Knowledge Management for Promoting Nanotechnology R&D, Innovation and Commercialization

By
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Agenda

- About CKMNT/ARCI
- Government of India’s Initiatives to promote nanotechnology
- A case study on assessing emerging nanotechnology application trends in agriculture using analysis of published patents
- Summary and Conclusions
ARCI, Hyderabad
Head Quarters (1994-95)
1. Surface Engg.
2. Nanomaterials
3. Ceramic Processing.
4. Laser Processing.
5. Non Oxide Ceramics
6. Carbon Materials
7. Sol-Gel Coating
9. Materials Charc. & Testing

ARCI, Secunderabad
Centre for Knowledge Management of Nanoscience & Technology (CKMNT) (2009)

ARCI, Chennai

ARCI, New Delhi Cell (1994-95)
Liaison & Patent Filing

ARCI is “Translating Research into Commercially viable Technologies”
# Key Infrastructure at CKMNT to provide KM services

<table>
<thead>
<tr>
<th>Literature Databases</th>
<th>Patent Databases/Analytics Software</th>
<th>Company Database</th>
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</table>

A team of about 35 R&D Scientists and about 12 Knowledge Management professionals in the area of nanoscience and technology are supporting CKMNT
What is Knowledge Management (KM)?

KM is an integrated approach for creating, sharing, and applying knowledge across all functions of business/innovation continuum to enhance organizational productivity, profitability and growth.

E.g. The knowledge about resource providers, customers, competitors, scientific & technological developments, Intellectual Property Rights (IPRs), assessment of technology, regulations, markets etc. to address the global challenges and to sustain their competitive position.

Most of the technologies/innovations originated from the public funded R&D institutions will be having the above knowledge gaps.
Crossing the “Valley of Death” in taking Technology to market

Development phases:
- Idea/R&D
- Proof of Concept/Prototype
- Pilot Studies/Product Development/Validation
- Commercial Production & Marketing
- Expansion & Growth

Cumulative cash flow
(from investment & operations)

Technological Valley of Death
Commercialization Valley of Death

Knowledge Gaps/Barriers

- Bibliometrics/Patent analysis/White space analysis, Prior art/Novelty search
- Collaboration opportunities
- Testing & Characterization services
- Market potential assessment
- Product Development/Prototype validation, Incubation, IP Protection
- Start-up Creation

IPR analysis (FTO), Licensing issues
- Technology assessment, Market assessment
- Techno economic feasibility analysis
- Process know-how/BEDP packages/DPRs
- Competition analysis, Regulatory analysis
- IPR valuation, Funding sources, Business plans
- Technology Transfer Facilitation Services
A Framework for Knowledge Management of NS&T at CKMNT
CKMNT Reports/Publications

Customised Reports:
- Nano-ZnO
- Nano-Copper
- Silver-Silica-Silicon Oil Composite
- Applications of Nanotechnology in Petroleum Sector

Multi-Client Reports:
- Nano-Sensors
- Guidelines and Best Practices
- Regulatory Frame Work
- Directory
- Newsletter
- Nanofibers
- Agriculture
**Some of Our Valued Anchor Clients**

<table>
<thead>
<tr>
<th>SABIC, Bengaluru &amp; USA</th>
<th>Höganäs</th>
<th>AGNI Pvt. Ltd., Hyderabad</th>
</tr>
</thead>
<tbody>
<tr>
<td>L'Oreal India</td>
<td>Resil Chemicals Pvt. Ltd., Bengaluru</td>
<td>Oil and Natural Gas Corporation Limited</td>
</tr>
</tbody>
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**Department of Science & Technology**

Ministry of Science & Technology, Government of India

IndianOil The Power of Possibilities
Government of India’s Nano Mission – Key Policies / Strategies

- **2001 - 2007** - Launched Nanoscience & Technology Initiative (NSTI)
- Other Agencies of the Government (DIT, DBT, CSIR, ICAR, DRDO, DAE, DIPP, etc.) also started promoting R&D in their own domains.
- Government investments during 2001-12 is about Rs. 15000 million (USD 300 million) which is about USD 30 million/year, against USD 1000 million/year by USA and Japan and about USD100 million/year by China.
- Nano Mission is the single largest source of R&D funding cutting across disciplines and institutions in India.

