee S.** Removal of arsenic from groundwater using low cost ferruginous manganese ore. *Water Research*, **V**.36 (3), pp 625-632 (2002).	2	39	41	0	4.87	5.86
P4	**Singh I.** Inhibition of Steel Corrosion by Thiourea Derivatives. *Corrosion,* **V***.49 (6), pp 473-478 (1993).*	0	34	34	1	0	2.12
P5	**Singh DDN, Dey AK.** Synergistic Effects of Inorganic and Organic Cations on Inhibitive Performance of Propargyl Alcohal on Steel Dissolution in Boiling Hydrochloric-Acid Solution. *Corrosion*, **V**.49 (7), pp 594-600 (1993).	4	28	32	3	12.50	2.00
P6	**Bose SK, Kumar R.** Structure OF Rapidly Solidified Auminium-Siliocon Alloys. *Journal of Materials Science*, **V**.8 (12), pp1795-1799 (1973).	2	28	30	2	6.66	0.86
P7	Rath, C, Anand S,Das RP, **Sahu KK**, Kulkarni SD, Date,SK,Mishra NC. Dependence on Cation distribution of particle size, lattice parameter, and magnetic properties in nanosize Mn-Zn ferrite. *Journal of Applied Physics*, **V** 91(4), pp 2211-2215 (2002)	2	27	29	0	6.89	4.14
P8	Balaraju JN, **Narayanan TSNS**, Seshadri SK. Electroless Ni-P composite coatings. *Journal of Applied Electrochemistry*, **V**.33 (9), pp 807-816 (2003).	4	20	24	3	16.66	4.00
P9	**Jha MK, Kumar V,** Singh RJ. Review of Hydrometallurgical recovery of zinc from industrial wastes. *Resources Conservation and Recycling*, **V** 33(1), pp 1-22 (2001).	0	24	24	3	0	3.00
P10	Rath C, Mishra NC,Anand S,Das RP, **Sahu KK,** Upadhyaya C, Verma HC. Appearance of supermagnetism on heating nanosize MnO.65.ZnO.35Fe_2O_4, *Applied Physics Letters*, **V**53 (1-2), pp475-477 (2000).	2	22	24	0	8.33	2.67
P11	Sekhar KC, Subramanian S, **Modak JM,** Natarajan KAI. Removal of metal ion using an industrial biomass with reference to environmental control. *International Journal of Mineral Processing,* **V.53** (1-2), pp 107-120 (1998).	1	23	24	1	4.16	2.18
P12	**Chatterjee P, Banerjee MK, Mukherjee KP.** Synergistic Inhibition of Inorganic Anions with Pyridine-Derivatives for Steel in Hydrochloric-acid. *Indian Journal of Technology*, **V**29 (4), pp 91-194 (1991).	0		23	4	0	1.28

P13	**Pati BB, Chaterjee P, Singh TB, Singh DDN.**Effect Propargyl Alcohal on Corrosion and hydrogenation of Steel in Hydrochloric-Acid Solution. *Corrosion,* **V**. 46(6), pp 354-359 (1990).	1	21	22	3	4.54	1.16
P14	**Singh M, Kumar R.** Structure of Liquid Aluminium-Silicon Alloys. *Journal of Material Science*, V.83), pp 317-323 (1973).	1	20	21	2	4.76	0.58
P15	Upadhyay C,Verma HC,Rath C, **Sahu KK,** Anand S, Das RP,Mishra NC. Mossbbauer studies of nanosize Mn1-x ZnxFe2o4. *Journal of Alloys and compounds,* **V** 326 (1-2) ,pp 94-97 (2001)	7	13	20	1	35.00	2.50
P16	Samantaray SK, **Mishra T, Parida KM**. Studies on Anion Promoted Titania 2: Preparation, Chracterisation, and Catalytic Activity Towards Aromatic Alkylation over Sulfated Titania. *Journal of Molecular Catalysis "A"-Chemicals,* V.156 (1-2), pp 267-274 (2000).	3	16	19	1	15.78	2.11
P16	Parsad BK,**Venkateswarlu K**, Modi OP, Jha AK, Das S, Dasgupta R, Yegneswaran AH. Sliding wear behavior of some Al-Si alloy: Role of shape and size of Si particles and test conditions. *Metallurgical and Materials Transaction "A"-Physical Metallurgy and Materials Science*, **V**29 (11), pp 2747-2752 (1998).	0	19	19	3	0	1.90
P17	**Narasimhan BRV, Prabhakar S, Manohar P**, Ginanam FD. Synthesis of gamma ferric oxide by direct thermal decomposition of ferrous carbonate. *Materials Letters*, **V**52 ((4-5), pp 295-300 (2002).	0	18	18	1	0	3.00
P18	Rath C, **Sahu KK**, Kulkarni SD, Anand S, Date SK, Das RP,,Mishra NC. Micostructure-dependent coercivity in monodispodersed hematite particles. *Applied Physics Letters*, **V**.75 (26), pp 4171-4173 (1999).	0	18	18	4	0	2.25
P19	**Prasad S**, **Pandey BD**. Alternative processes for treatment of chalcopyrite - A review. *Minerals Engineering,* **V.** 11 (8) pp 763-781 (1998**).**	0	18	18	1	0	1.80
P20	**Das NN, Konar J, Mohanta MK, Srivastava SC**. Adsorption of Cr (VI) from their aqueous solution onto Zr4+ - substituted ZnAl/MgAl- layered double hydroxides: effect of Zr+ substitution in the layer. *Journal of Colloid and Interface Science*, **V**.270 (1), pp 1-8(2004).	1	16	17	0	0	4.00
P 21	**Kumar S, Singh KK, Ramachandrarao P.** Effects of fly ash addition on the mechanical and other properties of porcelainised stoneware tiles. *Journal of Materials Science*, **V**.36 (24), pp 5917-5922 (2001).	2	15	17	3	11.76	2.43
P22	Murugananthan M**, Raju GB, Prabhakar S.** Separation of pollutants from tannery effluents by electroflotation.Separation and Purification Technology, **V**.40 (1), pp 69-75 (2003).	1	15	16	1	6.25	4.00
P23	**Ghosh A**, **Das S**,Chatterjee S, Mishra B, **Rao PR**. Influence of thermo- mechanical processing and different post-cooling techniques on structure and properties of an ultra low carbon Cu bearing HSLA forging, *Materials Science and Engineering "A"- Structural Materials Properties Microstructure and Processing*, **V**. 348(1-2),pp 299-308 (2003).	7	9	16	1	43.75	3.20
P24	**Pathak LC, Ray AK, DasA, Sivaramakrishnan CS, Ramachandrarao P.** Carbothermal synthesis of nanocrystalline aluminium nitride power. *Journal of the American Ceramic Society*, **V**. 82(1), pp 257-260 (1999).	0	16	16	1	0	1.78
P25	**Bahadur A, Mohantay ON**. Structural studies of hot dip Aluminized coatings on mild-steel. *Materials Transactions JIM*, V. 32(11), pp 1053-1061 (1991).	1	15	16	4	6.25	1.00

