Basic Research and Industrial Applications

Editors

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Prof. Dr. M.M. Qurashi
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July 2005

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Commission on Science and Technology for Sustainable Development in the South

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COMSATS Headquarters
4th Floor, Shahrah-e-Jamhuriat, Sector G-5/2, Islamabad.
Ph: (+92-51) 9214515-7, Fax: (+92-51) 9216539
URL: http://www.comsats.org.pk, email: comsats@comsats.org.pk

BASIC RESEARCH AND INDUSTRIAL APPLICATIONS

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Dr. Hameed A. Khan
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Commission on Science and Technology for Sustainable Development in the South

...The Government should make it mandatory for the industry to invest a part of its profits towards research, which is essential if the country's industry is to gracefully survive the upcoming regime of WTO.

...The Technical community should also devise ways and means for selling their expertise to the industrialists.

...The introduction of ISO culture is another significant landmark that has ensured, for the industry, a discipline whereby a consistent quality-production is possible at a low cost.

Dr. Samar Mubarakmand, N.I., H.I., S.I.
Chairman, NESCOM

(Excerpts from Dr. Samar Mubarakmand's address at Islamabad on July 8, 2004)

Basic Research and Industrial Applications

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FOREWORD

In an era where the standards and parameters for socio-economic development and prosperity are being dynamically shaped, continued scientific research is perhaps the only constant that lies at the heart of sustainable development and progress. Scientific research is the cardinal tool for human-beings to know and make use of nature. Its various types help play a distinct, yet overlapping role in the continuous uplift and betterment of mankind and its livelihood. In this context, the leading role of basic research, is momentous in creating new knowledge and providing scientific capital.

Basic or pure research is the extension of scientific and technical knowledge, not having any industrial and commercial intentions; it is the attempt of a researcher to access the frontiers of knowledge for the sake of knowledge alone. Nevertheless, it is the knowledge that basic research creates, which provides the intellectual material for formulating the applications that we today call technology. Without doubt, basic research lies at the heart of nearly every major discovery, known to us today.

It is no secret today that basic research, whether performed in scientific laboratories, R&D institutes, universities or within industry itself, has been critical in promoting nearly all sciences whether basic or applied. The knowledge-domains of physics, chemistry and other subjects are undergoing a metamorphosis, reflecting the dominance of inter-disciplinary unification, with the borders between the traditional research-areas being eroded and the continual merging of basic research and industrial applications. The inter-locking of basic discovery and technological innovation has today led to the emergence of chemical, engineering, electronics and transportation industries, as well as the many industrial uses of nuclear radiations, besides others.

Today, it is even more true than ever that basic research is the pacemaker of technological progress. Therefore, it must not be taken as a peripheral activity, but should be given due support in order to strengthen the industrial base for achieving development and progress especially in the developing countries.

To highlight the integral link between basic research and related industrial uses, COMSATS organized a meeting on "Basic Research and Industrial Applications" from 06 to 08 July, 2004, in collaboration with Chinese Academy of Sciences (CAS) and Islamic, Educational, Scientific and Cultural Organization (ISESCO). It further aimed at ascertaining the importance of basic research as one of the pre-requisites for innovation, which is essential for companies and nations, to remain competitive in the global village of today.

There were a total of 33 speakers in the meeting who made presentations in 7 Technical Sessions, of these 5 were foreign experts representing the countries of Switzerland, United Kingdom and China. Other participants included eminent researchers, heads of S&T institutions, scholars, students and representatives from some major industrial concerns. The proceedings of the meeting presented here comprise a selection of papers and the recommendations, at the end, which emerged during the conference.

I would like to express my gratitude to Prof. Sixiong Zhao, Executive Director, International Centre for Climate and Environment Sciences (ICCES), Institute of Atmospheric Physics, Chinese Academy of Sciences and to Dr. Faiq Billal, Director, Islamic, Educational, Scientific and Cultural Organization (ISESCO), for their sincere cooperation and support in organizing this meeting. I would also like to acknowledge the efforts of Dr. M. M. Qurashi, Mr. Irfan Hayee, Ms. Zainab H. Siddiqui, Mr. Imran Chaudhry and Ms. Nagina Safdar from COMSATS, whose dedication made possible the publication of this book.

(Dr. Hameed Ahmed Khan, H.I., S.I.)
Executive Director

BASIC RESEARCH: THE BASIS FOR NEW TECHNOLOGIES AND THE WELFARE OF SOCIETY

Herwig Schopper
President, SESAME Council, Geneva - Switzerland

ABSTRACT

Humanity is faced with great challenges, e.g. increasing population, globalisation, and sustainable environment. In order to cope with them a larger effort has to be made in developing science and technology, including fundamental science. Developing countries will have to make a large jump since otherwise the gap between industrialised and developing countries will widen instead of closing. For this purpose international cooperation will be essential, but scientific facilities will also have to be created in threshold countries. The European laboratory CERN at Geneva and the international centre SESAME in Jordan will be discussed as examples.

1. THE GREAT CHALLENGE

The world is confronted with the following major challenges:

- Growth of the world population up to 10 – 12 billion within the next 20 years;
- Globalisation of markets and worldwide competition;
- Industrialized societies are under rapid changes; employment in agriculture, as well as in industrial production is declining, but increasing for services and informatics (Figure-1);
- Impressive economic growth in the Far East; this region will become a major market, but also an important competitor (Figure-2);
- Urgent increase of needs in developing (but some even in industrialised) countries, e.g. hunger, water, environmental problems, unemployment, analphabetism, state deficits.

The following quotation "Humanity is being ravaged by disease; doctors are powerless against it; pollution is everywhere; men and women die daily in senseless ethnic conflicts; homelessness is rampant; people can't read; children are being killed in the streets" is not from our time but from the year 1350 from Italy, which shows that such problems existed also in the past. However, the main difference is that the problems are *now worldwide* and concern billions of people.

2. SCIENCE – BASED TECHNOLOGY AS FOUNDATION OF WELFARE

For many centuries, the standard of living had changed very little and a privileged life was reserved for a small class of nobility. During the century of enlightenment,

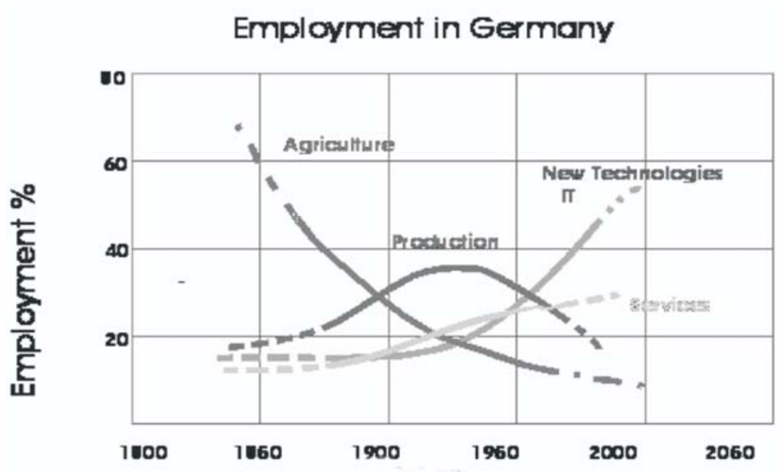

Figure - 1

intellectual giants like Gallileo and Newton laid the foundation for modern science which, in turn, became the source of technology. Only when from the middle of the 19th century, new techniques like the steam engine, railways, electricity, telephone and artificial fertilizers, were introduced, the standard of living could be improved for a large part of the population. Indeed! only extensive production, based on technology, can provide sufficient resources to enable a man to live in dignity. Thus, science-based technology has and will provide in the future the following benefits:

- Sufficient energy, food and shelter
- Liberating humans from drudgery and slavery
- Open access to information

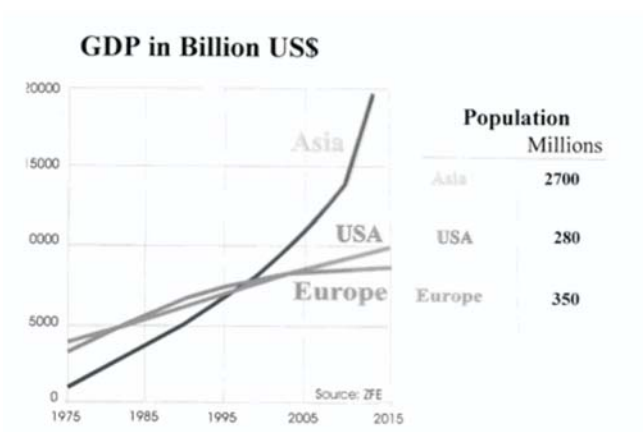

Figure -2

- Sustainable development, with the preservation of the environment
- Providing sufficient time for cultural, political and recreational activities

A long time ago, it was recognised that research is essential for society. For example, Werner von Siemens said in 1883: "Scientific research forms always the safe foundation of technical progress, and the industry of a country will never attain an internationally leading position and maintain it, if the country does not at the same time take a leading position at the frontier of scientific progress. To strive for this, is the best way to promote industry". Similar statements are made quite frequently by present day politicians. However, the necessary practical consequences are realised very rarely.

One of the major problems of our times is that short-term optimisation prevails, both in politics and industry, whereas long-term views are needed to cope with some of the most fundamental problems. Short-term strategies have, moreover, some negative consequences:

- Reduction of basic research in industry;
- Pressure for short-term benefits in applied research;
- Reluctance in industry to work with universities as partners;
- Adherence to existing technologies, instead of imaginative approaches;
- Main criteria are short-term profits ("share holders value").

To change such attitudes will not be easy, in a competition-oriented world. It might require the change of some of the basic ethical foundations, which sometimes can be achieved only when a smaller or larger disaster has proven that previous concepts did not work in the long run.

3. THE GENERAL MERIT OF CURIOSITY-DRIVEN (FUNDAMENTAL) SCIENCE

Apart from being the foundation of modern technology, basic science offers some specific merits itself by contributing to satisfy other than material needs.

During the past 200 years, physics, astronomy, chemistry and biology, in particular, have produced a completely new image of the world ("Weltbild"): teaching us about the position of man in the universe, proving that neither the earth nor mankind are at the centre of cosmos (indeed recently it was shown that even the kind of matter we are made of is not preponderate in the universe), that superstition is absurd and that natural phenomena can be understood in rational terms. As far as methodology is concerned, we learn that an objective and critical approach is very constructive and that we have to accept facts, even if they upset our daily-life thinking. Scientific methods help us find solutions to complex problems of social, economic and material significance, instead of attacking them emotionally.

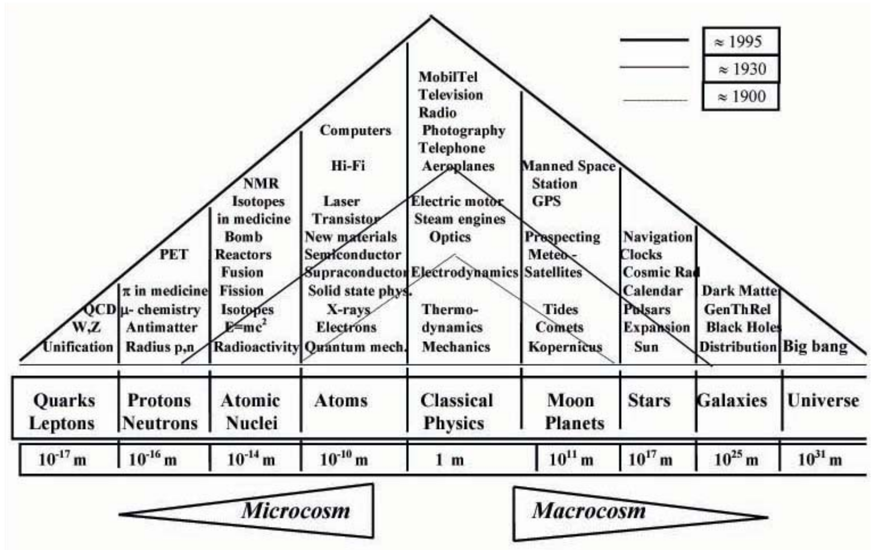

Figure - 3

But, as mentioned above, basic science is essential for progress in technology. Otherwise, over the centuries only some improvement in traditional tools might have happened, like developing better spears to kill animals or to improve oil-lamps instead of electric light.

Let me demonstrate, as an example, the general relation between basic physics and applications by looking back at history. For this purpose, I want to use the pyramid shown in Figure-3. Classical physics started to investigate phenomena determined by the human size, i.e. of the order of a meter. Later, it penetrated into the macrocosm to ever larger dimensions, on the one side, and into microcosm to smaller dimensions, on the other side. Starting from basic knowledge, which is represented along the base of the pyramid, applications and technologies developed and thus the pyramid grew vertically. Many modern technologies, like the steam engine, cameras, television, radio, etc, are off-springs of classical physics. Then the atom was discovered, quantum mechanics was invented to understand the atom and finally semiconductors, neon lamps, superconductivity, computers, etc., became inevitable for daily life.

The next step into the microcosm was marked by the discovery of the atomic nucleus and what followed was radioactivity. Einstein's famous equation linking energy and mass, nuclear fission, reactors, fusion and also the atomic bomb followed by and by. But also, isotope technology or nuclear magnetic resonance imaging turned out to be valuable tools for industry, medical diagnosis and therapy. A next step was made by the discovery of protons, neutrons and other particles and, particularly fascinating, the existence of antimatter, some of which has also already found applications. The final step at present is represented by the discovery of quarks and leptons. In a similar way, one can analyse the steps leading into the macrocosm, but this would take too much place here.

This shows that it takes some time for applications and technologies to develop from the foundations of basic knowledge. The pyramid grows slowly and, often, one has to wait several decades before the outmost corners, symbolising abstract research, are converted into new technologies and new products. How difficult it is to make predictions in this respect is illustrated by a story about Faraday. While engaged in investigating electromagnetic phenomena, he was visited by a representative of the Treasury who at the end of his visit said to Faraday something like, "Well, I did not understand most of your explanations; so therefore could you tell me at least what benefits your work will have for society?", whereupon Faraday answered, "This I cannot predict, but I am sure that one day your successors will levy high taxes on it.

"I see no logical reason why the pyramid should not continue to grow also in the future. The discovery of completely new phenomena leads to qualitative jumps in technology. They are not predictable and cannot be planned. The time-scales from the discovery to the market are very different and range from a few years to several decades. Only by exploiting qualitatively new discoveries, will it be possible to cope with long-term problems, like production and saving of energy, pollution of the environment or

Figure - 4

satisfying full access to information.

Apart from contributing to the solution of issues in the more distant future, some spin-offs of fundamental research lead to immediate benefits for society. Let me mention only one example. The World Wide Web was invented at CERN to satisfy the needs of the experimentalists working at the LEP facility, and nobody had the vision how it would revolutionise the use of networks.

Finally, one should not forget that fundamental science is an important element in forming an intellectual elite, particularly by attracting gifted young people. And ultimately, it is a very effective way of creating a truly international community of scholars, with common values like tolerance, fair competition, mutual understanding, and no discrimination because of race, religion or political system.

4. SOME ASPECTS CONCERNING DEVELOPING COUNTRIES

In spite of many efforts, there still exists a large gap between industrialised countries and the third world. Indeed, this gap is widening in some respects. The difficulty in closing this gap is because of the fact that the developed countries needed a long time, about 150 years, to get transformed from an agricultural economy into a knowledge and technology – based society. Such a long period is not acceptable and, hence, the third-world countries must now leapfrog. In order to achieve this, the attitude towards change must be revolutionized and a static society must become more dynamic! Change is a natural phenomenon in human affairs, and development is incompatible with a static and rigid view of the world.

Table - 1: List of CERN Member & Non-Member States

Users from Non- Member States	
Brazil	33
Canada	67
China	35
Croatia	17
Israel	33
India	59
Japan	103
Mexico	14
Pakistan	9
Russia	744
Turkey	20
Taiwan	18
USA	586
Others	125
Users from Non-Member States	**1863**
Users from 20 Member States	**4499**
Total of CERN Users	**6362**

But how can the societies make this leap? The answer is:

- Improve the acceptance of science and technology
- Increase funds for research (but this alone is not enough)
- Develop strategies for basic and applied research
- Establish technology-transfer, which must be accompanied by science-transfer
- Get integrated into communication-networks (WWW, GRID)
- Create your own research-facilities
- Get involved in international cooperations
- Improve information-access, overcome the digital divide

Each of these points would need a detailed discussion, which cannot be done here. Only a few remarks can be added. Accepting the need for science and technology implies also the recognition of the importance of scientists for society and the need to give them the proper social standing. An adequate remuneration is only a minor point, but as long as football stars or rock singers are the model for the young people (which is unfortunately the case in most industrialised countries), science will not be strongly rooted in society.

Another remark concerns transfer or acquisition of technology. Some decision-makers nurture the wrong belief that, whenever required, technology can be bought from outside. Such a hope is completely futile. A new technology must find a fertile ground, provided by well-trained scientists and technicians. A new technology cannot be exploited by reading publications or getting information from databases, but only by doing research oneself. A considerable amount of knowledge is "incorporated knowledge", which can only be tapped by personal contacts, sometimes with the most competent colleagues in a field. Such an "admission ticket" will only be given to good scientists in the developing country.

Finally, it should be noted that developing countries cannot be satisfied with obsolete technologies. They need the best up-to-date techniques which exist, not only to satisfy personal needs, but particularly to avoid damage to the environment. People will not be satisfied anymore with black-and-white television and they need cars producing as little pollution as technically possible.

5. EDUCATION AND TRAINING

The statement that teaching, education and training are indispensable for a country to become developed, is trivial. However, it is necessary that the teaching of natural sciences is performed at all levels—from elementary school to higher education. To achieve a better acceptance of science among the population, it is important not only to teach those who will later become professional scientists, but rather also those who later might not have any direct experience of science. Of course, such an education should be given to both sexes. To produce good teachers is of course, crucial.

When it comes to teaching at universities, it should be remembered that the progress in science is extremely fast, and what may be recent knowledge can be completely obsolete after a decade has passed. Therefore, it is extremely important to teach broad general methods, in addition to special knowledge. This implies the need to learn how to deal with complex problems i.e.:

– handle unexpected situations
– work in teams
– work in an international environment
– make the acquaintance of quality standards
– communicate and become a leader

6. COOPERATION AT LARGE FACILITIES, CERN AND SESAME

Participating in the research at large facilities, is an excellent tool to achieve some of the objectives mentioned above. It not only provides an extremely favourable possibility to promote science and technology, but also to foster international cooperation and thus contribute to a better understanding of people from different traditions, political systems and races.

Basic physics, like other fundamental sciences, using large facilities, provides excellent tools for international cooperation, since:

- the laws of physics are valid everywhere,
- there is no secrecy in basic science (neither industrial nor military), in spite of competition
- large facilities (accelerators, reactors, detectors, telescopes, etc) need scientific, administrative and political cooperation (sometimes at highest level),
- actual scientific cooperation, and not only exchanges of papers, creates confidence between people from different nationalities, cultures, mentalities and political systems.

In addition, other non-scientific qualities are taught and can be practised, e.g.

- to define and learn about quality standards (with no quota and only scientific or technical issues, comparable to world standards)
- learn to work inside a given budget and time-schedule
- practical experience with advanced communication-technologies, data-handling and computing.

Such objectives can be realised in an extraordinarily efficient way by international cooperation at large facilities. I would like to describe two examples briefly.

I. CERN

CERN was founded 50 years ago at Geneva under the auspices of UNESCO, in order to promote fundamental research in nuclear and particle physics in Europe. It was the first such European Organisation and not only became an outstanding model for an international scientific laboratory but has contributed also to a better understanding among people and nations of different traditions, mentalities and races, first in Europe and now world wide. It has realised several unique research facilities, the last one being the so-called LEP, an electron-positron collider, the largest research instrument ever built. It had been installed in an underground tunnel with a circumference of 27 km (Figure-4). After a decade of successful work, this facility was closed down in 2000 and in the same tunnel another project, the LHC, a proton-proton collider, is now being constructed.