Objectives of Nano Mission

- Basic Research Promotion
- Human Resource Development
- Research Infrastructure Development
- International Collaborations
- Orchestrating National Dialogue
- Nano Applications and Technology Development Programe
Achievements of Nano Mission

- Two institutions were set up i.e. Institute of Nanoscience & Technology, Mohali and National Centre for Molecular Materials Research, Thiruvananthapuram.
- 7 Institute-Industry joint projects were initiated
- About 12 units of Nanoscience were established as shared facilities in institutions of national importance
- About 10 Thematic Units of Excellence (TUEs) on selected themes were setup
- About 7 Centres for Nanotechnology, Nanotechnology Business Incubator were setup
- Large numbers of sophisticated characterization and fabrication facilities have been set up in the country.
- About 300 individual scientist-centric R&D projects were funded
- Development of standards for Nanotechnology and laying down a National Regulatory Framework Road map for Nanotechnology
- Nano Mission changed the Nation’s R&D Landscape in the NS & T area
- Some of the commercial products/technologies have come out
  - Nano hydrogel based eye drops
  - Flow sensors
  - Pesticide removal technology for drinking water
  - Water filters for arsenic & fluoride removal
  - Nano silver based antimicrobial textile coatings
  - Self cleaning coating for textiles
  - Hand held explosive detection device
  - Body hugging cardiac monitoring device
  - Nano cellulose technology
India ranks 3rd in global nanoscience R&D publications in 2013.

Global nano S&T publications by geographical regions in 2013:

- **Asia**: 60.7%
- **USA**: 20.8%
- **Europe**: 18.5%

Database used: Web of Science
### Case study: Nanotechnology for Sustainable Development of agriculture

#### Issue in agriculture and nanotechnology options

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Challengers</th>
<th>Nanotech Solutions</th>
</tr>
</thead>
</table>
| 1.    | Lower agricultural input efficiency              | ➢ Nano-fertilizers for slow release and efficient use of water and fertilizers by plants  
       |                                                  | ➢ Nanocides (pesticides encapsulated in nanoparticles) for controlled release, and nano-emulsions for greater efficiency  
       |                                                  | ➢ Delivery of nutrients and drugs for livestock and fisheries  |
| 2.    | Unsustainable farm management                    | ➢ Nanoparticles for soil conservation  
       |                                                  | ➢ Nanosensors for soil quality, plant health monitoring, precision agriculture and controlled environment agriculture.  
       |                                                  | ➢ Nano membranes for soil and water purification  
       |                                                  | ➢ Nano magnets for removal of soil contaminants  |
| 3.    | Agricultural productivity enhancement            | ➢ Genetic improvements of plants and animals  
       |                                                  | ➢ Delivery of genes and drug molecules to specific sites at cellular levels in plants and animals  
       |                                                  | ➢ Nano-array based gene technologies for gene expressions in plants and animals under stress condition  |
| 4.    | Vulnerabilities to climate change due to global warming | ➢ Nano-based gene technologies for crop breeds to withstand heat, salt, submergence or water logging  |

*Source: Nanodigest September 2014*
Publication Trends of Nano-Patents in Agriculture Sector

Total Patents: 5424

CAGR 26% (2000 - 2013)

Asia-Pacific 57%
North America 27%
Europe 10%
Others 7%

Publication year
Distribution of Patents for Asia-Pacific Region

China: 2276 (74%)
Korea: 374
Japan: 199
India: 72
Australia: 66
Taiwan: 48
New Zealand: 11
Malaysia: 8
Singapore: 8
Others: 30

Asia-Pacific Country
Distribution of Nano-patents in Different Sectors of Agriculture:

- Pesticides/Herbicides (Agri.) 43%
- Biocides (Agri.) 18%
- Animal Husbandary 8%
- Fertilizers 12%
- Horticulture 9%
- Nano Sensors 1%
- Threshing/Appartus 1%
- Harvesting/Mowing 1%
- Planting/Sowing devices 3%
- Soil Working Machinery/ Implements 1%
- Dairy Products 1%
Assignee Analysis:
Total Patents: 5424