Source: www.isiknowledge.com (Accessed on 28 December 207)
Author highlighted in bold represents author affiliated with NML, India.
SC-Self Citation, CO- Citation by others, TC-Total Citation, CTY-Citation Lag, DR-Diachronous ratio (determined by applying the following formula)

$$\text{Diachronous self Citation} = \frac{\text{Self-Citation to an article in SCI Database}}{\text{Total number of Citations Received to an Article in SCI Database}} \times 100$$

Journal-wise Citation of NML Papers

During 1972-2007, a total of 500 journals cited 2830 citation of NML research papers. The maximum papers were cited in *Materials Science & Engineering "A" - Structural Materials Properties and Processing* (Switzerland) with 125 citations, which constitute 4.41% of the total 2830; followed by *Transactions of the Indian Institute of Metals* (India*)* with 79 citations (2.79%), and *Journal of Materials Science* (USA) embodied 68 citations and shared 2.40% of the total citations. A list of top 20 journals is presented in Table 5.

Table 5: Journal Citing NML Scientists during 1972-2007 as per Science Citation Index (SCI)

Titles	Impact Factor (2005)	Papers Cited	Percentage	Cumulative
Materials Science & Engineering "A"	1.347	125	4.41	125
Transactions of the Indian Institute of Metals	0.215	79	2.79	204
J of Materials Science	0.901	68	2.40	272
Hydrometallurgy	1.163	59	2.08	331
Corrosion Science	1.922	53	1.87	384
J of Magnetism & Magnetic Materials	0.985	52	1.83	436
Surface & Coatings Technology	1.646	50	1.76	486
Corrosion	0.853	49	1.73	535
Metallurgical & Materials Transactions "A"	1.232	49	1.73	584
J of Hazardous Materials	1.544	40	1.41	624
Engineering Failure Analysis	0.410	38	1.34	662
Scripta Materialia	2.228	38	1.34	700
Bulletin of Materials Science	0.777	35	1.23	735
J of Applied Electrochemistry	1.282	35	1.23	770
Minerals Engineering	0.678	35	1.23	805
Separation Science & Technology	0.834	35	1.23	840
J of Materials Research	2.104	33	1.16	873
Materials Research Bulletin	1.381	33	1.16	906
Metallurgical & Materials Transactions "B"	0.874	33	1.16	939

(Source: www.isiknowledge.com, Accessed on 28 December 2007)

Journal Impact Factor

The dynamic and internal structures of any system of scientific communication are greatly influenced by varying quality of the primary journals in which scientific communications are published. Another journal evaluation factor, the ISI Journal Impact Factor (JIF), attracted calculation by dividing the number of current citations to items published in the two previous years by the total number of articles and reviews published annually by the Institute of Scientific Information (ISI), and the results are published in the Journal Citation Reports (JCR). JIF was originally envisaged only as an aid for scientific libraries for the evaluation of their choice of scientific journals. JIF today is used by anyone who analyses and evaluates research in regard to assessment and prioritizing the allocation of funds (Wallin 2005).

The number of citations it receives primarily determines the impact factor of any publication of a research output. The range of IF which spread over 404 journals carrying the 2830 citations of NML papers are grouped under nine broad range of frequencies (Table 6).