CERN Users (as of June 2004): After the collapse of the Soviet Union, the original number of 12 European member- states was increased to 20 by accepting several of the East European countries. Since LEP and LHC are the only facilities of their kind in the world, CERN has become a world laboratory, in practice. Formally, non-European countries participated in the CERN programmes as Associates, and one finds USA, Russia, Japan, India, Israel among them. With smaller countries, special cooperation-

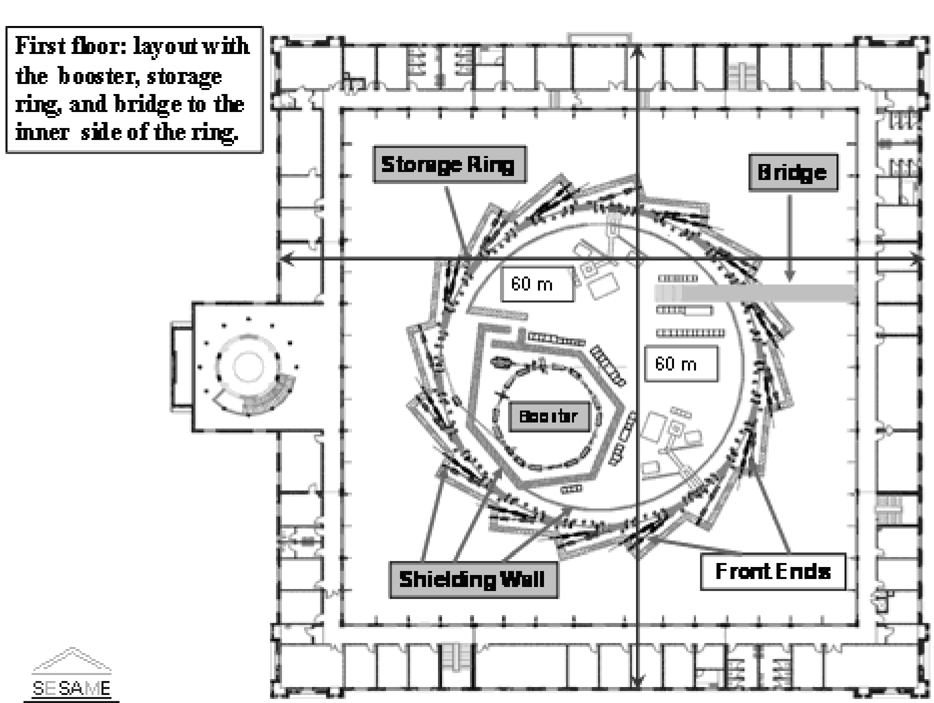

Figure - 5: Layout of SESAME

agreements have been established.

The strategy of CERN is that the laboratory plans, designs, constructs and later operates the installations, whereas these are mainly used by scientists coming from national universities or laboratories. In total, more than 6000 users spend various periods of time at CERN, to set up detectors and to take data, which they may then analyse at the home-institutions. The majority of users come from Member States, but a large fraction originates in non-European countries (Table-1).

Although the main interest is to study fundamental questions like the nature of the building blocks of matter and the forces which interact between them, there is a considerable technical spin-off. This is due to the fact that CERN had to establish a considerable competence in technical, data-handling and IT matters, in order to operate the facilities and satisfy the users.

The most spectacular development was the invention of the World-Wide Web, which was created at CERN in order to satisfy the communication-needs of the LEP experiments. Many developments in accelerator-technology find applications in industry and medicine. Synchrotron radiation sources are a direct child of particle-storage rings developed for elementary particle physics. In order to detect various particles and measure their energies, a variety of detector-techniques were developed (e.g. multiwire proportional chambers, crystal detectors, solid-states devices for precision measurements), which have found many applications for diagnostics in medicine, for material testing or even for customs inspections. For the operation of bubble chambers, the technology of superconductors has been brought from small laboratory-style to large magnets, which are ubiquitous now for nuclear magnetic resonance imaging in medicine. In many other areas, CERN has become a leader, e.g. in ultra- high vacuum or precise positioning of objects over large distances.

The new project, the LHC, will collide protons circling in opposite directions in two tubes and crossing at 8 points. The protons are guided by magnetic fields produced by superconducting coils at 2 degrees K. This will be the first application of superfluid helium in a large project.

II. SESAME

SESAME, a synchrotron radiation source for the Middle East and Mediterranean region, was recently created under the auspices of UNESCO as an autonomous intergovernmental organisation following the CERN model. It was unanimously approved by the UNESCO General Assembly and by the Executive Board (May 2002) accompanied by statements like "..is a model project for other regions....Quintessential UNESCO project, combining capacity-building with vital peace-building through science." It was suggested that UNESCO should provide seed-money for similar projects in other regions. After the Director General of UNESCO had received at least 6 letters from governments, expressing the wish to join the project, SESAME was legally fully established on 15 April 2004.

Presently, the members of SESAME are: Bahrain, Egypt, Israel, Iran, Jordan, Pakistan, Palestinian Authority and Turkey. For some additional countries, the ratification procedure is still going on. Observer Countries are: France, Germany, Italy, Japan, Kuwait, Libya, Russia, UK, US, where again ratification is not yet finished in some cases.

SESAME was initiated by a gift from Germany, providing components of the BESSY I facility at Berlin, which had an energy of 0.8 GeV; SESAME will be upgraded to an energy of 2.5 GeV. The layout is shown in Figure-5.

From about a dozen of sites proposed by 7 countries, a place near Amman in Jordan was selected. Apart from technical conditions, one of the main criteria was that all scientists from the world must be allowed to have access to that laboratory. As host-country, Jordan is providing generous support in making available (for free) the site, access-roads and other infrastructure. In addition, Jordan covers the cost for the building, whose construction started in summer 2003 and which is planned to be ready for installation of the facility in 2005.

Capital funds for the installation of the facility and its upgrading are sought from outside sources (EU, Japan, US…), whereas the operational costs have to be borne by the members. It is expected that first operation will start in 2008.

The domains to which SESAME can make contributions are:

- Biological and Medical Sciences
- Environmental Sciences
- Archaeology
- Material Science/Physics/Chemistry
- Industrial Applications

During an interim period between 2000 and 2003, several activities had already started. This is particularly true for training activities, for scientists and technicians, which were funded by sponsors such as IAEA in Vienna or the US.

Groups of users are presently being formed to design the first generation of beamlines, and proposals for experiments are discussed.

Hopefully, SESAME will open many doors, by promoting science and technology and bringing nations with different traditions, religions, races and political systems together. The members and the whole region will benefit, above all, in the following domains:

- a world-class synchrotron radiation laboratory will become available;

- providing an environment for collaborations, as well as individual development;
- it will be an advanced facility for scientific and technical training;
- people will learn how to cooperate, in particular to cooperate internationally;
- it will contribute to the UNESCO objective 'science for peace';
- interdisciplinary research will be fostered;
- various applications and technologies will be developed, with beneficial consequences for industry.

Is SESAME really needed in the region? Abdus Salam dreamed of several centres in the Middle East, including a synchrotron radiation laboratory. At a Symposium on the Future Outlook of the Arabian Gulf University, held at Bahrain in1983, he said, "We forget that an accelerator like the one at CERN develops sophisticated modern technology at its furthest limit....I cannot rejoice that Turkey, or the Gulf countries or Iran, or Pakistan seem to show no ambition to join this fount of science and get their men catapulted into the forefront of the latest technological expertise". He proposed a synchrotron radiation lab for Jeddah at Bahrain.

Fortunately, his regrets do not apply anymore, since all the countries he had mentioned are participating in SESAME and I am sure Salam would be happy about SESAME!

Sameen Ahmed Khan wrote: "…. It is very disheartening to note that many countries from the Middle East are yet to participate in the novel project SESAME. These countries are missing an excellent opportunity in the area of International Scientific Collaboration….. Scientific cooperation across the geographical and cultural borders helps stimulate not only the advancements of ideas in the professional field, but also the building of lasting bridges and the establishment of contacts on the personal and more importantly the international level. The costs involved for participation are not much for any country."

And finally, an Editorial on SESAME appeared in Nature (399,505,1999): " any potential funder is not to hold back, for this would be a worthwhile investment. Initiatives such as this, do not come around often. When they do, they should be supported unhesitatingly". (For more information see www.sesame.org.jo).

WHY BASIC SCIENCES ARE NECESSARY FOR TECHNOLOGY AND INDUSTRY

Riazuddin
Director, National Centre for Physics (NCP),
Quaid-i-Azam Unviersity, Islamabad

ABSTRACT

The role of science in human society has been vital. It has made enormous impact on the human intellect, has drastically changed human living and has given a new concept of man's place in the Universe. Having said that, let us discuss, in historical context the changes that the scientific process itself has gone through.

HISTORY

Greek Theoretical Tradition: For ancient Greeks, pure thought was much superior than the work with hands, not withstanding Archemede's laws on floating bodies.

The Golden Age of Science in Islam: The creation of the experimental spirit was primarily due to the Muslims, from the 8th down to the 12th century. Around 1000 CE, the well-known Ibn-i-Sina, Al-Biruni (973-1040 CE), Ibn-al-Haitham (965-1039 CE) were all empirical scientists, using methods of experiment.

Although they were better experimentalists than the Greeks, they did not often go much beyond observations. In general, they did not deduce basic scientific principles from observations; at the most, they deduced empirical laws from them. They were more interested in practical applications, rather than building a scientific edifice. Perhaps this is the reason that the Muslim civilization could not sustain the development of science. All those men were dead-end for Muslim civilization, but for Christian civilization, they were a beginning. There is no doubt that Western science is a Greek-Islamic legacy.

So-called Dark Ages Between 12th and 17th Century

Barely a hundred years after Al-Biruni and Ibn-al-Haitham worked, it appears that the creation of high science in Islam effectively came to an end. Mankind had to wait 500 years before its revival was reached with Galileo and his contemporaries. One thing worth pointing out her is the role of mathematics in science: the laws of nature are written in the language of mathematics; this statement is attributed to Galileo.

THE SCIENTIFIC PROCESS

The scientific process, having gone through the above process of evolution, now consists of three major steps:

- Theory, which supplies concepts;
- Experiment, which needs tools, supplied by skilled crafts;
- Computing-capacity, which supplies the mathematical steps of computation.

Concepts are needed to explain old things (in the form of empirical data) in new ways. Tools are needed to discover new things that have to be explained (in terms of concepts) or to discover things predicted by a concept-driven theory, so as to verify or discard a theory. Computing capacity is needed to:

i) Design mathematical models of systems that are too complex to measure or quantify directly, and to answer questions that were beyond understanding only a few decades ago;
ii) Supply electronic data-processing and simulation, increasing the power of scientific theories to interpret and predict new phenomena;
iii) Provide new computing-infrastructures for science and engineering collaborations, which are becoming increasingly international in scope and rely more and more on massive distributed archives.

TECHNOLOGY

Modern science is relatively new. Its roots date back to the 17th century. Technology, on the other hand, is pre-historic. The pyramids in Egypt are one example of ancient technology.

C.P. Snow, in his book "Two Cultures", divides the industrial revolution in the three phases. The first phase began at the end of the eighteenth century with the invention of the steam engine. It was mainly created by handymen, and academic science played a very small role in this phase. In fact, this phase preceded the science of thermodynamics, which was developed in the nineteenth century. Also in this century, two great conceptual revolutions, associated with Darwin (theory of evolution) and Maxwell (unification of electricity and magnetism), took place. In the second phase of the industrial revolution, Chemistry played a major role. Giant Chemical companies were established in Europe and USA.

In the *third phase* of the industrial revolution, atomic particles (like electrons, neutrons, nuclei and atoms) played a crucial role. There is not a single industry today that does not make use of atomic physics or modern chemistry. This revolution is based on the physics of the 20th Century. Note the qualitative change: the first phase preceded some great discoveries in basic sciences, while the third phase followed new discoveries in basic sciences: in particular, two conceptual revolutions created by relativity and quantum mechanics and the birth of atomic and sub-atomic world.

WHAT DRIVES BASIC SCIENCE RESEARCH?

Innate Curiosity, the desire to know the truth, without much thought how it will be used. Seeking answers to some practical questions, which could not be answered by the existing knowledge.

Let me give two examples: Louis Pasteur was led to fundamental discoveries about basic biology and disease by practical questions from medicine; wine making, and agriculture. Greoger Mendel discovered the basic laws of genetics when seeking practical answers to improve agriculture crops.

Basic Sciences are Essential for the following reasons

They form a part of General Education. Basic science shapes our mental environment, develops philosophical thinking, which supplies concepts. "Pure science is as fundamental to culture and national character as music, literature or art. A country has to support pure science, to keep the spirit of enquiry alive and, as such, to give its young people the freedom to wander along the path of curiosity", i.e. desire to know the truth. Pursuit of pure science is necessary for the existence of an intellectually and economically vibrant society.

The way of thinking that a scientist learns is supernally powerful. A scientist learns to solve a problem by analyzing it into small bits, taking care of all the important factors in that problem and attaching to each bit its due weight (the so called scientific method). That is how physicists are going into other fields: finance (for risk-analysis), computer software, biology and medicine.

Higher Education cannot flourish without basic research: which is needed to expand the frontiers of our knowledge; to further our social, economic; and scientific insights, to build new technological applications of our scientific insights; and above all to produce new generations of researchers.

Basic Sciences form the Backbone of Technological and Economic Development

Science also shapes our physical environment viz. influence of science on technology. Knowledge acquired by basic science has yielded a vast technical return.

"The vastness of the return is illustrated by the fact that the total cost of all basic research, from Archimedes to the present (day), is less than the value of 10 days of the world's present industrial production" (Weisskopf). There is no other enterprise, which has paid so much dividends with so little investment.

A nation must invest in basic science, since sustainable growth cannot be based on mere transfer of technology. Science is continually changing and, therefore, the technology it creates must also change. Unless the underlying scientific knowledge is there, the growth cannot be sustained. "If a society restricts itself to technology-transfer, then clearly, after some time, there will be nothing left to transfer if no new insights and phenomena are discovered by basic research": Samul C.C. Ting (1976 Nobel Laureate).

WHAT DRIVES TECHNOLOGY?

Unlike science, which is mainly driven by innate curiosity, technology is driven by many factors:

- **Curiosity and/ or fun:** A prime example is aeroplane flying. The Wright brothers invented flying because they were bored with the selling and repairing of bicycles, as well as for curiosity and fun.

Aeroplanes went through a strict Darwinian process of evolution, so that only the fittest could survive. Out of 100,000 types of aeroplanes, about 100 survived to form the basis of modern aviation. Because of the rigorous selection, the few surviving aeroplanes are reliable, economical, and safe. The modern jetliner has shrunk the world and, in a way, the aviation industry has transformed the world and helped traditional societies to modernise.

- **Industrial needs and role of basic research**

A prime example of peacetime need-driven technology is the invention of the transistor, which created a revolution in computers and communications. Mervin Kelly, who was then Executive Vice-President of the Bell Telephone Laboratories (BTL), reached the conclusion that neither mechanical (relay) nor vacuum-tube technology could provide for the foreseeable growth in telephone-switching needs and thus recognised the need for low power, high speed, compact switching elements.

The recognition of this need led to the formation of a Solid State Physics research group at BTL. This led to the invention of the transistor by Bardeen, Brittain and Schokley, then to the integrated circuits, programmable microprocessor, LSI, VLSI, etc. Thus semiconductor-electronics was built on basic physics research, but the driving forces for technological development were the 'needs' as recognised by certain people at BTL.

The other example is that of Dr. F.B. Jewett's recognition at AT & T of the need for audio amplification (again for the telephone system) and the awareness of the high potential for satisfying this need with electron beams. Thus was born the so-called high technology using atomic particles, so different from the technologies of coal and iron.

- **Another Role of Basic Research:** Science develops new tools and software in laboratories for its progress, and trains students and technicians to build them. These tools find uses outside. Some young people trained in this way become entrepreneurs and launch their own start-up companies, which then grow into large enterprises. There are many recent examples: Computer and Software technology, World-wide web developed at CERN for basic research, bringing a revolution in information-technology; Computed Axial Tomography (CAT) and Magnetic Resonance Imaging (MRI) scanning technology revolutionalized diagnostic techniques in medicine; the generation of codes for the secure transmission of data depends on the arithmetic of prime numbers; the design of large, efficient networks in telecommunication uses infinite-dimensional representations of groups.

If a nation has a will to transplant a technology, and competent men in the concerned technology did not exist, they are easy to produce, provided that basic scientific knowledge within the nation was there. A good example is nuclear technology where such men have played a crucial role.

- **National Security:** Historically, national security has played an important role in driving a technology. Just to give one example, in the Manhattan Project for the development of technology of nuclear weapons, physicists and those trained in basic research, played a crucial role.

- **Fourth phase of technology:** Technology today uses science with a time-delay of the order of 10 years (this may be shrinking); science, in turn, is driven by the new developments in technology. Thus a linear model of research, where knowledge moves in one direction from basic research to applied science to industry, no longer holds. In reality, multiple feed-back loops are needed. Thus, we may add a *fourth phase* to the industrial revolution, which took place after the Second World War. In this phase, interaction between basic research and technology become close.

The challenge today is to strike a balance between the pursuit of a scientific research for its own sake and its applications in other areas of science and technology. As a general rule, industrialized countries spend around 2.5% of GNP on S&T Research and Development. About 10 percent of this budget is spent on basic research, about the same amount on applied research, and twice as much on R&D related to “high technology”.

SCIENTIFIC AND TECHNOLOGICAL RESEARCH: AN IMPERATIVE FOR DEVELOPMENT
(***Keynote Address***)

Hameed Ahmed Khan
Executive Director, COMSATS, Islamabad.

ABSTRACT

The current pace of progress in various fields of life requires an appropriate action from all. It is imperative for nations to keep pace with the ever-changing scenario, in order to survive in the era of globalization. Science and Technology (S&T) are not an exception to this state of affairs and, in fact, these fields experience changes at a very rapid rate. Also considered as key engines for development, S&T demand an even more concerted effort to realize the goals of socio-economic development of nations.

This paper presented on the occasion of the 'Meeting on Basic Research and Industrial Applications' is based on a few chapters of the book titled "Scientific and Technological Research for Development". This monograph aims at bringing visibility to the nature of scientific and technological research, its historical importance and future implications for developed and developing countries alike. At the very outset, a clear picture of the different concepts of science and technology are highlighted, along with their mutual and exclusive attributes. With illustrations, examples and detailed accounts of success-stories, the ultimate objective of this paper is to underline the importance of scientific and technological research for sustained development and progress of any nation, in general, and developing nations, in particular, and to define strategies and plans of action for continued S&T research. Taking a different approach to this subject, this paper identifies the various myths that were associated with the phenomena under discussion and tries to quantify in tangible terms the benefits of the results attained so far. It also focuses on the different types of S&T research and categorizes their comparative importance to developing and developed countries. A frame-work for mutual cooperation for development is also presented, keeping in view the prospective benefits and desired objectives. Nevertheless, the consequent effects of neglecting this crucial tool for development have also been touched upon, while keeping in view the characteristics, needs and problems of the developing world and presenting a model for S&T research.

1 INTRODUCTION

The world is experiencing a period of unprecedented advances in science. Today, more than ever before, science and its applications, in the form of technology, are indispensable for development. Science has contributed immeasurably to the development of modern society, and the application of scientific knowledge continues to furnish powerful means for solving many of the challenges facing humanity, such as poverty-eradication, provision of health care, food and safe drinking water.

In an era where the standards and parameters for socio-economic development and prosperity are dynamically changing, continued scientific research is perhaps the only constant that lies at the heart of sustainable development and progress in the modern world. Science and technology are undoubtedly the most explicitly utilized tools and techniques to alter the outlook of societies, cultures, nations, economies, environment and, more importantly, life. However, to foster the continued improvement, refinement and enhancement in these fields of immense importance to mankind, scientific research is inevitable. Overall, it can be stated that scientific and technological research plays a pivotal and extremely crucial role in furthering scientific revolution and transferring its benefits to the general society.

2 SCIENCE AND TECHNOLOGY

The universality of science and technology as ever-growing and useful phenomena is a globally accepted idea. As a vehicle for development and prosperity, science and technology have never deserted mankind. In fact, they have always provided humanity with the means to grow, through applicable and implementable solutions for complex problems, and have continually served as instruments for building the prosperous world that we all live in today. Science and technology have also contributed to the current environmental, social and economic predicaments faced by humanity at the dawn of the 21st century, however, it is unanimously accepted that it is the use of S&T and not S&T itself, that has allowed these global challenges to come up. Needless to say, the importance and significance of science and technology, along with its pivotal role in the development, growth, productivity and prosperity of the world, cannot be undermined at any stage.