Assignee

Top 10 Corporate Assignee:
1. DOW AGROSCIENCES LLC (USA) - 71
2. MAANSHAN KEBANG CO LTD (CN) - 63
3. BASF AG (DE) - 56
4. SUZHOU SELENIUM CO LTD (CN) - 52
5. HEFEI QIANXISHANZHUANG (CN) - 42
6. XUZhou UNIFY CO LTD (CN) - 38
7. BAYER CROPSCIENCE AG (DE) - 36
8. ANHUI WANLI CO LTD (CN) - 30
9. ABRAXIS BIOSCIENCE INC (USA) - 27
10. DANGTU KEHUI CO LTD (CN) - 25

Top 10 University/Academic Institutes:
1. UNIV ZHEJIANG (CN) - 32
2. UNIV SHANGHAI NORMAL (CN) - 31
3. UNIV NANJING (CN) - 27
4. WUXI TONGCHUN (CN) - 22
5. UNIV LIAONING NORMAL (CN) - 18
6. UNIV SOUTH CHINA AGRIC (CN) - 17
7. UNIV BEIJING CHEM (CN) - 15
8. NAT UNIV OF UKRAINE (UA) - 12
9. UNIV TIANJIN (CN) - 12
10. UNIV CALIFORNIA (USA) - 10

Company 64%
University/Institute 28%
Independent Inventors 8%
Cluster Map of Top Nanomaterials used in Agriculture Sector

- Silica (338)
- Nanoemulsion (43)
- Zinc Oxide (195)
- Graphene (65)
- CNT (57)
- Fullorene (52)
- Silver (997)
- 194
- 82
- 23
- 39
- 88
- 56
- 24
- 2
- 1
- 11
- 2
- 48
- 43
- 39
- 2
- 2
- 2
- 1
- 2
- 2
3D Representation of Various Nanomaterials used by Top Assignees:

Nanomaterials include:
- Zinc
- Silver
- Copper
- Magnesium
- Iron
- Manganese
- Silica
- Gold
- Calcium carbonate
- Platinum
- Alkali metal
- Alumina
- Titania
- Graphene

Assignees include:
- Dow AgroSciences
- Maanshan Kebang
- Base AG
- Suzhou Selenium Valley
- Hefei Qianxishanzhuang
- Xuzhou Unify Fishing
- Bayer Cropscience AG
- Abraxis Bioscience Inc
- Dangtu Kehui Trading Co
- Kimberly-Clark
- Wuxi Tongchun New Energy
- Procter & Gamble Co
## Some successful ventures of nanotechnology in agriculture

<table>
<thead>
<tr>
<th>Products/Area</th>
<th>Application</th>
<th>Institution/Company</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nanocides</td>
<td>Pesticides encapsulated in nanoparticles for controlled release</td>
<td>BASF, Germany</td>
</tr>
<tr>
<td></td>
<td>Nano-emulsion for greater efficiency</td>
<td>Syngenta, Switzerland</td>
</tr>
<tr>
<td>Bucky ball fertilizer</td>
<td>Ammonia from bucky balls</td>
<td>Kyoto Univ., Japan</td>
</tr>
<tr>
<td>Nanoparticles</td>
<td>Adhesion-specific nanoparticles for removal of Campylobacter jejune from poultry</td>
<td>Clemson Univ., USA</td>
</tr>
<tr>
<td>Use of agriculture waste</td>
<td>Nanofibers from cotton waste for improved strength of clothing</td>
<td>Cornell University, USA</td>
</tr>
<tr>
<td>Nanosensors</td>
<td>Contamination of packaged food</td>
<td>Nestle-Switzerland, Kraft-USA.</td>
</tr>
<tr>
<td></td>
<td>Pathogen Detection</td>
<td>Cornell Univ., USA</td>
</tr>
<tr>
<td>Precision agriculture</td>
<td>Nanosensors linked to GPS for real-time monitoring of soil conditions and crop growth</td>
<td>USDA</td>
</tr>
<tr>
<td>Livestock and fisheries</td>
<td>Nano-veterinary medicine (nanoparticles, buck balls, dendrimers, Nano-capsules for drug delivery, Nano-vaccines; smart herds, cleaning fish ponds (Nano check); feed (iron nanoparticles)</td>
<td>Cornell Univ., USA</td>
</tr>
</tbody>
</table>

Source: Nanodigest September 2014
Nanoproducts used in Agriculture Sector

**Nano-Ag Answer by Urth Agriculture**
Reduced pest pressure, water consumption, algal blooms, remediate runoff.

**Khazra Nano Chelated Iron by Khazra**
Enhances photosynthesis process & speed of food prep. within plant leaves.

**TriGROW nano organic Fertilizer by Trigo World Inc**
Growth enhancer, soil nutrients improver. Increase yield by 10-35%.