Table 6: Distribution of Citations by the Impact Factor

Impact Factor Range	Number of Journals	Percentage	Number of Citation	Percentage
0	96	19.20	256	9.04
0.01-0.5	95	19.00	371	13.10
>0.51-1.0	98	19.60	761	26.89
>1.00-2.00	128	25.60	1065	37.63
>2.00-3.00	45	9.00	236	8.38
>3.00-4.00	19	3.80	84	2.96
>4.00-5.00	9	1.80	32	1.13
>5.00-10.00	9	1.80	24	0.84
>10.00-30.00	1	0.20	1	0.03
Total	500	100.00	2830	100.00

During 1972-2007, NML received a total of 2830 citations spread over 500 Journals. It is observed that, only 96 journals (19.20%) are noticed without Impact Factor (IF) and the remaining 404 (81.45%) are with IF. Table 6 depicts the journals classified according to the IF range which varies from 0.01-30.00 followed by citations. The findings reveal that IF range >1.00-2.00 covered the maximum number of 128 journals and 37.63% citations , followed by IF range >0.51-1.0 covered 98 journals with 26.89% citations, and IF range that falls between 0.01-0.5 include 95 journals with 13.10% citations. The highest impact factor of the journals were NML research findings cited in *Nature:* IF-29.271*;* followed by *Nanoletters:* IF- 9.847*, and Advanced Materials:* IF 9.103. Figure 4 unearths the number of citations at different IF range for last 36 years which can be referred to judge the quality of research and development carried out at NML.

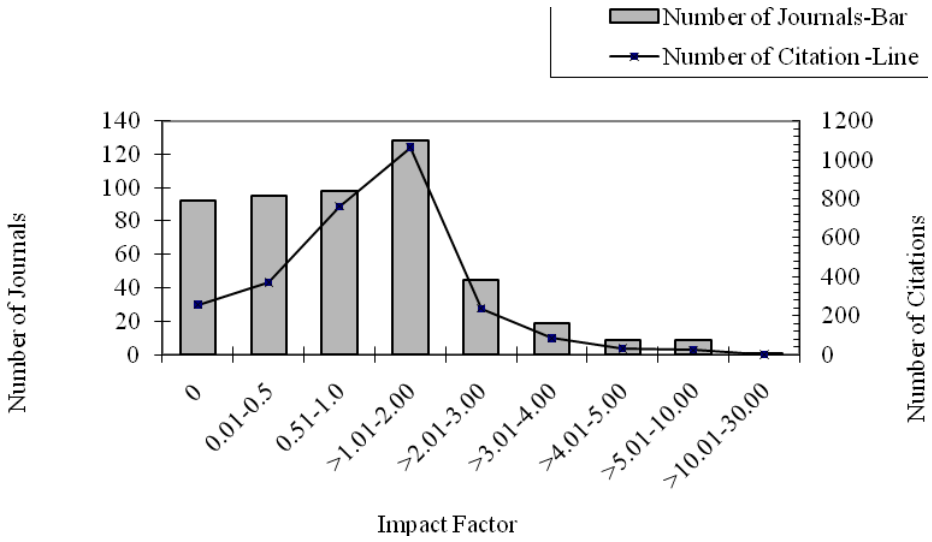

Figure 4: Plot of Number of Citation at the Different Impact Factor- Range during 1972-2007

Application of Bradford Curve

Bradford's Law of Scattering is the most popular and the best known among the several bibliographic concept, that try to describe the effective working of sciences by mathematical means. The law describes a quantitative relation between journals. Table 7 depicts analysis of journals based on number of citations followed by journals with rank. Figure 5 illustrates the Bradford-Zipf plot – the cumulative number of papers for each journal against the logarithm of its rank – for journals citing NML publications. It clearly demonstrates approximately the S-shape as the typical Bradford-Zipf plot, although the initial rise is somewhat faster than the typical one. The approximately linear portion appears at the journal rank of 25. The top 25 may be considered as the core journals that cited NML.

Table 7: Citation Trend of Journal during 1972-2007 as per SCI database

Number of Citations	Number of Journals	Cumulative Journals	Cumulative Journals Percentage	Total Number of Citation to Journal of Equal Rank	Cumulative Citations	Cumulative Citations Percentage
125	1	1	0.20	125	125	4.41
79	1	2	0.40	79	204	7.20
68	1	3	0.60	68	272	9.61
59	1	4	0.80	59	331	11.69
53	1	5	1.00	53	384	13.56
52	1	6	1.20	52	436	15.40
50	1	7	1.40	50	486	17.17
49	2	9	1.80	98	584	20.63
40	1	10	2.00	40	624	22.02
38	2	12	2.40	76	700	24.73
35	4	16	3.20	140	840	29.68
33	3	19	3.80	99	939	33.18
32	2	21	4.20	64	1003	35.44
28	1	22	4.40	28	1031	36.43
26	1	23	4.60	26	1057	37.34
25	5	28	5.60	125	1182	41.76
24	3	31	6.20	72	1254	44.31
23	2	33	6.60	46	1300	45.93
22	1	34	6.80	22	1322	46.71
21	3	37	7.40	63	1385	48.93
20	5	42	8.40	100	1485	52.47
19	2	44	8.80	38	1523	53.81
18	3	47	9.40	54	1577	55.72
17	2	49	9.80	34	1611	56.92
15	3	52	10.40	45	1656	58.51
14	3	55	11.00	42	1698	60.00
13	3	58	11.60	39	1737	61.37
12	2	60	12.00	24	1761	62.22
11	4	64	12.80	44	1805	63.78
10	3	67	13.40	30	1835	64.84
9	7	74	14.80	63	1898	67.06
8	5	79	15.80	40	1938	68.48
7	6	85	17.00	42	1980	69.96
6	6	91	18.20	36	2016	71.23
5	19	110	22.00	95	2111	74.59
4	50	160	32.00	200	2311	81.66
3	61	221	44.00	183	2494	88.12
2	57	278	55.60	114	2608	92.15
1	222	500 **CJ**	100.00	222	2830 **CC**	100.00