Generally used as a single term, science and technology are two different yet overlapping phenomena. Science is defined as a method for studying the natural world. Derived from the Latin word meaning 'knowledge', science uses observation and investigation to gain knowledge about events in nature. In science, men and women seek to collect facts or observations; look for patterns for regularities that are deemed laws; make hypotheses leading to experiments or predictions; and ultimately build theories which support (but never absolutely prove) and explain the foundational evidence. On the other hand, technology is the application of science to help people or to produce something useful. Technology draws on science and contributes to it.

3 SCIENCE AND TECHNOLOGY: DISSIMILARITIES

Besides the obvious difference reflected in the definitions of the respective phenomenas, science and technology differ in many other ways, as well. An interesting comparison of both these terms is elaborated in the following Table - 1.

As mentioned in the Table - 1, science is the product of human curiosity. Since remotest time, man has looked at nature and tried to explain natural phenomena. Technology, instead, is the product of human ingenuity. Man has been perfecting his tools, the

Table - 1

SCIENCE	TECHNOLOGY
Derived from the Latin word, meaning 'knowledge'	Derived from the Greek word meaning 'art or a skill'
A method for studying the natural world	The application of science
The product of human curiosity	The product of human ingenuity
A way of explaining the world	A way of adapting to the world

material with which they are made and the manufacturing techniques, for ages, in his struggle to survive (Papa, 2002). Another way to put it is that, science includes processes and a body of knowledge. Processes are the ways in which scientists investigate and communicate about the natural world. The body of knowledge includes concepts, principles, facts, laws, and theories. As Einstein said, "The whole of science is nothing but a refinement of everyday life". Technology, on the other hand, utilizes tools, techniques, and an applied understanding of science to design products and solve problems.

In the following words of some of the most famous scientists themselves, one can better judge the true meaning of science:

> *"Science cannot solve the ultimate mystery of Nature. And it is because, in the last analysis, we ourselves are the part of the mystery we are trying to solve" (Max Planck)*

> *"Science is facts. Just as houses are made of stones, so is science made of facts. But a pile of stones is not a house and a collection of facts is not necessarily science" (Henry Poincare)*

> *"Science must begin with myths and with criticism of myths". "Science may be described as the art of systematic oversimplification" (Karl Popper)*

Among the various differences between science and technology, one can easily identify the core differentiating-features in their respective methods, goals, and operation. Moreover, the difference of working, in terms of methodology, objective and operation, is also evident between the scientist and the engineer. Primarily, the basic functions of science and technology vary. As a matter of fact, science operates independently of society, i.e. autonomously. In the case of technology, one can say that it also has a way of its own; however, the working of technology is essentially laid out by the standards devised and enforced by the society, in which it is operating. The demands that drives technology are extrinsic in nature; however the demands in science are usually derived intrinsically (MacCormac, 1998).

Another way to distinguish between science and technology is to understand that, very occasionally is the methodology repeated while conducting science. On the contrary, the industry very frequently repeats, over and over again, a previously employed methodology. Moreover, science needs an intellectual environment to practice, a setting largely determined by the organization or institution in which it is being conducted. For technology to be useful, it has to be situated socially; however an intellectual setup is nonetheless required. Another distinguishing feature is that the community of science is the entire society, while that of technology is the customer, whose specific needs and wants, the technology is fulfilling. As is commonly known and understood, the end-product of a scientific endeavor is knowledge, both in terms of the scientific papers and related literature. This product of science is a public good, which is utilized in a mutually sharing fashion that, most certainly, implies that more for one does not translate into less for another. All in all, the entire human race benefits from the findings of scientific discovery, without having to pay an extra penny. On the other hand, the finished output of technology is usually a machine, a chemical or a process. The product of technology is usually a consumer-based item, an additional item of which adds to the overall production-cost. Essentially, the goods of technology are what we can term as private, consumer-driven items.

Yet another major difference between science and technology is that of their cultures. Within science, the outcomes of the research-endeavors are considered to be free-of-cost goods. A scientist's basic search is usually discrete, and investigators seldom share, while competing against each other, however, once the search is complete and the discovery has been made, the results are the property of the entire human race and are at the disposal of mankind without a cost. Usually, the scientific culture provokes the scientist to let everyone know of his work, in any possible way that he can. On the contrary, technology is confidentially developed. The development of publications is unintentional and patents are usually used to protect the technology from becoming public property. The objective of the technologist is to prevent the spread of his technology without his permission.

The support for science and technology also differentiates the two in a manner that science pays for its conduct in an indirect fashion, while technology pays for itself in a direct way. The value of the work of an engineer is assessed directly from the output of his work. The value of a scientist's work, however, is assessed essentially from the presumed worth of his work's contribution to the society or the difference that his work makes to the foundations of a particular technology in its nuptial stage. It is nonetheless a fact that the product of technology pays back more than the actual cost of scientific research. Science and technology both need the freedom to work; however technology essentially requires more of this freedom than does science. It is a well known fact that even in industrial research, success has come out through able workers who were left alone to do what they wanted to do, i.e. uninterrupted. As we know, the technologist and the engineer are primarily motivated by the society, while the scientist's motivation is drawn from within. There is undoubtedly a profound difference between the working of the technologists and scientists and their skill, but there is also a fundamental relationship between the two, in the sense that they themselves and the effects of their work have changed and are continuing to change the life of mankind in a deep and long-lasting manner.

4 SCIENCE AND TECHNOLOGY: SIMILARITIES

Knowing the various dissimilarities between science and technology, one cannot help but realize the obvious connection between the two. Technological problems create a demand for scientific knowledge and modern technologies make it possible to discover new scientific knowledge. In a world shaped by science and technology, it is important for us to know how science and technology connect with all content-areas.

Since Galileo made his first telescope, science has used the most advanced technical devices to collect experimental evidence to support or refute theories. Furthermore, Maxwell's equations aside from being beautiful, have generated lots of technologies. In fact, most branches of science - mechanics, thermodynamics, electromagnetism, optics, chemistry, medicine - have generated their industries. So it is true that science and technology are activities that complement each other very well (Papa, 2002). Richter, a modern technologist once said, "*Today's technology is based on yesterday's science; today's science is based on today's technology*". Science, which is bringing new discoveries expected to create new industries everyday, cannot be done without, for example, the lasers and computers that have been developed from previous science. The pace of progress in this direction is so fast that for a large number of high-tech industries, today's technology is based on today's science.

Science and technology are both considered as human activities. Science and technology are equally blamed for the unsustainable condition of the world today. Nonetheless, the nature of both these concepts is complex yet revolutionary. They both attempt to solve predicaments faced by humanity and, side by side, also generate new and complicated ones. It is their trait to open up new avenues of possibilities for the human race, which were non-existent otherwise. Undoubtedly, some of the new avenues that open up for the society are loved by it; for instance, Television and Microwaves. Others are necessities, such as synthetic materials and food preservation. There is another category of this avenue which man needs, but essentially does not want, such as nuclear power. Today, the conditions and environment for technology and science have changed equivalently. As an example, one may note that the development, improvement and potential use of nuclear-technology is not a factor determined by the potential of science-based technology, but it is determined by the society's overall attitude towards it. This can be expressed in the words of Weinberg who said that "nuclear technology is limited by the society's inability to exert the eternal vigilance needed to ensure proper and safe operation of its nuclear energy stem".

Given the noteworthy current advances in the realms of science-based technology, one cannot help but note that the human adjustment to his habitat to his preferences is as constrained as is his understanding and knowledge of physical reality through science.

The laws of nature and the state of the art limit both science and technology. For example, deriving electric power from nuclear-fusion sources would violate no law of nature, is presently beyond the state of the art. Furthermore, they are also restricted by the structure of the society and the political/legal systems of its environment. Just like science, technology is limited by the inaccuracies of its practitioners and by the side-effects that are packaged with its benefits. According to another approach by Earl R. MacCormac of the Duke University Medical Center, symmetry and asymmetry between science and technology relate in three distinct ways (MacCormac, 1998). These he described as:

- One, science and technology possess similarities, which are symmetrical and dissimilarities that are asymmetrical.
- On the other hand, each entity possesses internal mathematical symmetries and asymmetries.
- Lastly, the symmetries and asymmetries found within science and technology arise from symmetries and asymmetries found in the physical world—both natural and human-made. While science seeks to understand the nature of the physical universe, technology or engineering seeks to construct artifacts to modify the world. Engineers design structures and machines for human purposes, often largely independent of scientific theories.

MacCormac says that one way of discovering similarities and differences between science and technology is to examine the values held by each, and observe where they overlap and where they don't. Scientists often distinguish between the internal values, which scientists assume and the external values that society imposes upon science. For example, scientists pursue knowledge of the physical world for its own sake regardless of the consequences of that knowledge. This dedication to knowledge for its own sake is a value we may call 'internal'. The consequence of that knowledge, however, is a value we may call 'external'. Chemists who synthesize a new compound are excited about that scientific achievement and may also deny side by side, any responsibility that this product may be used for chemical warfare in the battlefield. A reasonable premise for the defense of pursuing knowledge for its own sake is that if research would be limited due to its unexpected possibly harmful outcomes, then almost no scientific investigations could be undertaken. No one can tell in advance how the results of scientific knowledge will be used, however some commitments are made to justify the ongoing scientific research.

Furthermore, honesty, which can be termed as the commitment to the truth, exists as the most revered internal value of science. The ethical value of honesty is in the limelight of science as a field, because without trust, the experimental performance of the researcher cannot be acceptable. Beauty also infuses into science as that internal value which assumes several forms of expression. Scientists claim beauty in the fit of their theories to the material world as established by experiments. Theories are called beautiful in terms of their internal structure, i.e. how the concepts interact with each other and how the concepts themselves find expression in equations and algorithms alike. According to MacCormac, technology possesses similar internal values of a commitment to truth and expression of beauty as does science. But, the slight difference that exists is that technology does not pursue truth for its own sake because its nature depends upon a teleology which bleeds the difference between internal and external values. It is very rare that technological knowledge takes the form of pure investigation. Instead, technological knowledge exists as practical knowledge, which provides insight into how to build things, and knowledge of how those things will carry out their purpose and aim. For example, engineering knowledge about computers includes architectural design of hardware along with knowledge of the possibilities of developing software to execute various functions like the solution of equations, word-processing packages and statistical packages.

MacCormac concludes by saying that basically, science and technology have different fundamental commitments. Science pursues knowledge alone and technology pursues knowledge for the purpose of improving human life and culture. Scientists try to live within the world of internal values, while engineers eagerly express their internal values of honesty and design in structures and machines that express external values. Some salient features and observations regarding science and technology, their peculiar patterns and resultant outcomes are captured in a nutshell as follows:

- Experience shows that today's technology is based on yesterday's science; today's science is based on today's technology.
- It has been discovered that the road from science to new technologies is not a straight highway, but a kind of spiral of science, enabling new technologies that, in turn, allow new science which again creates new technologies and so forth.
- The process of development follows somewhat the following journey: Science enables industry to develop new technologies, and to reduce scientific discovery to practical application effectively and quickly. For this to happen, there must be a continual interaction between scientists in laboratory and engineers in industry.
- This rather simple picture does not explain a kind of third dimension that shows how, in developing new technologies and products, results from many areas of science and technology usually must be combined. It is believed that, there is a kind of "double helix" in the interaction of science and technology. Science is one strand of the helix; the other strand is technology. The two are inextricably linked, and either can advance in the long run without advances in the other. Policymakers in government who think that focusing on short-term applied work can increase economic competitiveness ignore at their peril the implications of the science-technology double helix for one-term development. To advance along this double-helix fundamental science is necessary to develop new capabilities that benefit humanity.

Science and technology are activities that involve human values. The social, cultural, and environmental contexts within which they occur influence the conduct and content of science and technology. Vice versa, science and technology influence the social, cultural, and environmental contexts within which they occur. All in all, science

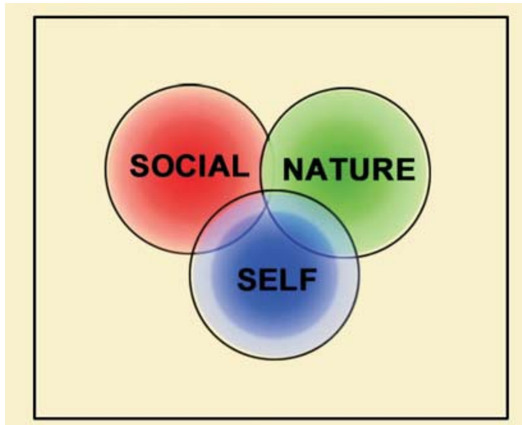

Figure - 1: The Three Worlds of Knowledge

and technology have reciprocal effects and their interrelationships vary from time to time and place to place. The Figure - 1 represents the three contexts of knowledge in general and scientific knowledge in particular, namely self, nature and social.

In Figure - 1, it is demonstrated that the frontiers of knowledge, essentially exist at the boundaries of the worlds of nature, self and social. These frontiers are also present where each world of knowledge intersects another. Indeed the area where all the there intersect is the most critically important area with regards to knowledge itself.

A particular misconception about science that generally exists in the minds of certain people is that science creates certainty. This is quite an untrue notion as knowledge is not a limitless phenomena. On the contrary, it is essentially limited by three key factors namely distance, time and theory. Figure - 2 and Figure - 3 depict how time and distance influence the relative certainty of knowledge.

Figure - 2 demonstrates the level of certainty of scale, or distance as against the relative certainty of knowledge. This is essentially a hypothetical cross-section of the sphere of knowledge as against an axis of distance expressed in metres. This figure essentially illustrates that the level of certainty depends upon knowledge. It says that the level of certainty of the realm of Physics is higher than that of Chemistry, which in turn is greater than that of Biology and Physiology and so on and so forth. Moreover, the certainty of knowledge of the behaviour of very large systems is limited. Although the behaviour of individual atoms is not certain, thermodynamic quantities can be defined which are certain.

Heisenberg's uncertainty principle provides the theoretical base for much of modern physics, chemistry and biology and is a part of the foundation of quantum mechanics. This uncertainty principle states that one cannot simultaneously define the momentum and location of a particle. It further states that one cannot simultaneously

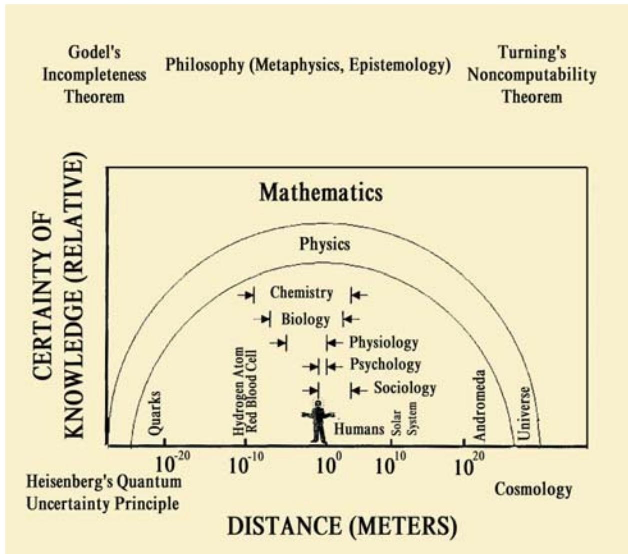

Figure - 2: Limits on Knowledge: Effects of Scale

establish both the energy and the time of a particle. Heisenberg's uncertainty principle shows that there is a limit to knowledge at very small scales. The sphere of knowledge (Figure - 2) demonstrates that there are at least two other limits to man's ability to understand and forecast the world. These limits are invariably independent of observation and are known as the '*Gödel's incompleteness theorem*' and the '*Turing's non-computability theorem*'.

Gödel's incompleteness theorem states that "*You may know it but you can't prove it*". On a later stage, the Gödel's theorems were extended by A.N. Turing whose non-computability theorem states that "*You can't prove it by computing it*". The study of the nature of knowledge, which is called 'epistemology', further exemplifies the fact that that there is a theoretical limit on certainty of what we know or can possibly know. The problem essentially lies in the process of defining the criterion for judging the truth and falseness of the manifestation of things.

Figure - 3 essentially illustrates the effect of time on the certainty of knowledge. It demonstrates that when the duration of time is in the scale of man's general perception, i.e. in seconds, minutes and hours, the certainty of both observation and knowledge is high. But given the circumstances, when we extrapolate backwards in time, i.e. the sphere of historians, archaeologists, geologists, etc, the level of certainty of knowledge decreases with the number of years of extrapolation. A fascinating aspect of time itself is mankind's capability to extrapolate backwards and forwards. Cosmologists freely predict physical events in time backwards by 10^{17} seconds and forwards by equally sizeable increments. As per the figure, the level of certainty of these extrapolations is very low.

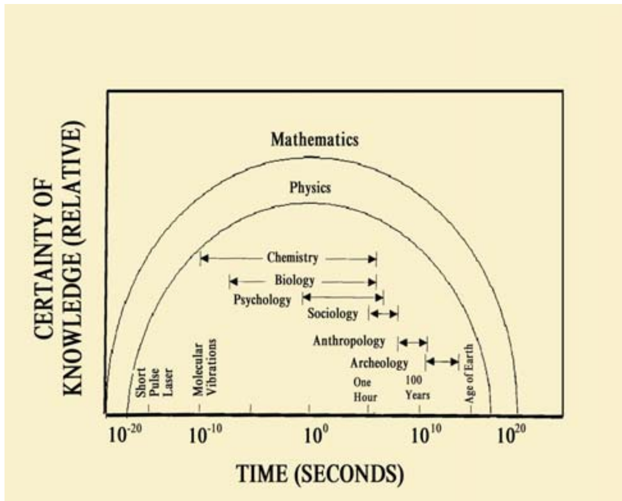

Figure - 3: Limits on Knowledge: Effects of Time

According to Hawking, time doesn't exist as a fundamental property of the universe. He says that we experience only transitory moments called 'nows'. Indeed, our brains incorporate the immediate 'nows' into what we assume as a continuous and non-stop flow of time, it is on the contrary just an illusion. As a final thought, it can be said that there are essentially three limits on comprehending the universal nature of things. First, we must not put our trust in knowledge as such that we forget mortality. Two, we must always apply knowledge to achieve that which is good rather than that which is not. And lastly, we must not presume to attain the mysteries of God by studying nature itself.

5 SCIENTIFIC RESEARCH

The explosive growth of scientific knowledge and continuing developments in technology are transforming society. Today, while we are hailing the advent of the 'Information Age', it is a well-known fact that it is the very breakthrough in the fields of computer science and communication science that knocked open the gate to this age. Obviously, the important role that scientific research has played in the development of human society has been universally recognized. The whole world is emphasizing knowledge and the role of science and technology as the primary productive forces has consequently increased manifold.

Scientific research is the cardinal tool for mankind to know and reform nature. Activities of scientific research date back to the early stages of human society. Scientists today continuously get familiarized with the universe, understand its objective laws by thinking and practice, and apply the knowledge they have acquired in guiding practice, creation and invention. The remarkable accomplishments of the human race are just monuments of scientific research activities of the past (Mianheng, 2002). As Albert Einstein said:

"The process of scientific discovery is, in effect, a continual flight from wonder"

The progressive development of the human society has placed an ever-increasing demand on scientific research. On the one hand, the issues for scientific research have become accentuating and complex in an unprecedented manner. Nowadays, the forefront of scientific research is marching towards the untouched areas in leaping bounds in both micro and macroscopic directions. Whether with microscopic particles and nanometer technology in physics or with chromosome and gene in bioscience, scientific research has advanced to create a complex and abstract world, which in turn raises new formidable tasks for scientific research to overcome. All in all, the development of science and technology has given impetus to social progress. Meanwhile the contents and methods of scientific research have also been innovated continuously (Mianheng, 2002). As a wise man once said:

"*Scientific discovery makes invention possible*."

A similar idea was floated by Sir Isaac Newton, who said that:

"Who ever has undergone the intense experience of successful advances made in (science), is moved by profound reverence for the rationality made manifest in existence"

Today, scientific research is a highly controversial issue. Many scientists, technologists, industrialists, planners and policy-makers are commenting on and questioning the value of various types of scientific research. Some of the issues being debated are:

- Who should be paying for basic research?
- Should governments spend less of the taxpayer's money on basic research in order to concentrate more funding on research projects that have potential economic value? Should public funds be used to subsidize applied research being carried out by private industrial companies?
- Is basic research viable and necessary especially when it comes to developing and underdeveloped countries?
- Should the impetus be to harness and conduct applied research or basic research and what should be the balance, if any?

As is clear from the crux of the debate, the issue is primarily focused at the two branches of scientific research, namely basic and applied. However, before one attempts to answer these important questions, one needs to get a better and deeper understanding of the meaning and value of not only basic and applied research, but also the other types of scientific research contributing to development and making an impact on today's technology.