**NANOMOL by Alert Biotech**
Improves immune system, root, fruit, enzyme and auxin production, Dosage: 1gm/lit

**Nano Kalibre Plus by Agri Sciences Tarim Ve Ilac**
Increases fruit weight, fruit stays perfectly attached onto stem. Dosage: GRAPE, KIWI 50-75 cc / 100 l water

**Nano-Gro by Agro Nanotechnology Corp**
1-pellet (⅛") is capable of treating 42 kg of wheat seeds or 33 tomato plants. Increase yield by 20%
Nanotechnology in Agriculture: The Indian Scenario

- India is a land of Agriculture and accounted for about 14% of GDP in 2012-13.
- The major challenges facing Indian agriculture are:
  - Growth rate of a meager 1% in food grain products
  - 30% of Agri. & Horticulture produce is being lost due to inadequate storage facilities
  - Plateauing of yield
  - Emergence of new biotypes of pests and pathogens
  - Mitigating the impact of climate change
  - Declining land availability for agriculture and water scarcity
  - Food security is at risk.
- Major R&D Infrastructure: 99 ICAR Institutes, 53 Agriculture Universities
- Major Funding Institutions: DARE/ICAR-NAIP under World Bank CSIR-DBT, DST, UGC, Rs. 2500 million (USD 45 million)
- There is an urgent need for innovative strategies such as Adoption of Nanotechnology in Agriculture to ensure food security
- Major Areas of R&D
  - Environmental safety of Nanotechnology
  - Use of micro and nano encapsulated techniques for food processing and storage
  - Developing delivery systems having high efficiency and bio-availability for micro nutrients
  - Nanosensors for disease monitoring, soil & water productivity
  - Coating of ZnO nano particulars on seeds as a nutrient and anti microbial protection during germination
- 15 companies in India are manufacturing/ Marketing nano products for agriculture
Indian Scenario – Total Nano-patents in Agriculture Sector = 72

Publication Trends:

<table>
<thead>
<tr>
<th>Year</th>
<th>Patents</th>
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<tbody>
<tr>
<td>2005</td>
<td>2</td>
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<tr>
<td>2006</td>
<td>1</td>
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<td>2007</td>
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<td>2011</td>
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<td>2012</td>
<td>13</td>
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<tr>
<td>2013</td>
<td>17</td>
</tr>
<tr>
<td>Sep, 14</td>
<td>16</td>
</tr>
</tbody>
</table>

Assignee:

- COUNCIL SCI & IND RES: 6
- INDIAN INST TECHNOLOGY: 5
- AGHARKAR RES INST: 3
- BIJAM BIOSCIENCES: 3
- TATA: 3
The patent filing activity showed almost 2-fold increase in 2013 from 2012, which shows the rapid growth in R&D activity and interest in this subject area.

China has emerged as the major player in this area with 42% of global patents followed by USA and Korea with 26% and 7% respectively. India’s share is only 1.3%.

Corporate sector is far ahead as (64% patents) compared to academic sector (28%) in filing patents. Dow Agrosciences LLC and Maanshan Kebang Ecological Fat Co Ltd are the top active corporate players with 71 and 63 patents.

Majority (43%) of patents are on Pesticides/Herbicides followed by Biocidal and Fertilizers with 19% and 12% respectively.

Widely used nanomaterials are Silver, Silica, Zinc oxide, Graphene, Carbon nanotube, Fullerene etc.

There are about 150 Nanobased products in the market which are used to improve the agriculture productivity E.g. NANO-AG ANSWER, Nano-Gro, YIC Nano Plus, Nano Kalibre Plus, Nano Zinc, NanoFert, etc available in the market.

Since China, Korea and Japan are the major players in Asia Pacific region more open innovation approaches may be promoted through an appropriate institutional mechanisms for the LDCs.

Lack of technology and market assessments, IPRs, safety & regulatory issues and access to risk capital are the major barriers for innovation and commercialization of nanotechnology based products.
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Organizers of the Forum: UNAPCTT, ESCAPE, MOSTI
Thank You