CJ=500 Total number of journals cited NML papers

CC= Total number of citations received by 500 journals

Average citation per journal= (CC)/ (CJ) =2830/500 = 5.66

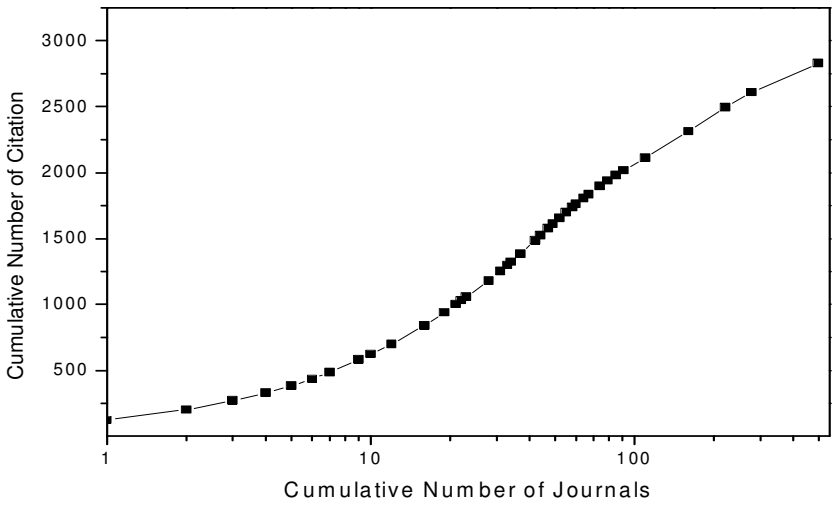

Figure 5: Bradford's Curve of Journal Ranking and the Cumulative Number of Citations

Country-wise Distribution of Citing Journals

The quantum of citations of any research output and intellectual thought content depend upon several factors such as quality and authenticity of research output, subject of investigation, nascence and validation of the invention or findings, and sometimes the popularity of the researchers and scientists along with the flow of fund and infrastructure. The priority for a nation on research and stimulus often help to increase the research output. In order to determine the number of citations each nation or country receives, the resultant data are depicted in Table 8 for statistical analysis.

All countries appeared in the "country of affiliation" field in the citing papers were counted. In all, there were 73 countries in the citing papers with a total of 2830 frequencies. The most frequently occurred countries in the citing papers were: India (1018, 35.97%) with 90 institutions/organisations were involved in citing NML research findings; followed by Peoples Republic of China (333, 12.01%) with 279 institutions/organisations citing NML papers, and United States of America (USA) (88, 9.85%) with 88 institutions/organisations participated in citing NML papers. Analysis reflects a huge number of countries citing NML research findings in their respective research. It can therefore be safely inferred that NML research is of international conformity and it has acclaimed worldwide recognition in its research field.

Table 8: Country-wise Distribution of Citing Journals (1972-2007)

Citing Country	Number of Org/Inst Cited	Numbers Of Citations	Percentage	Cumulative
India	90	1018	35.97	1018
China	69	333	12.01	1358
USA	88	279	9.85	1637
Japan	30	112	4.02	1751
Turkey	30	98	3.46	1849

Spain	23	81	2.86	1930
South Korea	22	80	2.82	2010
Egypt	18	76	2.68	2086
France	18	61	2.15	2147
England	18	59	2.08	2206
Germany	24	55	1.94	2261
Australia	18	51	1.80	2312
Brazil	13	43	1.51	2355
Canada	10	38	1.34	2393
Iran	10	30	1.06	2423
Poland	16	26	0.91	2449
Italy	9	25	0.88	2474
Taiwan	4	22	0.77	2496
Portugal	6	21	0.77	2517
Finland	6	19	0.67	2536
South Africa	7	19	0.67	2555
Greece	4	18	0.63	2573
Switzerland	5	18	0.63	2591
Sweden	4	17	0.60	2608
Russia	4	16	0.56	2624
Mexico	3	16	0.56	2640
Czech Republic	3	12	0.42	2652
Morocco	10	11	0.38	2663
Belgium	3	10	0.35	2673
Hungary	4	10	0.35	2683
Ukraine	6	9	0.31	2692
Norway	3	9	0.31	2701
Cuba	2	8	0.28	2709
Romania	3	8	0.28	2717
Bangladesh	4	7	0.24	2724
Singapore	3	7	0.24	2731
Austria	3	6	0.21	2737
Chile	4	6	0.21	2743
Scotland	4	6	0.21	2749
Croatia	3	6	0.21	2755
Argentina	5	5	0.17	2760
Thailand	3	5	0.17	2765
Netherlands	3	5	0.17	2770
Denmark	2	5	0.17	2775
Malaysia	2	4	0.14	2779
Slovenia	1	4	0.14	2783
Israel	2	4	0.14	2787
Lithuania	2	3	0.10	2790
Pakistan	3	3	0.10	2793
Yugoslavia	1	3	0.10	2796
Luxembourg	1	3	0.10	2799
Slovakia	1	2	0.07	2801
Algeria	1	2	0.07	2803
Nigeria	2	2	0.07	2805
Ireland	2	2	0.07	2807
Ghana	1	2	0.07	2809
Lebanon	1	2	0.07	2811
New Zealand	1	2	0.07	2813
Tunisia	2	2	0.07	2815
Vietnam	2	2	0.07	2817
USSR	1	1	0.03	2818