Scientific research can be broadly categorized as follows:

i. Basic Research
ii. Applied Research
iii. Mission-Oriented Research
iv. Problem-Oriented Research
v. Industrial Research

5.1 Basic Research

Basic, fundamental or pure research is driven by a scientist's curiosity or interest in a scientific question. The main motivation is to expand man's knowledge, not to create or invent something. It can be further defined as a scientific research, performed without any practical end in mind. One of the most distinguishing characteristics of basic research is that it cannot be easily defined operationally and cannot be tested in advance for utility. In this type of research, the process of innovation is interwoven with the production of new knowledge. Consequently, basic research is righteously termed as the 'mother' of all inventions, because it provides the requisite 'scientific capital' (new scientific knowledge and understanding) that is needed for technological breakthroughs and for finding solutions to important practical problems.

Basic Research is aimed at gaining more comprehensive knowledge or understanding of the subject under study, without specific applications in mind. Some general examples of basic research include, research on the chemical properties of bacteria, analysis of the interaction of the oceans with the atmosphere, and investigation of neural pathways in the human brain (AAU, 2002). Another way to describe the concept is to say that objective of basic research is to gain more comprehensive knowledge or understanding of the subject under study, without specific applications in mind. In industry, basic research is the research that advances scientific knowledge but does not have specific immediate commercial objectives, although it may be in fields of present or potential commercial interest. Understanding how a protein folds or how a specific molecule elicits a particular biological response are also examples of basic research. More examples of the questions in which basic-science investigations probe for answers include:

- How did the universe begin?
- What are protons, neutrons, and electrons composed of?
- How do slime molds reproduce?
- What is the specific genetic code of the human being?

Basic research is that component of knowledge, which does not involve any immediate or foreseen commercialization or commercial viability. The ultimate objective is therefore not to serve any pressing need or attend to a current problem, but to aim at discovering knowledge with a universal perspective and a broader horizon. This trait of basic research allows many an invention and technologies to stem from the accumulated knowledge-reservoir built, through continued basic research. Informational input attained from conducting basic research is the essence for instigating inventive activities. More specifically, answers to scientific questions are the building blocks for technological innovation and catalyst to further scientific development, and basic research undoubtedly is the essential means of gathering such answers.

5.1.1 Importance of Basic Research

Over 200 years ago, at the beginning of 1782, the German physicist and philosopher Christof Lichtenberg wrote in his diary referring to the planet Uranus, which was discovered in 1781:

"To invent an infallible remedy against toothache, which would take it away in a moment, might be as valuable and more than to discover a new planet... but I do not know how to start the diary of this year with a more important topic than the news of the new planet".

The question Lichtenberg unreservedly raised, of the relative importance of looking for technical solutions to specific problems, and of searching for new fundamental knowledge, is even more relevant and significant today than it was in his times (Smith, 1998).

It is inevitably true that the search for fundamental knowledge, motivated by curiosity, is as useful as the search for solutions to specific problems. *"Basic research leads to new knowledge. It provides scientific capital. It creates the fund from which the practical applications of knowledge must be drawn. New products and new processes do not appear full-grown. They are founded on new principles and new conceptions, which in turn are painstakingly developed by research in the purest realms of science"* (LBNL [online]).

One of the fundamental reasons as to why we today have practical computers and did not have them about 100 years ago is because of discoveries in fundamental physics, which formed the basis of modern electronics, developments in mathematical logic, and the need of nuclear physicists in the 1930s, to develop ways of counting particles. Assuredly, it had nothing to do with the need to develop computers (Smith, 1998). Today, it is truer than ever that basic research is the pacemaker of technological progress (LBNL [online]). Technology upon technology originates from fundamental discovery, often unforeseen and unpredicted. Careful studies indicate that basic research serves as a foundation of the modern technology. The following important contributions in this regard are worth noting:

i. It provides the required basic knowledge or acts as a "Scientific Capital" necessary for making the application a reality. It is firmly believed that industrial development would eventually stagnate in the absence of the supporting basic research. This stage is felt only when the "Scientific Capital" runs out.

ii. Broad based basic research is a prerequisite for solutions to different problems. Solutions are not forced or obtained abruptly. They are preceded by necessary knowledge, often obtained by basic research.
iii. Basic research provides the foundation of education and basis of training the people working in industry and technological set up.
iv. It cultivates scientific climate, conducive to understanding the objectives of technology.
v. Basic research serves as a source of intellectual standards for applied research.
vi. It is the net exporter of technique to industry. Techniques such as vacuum technology, cryogenics, x-ray diffraction, radioisotopes, etc., with their origin as techniques of basic research are commonly used in industry these days.
vii. Basic research, therefore, must not be taken as a peripheral activity or to be forced to provide short-term solutions under excessive pressure and/ or limited support.

Fundamental research has been well supported by many leading scientists of the world. As Alistar M. Glass notes in his article on fiber optics:

"Fundamental research in glass science, optics and quantum mechanics has matured into a technology that is now driving a communications revolution"

Subjects of great technological and medical importance that originated from basic physical research include among many, nuclear magnetic resonance, semiconductors, nano-structures, superconductors and medical cyclotrons.

There is a strong view among experts regarding the output of research. The proponents of this view suggest that it is the targeted, goal-oriented research that brings about useful products and innovations. Examples from daily life are also cited to support this claim, but it should be kept in mind that numerous examples could also be found, which indicated that many a products were developed as a result of basic and fundamental research. Also, funds these days are allocated more towards goal-oriented research and less emphasis is put on basic research. Still, the importance and usefulness of basic research cannot be denied and sustainability of results can only be achieved with an optimal distribution of resources between applied and basic research. It is a proven fact which history has repeatedly demonstrated, that it is not possible to predict which efforts in fundamental research will lead to critical insights, about how to address a particular problem. It is therefore, essential to support a critical number of worthwhile projects in basic research so that key opportunities do not go unrealized and waste. As there is no doubt that basic research's aim is to complete the blanks in mankind's understanding of how life processes work, there is also no skepticism about the enormously beneficial results that basic research has lead to in terms of its practical applications. The society today, reaps enormous benefits from basic research and its applications, which in the form of technologies have saved millions of lives and made many others far more comfortable and meaningful than ever before.

Dr. Allan Bromley of the Atomic Energy of Canada says that the unprecedented boom in the American economy had little to do with new approaches to fiscal management, and all to do with past investments in science. Federal investments in science produce cutting-edge ideas and a highly skilled workforce. Two simple discoveries – the transistor and the fibre-optic cable are at the root of this boom. He added that,

"Anyone skeptical of this should turn off the computer for a day as to see how much work gets done."

In a nutshell, the importance of basic science can be expressed in the words of Dr. George Smoot of the Lawrence Berkeley National Laboratory:

"*People cannot foresee the future well enough to predict what's going to develop from basic research. If we only did applied research, we would still be making better spears*."

5.1.2 The Unpredictable Nature of Basic Research

As discussed earlier, the results of most of the basic research work contained unexpected practical applications in store. Such is the uncertain future-impact of basic research work that some entirely wrong predictions were made regarding their practical utilization. History of scientific research contains a number of such instances. Following are a few illustrative and interesting examples:

- According to Rutherford, "the energy produced by the breaking of the atom would be a very poor kind of thing". Later developments showed the extent to which he underestimated this great source of energy.
- It is surprising that even Einstein could not possibly foresee how his mass energy relationship would lead to the release of nuclear energy. He said in the year 1932, "there is not the slightest indication that nuclear energy will ever be obtainable. It would mean that the atom would have to be shattered at will". Nuclear power generation became a reality quite some time ago, and has since then been playing an important role in meeting the demands of the modern world, proving Albert Einstein's statement wrong.
- Faraday on the other hand, could covertly foresee the practical usefulness and future applied nature of his work on electricity and magnetism. It is said that around 1850, Mr. William Glandstone (the then Chancellor of Ex-Chequer and later Prime Minister) visited Faraday's laboratory and asked him, "This is all very interesting, but what good is it?" Faraday replied, "Sir, I do not know, but some day you will tax it". Faraday's reply was rather a visionary one.
- A decade ago every-one regarded superconductivity a dead field. But in 1987, Alexs Muller and Georg Bednorz were awarded the Nobel Prize in Physics for the discovery of new kind of superconducting material with much higher transition temperatures, and it did not fit the model of the Bardeen-Cooper-Schrieffer theory. We still do no fully understand how these materials work, but applications have already begun.

- Charles H. Duell, of the Office of Patents said in the year 1899 that, "everything that can be invented has been invented". Obviously, he seriously misjudged the potential of basic and applied science/research.
- Popular Mechanics said in the year 1949 that, "computers may weigh no more than 1.5 tons". Pocket computers and other compact computer types evidently nullify the validity of this statement.
- Another such statement was issued by Ken Olson, President of Digital Equipment Corporation, who said in 1977 that "there is no reason anyone would want a computer in their home". Today, there is rarely a reason why one wouldn't want o have a computer at home.
- "This 'telephone' has too many shortcomings to be seriously considered as a means of communication. The device is inherently of no value to us." This is a piece of text from the Western Union internal memo issued in 1876, which seriously underestimated the utility of a device that is an integral part of the conduct of modern day livelihood.
- "The wireless music box has no imaginable commercial value. Who would pay for a message sent to nobody in particular?" This statement was made by David Sarnoff's associates in response to his urgings for investment in the radio in the 1920s.
- "Heavier-than-air flying machines are impossible." Lord Kelvin, President of the Royal Society said this in 1895, which the Wright Brothers disproved in the nineties.
- "So we went to Atari and said, 'Hey, we've got this amazing thing, even built with some of your parts, and what do you think about funding us? Or we'll give it to you. We just want to do it. Pay our salary; we'll come work for you.' And they said, 'No'! So then we went to Hewlett-Packard, and they said, 'Hey, we don't need you. You haven't got through college yet.'" A recollection of events narrated by Apple Computer Inc. founder Steve Jobs, when he attempted to get Atari and HP interested in his and Steve Wozniak's personal computer.
- "Professor Goddard does not know the relation between action and reaction and the need to have something better than a vacuum against which to react. He seems to lack the basic knowledge ladled out daily in high schools." 1921 New York Times editorial about Robert Goddard's revolutionary rocket work.
- "Airplanes are interesting toys but of no military value." Statement of Marechal Ferdinand Foch, Professor of Strategy at the Ecole Superieure de Guerre.
- "Louis Pasteur's theory of germs is ridiculous fiction". Statement made by Pierre Pachet, Professor of Physiology at Toulouse in the year 1872
- "No flying machine will ever fly from New York to Paris." Orville Wright made this comment unaware of the potential his work would acquire in the later years.

The uncertain / unpredictable nature of the curiosity drive based research work (i.e. concerning product /practical / main field /area of the final impact) is further illustrated by some more examples summarized in the Table - 2.

It is also interesting to note that applied form of research (the products that are developed) can somehow be linked to the fundamental research; examples can be given in this regard as transistor was developed as a result of research in condensed matter Physics, and Magnetic Resource Imaging technology was developed due to investigations in nuclear magnetic movements. A conversation between Socrates and Glaucon can be used to support the claim:

Socrates: Shall we set down to astronomy among the subjects of study?
Glaucon: I think so, to know something about the seasons, the month and the years is of use for the military purposes, as well as for agriculture and for navigation.
Socrates: It amuses me to see how afraid you are, lest the people should accuse you of recommending useless studies.

More recently, Frances W. Clarke of the U.S. Geological Survey, in a speech also protested that:

"Every true investigator in the domain of pure science is met with monotonously recurrent questions as to the practical purport of his studies; and rarely can he find an answer expressible in terms of commerce. If utility is not immediately in sight, he is pitied as a dreamer, or blamed as a spendthrift."

The return on investment in basic research is not often so immediate. However, over the long term, it can impact substantially, and often as least expected. Indeed, investment in basic research produces a multifarious payback, a clear example of which is the creation of an entire new economy based on information technology (Birgeneau, 2001).

5.2 Applied Research

Applied research is designed to solve practical problems of the modern world, rather than to acquire knowledge for knowledge's sake. The focus of applied research is on defined outcomes i.e. to solve problems, to make decisions and to predict and/or control. It is fundamentally carried out to achieve certain goals and convert the findings of basic research into practical applications.

Applied research is aimed at gaining the knowledge or understanding to meet a specific, recognized need, or solve a specific problem. It includes investigations oriented to discovering new scientific knowledge that has specific objectives, for example with respect to systems, products, processes, or services. Finding a better treatment or diagnostic for a disease is also an example of applied research.

The three predominant characteristics of applied research include:

- Generation of knowledge which will influence or improve clinical practice
- Potential for contributing to theory development, and that the

Table - 2: Scientific Fields and Technological Areas Benefiting From Fundamental Research in Diverse/Unrelated Subjects

Original Research Work or the Basic Emphasis (and / or the Field of Interest)	Field / Area which Finally Benefited or the Final Product Resulting Due to the Research Work so Carried Out
• Fundamental research in glass science, optics and quantum mechanics	• Fibre Optics – Revolutionary Technology in communications
• Basic Research on Tetrafluoroethylene to aimed at preparing new refrigerants	• Teflon – A material with extremely useful industrial application
• Research work on drug AZT, was carried out to find a remedy against cancer	• Useful Progress made in obtaining Anti AID drug
• Rosenberg's research on the potential effects of electric fields on cell division	• Discovery of an important drug against cancer
• Kendall's work on the harmones of the adrenal gland	• Resulted in the identification/ formation of an anti-inflammatory substance
• Carothers' research work on giant molecules	• Let to the invention of Nylone
• Block and Purcell's fundamental research work in the absorption of radio frequency by atomic nuclear in a magnetic field	• The research work led to a very important technique of magnetic /medical resource imaging (MRI)
• Cohen and Boyer's work on the development of gene splicing	• Produced better insulin along with other useful products
• Haagen – Smit's work on air pollution	• Spawned the catalytic converter.
• Reinitzer's important work on the discovery of liquid crystals	• Important contribution in further development of computers (particularly flat panel television screen) and the discovery of laser. • Laser, which was initially a laboratory curiosity has found important applications such as the reattachment of a detached retina and the reading of barcodes in supermarkets.
• Various projects carried out in "Basic Physical Research"	• Subjects of great technological and medical importance such as: - Nuclear magnetic resource - Semiconductors - Nanostructures - Super conductors

continue...

...continued

• Fundamental Basic Work in Condensed Matter Physics (1920s – 1930s) • Rabi's work on Nuclear magnetic Movements (1938)	- Making useful … applications - Carrying out medical applications • Development of Transistors (1950s) • Magnetic / medical Resource Imaging (MRI) (1980s)

- Researcher has access/control over phenomena being studied

Applied research is carried out to find practical solutions for current pressing needs. In essence, the problems of the society in general and the industry in particular are assessed and addressed by applied research, which results in the improvement of a product or a system. This research is primarily done because the performer "expects to benefit from it in some direct way, such as through a future business return or a direct financial interest" (Lukasik, 2000).

In other words, applied research is work that translates into products, goods, or services that contribute to the GNP. It is the investigation of some phenomena to discover whether its properties are appropriate to a particular need or want. It aims to answer real world questions and not just abstract and theoretical ones. It focuses on solving problems, evaluate projects and make policy or managerial decisions and plan and forecast. All in all, applied research is that kind of activity whose informational output is an input in the production of commodities. General examples of applied research would include using bacteria to inoculate plants against particular diseases, developing computer models of the atmosphere to improve weather forecasting, and creating drug therapies for brain-related illnesses (AAU, 2002). Further example of what applied researchers may investigate, include ways to:

- improve agricultural crop production
- treat or cure a specific disease
- improve the energy efficiency of homes, offices, or modes of transportation

All in all, applied research is an original research just like basic research, but is driven by very specific, practical objectives. Examples are all research for the formulation of public policy (education, health, economic, environmental etc); research into how industrial development can take place with simultaneous protection of the environment; research into the provision of adequate, cheap housing; and research around finding cures for diseases.

5.2.1 Importance of Applied Research

As mentioned, applied research is aimed at gaining the knowledge or understanding to meet a specific, recognized need, or solve a specific problem. Many of the modern day scientists are arguing the viability, significance and importance of applied research against basic research. This argument is augmented by the premise that global overpopulation, pollution and the overuse of natural resources is consistently generating complex problems for the human race and science should now be directed towards improving the human condition by providing pragmatic solutions rather than indulging in knowledge seeking endeavors only, which have no immediate direction in sight.

Whatever the argument, one cannot neglect the importance and significance of applied research, be it yesterday, today or tomorrow. Applied research leads to inventions. This process is usually spread over a large span of time and normally a large number of people are involved in attaining invention stage. There have been many historical examples in which applied research has had a major impact on our daily lives. In many cases, the application was derived long before scientists had a good, basic understanding of their underlying science. This phenomena may be illustrated by envisioning a scientist saying to himself, "I know it works; I just don't really know how it works!"

The invention of transistor was also a revolutionary application of scientific research and proved to be a major milestone for the electronics industry all over the world. It also proved to be a starting point for the design and manufacture of integrated circuit (ICs). Before this discovery, vacuum tubes were used as the alternate means (as triodes) in electrical devices. Scientific research and experiments also lead to may other noteworthy developments in various other fields such as health and medicine. These included developing of vaccines for polio (1953), rabies vaccine (1885), and pencillium (20th Century).

5.3 Mission Oriented Research

A simple definition is as follows:

"A broad based research, carried out in support of a particular Mission or the achievement of a certain Technological Goal".

The 'Mission' or the 'Technological Goal' could be any broad based programme aimed at the developmental work of a certain scientific system or establishment of a proper infrastructure / know how, necessary to make the project 'Critical' and workable for the aim with which it was initially started. It may consist of different combinations / phases of "basic" and "applied" research project / sub projects. Some of the examples of "Mission Oriented Research" are:

i. Development and Establishment of Nuclear Energy Programme
ii. Research leading to the Development of Radar System, Missile Programme, Space Exploration, etc.
iii. Research aimed at Cancer cure. Mission-oriented research focuses on developing new knowledge of direct relevance.
iv. Research aimed at controlled Fusion / thermonuclear reactions
    - Development of X-ray lasers.
    - Understanding the Effects of Radiation on Matter.
    - Development of a cure for cancer, aids, etc.

It is interesting to note that Mission oriented research does not deal with only applied research, but also greatly contributed in the advancement of basic research with the development of new gadgetry helpful for the generation of new and high level basic knowledge. Some of the examples are:

i. Basic research in superconductivity greatly benefited from the programme carried out for the development / advancement of new energy sources.
ii. Space programme helped (and vice versa) in securing handsome government grants for the advancement of atomic and molecular physics.
iii. Basic research in atomic, molecular radiation, and radiological physics for example, draw valuable support from Organizations carrying out extensive research / programmes in studying the effects of different types of radiations on living cells.

As mentioned earlier, Mission oriented research, in many ways, contributed enormously in the further improvement/ progress in the Basic Research domain by developing new and advanced methodologies, processes experimental techniques and instrumentation. Some typical examples are as follows:

a. Mission oriented research in Defence related projects resulted in tremendous progress / development in computer science / technology. This remarkable development could not take place if carried out for carrying out basic research alone. It was the "impetus" and "support" given by the Missions of "Defence" and "Space Race".
b. Nixon's programme dealing with cancer was started with a mission of finding a cure for cancer. The mission did not succeed as such. However, it gave a tremendous boost to the advancement of "Biotechnology".
c. Reagan 's stars war initiative was taken with the objective of realizing a "protective shield" against a possible nuclear attack" The work so carried out did not help in achieving this objective. However, surprisingly it resulted in useful research output in the field of new materials and yielded valuable insight in light sources such as X-ray lasers.

It is, thus, clear that in Mission Oriented research, the benefit is mutual, i.e. the applied and basic research help each other. Experience shows that this mutual benefit is maximum when the interpretation of "Mission Relatedness" of "basic Research was not narrowly defined".

5.4 Problem Oriented Research

Problem oriented research is simply defined as 'research work carried out to solve a specific problem arisen during a certain research programme'. This is relatively, a narrow research activity aimed at some difficulty or hurdle faced during a broad research activity. It can also be aimed at solving certain technical fixes. In certain cases it may be required to be carried out to find out a quick / immediate (on relative time scale) solution to meet certain societal needs. Some specific examples may be as follows:

- Problems relating to public health, pollution, etc. Other immediate public concern problems such as water, energy, transportation, waste disposal, etc.
- Suitable replacement of useful but hazardous materials – such as PCBs (polychlorinated biphenyls), CFCs (chlorofluorocarbons), etc.