Colombia	1	1	0.03	2819
Saudi Arabia	1	1	0.03	2820
Venezuela	1	1	0.03	2821
Indonesia	1	1	0.03	2822
Jordan	1	1	0.03	2823
Albania	1	1	0.03	2824
Estonia	1	1	0.03	2825
Kuwait	1	1	0.03	2826
Oman	1	1	0.03	2827
Sri Lanka	1	1	0.03	2828
Syria	1	1	0.03	2829
U. Arab Emirates	1	1	0.03	2830

(Source-www.isiknowledge.com. Accessed on 28 November 2007)

Core Authors Cited in NML Papers

This study also aims to unmask those key authors who have been cited in NML papers. It has been universally accepted in the bibliometric world that, the more and more an author is cited, the greater the impact of his/her publications would be. An author is considered prolific and respectable if the researchers/scientists in the similar filed cited his/her contributions more frequently.

All the authors appeared in the cited papers were counted. In all, there were 1091 authors in the paper citing NML publications which had 2830 authorship. The ratio of authors and cited articles comes to 2.59. Cited authors with authorship for the entire citation of the 36 years period are listed in Table 9. This seems to indicate how well and scientifically the research is carried out at NML with mainstream research in the area of minerals, metals, metallurgy, and materials science. The core authors cited were obviously from NML itself. It is interesting to note that, most of the cores cited authors are also the highly productive scientists. The top three core authors whose names have appeared in the cited papers of NML with their authorship were S.K.Das with 45 papers (1.59%) from the total 2830 citations; followed by A.K.Ray (36 papers; 1.27%) and A.Mitra (31 papers; 1.09%).

Application of Lotka's Law

Lotka's law describes the frequency of publication by an author in a given field and states that the number of authors figured in contributions is about $1/n^2$ of those making one and the proportion of all contributors that make single contribution, is about 60%. This means that out of all the authors in a given field, about 60% authors will have just one publication each; 15% will have two publications each ($1/2^2$ of 60); about 7% of author will have three publications each ($1/2^3$ of 60) and so on. Further, according to Lotka's law of scientific productivity, only six percent of the authors in a field will produce more than 10 articles. Lotka's law, when applied to large bodies of literature over a long period, can be accurate in general, but not statistically exact. The general form of Lotka's law can be expressed as under $Y=C/X^n$ Where Y is in the percentage of author, X is the number of articles published by an author, C is the constant and n is the log-log plot.

Table 9: Authors Citing NML Papers during 1972-2007 as per SCI database

Author(s)	Cited Papers	%	Author(s)	Cited Papers	%
Das, SK	45	1.59	Venkatachari, G	9	0.31
Ray, AK	36	1.27	Bagchi, D	8	0.28
Mitra, A	31	1.09	De, PK	8	0.28
Das, S	25	0.88	Fahrenholtz, WG	8	0.28
Ghosh, RN	23	0.81	Gupta, KK	8	0.28
Ramachandrarao, P	22	0.60	Kumar, A	8	0.28
Panda, AK	21	0.74	Kumar, BR	8	0.28
Ram, S	21	0.74	Mohanty, ON	8	0.28
Pandey, BD	20	0.70	Mu, GN	8	0.28
Chatterjee, S	19	0.67	Raju, GB	8	0.28
Chattoraj, I	19	0.67	Ranganathan, S	8	0.28
Mukhopadhyay, NK	19	0.67	Ray, HS	8	0.28
Das, G	17	0.60	Roy, N	8	0.28
Tarafder, S	17	0.60	Rupa, PKP	8	0.28
Ghosh, A	16	0.56	Sarma, DS	8	0.28
Pathak, LC	16	0.56	Sendhilnathan, S	8	0.28
Prakash, S	16	0.56	Shibli, SMA	8	0.28
Mishra, SK	15	0.53	Sivaramakrishnan,CS	8	0.28
Narayanan, TSNS	15	0.53	Srikanth, S	8	0.28
Quraishi, MA	15	0.53	Takasugi, T	8	0.28
Singh, DDN	15	0.53	Upadhyay, C	8	0.28
Singh, R	14	0.49	Wang, J	8	0.28
Agrawal, A	13	0.45	Wu, SH	8	0.28
Sivaprasad, S	13	0.45	Dana, K	7	0.24
Bhattacharjee, S	12	0.42	Dwivedi, DK	7	0.24
Jing, ZH	12	0.42	Godkhindi, MM	7	0.24
Ranganath, VR	12	0.42	Goswami, B	7	0.24
Sahoo, Kl	12	0.42	Hilmas, GE	7	0.24
Bhattacharya, DK	11	0.38	Mukherjee, S	7	0.24
Chaudhuri, S	11	0.38	Muralidharan, S	7	0.24
Chowdhury, SG	11	0.38	Murty, BS	7	0.24
Jana, Rk	11	0.38	Rajeswari, S	7	0.24
Rao, V	11	0.38	Ravichandran, K	7	0.24
Sinha, A	11	0.38	Sahay, SK	7	0.24
Das, RP	10	0.35	Seshadri, SK	7	0.24
Ghosh, S	10	0.35	Singh, AK	7	0.24
Godiwalla, KM	10	0.35	Srivastava, VC	7	0.24
Kumar, V	10	0.35	Tiwari, YN	7	0.24
Mclean, M	10	0.35	Venkateswarlu, K	7	0.24
Ray, RK	10	0.35	Ahmad, S	6	0.21
Sahu, KK	10	0.35	Anton, JG	6	0.21
Verma, HC	10	0.35	Bahadur, A	6	0.21
Anand, S	9	0.31	Bose, SC	6	0.21
Kumar, R	9	0.31	Das, DK	6	0.21
Ray, KK	9	0.31	Demura, M	6	0.21
Reed, RC	9	0.31	Hirano, T	6	0.21
Roy, PK	9	0.31	Jamal, D	6	0.21

Analysis and Interpretation

Table 10 shows that all single authors contributed a total of 648 citations (59.39%); followed by 2 authors contributed 148 citation (13.56%) and 3 authors registered 62 citations (5.68%). To validate Lotka's Law, a plot was made by a number of authors and the percentage of their publications. As shown in log-log plot of Figure 6, low and medium productive cited authors are not a good fit but the high productive authors can be said as a good fit in the line. Authorship pattern for authors cited NML papers is not inconformity with the original Lotka's law. This is true that, over the passage of time, the profile of research in a given field has transformed and the trends of applied or multidisciplinary research outputs are not being fit into the old established laws, however this can be debated (Patra and Chand 2005). Metallurgy and materials science is also of multidisciplinary nature because it is assimilated with physical science, chemical science, environmental science, earth science and other branches of science and technology.

Table 10: Authors and their Number of Citations (1972-2007) as per SCI database

Number of Citation by an Authors X	Numbers of Authors Y	Percentage of Authors	Cumulative Author	Total Citation XY	Cumulative	Percentage
1	648	59.39	648	648	648	22.89
2	148	13.56	796	296	944	33.35
3	62	5.68	858	186	1130	39.92
4	82	7.51	940	328	1458	51.51
5	38	3.48	978	190	1648	58.23
6	27	2.47	1005	162	1810	63.95
7	16	1.46	1021	112	1922	67.91
8	22	2.01	1043	176	2098	74.13
9	6	0.54	1049	54	2152	76.04
10	8	0.73	1057	80	2232	78.86
11	6	0.54	1063	66	2298	81.20
12	4	0.36	1067	48	2346	82.89
13	2	0.18	1069	26	2372	83.81
14	1	0.09	1070	14	2386	84.31
15	4	0.36	1074	60	2446	86.43
16	3	0.27	1077	48	2494	88.12
17	2	0.18	1079	34	2528	89.32
19	3	0.27	1082	57	2585	91.34
20	1	0.09	1083	20	2605	92.04
21	2	0.18	1085	42	2647	93.53
22	1	0.09	1086	22	2669	94.31
23	1	0.09	1087	23	2692	95.12
25	1	0.09	1088	25	2717	96.00
31	1	0.09	1089	31	2748	97.10
36	1	0.09	1090	36	2784	98.37
45	1	0.09	1091	45	2830	100.00

(Source:www.isiknowledge.com)

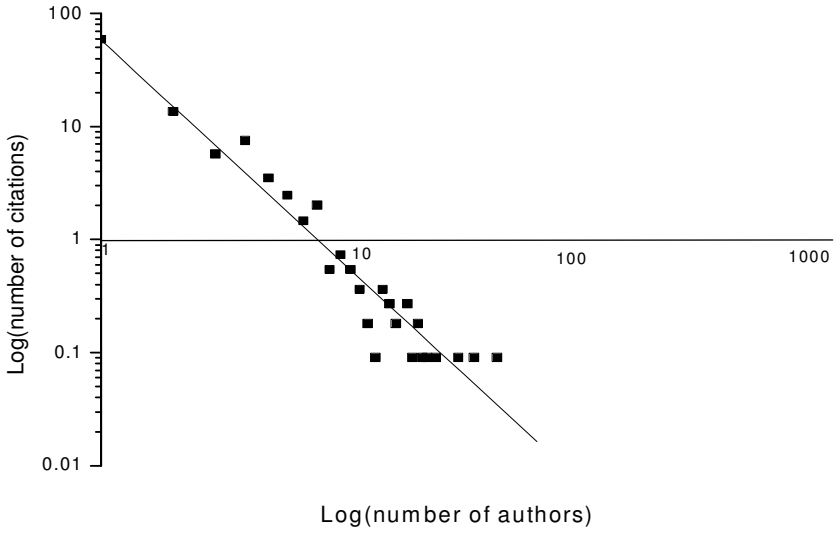

Figure 6: Authorship Pattern for Authors Cited NML Papers

Identification of Institutions Citing NML Papers (1972-2007)

A citation study facilitates in framing the structure of knowledge and links one research area to another or within one research area. Similarly, institutions/organisations citing papers reflect some relation in works areas. Therefore, it may open the avenue of collaboration among the citing institutions. It has become not only imminent but also necessary for nations to have collaborative research among developed and developing countries in order to accept the emerging challenges posed by population explosions. A total of 655 institutions have been identified for citing NML papers in their respective research findings. Table 11 depicts the lists of top 30 institutions which have cited NML papers.

The top three institutions/organisations that cited NML papers are from India, with the National Metallurgical Laboratory taking the lead (327 citations; 11.55%), followed by Indian Institute of Technology (174 citations; 6.14%) and Banaras Hindu University (61 citations; 2.15%). Few anonymous addresses were also found, which had been ignored for the purpose of this study and these addresses are categorized into the category "Others". Findings in the subsequent section indicate that universities are leading in citing NML papers.