Problem-oriented research is primarily concerned with current issues and problems as well as the relevant social actors and stakeholders. The primary objective of this type of research is to analyze perceptions of the problems at hand, related models for action and means of knowledge and then to transform these into scientific questions and research strategies. This research claims to bridge the gap between natural, humanities and social sciences, and uses the impetus on predicaments to reach interdisciplinary and/or transdisciplinary approaches. The fundamental goal is to amalgamate scientific analysis with action keeping in mind the interests of societal decision-makers and stakeholders (ITAS, 2000). To achieve the goal of problem-oriented research, scientific, technical and sociological theories, methodologies and data must be methodically interlinked and acquainted with the visions of sustainable development or recycling economy, or more specifically visions of a technological nature or those related to ethical standards. By doing this, problem-oriented research focuses more on the relationship between normative determinations and empirical analysis of results. What lies at the heart of problem-oriented research is essentially the integration of social reflection and the dynamism of scientific knowledge into decision-maker's strategies for action (ITAS, 2000).

Problem-oriented research develops out of the specific requirements of the business world and public authorities, but also out of needs which arise in new areas with growth potential. It is implemented on the basis of cooperation between the actors involved in carrying out research and the actors who need the results and skills which emerge from the research process, including scientific methods of solving problems. From a scientific perspective, problem-oriented research can be both basic research and so-called applied research. In order for problem-oriented research to produce innovations and sustainable growth, there must be high standards of scientific quality and on-going cooperation between the actors involved, in order to promote mutual interaction and learning. When a satisfactory level of interaction is reached, needs-based research can produce internationally outstanding scientific results, effective innovation processes and growth.

5.5 Industrial Research

Scientific discoveries coupled with technological developments enable industrial section to convert the new knowledge so gained to practical applications in an effective manner. Such a conversion of new knowledge to industrial products should preferably take place as early as possible, if an effective edge over other competing industrial set ups is to be achieved. In addition to this, industry carries out its own research programme. This research, carried out by industry under its own programme is generally known as Industrial Research. Industrial research predates invention, involves highly knowledgeable (men of vision) and is aimed at obtaining ingenious knowledge and new ways that facilitate the emergence of new technology. It is, therefore, clear that it is extremely important to get new and good ideas which enable the industry to (a) improve the quality and usefulness of its products and (b) make them relatively more durable and inexpensive. It clearly indicates that many industrial set ups are well aware of the importance of new/basic knowledge, because it acts as the seed for obtaining a better and more efficient product, which will ultimately result in increased profit and better financial gains for the industry concerned.

Experience shows that there seem to exist (a) "time continuous" from fundamental knowledge to a usable / marketable industrial products and (b) "diffusion time", a period necessary for the diffusion of "technological innovations". It is interesting to note that both of these durations seem to be getting shorter and shorter with the passage of time. For example:

- For the time continuous for the Principle of Photography, was 200 years, while the diffusion time for the same was only 40-50 years.
- In the case of Liquid Crystals it took 80 years until the fundamental knowledge was actually converted into products, while it took the Electrical Motor only 40 years.
- The time continuous for Nuclear Power and the Transistor is the same i.e. only 5 years, while the diffusion time for the Transistor is an unexpected 15 years
- Transparent Plastics took only 2 years to move from basic knowledge to marketable items.
- The time continuous for Nylon is 10 years.
- Superconductivity is also one such area for which Theodore H. Geballe said:

  "It took half a century to understand Kamerlingh Onne's discovery, and another quarter to make it useful. Presumably, we wont have to wait that long to make practical use of the new high-temperature superconductors."

6 CONCLUSIONS AND RECOMMENDATIONS

In the twenty-first century science must become a shared asset benefiting all people on a basis of solidarity only. Science is a powerful resource for understanding natural and social phenomena and its role promises to be even greater in the future as the understanding of mankind regarding the growing complexity of the relationship between society and the environment becomes deeper. The continuously increasing need for scientific knowledge in public and private decision-making, including the significant role of science in the formulation of policy and regulatory decisions has been adequately emphasized and ascertained. It is also agreed and understood that scientific research is a major driving force in the fields of critical importance to mankind and that greater use of scientific knowledge is a prerequisite to development. Deciphering from the facts, it is also clear that there is an urgent need to reduce the gap between the developing and developed countries by improving scientific capacity and infrastructure in developing countries. The importance for scientific research and education and the need for full and open access to information and data are important considerations as well. It is therefore necessary that a new relationship between science and society must be contemplated so that humanity may cope with pressing global problems such as poverty, environmental degradation, inadequate public health, and food and water security and population growth. Nevertheless, there is a need for a strong commitment to science on the part of governments, civil society and the productive sector, as well as an equally strong commitment of scientists to the well-being of society.

As is clear from the above-stated deliberations, basic research is performed without thought of practical ends and results in general knowledge as well as understanding of nature and its laws, whereas applied research aims at giving complete specific answers to important practical problems (LBNL [online]). In essence, basic research is motivated by curiosity and applied research is designed to answer specific questions. J.J. Thomson, the discoverer of the electron, explicitly outlined the difference between basic and applied research in a speech delivered in 1916:

"By research in pure science I mean research made without any idea of application to industrial matters but solely with the view of extending our knowledge of the Laws of Nature. I will give just one example of the "utility" of this kind of research, one that has been brought into great prominence by the War - I mean the use of X-rays in surgery...
Now how was this method discovered? It was not the result of a research in applied science starting to find an improved method of locating bullet wounds. This might have led to improved probes, but we cannot imagine it leading to the discovery of the X-rays. No, this method is due to an investigation in pure science, made with the object of discovering what is the nature of electricity…

Applied science leads to reforms, pure science leads to revolutions and revolutions, political or scientific, are powerful things if you are on the winning side".

The relative importance of “Basic” and ‘applied’ Research is a widely discussed topic of today. It is equally important to note that applied research does not always follow basic research, as was the case in the development of large Radar Antennas for applied purposes, which led to basic research in Radar Science and Radio Astronomy as well as the case of the development of pure materials for technological applications, which stimulated fundamental investigations in Solid State Physics, but the loop does not necessarily end here. This is not always a one-way street.

People such as James Watt, who was an applied researcher in the field of steam engines, contributed considerably to the basic fields of mathematics and physics. Virtually, the whole basic field of thermodynamics was developed by applied science. Lavoisier, the founder of modern chemistry, was launched into his career by two applied projects: lighting the streets of Paris and developing a new process to produce saltpeter. It was these projects that led to and funded his later experiments in which he proved the conservation of mass, and discovered how oxygen functions in combustion. Carnot's work on engines led to the discovery of the second law of thermodynamics. Clausius, building on Carnot's work, proposed the property of entropy. Kelvin's work on engines led to the concept of available energy. Again, working with simple engines, Joule bridged the gap between heat and physical work. Gibbs, combining all of these insights, published signal works in chemistry, widely renowned as fundamental ‘basic’ discoveries in chemistry.

Evidently, there is a very impressive example of applied work on engines leading to Gibb's insights on chemical equilibria and chemical thermodynamics, including free energies, energies of formation, and all of the mathematical techniques that underlie virtually all of modern chemistry. It is therefore important to note that discoveries do not necessarily take the route from basic to applied. It is therefore important to make it clear that all research has objectives, and that all research is aimed at usable results. It may well be that basic research in the main sets its targets within the world of research itself, whereas applied research is aimed at objectives and applications outside the world of research. But the boundary is not at all clear. Much basic research eventually turns out to be applicable, and applied research has often made weighty contributions to the development of research as such.

The generally accepted view is that basic research is primarily conducted in universities, whereas applied research is a matter for research institutes and private companies. In fact there is a good deal of applied research in universities, and also basic research in the outside world. It is impossible to say anything about the importance, quality or degree of difficulty of research merely by describing it as either basic or applied research. All research must be judged by its results, and by the degree to which it achieves its objectives. Hence, it is necessary to know the objectives, even if one does not wish to label the research in question in one way or another. It may also be emphasized at this juncture that experience shows that best results in applied research are obtained in cases where the scientists given the task to carry it out, are knowledgeable and have a sound background in ‘Basic Science’. If their knowledge in basic science is limited and/or narrowly channeled, the 'applied product' is expected to have limited utilization. It is, therefore, strongly advisable that 'applied science' must be coupled with 'basic science' or 'basic little science'.

It is hoped that through science-based technology a route to a brighter and prosperous future is made that would improve the condition and overall life of man. Interwoven with this promise are two important elements that need stressing. First, whether science-based technology will provide the necessary answers for all of the earth's people and make the earth a more equitable place. The answer to this question will depend more one man's values and less on his science and technology. On the other hand, man must become knowledgeable, wise, brave and unselfish enough to forego technologically brilliant ideas when they are more damaging than beneficial. As Bertolt Brecht, Galileo once said:

"Science knows only one commandment: contribute to science"

Strategic recommendations for the developing countries in order to effectively carry out scientific and technological research for socio-economic stability and development, are as follows:

A

- The developing countries must understand and realize the importance of science and technology for development and utilize it optimally for their sustained progress and prosperity. For this, the government as well as the masses must be educated and apprised of the pivotal nature of S&T.
- They should aim to adopt technologies to local circumstances if these are imported from abroad, because local research is necessary to make imported technologies function according to desired standards.
- They should integrate and incorporate new sciences into education. This is one of the prerequisites for sustainable development and for the provision of a well-trained and well-equipped workforce. High-quality education must therefore be put in place early in the development process.
- On the one hand, developing nations must rethink their scientific and technological priorities in the face of growing economic constraints and new political and ethical realities, while on the other, they must strive to build the capacity necessary for effective teaching and research in science. Education and research represent long-term investments in human capital that yields large returns in economic growth.
- The input of scientists along with industrialists, educationist and technologists, must be inculcated in the policy-making process, so that long-term strategies may include the scientific benefit factor within them.

B

- Developing countries would simultaneously have to make a special effort to push science and technology to the forefront of their domestic policy agenda. They must realize and understand the relative importance and benefits of basic and applied research, and they must strike a balance between them at the overall national/government level and not only at an agency by agency level.

- There must be a tighter linkage between basic research and national goals, which should be the criterion for research support.
- For the distribution of basic research funds, all proven performers should be adequately funded. Investment should also be made in areas that offer results of the broadest applicability across other scientific disciplines. The support of young scientists must be carried out for the generation of new ideas, and support should also continue for centres of excellence so that the necessary scientific infrastructure could be provided which could serve a greater number of investigators.
- As industrial contributions to long-term R&D are decreasing, the governments of developing and developed countries alike should mirror the situation by maintaining or increasing their long-term commitments to fund-allocation.
- Cooperation is an integral element for sustained progress, both at the individual and collective level. It is therefore suggested that engineers, scientists and other experts, who are both applied thinkers and basic thinkers, must work together as a team and their efforts must be synergized to produce desired results.

C

- The building of scientific capacity should be supported by regional and international cooperation, to ensure both equitable development and the spread and utilization of human creativity without discrimination of any kind against countries, groups or individuals. Assurance must be made that cooperation should be carried out in conformity with the principles of full and open access to information, equity and mutual benefit.
- Mutual cooperation, especially in the fields of science and technology, economy and trade, and information and culture, must be instigated on a larger scale, so that conjoined efforts could help achieve the mutually desired result of sustainable development.
- The technological gap however daunting and grave, still offers new opportunities for newcomers and investment in R&D and, at this stage, has great possibilities for economic returns from improved technologies. On the other hand, however, the supply aspect of the national industrial R&D system must be improved to ensure continued effectiveness.
- They must avoid the allure of costly but ineffective research programmes and establish a system that rewards solving practical problems.
- It is also recommended that the planning authorities in government, industry and research institutions should identify priorities and establish national R&D programmes to serve the industrial strategies for the development of technology domains. This will allow for concentrated efforts towards improving the overall economic situation of the subject country.

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THE ROLE OF UNIVERSITY - INDUSTRY PARTNERSHIP IN ENHANCING BASIC RESEARCH AND INDUSTRIAL APPLICATIONS IN PAKISTAN

Zaffar M. Khan
Director
Advanced Engineering Research Organization (NESCOM)
Wah - Cantt.

ABSTRACT

Technology-led industrialization has become a major factor in developing countries and in the countries having their economy in transition. Researchers at universities and managers in industries are deeply involved in technological and socio-economic issues for sustainable industrial growth, but they are working in isolation. Most of the research work is carried out in universities but the fruits of its commercial exploitation are not reaped by industry. It is therefore, important to bridge the gap between academia and industry for sustainable economic growth and effective industrialization. The perception and level of the university – industry partnership is, however, different in developed and developing countries.

This paper will examine the role of academia and industry in promoting basic research and its industrial applications, keeping in view global competitiveness, liberalization of market-economy and the information-revolution. It will also recommend practical solutions for accelerating the university – industry interaction in developing countries, in order to promote basic research and its industrial applications.

1. INTRODUCTION

The advancements in sciences and technologies have often determined the socio-economic standing of civilization, from the stone to the space-age. Invention of the wheel has progressively led to the industrial revolution, which in turn, spurred manufacturing-based economy in United Kingdom at the dawn of the eighteenth century. The world is now witnessing a period of dynamic changes. The global wealth is now less concentrated in factories, lands and raw materials, but more in knowledge, skill and human resources. There has been an exceptional growth of knowledge in advanced countries, which is continuously pushing the frontiers of technological envelop to new regions through new patents, databases and journals. Advancement in information-technology has made this ever-increasing volume of knowledge more accessible, effective and powerful. Networked/distributed computer-systems and the internet ensure availability of knowledge at dizzying speed for those who have the wisdom to use it for industrial applications.

The economic liberalization is turning the planet earth into a global village, thus diminishing the geographic boundaries. The combination of knowledge-based revolution with economic liberalization requires a new set of rules, skills and attitude for survival in the world-trade regime. If the developing countries do not readjust themselves to the new realities, they run the risk of economic marginalization and intellectual starvation. The result will be increased poverty, unemployment and crime-rate, which shall threaten the civic virtues, impair the social fabric and destroy the human values of society. It is, therefore, important for the developing world to pursue the rising star of higher education for sustained economic growth, by close interaction of industry with educational institutions. This paper will identify means and ways for strengthening effective basic research and industrial applications through appropriate university – industry interaction. This involves examining the existing educational, industrial and governmental practices, procedures and programs. It will recommend practical solutions for developing effective industry-academic collaboration in developing countries [1].

2. THE SOCIO-ECONOMIC DYNAMICS OF UNIVERSITY-INDUSTRY PARTNERSHIP

Buddhist monasteries had established one of the earliest educational institutions in the Indo-Pak subcontinent for religious education of monks at Taxila in 4th century. After the advent of Muslims, new cities (such as Multan and Lahore) rose to prominence, due to religious institutions such in 8th century. It was not until 1857 that the British established three universities of modern learning. The first university established by the British was the University of The Punjab at Lahore in 1882. After creation of Pakistan, the Sindh University received its charter in 1947. Thus Pakistan received a very weak base of higher education. During the first ten years of its existence, the number of universities remained stagnant at four. Three universities were established during the 1958-68 period; the number rose to 15 during the period 1968-78 and 22 during the period 1978-88.

The period 1978-89 saw the optimum expansion of universities. A number of engineering universities were given a charter at that time. There are currently limited public-sector universities in Pakistan. Establishment of Higher Education Commission (HEC) has revitalized the academic institutions, HEC having played a historic role in revamping the academic system in Pakistan. It has also made best efforts to bridge the gap between academic and industrial organizations by supporting commercialization of research through various incentives/packages.

The reason for the deplorable condition of engineering education in the subcontinent can be traced back to the British period. There were two models of educational system prevailing in the British Empire during the nineteenth century. The British introduced an educational system in this subcontinent that was based on University of London model that involved extensive course-work rather than the University of Cambridge model that involved research work. As a result, research, design and development could not emerge as dominant components in the curricula of various universities, right from inception. The above situation created diverging trends between the two principal pillars of society. The industry did not demand results from academia and the research findings in academic institutions largely remained unutilized. The situation was further aggravated by industrialists who looked to the industrialized countries for import of finished products or to technology-transfer on turn-key basis, instead of sponsoring R&D in local universities. Such practices have led to uneven distribution of resources devoted to R&D between the developed and developing world. The developed economics account for 94% of R&D expenditures and 89.4% of researchers, while the developing countries are left with 6% of expenditure and 10.6% of researchers.

During 1982-85, seventy six firms, belonging to seven industries in USA, identified new products that could not have been developed in the absence of academic research. Those products accounted for about US$ 24 billion of sales in 1985. Taking into account the total spending on research and development in the academic sector and other expenses needed to generate the final product, this study estimated a social rate—of return that exceeds 20% p.a. The analysis of growth-data of G7 countries and East Asian emerging economies revealed that there is a positive correlation between the size of the residual growth and R&D investment. UNESCO World Science report, 1998, indicated that R&D performance of academic institutions constitutes 0.46% of GDP in USA and 0.38% of GDP in Canada [2].

In Cognizance of the above situation, the Colombo-Plan Bureau conducted a series of seminars on approaches of cooperation between industry and training institutions in a number of member countries in the 1970s. These Seminars, highlighted that, in some countries, training is planned by the educational agencies without serious reference to the needs of industry. Ministry of Education of the Government of Pakistan organized a National Workshop about academia-industry cooperation at Karachi in 1980. The participants identified a wide range of factors leading to poor academia-industry partnership, which included lack of knowledge about industrial discipline, ignorance about potentials and capabilities of trainees, lack of imagination, vision and persistence, in engineering institutes, as well as absence of legislation to enforce industrial training and tendency of industry to compromise on the quality of manpower. Asian Development Bank conducted a study in 1989 about lack of coordination between academia and industry. It was emphasized that such cooperation was essential to facilitate the transition of students from education to actual work. The report pointed out that employers regarded the engineering education as insufficient, due to inadequate communication between industry and academic institutions. UNESCO organized workshops for promoting "university – industry cooperation" in eighteen developing countries, including Pakistan during Feb – Mar, 2000, to bridge the gap between industry and academia. The workshop determined that the level of productivity growth, balance of payment, export-performance and innovation are indeed related to partnership between industry and academia [3, 4].

3. THE NEED AND REASONS FOR COOPERATION

Technologies being applied today in the industry, are founded upon the scientific research and development in the classroom yesterday. Hence the well-being of society, in the next century, pivots on the scientific research that is being carried out now in universities. Research, which can start modestly in the form of a laboratory experiment or an equation written on a blackboard, can eventually lead to a vast and varied number of industrial applications. This has been the case with fundamental research carried out on the structure of atomic nuclei, which led to the discovery of nuclear energy. Research in solid-state physics has radically transformed the market with an immense range of products and systems, such as digital watches, television receivers, video-recorders, health-care equipment and many other familiar products. Space-research program has yielded many valuable benefits in fields such as telecommunications, remote sensing, new materials, and transport systems. Incorporation of microprocessors, into existing technologies, has produced a generation of new products with improved performance. Advances in information-technology combined with progress in computers, video-recorders, telecommunications and fiber optics, have transformed education, increased the efficiency of organizations and permitted better use of human and material resources.

Remote sensing, robotics, nanotechnology and biotechnology need dynamic interactions between industries and academic institutions. These interactions are weak in the developing countries, in which science is perceived as an ornament rather than a necessity. High technologies require highly skilled professionals, because these are based on knowledge and skilled intelligence. Underdeveloped nations lack the critical mass of trained manpower to initiate such industrial projects. Economic scarcity, bureaucracy, political discrimination, rigidity in approach, short-sightedness and poor accountability do not allow the intellectuals in developing countries to concentrate single mindedly on bridging the gap between industry and academia.

If engineering education is taught in isolation from industry, this education will be rendered a purely theoretical and class-room exercise. To make engineering education more productive, it is necessary to know the needs of industries, because they provide employments to the graduates. Cooperation between engineering institutions and industry is mutually beneficial to the industry, institution, students, teacher and the society. It simulates industrial environments in engineering-institutions, which also helps students to ease the transition from classroom to the production floor. The main reason for lack of cooperation between industry and academia in developing countries is the absence of incentives and motivation. If any university makes efforts to cooperate with industry, there is no system to recognize its efforts. Similarly, if any industry provides training facilities to the students, it does not get any direct benefit. On the contrary, it may find itself fatigued due to over-involvement. The industries also feel hesitant to involve academia because [5]:

- Industries consider such training as interference in production-schedule, resulting in loss of production or lowering of the quality;
- The indiscipline and careless attitude of the students in the present institutional environment also discourage the industries to interact with them;
- The trade unions consider the student-body as their would-be competitors;
- In the absence of competition and enjoying a protected home-market, the industries are content with lower level of trained persons;
- Lack of industrialization, as well as its sophistication, does not permit adequate facilities;
- Instead of changing itself according to global trends, the traditional attitude forms barriers of resistance to the system.