Sectoral Distribution of Citations

Out of the 655 institutions citing NML papers, a total of 471 (71.90%) are academic institutions, followed by research and development institutions/organisations (103; (15.72%) and industries (46; 7.02%). Figure 7 presents the sector-wise distribution of citations received by NML papers from various types of institutions.

Table 11: Institutions/Organisations Cited NML Papers during 1972-2007 as per SCI database

Institutions/Organisations	Country	Numbers of Citations	%	Cumulative
National Metallurgical laboratory	India	327	11.55	327
Indian Institute of Technology	India	174	6.14	501
Banaras Hindu University	India	61	2.15	562
Regional Research Laboratory	India	36	1.27	598
Chinese Academic of Sciences	China	29	1.02	627
Def Met Res Laboratory	India	24	0.84	651
Cent Electrochem Res Institute	India	22	0.77	673
Cent Glass & Ceram Res Inst	India	20	0.77	693
CNRS*	France	20	0.77	713
CSIC**	Spain	20	0.77	733
University of Cambridge	USA	20	0.77	753
Shandong University	China	18	0.63	771
Taiwan University	China	18	0.63	789
Tohoku University	Japan	18	0.63	807
Aligarh Muslim University	India	17	0.60	824
National Institute of Technology	India	16	0.56	840
Imperial Coll Sci Tech & Med	UK	15	0.53	855
Istanbul Technical University	Turkey	15	0.53	870
National Inst Mat Science	Japan	15	0.53	885
University of Madras	India	15	0.53	900
Indian Institute of Sciences	India	14	0.49	914
National Cheng Kung University	Taiwan	14	0.49	928
Shanghai Jiao Tong University	China	14	0.49	942
Tsing Hua University	China	14	0.49	956
Bengal Eng & Science University	India	13	0.45	969
Cairo University	Egypt	13	0.45	982
Cent S University Technology	USA	13	0.45	995
Qingdao Technol University	China	12	0.42	1007
Qufu Normal University	China	12	0.42	1019
Ain Shams University	Egypt	11	0.38	1030

Centre National de la Recherche Scientifique , France* ,Consejo superior de investigaciones cientificas , Spain ** *Total Institutions: 655*

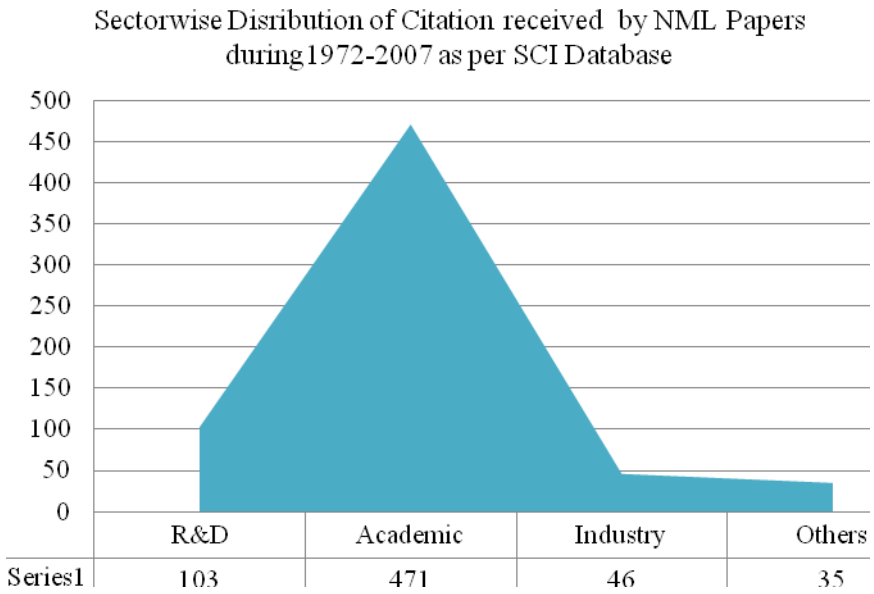

Figure 7: Sectoral Distribution of Citation Received from Institutions (1972-2007)

Global Distribution of Citations Received by NML during 1972-2007 as per SCI Database

The global reputation of research institution/organisation can be traced out by analysing citations globally. This study shows that the NML research on minerals, metals, metallurgy, and materials science has been cited from almost all parts of the world.

The findings as depicted in Table 12 and Figure 8 reveal that, the maximum citation of NML papers comes from Asia (298 organisations from 23 countries with 1740 citations; 61.48%); followed by Europe (175 organisations from 28 countries) with 489 citations (17.27%). A total of 175 organisations from North America contributed to 350 citations. The global distribution of NML papers with their citations reflects its worldwide recognition and validity of scientific activities in the field of minerals, metals, metallurgy, and materials science.