4. THE PREREQUISITES FOR EFFECTIVE INTERACTION

The pattern of university – academia interaction is determined by a specific set of academic and industrial organizations in a country. The tradition and perceived role of the university determine the degree of research and training for industry. There is no single model to describe effective university/industry collaboration; much depends on the needs of firms whose interests are to be served, as well as on the capacities of the university-system to support them. In each country, a detailed analysis of the industrial structures, attitudes and opportunities is needed to facilitate the establishment of a constructive relation with universities, in accordance with national objectives. **In all cases, the usable collaborative arrangements in training and research, which have been appreciated by all parties, have been based on:**

- The existence of a long–term planning effort, an articulated strategy for growth and a detailed manpower-plan in the industry;
- A management-structure that can flexibly absorb external advice and training program;
- A willingness to pursue actively the recruitment and sustenance of the highest possible level of qualified personnel;
- An understanding of the university ethos, regarding exchange of information, diffusion of results, etc., through training program.

From the point of view of governments, the primary objective of university/ industry relations in training and research is generally to contribute to the national economic performance by enhancing and perhaps accelerating the process of technological innovation. For industry, it usually means access to adequately trained personnel, to scientific and technological information and, occasionally, to research results. For the universities, it is a potential source of resources and funds. Finally, for research scientists, stronger relations with firms (which have been pioneers in certain disciplines) are often seen to be a necessity from the point of view of research and post-graduate training. These provide cross-fertilization and breeding-ground for innovative capabilities of production engineer [6].

5. CO-RELATION BETWEEN BASIC RESEARCH AND INDUSTRIAL APPLICATION

A research paper regarding 'Composite Armor' in Military Defence was presented by the author in the first international seminar about Tank Technology at Heavy Industries Taxila, 1994 [7]. An International workshop about 'Kevlar in Ballistics' was organized, in collaboration with Dupont International, at College of Electrical and Mechanical Engineering, National University of Science and Technology in Oct. 1997. After successful conduct of this workshop, the Dupont company gave a commitment to provide, free of cost, test samples of kevlar (fabric) to the undergraduate/graduate students for the research regarding impact-resistance of composites. This triggered research about impact-resistance of composites in the Department of Mechanical Engineering, College of Electrical & Mechanical Engineering. The research work about impact-analysis of composites determined that a specific number of layers of kevlar fabric, stitched and oriented in appropriate direction and backed by trauma-pack, effectively stopped the incoming projectile [8]. This led to fabrication of a few prototypes of body- armor, such as bulletproof jacket and helmet by undergraduate students. The jacket and helmet was tested by firing 7.62 mm and 9 mm ammunition from a distance of 5 meters using G3 and MP5A weapons, respectively. The body armor effectively stopped the bullets with minimum trauma effects.

The research concepts were then commercialized by establishing production-line of the jackets and helmets at Advanced Engineering and Research Organization, as indicated in attached Brochure. Successful tests/trials and practical demonstration led to winning contracts worth more than Rs. 30 million from PAF, NESCOM, Punjab Rangers. Other contracts worth Rs. 50 million are expected in the near future from local and foreign customers.

This represents a classic example about transformation of basic research, carried out at academic institution, into real-life industrial application at an Advanced Engineering Research Organization.

6. A CASE-STUDY OF ACADEMIA – INDUSTRY LINKAGE

The National University of Science & Technology (NUST) was established through presidential ordinance in Rawalpindi, Pakistan, during 1991. This new class of progressive technical university aims to impart engineering education to students through close interaction with industry. The following steps were taken to promote close interaction of the university with local industry [7]:

- *Updating of Syllabi:* The syllabi of Electrical and Mechanical Engineering program were revised to meet the latest industrial requirements, through a series of meetings attended by educationists, industrialists and academia at Higher Education Commission;
- *Joint Research Projects:* Faculty members were given incentives for attracting industry to sponsor their research projects. This triggered a number of joint

research projects, which addressed real problem-areas of local engineering industry;

- *Open Houses:* Open houses were held at College of Electrical and Mechanical Engineering for representatives of local industry during Nov, 2000 and May, 2004. This novel experiment provided a rare window of opportunity to industrialists, to examine student's projects and carry out talent-hunt for employing students with potential;
- *Internship:* Internship is organized by the university management, for the students to visit local industrial organizations for a period of 6 – 8 months. This exposes the students to industrial environments and prepares them well to face new challenges in their professional career. Motorola, Lahore, and Rastgar Engineering Co. (Pvt.) Ltd, Islamabad, found this experience highly rewarding for the students and firms;
- *Industrial Visits:* Visits are often organized during the course of studies. The student members of Society for Experimental Mechanics visited Pakistan Aeronautical Complex, Kamra, during Oct, 2001, to foster industrial relationship.

7. SOME PRACTICAL RECOMMENDATIONS

The following practical recommendations could greatly facilitate effective academic – industry interaction:

- *Advisory Boards:* Advisory Boards should be formed, comprising the representatives of government, university and industry at national, provincial and university level, in order to coordinate, harmonize and streamline the technical cooperation between industrial and educational institutions.
- *Faculty Members:* Faculty members should be associated as members/co-opted members of various research and industrial committees. The faculty members should be attached with local research and industrial organizations to carry out work on their problem-areas, particularly during summer vacations. Their industrial exposure will contribute towards creation of industry-oriented culture in universities, which will have an impact on socio-economic uplift.
- *Curriculum and Placement Committees:* Curriculum committees should be formed in each department to constantly monitor and update curricula, according to the changing needs of industry. The committee should meet twice a year in each department of the university. The curriculum should emphasize entrepreneurship rather than seeding of jobs in the industry. Universities should set up placement bureaus, by appointing a faculty member as incharge at the department-level to explore job-opportunities for graduates in the industry.
- *Internship:* Internship of about 8-12 weeks must be made a mandatory requirement of the degree for every student. The Pakistan Engineering Council should make it compulsory and monitor the internship program.

- *Development and Commercialization of Indigenous Technology:* Indigenous technology should be promoted through joint research-projects between academia and industry. The new products and processes developed by the university-system need aggressive commercialization. Investors have to be encouraged by liberal loan-facilities, risk-coverage, tax holidays, and protection against imports for limited periods. With these facilities, industry would feel comfortable enough to utilize the fruits of locally developed technology.
- *Research and Development Corporate:* In order to translate the results obtained at the laboratory level into those at the semi-commercial level, it is highly desirable that a development organization is created, which should be equipped with appropriate technological and marketing capabilities. Several countries, including Korea, India and lately Pakistan, have created such corporate organizations, which are doing useful work.
- *Manpower Development:* Development of manpower poses different problems at various stages. Industrial manpower needs to be trained in educational institutions by organizing short courses, seminars and workshops. Fresh graduates from universities often lack practical experience and need exhaustive training, which can be provided through on-the-job training designed jointly by academia and industry.
- *Industrial Tours:* To make industrial tours of faculty and students more effective, a pre-visit orientation session should be organized to identify problems being faced by the industry. A post-visit session should also be organized to analyze the visit and lessons learnt. Industrial tours should also be organized for teachers.
- *Chairs:* The universities should make efforts to motivate trade-associations/ and industrialists to establish chairs and equip laboratories in various departments. This donation may be treated as tax-deductible by taxation department. The universities may sign Memoranda of Understanding with Chamber of Commerce and Industries, Trade Associations and Ministry of Production, for effective sharing of information and exchange visits.
- *Venture Capital/Tax Exemption:* Venture capital should be provided by the government/industry for purchase of hardware by the universities. The allocation of funds by an industry for research to be conducted in universities should be tax-exempted. Wherever required, bank-loans at lower mark-up should be provided, so as to promote technology.

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GOVERNMENT-UNIVERSITY-INDUSTRY RESEARCH ROUNDTABLE: *CULTIVATION OF A COOPERATIVE RESEARCH ALLIANCE FOR MITIGATION OF ENVIRONMENTAL PROBLEMS*

Khalid Farooq Akbar
Government College Sahiwal
Sahilwal.

ABSTRACT

It is generally believed that basic research is the pursuit of knowledge far way from commercial benefits. Further, if the research in question is linked to commercial enterprises, it would not qualify to be termed as 'basic research'. Therefore, when we study interactions between academic institutions and industry, it would follow that private companies interested in making a profit would give a low priority to basic research in the business strategies they pursue. However, different studies have shown that basic research can significantly contribute in fostering interactions of companies with government funded laboratories of academic institutions.

INTRODUCTION

Recent developments in basic sciences and their sub-fields such as ecology, environmental chemistry and renewable energy technologies can help us to find solutions for our environmental problems such as pollution control, conservation of biodiversity and natural resource management. The basic research in these areas in state-funded academic institutions has the potential to enhance quality of life and spur the national and local economies throughout developing countries. The industries using the new environmental management systems based on basic research hold the potential to create jobs, reduce environmental hazards and achieve the target of sustainable development. However, fulfilment of this potential requires the transfer of results of basic research to industry and society. Industries can be motivated to invest in environmental research, which has the potential to produce high returns through sale of breakthrough products. However, the high risks associated with such investment offset the incentives. Without government-university-industry cooperation to offset the long-term, capital intensive research in relatively young environmental science, such technology transfer will not occur. The long-term and capital intensive nature of the modern research activities makes research investments in these fields an expensive and high-risk endeavour. Thus cooperation between academia and industry is necessary to spread the costs and lower each party's risk. In the past, research fundings that encourage university-industry cooperation have played important roles in the development of technical breakthroughs to solve problems in the field of health, agriculture and energy. Promoting this cooperation in environmental fields is particularly important because these technologies are young and need long–term and capital intensive research.

Historical evidence from the West demonstrates that university-industry cooperation can surpass the individual abilities of universities, industry and government to develop and transfer technologies into the market place. This cooperation has evolved over time as a response to lack of resources, inability to transfer results of basic research to field, and the increased demand for innovation. When demand of technological advancements increases, university-industry alliances funded by the government, have met the demand that independent institutions are unable to fill. These arrangements ensure that specific industries became globally competitive, universities gained access to industrial resources, and consumers obtained access to beneficial inventions

A shift in emphasis of university research toward more extensive connections with the needs of civilian industry can benefit industry and universities if it is done in the right way. That way, in author's view, is to respect the division of labour between universities and industry that has grown up with the development of basic and applied sciences, rather than one that attempts to draw universities deeply into a world in which decisions need to be made with respect to commercial criteria. There is no reason to believe that universities will function well in such an environment, and good reason to believe that such an environment will damage to the legitimate functions of universities. On the other hand, binding university research closer to industry, while respecting the condition that research be 'basic' in the sense of aiming for understanding of nature rather than short-turn practical pay off, can be to the enduring benefit of both.

This paper provides a brief over view of the benefits of basic, cooperative research in environmental science and describes why neither universities nor industries can individually develop and promote the adoption of marketable environmentally safe systems and products. It also discusses the conflicts-of-interest concerns that can arise in such a cooperative environment and indicates how the government can help in strengthening this cooperation to achieve sustainable development.

BASIC RESEARCH TO ADDRESS ENVIRONMENTAL PROBLEMS

It is generally believed that basic research is the pursuit of knowledge far removed from commercial benefits. Further, if the research in question were linked to commercial enterprises, it would not qualify to be termed as 'basic research'. Therefore, when we study interactions between academic institutions and industry, it follows that private companies interested in making profit would give a low priority to basic research in the business-strategies they pursue. However, various studies have shown that basic research can significantly contribute in fostering valuable interactions of companies with government-funded laboratories of academic institutions. Recent developments in basic sciences and their sub-fields, such as ecology, environmental chemistry and renewable energy technologies, can help us to find solutions for our environmental problems like pollution-control, conservation of biodiversity and natural-resource degradation. The basic research in these areas, in public institutions, has considerable potential to enhance quality of life and spur the national and local economies throughout developing countries.

Like most developing countries, Pakistan faces serious environmental problems. Rapid growth of population and unbalanced economic growth have put enormous pressures on the country's natural-resource base and have significantly increased the levels of pollution. For example, between the 1960s and 1990s, the use of water for agriculture and industry increased more than twofold, creating problems of water-logging, soil- salinity, water-shortage and water pollution. Because few idle natural resources remain untapped, future economic and population-expansion portends increased pressures on the country's meager resource-base and worsening environmental problems, some of which have already reached critical levels. In addition, with the introduction of WTO in 2005, there are pressures on our farmers and industrialists who produce exportable goods to adopt green and environmentally safe methods and technologies in their productive systems. Otherwise, in future, the exports of our cotton, fruits, textiles and other products may be seriously hampered. So, finding effective solutions to our environmental problems is not only mandatory for the sake of environmental solutions, but is equally important for economic reasons.

The development and application of new environmental management systems and technologies, to mitigate current environmental hazards produced by industrial and commercial activities, needs long-term and capital-intensive research activities. The industries using the new environmental-management systems and technologies, based on basic research, hold the potential to reduce environmental hazards, create jobs and achieve the target of sustainable development. However, fulfillment of this potential requires the *effective* transfer of results of basic research to industry and society.

BENEFITS OF UNIVERSITY-INDUSTRY RESEARCH COOPERATION

At present, there is little interaction between academic institutions and the needs of the productive sectors, in general, and industry, in particular. For promotion of R&D and to tap the benefits of basic research, the linkages between university and industry will have to be properly strengthened. If this cooperation is established, it will increase the funding of research in basic sciences related to environmental issues and reduce the chances that such research will go unfunded. In return, industrial and business organizations would receive the results of this research to improve their environmental profile. In addition, university-industry linkage in basic research can help in the transfer of new technology from university labs to the market-place. Otherwise, researchers may fail in converting their discoveries into usable products.

University-industry relationships hold forth the promise of developing and transferring environmental technologies and products helpful to sustainable development more efficiently than academia or university can do, individually. Discoveries and patents obtained under these relationships can profoundly enhance the quality of our lives. This cooperation may result in better economic gains, by reducing pollution and its allied problems of health, economic burdens and global climatic issues. Thus, new processes and products developed through these innovations, supported by capital formation and entrepreneurship, are essential for real economic growth.

PROBLEMS ARISING FROM UNIVERSITY-INDUSTRY LINKAGE

Though cooperation between university and industry can speed up the achievement of the target of sustainable development, it has certain drawbacks and raises issues that need an elaborate analysis and extensive scrutiny in order to foster this cooperation on realistic grounds. Some of these are discussed here, one by one.

Differences in Research Objectives/Priorities: The main or driving objective behind the cooperative research between academia and industry is increased profit that can affect the nature of university research. Short-term objectives of a company could be quite opposite to the theoretical and far-sighted efforts of the university-population.

Secrecy of R&D Activities: In a competitive world, the industries usually carry out their R&D activities in a secret manner that is against the norms of open, freely accessible mode of activity in academic institutions. It is generally feared that university-industry cooperation could introduce un-desirable secrecy into the scientific process. Profitable research-findings may be kept confidential, remain unpublished, or their publication delayed, in response to industry's demands for privacy or security of proprietary data.

Loss of Academic Freedom: Science originates from our natural curiosity to learn about the world and ourselves. To be truly free, it must be pursued objectively and dispassionately, and should not be driven by thoughts of profit, glory or material gains. This may appear to be common sense, but increasingly today, science is being compromised by commercial interests, which create a serious issue of academic freedom for the R&D scientists. There are many instances where scientists hired for a particular job by an industry were refused the right to discuss or publish their results without the permission of the company. Even university or government research scientists, when they accept grants from industrial organizations, are bound by the terms and rules of collaborative contracts, which can greatly restrict their work and hand their bosses the ultimate sanction over results, publication and even interpretation. There are sound fears that, by accepting money from an industry that has aggressively set out to dominate and modify many aspects of life and society, science and the scientists may become servants of multinational concerns whose motives are at best questionable, and sometimes detrimental to our environment.

Research Misconduct: There are fears that private sponsorship of research may destroy the purity of research and that scientists may be tempted for misconduct to reap individual benefits. The researchers in universities carry out their research to reveal the truths of nature, in an objective manner, regardless of its commercial effects. The examples of investigators' misconduct arising out of industry-sponsored research include distorting results of research, keeping negative findings secret, and loss of objectivity. For example, in USA, in a classical example of profit-oriented research cover-up, Dow Corning developed and marketed Silicon Breast implants, without disclosing its own scientist's concerns that these implants could leak and rupture. The serious health-problems caused by silicon-implants surfaced only after a decade of sales. For a decade, Dow sold 150,000 breast-implants each year and reaped huge profits, while thousands of women paid the price for the company's silence regarding the negative impacts of the implants.

Exploitation of Public Funds: Since the R&D activities are mainly funded by public funds, collected from tax-payers, there is a danger of exploitation of the public funds without providing adequate returns to the public. In such case the common people who pay for the funding of public academic institutions involved in research with industry, are hit twice because they are deprived of the benefits or have to pay exorbitant prices for products developed with their tax-money.

The above-mentioned issues may create many socio-economic problems. If universities and industry enter into profit-oriented R&D activities, without caring for goals of basic research; openness, academic freedom and unbiased research, these activities may damage the whole set-up of R&D in governmental institutions. If university-industry collaboration in scientific research is strengthened without dealing with these problems, there are fears of undesirable social, economic and academic repercussions.

CONCLUSIONS

Historical evidence demonstrates that university-industry cooperation can surpass the individual abilities of universities, industry and government to develop and transfer environmental technologies into the market-place. This cooperation has evolved over time, as a response to lack of resources, inability to transfer results of basic research to the field and the increased demand for innovation. When demand for technological advancements increases, university-industry alliances, funded and regulated by government, have met the demand that independent institutions are unable to fill. These arrangements ensure that (i) specific industries become competitive, (ii) universities gain access to industrial resources and (iii) consumers obtain access to beneficial inventions.

A shift in emphasis of university research toward more extensive connections with the needs of civilian industry can benefit both industry and universities, if it is done in the right way. That way, in the author's view, is to respect the division of labour between universities and industry that has grown up with the development of basic and applied sciences, rather than one that attempts to draw universities deeply into a world in which decisions are made in the light of commercial criteria. There is no reason to believe that universities will function well in such an environment, and good reason to believe that such an environment will damage the legitimate status of universities. On the other hand, binding university research closer to industry, while respecting the condition that research be 'basic' in the sense of aiming at understanding of nature rather than short-term practical pay-off, can be to the enduring benefit of both.

Despite many difficulties, Pakistani institutions and industries have now developed and acquired several technologies, so far without much help or support from the government. If adequate governmental support were made available, more extensive cooperation could be established between academia and industry. This would help Pakistan to acquire innovative solutions to our environmental problems. Government has the responsibility to support the establishment of a viable system for the supply of outward-oriented R&D, where academia/scientists and industrial managers interact to assist Pakistani firms to get the most out of their technological choices. For example, by imposing green-taxes or offering tax-incentives, the government can motivate industries to invest in basic research, which has the potential to produce high returns through sale of breakthrough products. Without government-university-industry cooperation, to offset the problems of long-term, capital-intensive research, such technology transfer will not rapidly occur.

BRIDGING THE GAP BETWEEN BASIC SCIENCES AND INDUSTRIAL APPLICATIONS: HUMAN RESOURCE DEVELOPMENT AT PAEC

S. Arif Ahmad*, Tariq Hayat, Amer Mahmood
Director, Chairman's Secretariat and Safety
Directorate of Safety, Pakistan Atomic Energy Commission, Islamabad

ABSTRACT

R&D, in the basic sciences, deals with many variables of a problem, irrespective of their impact in terms of economic or other dividends-both short-term and long-term. Consequently, this activity is bound to increase the knowledge of mankind exponentially, primarily due to the involvement of a number of institutions and researchers globally. On the other hand applications, more specifically industrial applications, are usually driven by market-forces, viz. product-performance and economics, as well as by strategic interests occasionally; as such economic factors play a dominant role. We have put forward some suggestions, based on proven history in the north, for implementation in regions of the south. These include some general strategies for the south, with particular emphasis on human-resource management and knowledge-management. However, some difficulties, both inherent and imposed, are also mentioned.