Table 12: Continent wise Distribution of Citation of NML Publications during 1972-2007

Continent	Numbers of Countries	Number of Org./Inst.	Citations Received	Percentage %	Cumulative Citations
Asia	23	298	1740	61.48	1740
Europe	28	175	489	17.27	2575
North America	4	101	350	12.36	2090
Africa	6	43	120	4.24	2699
South America	4	19	78	2.75	2777
Oceania	2	19	53	1.87	2830
Total	67	655	2830	100.00	-

Source: www.isiknowledge.com

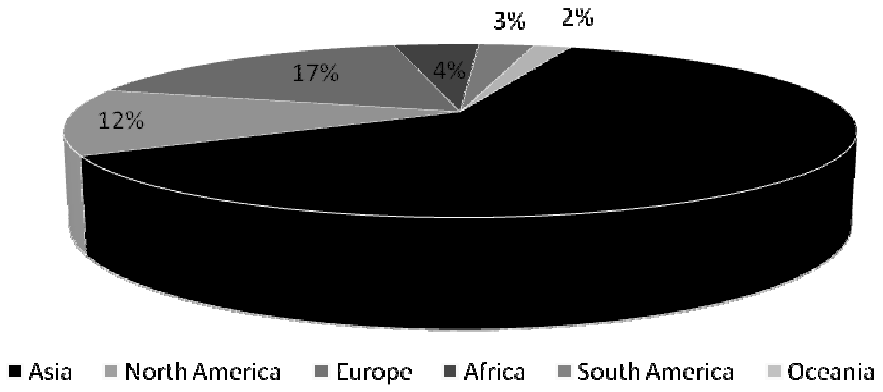

Figure 8: Continent-wise Distribution of Citations Received by NML Papers during 1972-2007

Language-wise Distribution of Citations

During 1972-2007, NML papers received a total of 2830 citations in 12 languages as depicted in Table 13. English remains the dominant language (2738 papers; 96.74%) followed by Chinese (30 papers; 1.06%) and Japanese (20 papers; 0.70%). The other works citing NML papers are in Russian (10), French (8), Spanish (8), German (7), Czech (3), Portuguese (2), Romanian (2), Hungarian and Polish (1 paper respectively).

.

Table 13: Language-wise Distribution of Citation

Rank	Language	Number of Citation	Percentage	Cumulative	
				Citation	Percentage
1	English	2738	96.74	2738	97.74
2	Chinese	30	1.06	2768	97.80
3	Japanese	20	0.70	2788	98.50
6	Russian	10	0.35	2798	98.85
7	French	8	0.28	2806	99.13
4	Spanish	8	0.28	2814	99.41
5	German	7	0.24	2821	99.65
8	Czech	3	0.10	2824	99.75
9	Portuguese	2	0.07	2826	99.82
10	Rumanian	2	0.07	2828	99.89
11	Hungarian	1	0.03	2829	99.92
12	Polish	1	0.03	2830	100.00

(Source:www.isiknowledge.com)

Extent of Citations and Categories of Citing Documents

It is very important to know what has been published, where has it been published and the type of communication channel chosen for the said publication in order to it to gain visibility. A quality paper published in an internationally well-known journal has the tendency to attract scientists instantly and receives many citations whereas an important paper published in an unknown journal may remain dormant and uncited for years in spite of its high potential research value.

Out of 2830 citations received by NML, 2672 (94.41%) were journal articles, followed by 131 (4.62%) technical reports, 11 (0.38%) notes, 9 (0.31%) letters, 5 (0.17%) editorials and 2 (0.07%) others (comprising 1 Correction Notes and 1 Meeting-1). Figure 10 presents the findings.

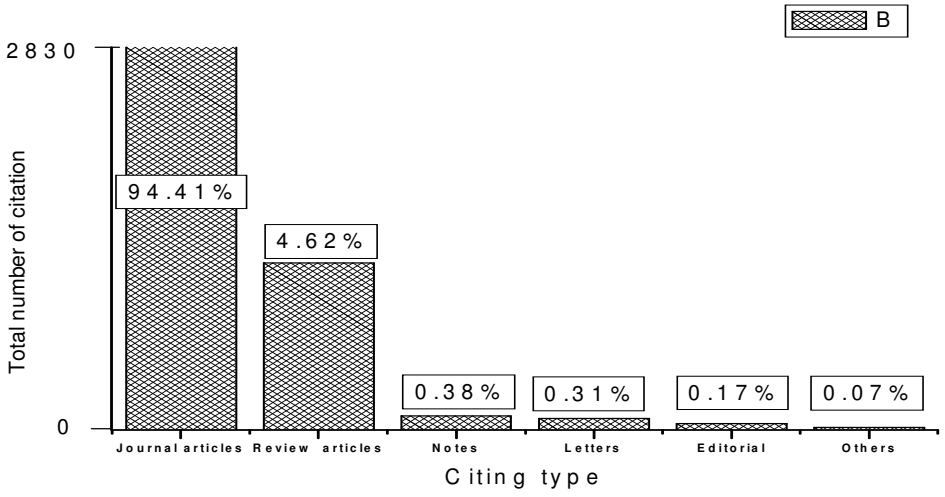

Figure 10: Types of Documents Citing NML Publications during 1972-2007

CONCLUSION

The quality of NML papers is well reflected through citation and IF. The study shows that, during the last 36 years NML publications received a total of 2830 citations that spread over 500 periodicals with IF ranges varying from 0.02 to 30.00. NML's valuable research works were cited by a total of 655 world reputable institutions/organisations from 73 countries and published in 12 languages. The different institutions/organisations citing the papers may open up the avenue for future collaboration of research and development in the area of minerals, metals, metallurgy, and materials science with NML, India. This study can be enhanced by including more bibliometrics parameters and a comparative study may be pursued with a similar type of research and development laboratory at the national, regional and international level.

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