Finally, a case study is presented of an organization of the south, i.e. PAEC of Pakistan. If a country's leadership takes bold timely decisions, with support at societal level, high technology can be introduced and sustained successfully in a developing country. The role of technical leadership is also very important. Its vision, technical competence, and ability to fire the imagination of the workforce contributes greatly to success. PAEC has planned and implemented successfully numerous projects of self- reliance and economic realization including:

- *A) R&D in basic sciences (PINSTECH, NIBGE, NIAB, etc.);*
- *B) Human resource development (PIEAS, KINPOE, CTC, NIBGE, CHASCENT etc.);*
- *C) Successful industrial applications (HMC-3, NDT, KANUPP, NIAB etc.); and*
- *D) Knowledge-management in indigenization of nuclear technology.*

INTRODUCTION

Let us start with the reproduction of some definitions of immediate concern, Appendix. These definitions and their possible mutual interplay are very important for the purpose of this paper. Our focus is on the evolution of basic research, usually initiated in the field of basic sciences, going on to industrial applications via applied research and working application. This has been depicted in the following Figure-1 in its simplest form.

Appendix: Terms of Significance and Their Definitions	
Applied Research:	Original investigation, undertaken in order to acquire new knowledge directed towards a specific practical area or objective.
Basic Research:	Experimental or theoretical work to acquire new knowledge of phenomena and facts.
Basic Science:	Knowledge relating to fundamental facts or principles.
Diffusion:	Promotion and sale of a new product or process.
Innovation:	The exploitation of new ideas.
Joint Venture:	Entity set up by two or more companies, in which the parent firms have a shareholding and typically representation on the joint venture's board of directors.
Technology:	The practical application of scientific or technical possibilities for attaining performance-characteristics of products and processes

A form of mutual interplay can be seen depicted in Figure-2. However, it has to be noted that in this interplay, innovation initiates an activity where other parameters of significant importance interact with each other. (Figure-2)

The question now arises "Is it so simple?" The answer is "no", and it is obvious from the fact that among the comity of nations. most nations are either developing or under-developed. Alternatively speaking, most nations in the world do not have: i) critical mass in basic research; and ii) significant number of industrial applications. Why is it so? we have tried to address this in a seven-step formula, given below:

1. *Basic idea:*
   a. Development of basic sciences, at least above a certain threshold level;
   b. Recalling and recounting the successful applications in the North;
   c. Lessons learned;
   d. Adaptation/transformation;
   e. Appraisal of constraints on science in the South.
2. *Prerequisites.*
3. *Knowledge, its development and management, for short-term as well as for long-term.*
4. *Enumeration of facilitators and difficulties.*

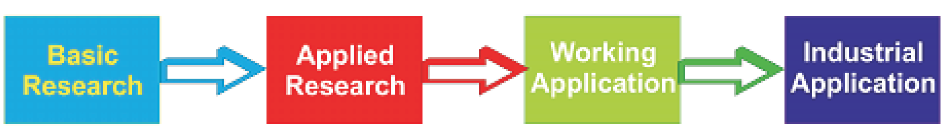

Figure-1: Stages of Evolution of Basic Research into Industrial Application

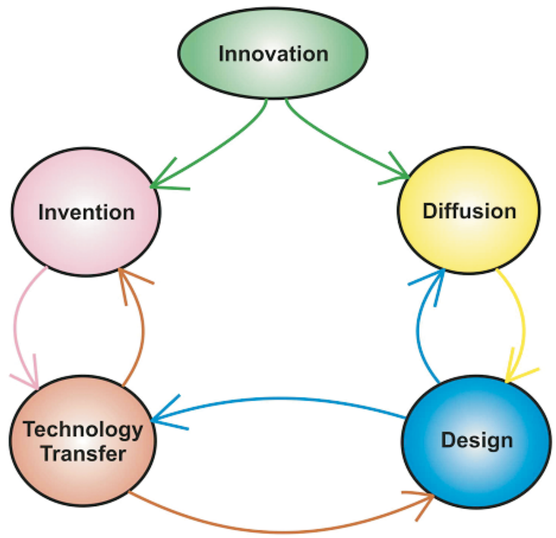

Figure-2: Mutual Interplay of Innovation and Other Parameters

5. *Formulation of strategies.*
6. *Talent should be put before technology, to groom both scientists and leaders.*
7. *Social contract for science, to acknowledge that endless growth is not possible particularly for countries currently suffering from scarcity of resources.*

Finally, we will put forward a case-study of PAEC, for successful implementation of this strategy for: a) infrastructure development; and b) human resources development.

BASIC IDEA

Every region and nation has contributed towards the development of basic sciences. Countries of the South have contributed in scientific developments, in the initial stages of scientific evolution. For examples, Chinese scientists had successfully developed gunpowder and printing. Similarly, Muslim scientists from different regions have also contributed a lot in the development of science & technology, notably men such as Avicenna, Al-Khawarzmi, etc. However, these days contribution to basic sciences is heavily dominated by the North. The basic idea now is to develop basic sciences, in the national scenario, to such an extent that:

- An infrastructure exists that is capable of supporting sustainable R&D activities, at least in some selected fields, and
- A human resource base, of sufficient vastness, capable of conducting R&D at the frontiers of some selected fields of science.

In addition to these, the infrastructure and human resource (HR) base should be competitive and constantly interacting with other national and international scientific communities. This is being done in the European Countries and North America. We can recall specific examples from successful applications in the North, e.g. UK has laboratories of repute to conduct R&D in their centers of excellence that are still known to the world for their rich heritage. There was a galaxy of scientists associated with these laboratories and these scientists conducted R&D there, examples are the Rutherford laboratory and the Cavandish laboratory.

Subsequently, this R&D is converted into applications which when it gathers pace, is termed as a revolution. Most recent of the examples is the communications-revolution. The nations that benefited from this communications-revolution range from larger nations, such as USA, to smaller nations, such as Finland. However, all the nations that benefited have one thing in common: relevant infrastructure and HR base.

LESSONS LEARNED

The evolution from basic research to applied research and ultimately to industrial applications, basically depends on the prevalent social conditions and pressing needs. For example, there was a pressing need for communications links in the vast British Empire as well as in USA. The British emphasized the need for a strong navy and railways, while USA emphasized the need for road communication and established an automotive industry.

ADAPTATION / TRANSFORMATION

Majority of the countries in the South have already adapted the successful industrial applications of the North, such as railways, automotive assembling, etc. However, we here emphasize that more and more of the successful applications need to be locally adapted, such as the more recent example of telecommunication-media adaptation. For example, wireless local loop (WLL) technology developed and matured in the North is now being adopted in Pakistan, possibly due to the reasons of population-concentration in small pockets and the desire of clusters of people to interact among themselves.

Appraisal of Constraints on Science in the South

Constraints on the science in the South are: 1) Almost non-existant infrastructure; 2) large populations, concentrated in small pockets; 3) Low venture-capital; and 4) Low level of resources (financial and relevant specialized human resource).

PREREQUISITES

Here, we will enumerate the prerequisites for basic research and its evolution into industrial applications. These are:

i. Knowledge-base with sufficient spread;
ii. Realization and recognition of rights, including patents and intellectual property rights;
iii. Role of facilitator / government (developed economies / developing economies models);
iv. Awareness about benefits of application;
v. Projection of role models;
vi. Provision of venture-capital;
Vii. Sustainability.

KNOWLEDGE

The Encyclopedia Britannica's definition of knowledge is "A person's range of information or understanding". To understand knowledge-management and knowledge-transfer, it is helpful to examine the distinctions between data, information, and knowledge. The Working Council of the Federal Chief Information Officers Council, USA, describes these as:

Data → *Unorganized facts*
Information → *Data + context*
Knowledge → *Information + judgment*

Knowledge Development

Various options available for the development of knowledge in the South are:

i. Local production of knowledge, through basic research;

Figure-3: Knowledge-Management in Human Resource Development (HRD)

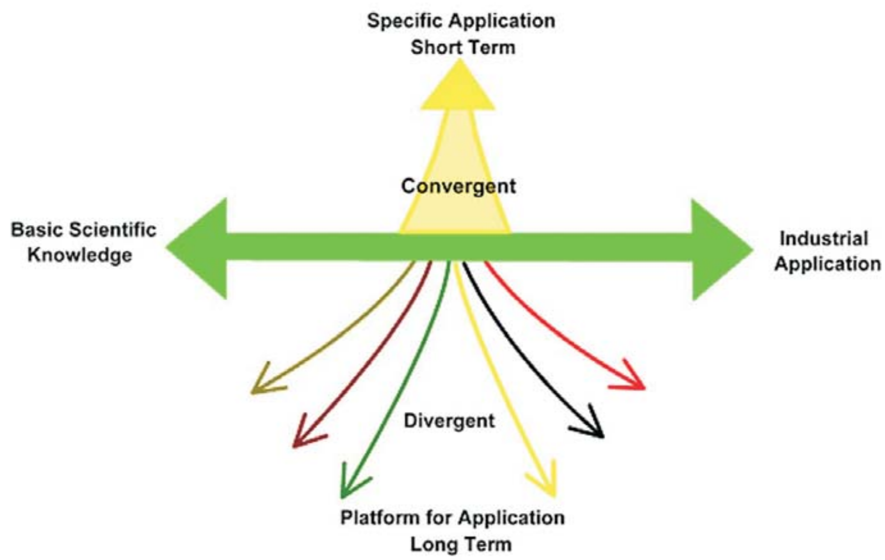

Figure-4: Depiction of the Process: Basic Scientific Knowledge to Industrial Application

ii. Nurturing of "foreign knowledge";
iii. Spread of knowledge via local fora, both general and professional;
iv. Projection of role- models.

Knowledge Management

Knowledge management is mostly concerned with the exploitation of the knowledge available to decision-makers at the time of making a decision. The following factors are important in this respect:

i. Type and extent of knowledge needed;
ii. Availability of expertise;
iii. Knowledge-Gap Assessment—fields and timeframe;
iv. Experts are more mobile in the North than in the South;
v. Transformation of knowledge via incentives.

Please refer to Figure-3 for the mutual interplay of different issues of knowledge-management in human resource development (HRD).

FACILITATORS AND DIFFICULTIES

The role of the facilitator is either played by the governments, in the developing economies, or by other stakeholders in the developed economies. The following should be considered in this respect:

i. Fora for the keepers of knowledge: think-tanks should be established and promoted;
ii. Governmental institutions; and
iii. Consumer base.

However, it is to be acknowledged that facilitators are needed when there are difficulties. A list of some prominent difficulties in the South is presented below:

- Inherent
  - Small knowledge-base
  - Priorities
  - Policy-Makers not fully cognizant of ground-realities
- Imposed
  - Monopolistic approach
  - Investor's priorities, sometimes biased
  - Intellectual property rights (IPR)
    - Genuine
    - Humane approach towards people in the South is needed, so as to foster quicker development by circumventing IPR of the rich North

STRATEGIES

We propose a three-pronged approach:

1. Institutional support in the form of donations, land grants, and technology parks. It may be noted that donations may be private or governmental. In USA, land has been granted to universities in 1866, 1890 and 1994, to make them self-sufficient [1]. The concept of technology-parks has been very successful in the world, e.g. Sandia Science and Technology Park, Albuquerque, New Mexico, USA [2].
2. Arrangements should be made for easy access to private knowledge, such as patents and other "high-dividend specialized technology" in the hands of multinationals. This may include modern electronic documentation and access-system for patents. In case of multinationals, they can be convinced of reasonable amount/volume of consumption of their products. This has already been demonstrated by India in the field of pharmaceuticals.
3. Talent-nurturing and technology-assimilation; in this connection, it is good to mention that talent- nurturing includes the following:
   a. Public support for research: from information to capability;
   b. The changing geography of innovation;
   c. Reshaping of public and private knowledge;
   d. Increasing the stock of useful knowledge;
   e. Supply of skilled graduates

f. Adaptation of new instrumentations and methods;
g. Development of new networks and linkages;
h. Enhancement of technological problem-solving capacity;
I. Provision of new knowledge.

SOCIAL CONTRACT FOR SCIENCE

It is worth mentioning that growth in science is not a continuous phenomenon, which has been amply demonstrated in the past, at least for periods of saturated growth having short duration. It is likely that this growth may saturate even in global terms. This and other concerns, such as pollution, population and limited food-supply, have been studied with a particular emphasis on social aspects in the following:

1. Limits to Growth report (1972, D. Meadows et al) [3]: The model, considering food, capital, pollution, population and natural resources only, used in the report is meant to be used by the decision-makers. It stated that, if current growth-trends are maintained, the limit to growth will be achieved in 100 years time. However, by reaching global equilibrium, with effective control and new technology, this limit can be pushed further.
2. Our Common Future report (1987, G. Brundtland) [4]: Presented at the UN World-Commission on Environment and Development, suggested that two contradicting needs, i.e. rapid improvement of living standards in the developing countries and preservation of the global environment can be met simultaneously, in spite of considerable difficulties. The report confirms with conviction that the progress in science and technology will pave the way to achieve this aim.

3. UN Conference on Environment and Development (1992, Rio de Janeiro) [5]: The message was “nothing less than a transformation of our attitudes and behavior would bring about the necessary changes to halt destruction of earth’s natural resources”.

4. Declaration on Science (1999, Budapest) [6]: It states that the practice of scientific research should no longer be conducted for purely academic purposes, but should aim at acquiring exploitable knowledge, which benefits society in terms of progress, peace and development. In other words, science is a social function that serves society.

The item 1 considers that the system-dynamics model, if applied to essentials to sustain life will result in readjustment of global equilibrium, probably with sharp and naturally imposed decline of population. On the contrary item 2 suggests that there is a hope, as has been done in optimistic scenario of item 1, that technological solutions can be provided. Item 3 suggest that transforming the attitude and behaviors of society in a positive manner is needed, on emergency basis, to lessen the effects on the environment. Item 4 again stresses the need that the portfolio of science be tailored for betterment of suffering humanity.

CASE HISTORY: THE PAKISTAN ATOMIC ENERGY COMMISSION (PAEC) [7]

The definitions of Appendix, Figure-1 & Figure-2, may be recalled, where it is shown that the basic research can be evolved into industrial applications. The PAEC has taken initiatives in basic research, e.g. in nuclear physics, agriculture, health, etc., and successfully transformed them into applied research and industrial applications. For example, one leading research institute of PAEC, i.e., Pakistan Institute of Nuclear Science & Technology (PINSTECH), has contributed in the Health-sector (radiopharmaceuticals), Agriculture-sector (laser land-leveler) and Industrial sector (fire-resistant cables). PAEC's approach has been evolutionary and followed a certain time-schedule, depending on the maturity of a particular preconceived stage. The case-history is presented to highlight only two particular aspects:

- Infrastructure development;
- Human resource development.

Infrastructure Development

The Pakistan Atomic Energy Commission had been entrusted with several tasks of national importance, involving high technology. But the prevailing industrial setup in the country was not supportive at all. To proceed forward and deliver, the PAEC has developed infrastructure units of its own, some of which are mentioned here:

- Pakistan Institute of Nuclear Science & Technology;
- Heavy Mechanical Complex-3;
- National Center for Non-Destructive Testing;
- Pakistan Welding Institute;
- National Institute for Biotechnology & Genetic Engineering;
- Nuclear Medical Centers (13 in number);
- Non-PAEC institutions (numerous institutes supported by PAEC, including NCP, QAU).

Human Resource Development

During its continually developing phase, the PAEC felt that development of infrastructure alone can not help in achieving the assigned goals. Thus, it was decided that, at an appropriate time, human resource development should be initiated in parallel. This is now being felt at the national level and the National Commission for Human Resource Development has been set up. The following Human-Resource institutes have been set up by PAEC:

- Pakistan Institute of Engineering & Applied Sciences;
- Computer Training Center;
- KANUPP Institute of Nuclear Power Engineering;
- National Institute of Agriculture and Biology;

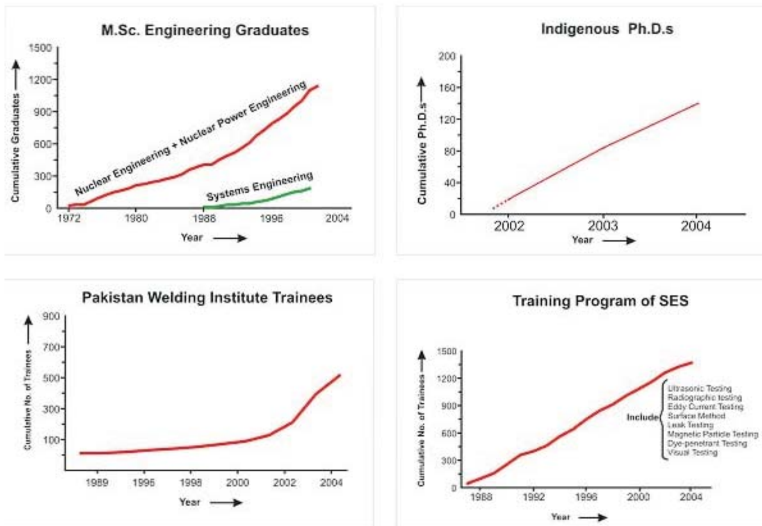

Figure-5: Human Resource Development at PAEC

- National Institute for Biotechnology & Genetic Engineering;
- CHASMA Center for Nuclear Training.

The variety of human-resource development program, listed below, and the performance of some of these is shown in Figure-5.

- Nuclear Engineering;
- Nuclear Medicine;
- Systems Engineering;
- Genetic Engineering;
- Nuclear Power Engineering;
- Process Engineering;
- Information Technology;
- Medical Physics.

Figure-5 shows that the PAEC has trained its human resource at its own training institutes, for specific specialized needs, as well as persons from other national institutes, for Ph.D. studies. Many others have been trained at prestigious institutions abroad. However, it is worth mentioning that the timing of human resource development (HRD) needs to match with the PAEC objectives, rather than the availability of the financial resources. Hence, HRD was in synchronization and in harmony with the overall program. It may be recalled that Pakistan got its first research reactor, PARR-1, in 1965 and its first nuclear power plant, KANUPP, in 1972. Pakistan was then placed under sanctions, even embargo in many fields, starting from 1976 onwards. If the HRD efforts had been not launched then, it was quite possible that Pakistan's nascent program could not take off.

It may be noted from Figure-5 that the needs for nuclear medicine and medical physics personnel were realized, to meet the demands for treatment of cancer patients. At present, 13 medical centers of PAEC are treating nearly 325,000 patients (including Afghan refugees). On the agricultural front, PAEC agriculture research centers have successfully introduced new high-yield varieties. For example, in cotton alone, PAEC's efforts have been able to successfully enhance Pakistan's GDP to the tune of $ 100 million / year, which is enough for financing a small nuclear power plant every 6 years or so. This will help in creation of jobs in agricultural sector, as well as in power-generation, which would further contribute towards increasing the volume of the economy. It can be said that, at least in nuclear knowledge, the program is self-sustaining. Even in case of agriculture and medical fields, there is a significant demand for Pakistani experts abroad. This is being done under several IAEA sponsored projects. We believe in sharing knowledge with other countries of the South., The PAEC, under the umbrella of IAEA, has trained personnel from many countries of the South, ranging from Vietnam to Mongolia to Algeria, in a variety of courses. These academic programs range from short courses to Ph.D.

CONCLUSIONS

Based on PAEC's success-story, we can conclude that, if the leadership of a country is bold enough to take right decisions, timely, and the people of a country have commitment at societal level, high technology can be introduced even in a developing country. The role of technical leadership is also very important. Its vision, technical competence, and ability to fire the imagination of the work-force helps in implementing the national policies successfully.

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COLLABORATION BETWEEN UNIVERSITY AND INDUSTRY FOR BASIC AND APPLIED RESEARCH

Khalid M. Khan
Vice Chancellor
University of Arid Agriculture, Rawalpindi

ABSTRACT

In the present age of globalization, economic condition is a major challenge for any state. In this regard, the university system needs to be more responsive to the community and produce trained manpower with higher degree of responsibility and relevance to the demands of the state. It must emerge as an intellectual lighthouse by improving its capacity to cater the increasing demand of basic and applied research. Simultaneously, the government and industrial sector must play active role in supporting and interfacing with universities for mutual benefits and integration of knowledge, experiences and research potential.

The "Triple Helix" thesis is emerging as a result of transformation in the functions of university, industry and government. The arrangements and coordination among the three institutional spheres provide input and sustenance to the science based innovation process. In this new configuration, the academia can playa role as a source of knowledge and regional development in addition to its traditional role of producing manpower and technical knowledge. The university thus becomes an agency of economic development through basic and applied research.

The "Triple Helix" model can be considered as a "multi-structural/multi-functional frame work" in contrast to structural -functionalist model in which a single function was expected to be carried out by a single institution. In the former, the three dynamics are considered as degrees of freedom of a complex system. This degree of freedom will be a source of better understanding between the three stake holders and lead to a viable cooperation and collaboration.

The collaboration of university-industry-government will assist in better utilization of resources (physical, financial and human), producing better trained manpower, organized problem oriented and applied research activities and technological developments concurrent to the needs of the society. This paper discusses some strategies to strengthen the linkage between universities and the industry.

INTRODUCTION

In the present age of globalization, the economic and financial viability is a major challenge for any state. In this regard, the university-system needs to be more responsive to the community and produce trained manpower with a higher degree of responsibility and relevance to the demands of the state. It must emerge as an intellectual lighthouse, by improving its capacity to cater for the increasing demand for basic as well as applied research. Simultaneously, the government and industrial sector must play an active role in supporting and interfacing with universities for mutual benefits and integration of knowledge, experiences and research potential.

The "Triple Helix" thesis is emerging as a result of transformation in the functions of university, industry and government. The arrangements and coordination, among the three institutional spheres, provide input and sustenance to the science-based innovation process. In this new configuration, the academia can play a role as a source of knowledge and regional development, in addition to its traditional role of producing manpower and technical knowledge. The university, thus, becomes an agency of economic development through basic and applied research.

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The collaboration of "university-industry-government" will assist in better utilization of resources (physical, financial and human), producing better trained-manpower, organized problem-oriented and applied research-activities and technological developments concurrent with the needs of society.

STRATEGIES

Although there are a great many unanswered questions, especially related to the agriculture sector, the following strategies are recommended to achieve the goals under the tripartite arrangements:

1. Build Greater Public Understanding and Awareness

The public and private universities should be encouraged to develop their own strategic plans for university-industry-government linkage, with clear guidelines and procedures to guide the institutions, interface with the particular industry and with society in general.

2. Vision and Commitment

Commitment and vision are the most essential factors to determine the success of the linkage-implementation.

3. **Capture Emerging Trends**

The educational needs of the society have been changing day by day, and there is now a clear pathway towards the provision of "Life-long Learning" and continual education. So, the universities must be prepared to meet the new demands of society.

4. **Work-Experience as Essential Part of Curriculum**

Producing just graduates is not appreciated by the world of works. They must be equipped with working-knowledge, "hands-on-experience", ability to work and posers initiatives.

5. **Appropriate Mechanisms and Activities for "University-Industry-Government" Linkage for Development**

Existing measures and programmes, which could relate to the activities, should be focused and redefined in order to offer special consideration to the envisaged linkage. The Institution should play a critical role as a local knowledge-base and a window into the world of knowledge depositories for local industries.

6. **Balanced Weightage to Basic and Applied Research**

The emphasis on basic and applied research should be balanced, so that both components should add to the innovation and application of research.

7. **Improve the Flow of Communication and Information-Technology**

Communication is an important key to successful activities and therefore measures should be taken to strengthen the mechanisms to facilitate communication.

8. **Provide and Enhance Incentives and Support for Cooperation**

To facilitate the flow of resources, the companies and individuals must be encouraged to provide support to the universities, in the form of scholarships, endowment-funds and research grants.

9. **Internship of Faculty and Post-Doctoral Fellows**

The internship will provide a feedback to the linking institution, refresh the knowledge, enhance work-experience and help to conduct problem-based research.

10. **Provide a Proper Coordinating Center for the "University-Industry - Government" Linkage**

This center will serve as a focal point to implement plans and enhance productive relationship among them.

COMMERCIALIZATION OF TECHNOLOGIES: TECHNOLOGY-BUSINESS INCUBATOR (TBI)

Anwar-ul-Haq
Chairman, Pakistan Council of Scientific Research and Industrial Research (PCSIR)
G-5/2, Islamabad

ABSTRACT

Technology-Business Incubator (TBI) is a facility/ organization that helps the initial growth of technology-based companies by providing shared facilities. They meet the entrepreneur's technical needs, with regard to training, organizing business, production, marketing and finances. By setting up these TBIs in Pakistan, there will be general improvement in capacity-building of industrial sector and trading business. We need many tools for up-gradation to meet the new challenges of the national and international market. These tools may be Technical education; Practical training; Updating and strengthening of Pilot Plants; Use of information-technology & Internet.

All the tools under one amberella, that is TBIs, constitute a good effort for developing business through Commercialization of the products/processes developed by PCSIR and other Public-Sector R & D organizations.

INTRODUCTION

Business Incubators have been established in many countries since long. Incubators were introduced to China in the late 1980s, and now China has 400 incubators—the second highest after the United States. They are providing all-round legal, taxation and financing services to small and medium-sized enterprises. Beijing is one of the first Chinese cities to try such a system for developing the high-tech industries. Currently, some 980 high-tech enterprises in the city are being supported by the incubator system.

Many Business-Incubators in Developing Countries are being supported by UNDP and the national governments; some examples of projects underway in Africa, Asia and Latin America are:

- WUHAN Technological Innovation Centre, China;
- University-Industrial Linkage, PUNE, India;
- Shriram Industrial Research Institute, Delhi, India;
- Southern Luzon Industrial Estate, Philippines;
- "INNOTECH" sponsored by research-University- Government, Trinidad, West Indies.

There are various types of Incubation Systems. The following are the most common:

- Technopole: Urban structure consisting of research laboratories, universities, new high-tech enterprises involving technology-transfer;
- Science Parks: Set in close proximity to higher-education institutions, for new startups established by academics and R&D units wishing to commercialize their research;
- Industrial Parks: Manufacturing and factory-units provided for tenants.

REQUIREMENT OF BUSINESS-INCUBATORS IN PAKISTAN

There is a serious need for Business Incubators in Pakistan, because of the present high unemployment-rate of educated persons and no proper means of HR training. Moreover, most of the talented educated persons lack technical and financial resources to enter into a new business. Most of the time, investors fail in business, by entering into wrong businesses or due to lack of business-skills.

The basic requirements for typical Business Incubators are as given below:

- Building; available on flexible, affordable and temporary basis, in the form of either offices or workshops.
- Common Services; including Secretarial support and shared use of office-equipment, meeting rooms, canteen facilities and machinery.
- Enterprise Counseling; namely "Hands On" assistance, with regard to business- planning, management-training, accounting, legal, marketing and financial expertise.
- Access to finance and specialist advice; through favorable terms of loans to the entrepreneurs and access to R&D activities.
- Networking activities; inside the premises among the entrepreneurs and outside-linkage with the industry/ business sector.
- After-care; continuing assistance to its tenants, after they move out and also offer advisory services to small businesses in the region.

STAKE-HOLDERS/ PROMOTERS OF BUSINESS-INCUBATORS

The following can be the promoters/stake-holders of these business-incubators:

- Local government/ Regional Authorities;
- Academic Institutions;
- Research & Development Organizations;
- Chamber of Commerce/ Trade Unions;
- NGOs;
- Private Investors;
- Banks/Financial institutes.

FEASIBILITY REPORT OF BUSINESS-INCUBATOR

The feasibility of establishing a Business Incubator should consider the following points:

- Local support;
- The developmental priorities of regional, provincial and central governments;
- Entrepreneurial potential of the area;
- Strength and weakness of the region, with regard to industry and small-business sector;
- Type of services available e.g. premises, support for R&D, universities, etc;
- The Target Market of the Business-Incubators should be delineated;
- Type of businesses, i.e. new businesses or existing enterprises with growth-potential;
- Economic priorities, i.e. industries that need to be developed in the region;
- Types of technologies that could be realistically developed and the scope of promoting innovation;
- It is a long-time venture (3-5years before breakeven point is reached);
- Results are obtained in terms of jobs-creation, social uplift of the area and technical advancement of the local industry.

INCUBATOR SPONSORSHIP & FINANCING

- Institutions like Chambers of Commerce / Associations, Universities, R& D organizations;
- Large industrial undertakings;
- Public authorities;
- NGO's;
- International Donor Agencies.

PROGRAM FOR DEVELOPMENT OF ENTREPRENEURSHIP

The Entrepreneurship Development Program includes the following:

- Innovation; established training methods for generating ideas should be included in Business-Incubator training-services and supported by local/ foreign experts.
- Skills; business techniques, business planning, book keeping, costing, personnel management, etc.
- Marketing Advice; Market research to identify products and services, marketing and sales training and advertising techniques.
- Usage of common facilities and networking among tenants.
- Finance; Assistance in making applications to bank and arrangement of loans on favorable terms.

INDUSTRIAL /BUSINESS TRAINING OF STUDENTS, AS INTERNEES DURING COLLEGE/UNIVERSITY COURSES

- It is very important that the students should be provided an opportunity of working as internees in industries or business organizations.
- This will help them to understand the environments and get hands-on-training, which will help them to better to understand their educational courses.
- Most important of all, it will create an atmosphere of collaboration between Academia, Industry and R&D Organizations.

ASSESSMENT OF THE OPERATIONAL EFFICIENCY OF THE BUSINESS-INCUBATORS

The assessment of the operational efficiency of the Business-Incubators is generally done after 2-3 years, considering the following factors:

- No. of enquiries received and converted into successful admissions.
- The number of new start -ups and subsequent failure-rates.
- Success in imposing exit-criteria and achieving a reasonable turnover of tenants.
- Success in achieving positive cash-flow, measured against original forecast.
- Local impact, job creation.
- Commercialization of R&D projects.
- Import substitution.

RISK-FACTORS TO BE CONSIDERED BEFORE STARTING A BUSINESS-INCUBATOR

There are the following risks-factor involved in setting up Business Incubators.

- Inappropriate strategy.
- Inappropriate location.
- Unskilled and inappropriate promoters.
- Excessive specialization.
- Faulty legal structure.
- Wrong market-analyses.
- Inadequate startup and cash-flow funds.
- Poor Incubator-management.
- Non- transparent criteria for admission and exit.
- Lack of necessary resources outside the incubation-system, e.g. financial, labour, raw materials, etc.

MODEL INCUBATOR IN THE UK

Training & Enterprise Council (TEC) networks in the UK.

- TECs are local, employer-led organizations, incorporated as private companies, limited by guarantee.
- They are responsible for delivering most government-funded training and enterprise programs in the UK.
- TECs operate through a contract with public authorities, setting out performance- targets, e.g., A specified number of successful new businesses each year, or to provide training according to the targets set in the contract.

SOURCES OF GRANTS FROM INTERNATIONAL ORGANIZATIONS

The following International Organizations can provide funds and cooperation:

- Bank of European Investment (BEI).
- United Nations Development Program (UNDP) e.g. Financial Assistance as Technical Support Services (TSS-1), Special Funds as TSS-2, Project Development Facility (PDF), Special Program Resources (SPR), etc.
- UNIDO, e.g. Self-financing Trust Funds, Industrial Development Fund (IDF), Third-Party Trust Fund. IDF is a specialized fund for technically innovative industrial projects of a non-traditional nature and for global projects oriented towards regional and interregional cooperation.
- World-Bank loans are also available for the following infrastructure: Energy, Agriculture, Education, Environment, Health and Urban and Rural Development.

PLANS IN PAKISTAN

It is proposed to set up the following Business Incubators in the undermentioned cities initially in Pakistan. The following stakeholders/promoters will be common in all these Business Incubators:

- Ministry of Science & Technology (through PCSIR)
- Export Promotion Bureau
- Ministry of Industries (through SMEDA)
- Local Govt.
- Local Chamber of Commerce & Industries
- SME Bank

Sialkot

Focusing on the Surgical and Sports industries, for manufacturing and export; the additional promoters for the proposed Business Incubators are as follows:

- Surgical & Sports Goods Manufacturing Associations.

Gujrat

Focusing on Fan industry; for manufacturing and export, the additional promoters for the proposed Business Incubators are as follows:

- Fan manufacturing Association.

Gujranwala

Focusing on Light Engineering Industry; the additional promoters for the proposed Business Incubators are as follows:

- Large Engineering Units of the area.

Peshawar

Focusing on Food Processing and Herbal Extracts for Food and Medicines; the additional promoters for the proposed Business Incubators are:

- NGOs.

Lahore

Focusing on Automotive, Textile & Engineering; the additional promoters for the proposed Business Incubators in LAHORE are as follows:

- APTMA
- Automobile Association

Focusing on IT, Software, the additional promoters for the proposed Business Incubators in Lahore (2 Systems) are:

- Ministry of Information Technology.
- Software Export Board

Karachi

Focusing on Textile & Leather, the additional promoters for the proposed Business Incubators in Karachi are as follows:

- APTMA and Leather Association.

Focusing on Electronics, IT and Software, the additional promoters for the proposed Business Incubators in Karachi are as follows:

- Ministry of Information Technology.
- Software Export Board.

Focusing on Automotive and Engineering, the additional promoters for the proposed Business Incubators in KARACHI are as follows:

- Automobile Association

Faisalabad

Focusing on Textile, the additional promoters for the proposed Business Incubators in Faisalabd are as follows:

- APTMA.

IMPERATIVES OF INDUSTRIAL RESEARCH

Saquib Mohyuddin* and Mohammad Khan**

**Chief, **Head Research, National Productivity Organization*
Ministry of Industries & Production, Islamabad

ABSTRACT

During the last few years, radical changes have occurred in the global science and technology. Unfortunately, in developing countries, research whether basic or applied has not been given due importance. Therefore developing nations are facing the challenge of devising innovative strategies. The situation in Pakistan is not much different.

In future, economic prosperity and development will primarily be knowledge-driven. In order to achieve economic autarky, significant advances in our understanding of both physical and biological phenomena is of vital importance. But the situation on the ground is not very encouraging as far as Pakistan is concerned. Although we have made some headway in the field of information technology, yet a lot needs to be done in this and other areas as well.

There is a dire need of paying due attention to R& D activities in developing countries, particularly in Pakistan. Essentially, there are two broad categories of business research: basic research and applied research. Research done primarily to enhance the understanding of certain problems that commonly occur in an organization is called basic or fundamental research. The research done with the intention of applying the results of the findings to solve specific problems is called applied research. In the context of developing countries and considering the fact that the industrialized countries are hesitant to the transfer of technology, we may say that some basic research is needed. On the other hand, the huge gap in the performance of the economies of the developed vs developing world call for applied research.

Realizing the importance of both types of research, National Productivity Organization is engaged in both basic as well as applied research. In the area of basic research, is a Benchmarking study completed in the spinning sector wherein eighty best practices have been identified. A report is also published on productivity and cost-indices, besides various productivity indicators. Various other studies, like Performance of Seven Selected Export-Oriented Manufacturing Sectors; Automotive Industry and Training Need Assessment are in the pipeline.

INTRODUCTION

The strong investment in industrial research and development, with growing emphasis on directed basic research, and even stronger investment in information technology and venture-capital, should enable any country to maintain its momentum in technology-innovation well into the new competitive world.

The historical experience of advanced economies shows that establishing a broad and robust domestic industrial base holds the key to successful development, because of its potential for strong productivity and income-growth. This process is associated with a strong investment-drive in industry, rapidly rising productivity and growing share of the sector in total output and employment. Pakistan had virtually no industrial base in 1947. There were only a few small-scale agriculture-based units, three textiles mills and a cement plant. Starting with hardly any industrial base at all, the country has now been able to build up an impressive diversified industrial base. At that time, there was little pressure on industry to become more efficient, as whatever was produced was immediately consumed locally. However, soon the situation changed, both in public and private sector. At present, the share of industrial sector in GDP is 24.5% and it has overtaken agriculture which stands at 23.3 percent.

Now, there is more emphasis on value-added products, sophisticated chemicals and other basic industries, defense- related industries and industries based on hi-tech, such as IT industry, new materials and biotechnology. Globalization of trade, liberal imports and compulsion to produce quality and standard products, to compete in the international market, has now compelled the developing countries (including Pakistan) to adopt policies of liberalization, deregulation and privatization and to invest more in science and technology. The transition towards energy-based and physics- based industries, has to be well planned and also supported with the small and medium-scale industries.

Research and development (R&D) are interrelated, cyclic, evolving and adaptive processes. The three major stages of R&D, as defined by the National Science Foundation, are as follows:

- Basic research
- Applied research, and
- Development

Basic Research: The objective of basic research is to gain more comprehensive knowledge or understanding of the subject under study, without specific applications in mind. In industry, basic research is defined as research that advances scientific knowledge but does not have specific immediate commercial objectives, although it may be in fields of present or potential commercial interest. Understanding how a protein folds, or how a specific molecule elicits a particular biological response, are examples of basic research.

Applied Research: The aim of the applied research is to gain knowledge or understanding to meet a specific, recognized need, or solve a specific problem. Applied research ranges over investigations oriented to discovering new scientific knowledge that has specific objectives, for example with respect to systems, products, processes, or services. Finding a better treatment or diagnostic, for a disease, is an example of applied research.

Development: It is the systematic use of the knowledge or understanding, gained from basic and applied research, directed toward the eventual production of useful materials, devices, systems, or methods, including the design and development of prototypes and processes. Making a new vaccine against AIDS, and testing it on animals, is an example of development.

SIGNIFICANCE OF BASIC AND APPLIED RESEARCH

There are a number of activities that are essential for the success of business/firms in high-tech industries that depend heavily upon a basic-research capability. Rosenberg [1990] discusses several of those factors:

- Basic research enables firms to understand better how and where to conduct applied research.
- The outcome of much of applied research cannot be properly evaluated without a sufficient capability in basic research.
- Further product-line of the firm and the kinds of process-technologies that ought to be adopted are influenced, to a large extent, by a firm's capability in basic research.
- A basic research capability will enhance the efficiency with which other types of research are conducted.

It is important to invest time and money in applied research and product-development. The challenge of reducing knowledge to practical applications, in the form of a product, is an intellectually satisfying pursuit and an obvious necessity for industry.

Nathan Myhrvold, Chief Technology Officer at Microsoft Corporation, once said; "I spend a fair amount of my own time in applied research, but technological progress cannot continue without the input of basic research and the conceptual breakthroughs it makes possible. In order to reduce knowledge to practice, one must have the knowledge in the first place. Science is the raw material that applied research and engineering refine into their products".

Currently, governments around the world seem to believe that an emphasis on applied research will straightaway lead to creation of national wealth. By doing so, they are undervaluing the real contributions made by fundamental research to that same end. Scientists opine that the necessary and sufficient condition to enhance the productive capacity of a nation lies in the strong foundation of basic research and its dynamic application. Most scientists believe that the best way to enhance the capacity of a nation, is to create a strong applied-research culture, based on a vibrant and foundation of dynamic fundamental research.

The Japanese Experience: Japan is currently in the midst of a severe economic crisis. Despite this predicament, the Japanese government has not, as might have been expected, reduced its expenditure on research, particularly fundamental research. In fact, it has done the opposite. It has increased the research-expenditure. No doubt, this decision was based on the argument that if Japanese technology had made them the second largest global economy, it will do so again. Twenty five years ago, it was difficult for the Japanese to induce foreign scientists to work in Japan. Their exchange-programs were mainly there to support Japanese fellowships in the US and elsewhere. Today, this trend has been completely reversed by the steady stream of the best foreign scientists into Japan.

The Role of Private Enterprise: The German company "Bayer" is credited as being the first to establish its own R & D laboratory. Using a strategic basic-research approach, it developed aspirin, the world's largest-selling single pharmaceutical. Other companies quickly followed this lead, almost without exception. These enterprises relied on close links to scientific information derived primarily from research in universities.

RELATIONSHIPS BETWEEN INDUSTRY AND UNIVERSITY

In 1980, a study of manufacturing firms noted a correlation between basic-research expenditure and productivity [Mansfield, 1980]. A subsequent study [Mansfield, 1991] of 76 manufacturing industries showed that universities provided 11% of new products and 9% of new processes, thus showing how universities (supported mainly by public-funds) and industries can develop a synergy. In more recent times, this type of interaction has gathered pace [Mansfield, 1995].

CURRENT STATUS AND NEED FOR INDUSTRIAL RESEARCH IN PAKISTAN

The advancement and modernization in the industrial structure and management, will need a large number of qualified and trained engineers, scientists, technicians and skilled workers. High-quality education is, thus, the basic need for acceleration of industrial processes of the country.

The industrial sector is still confronted with inefficiencies, lack of competitiveness, high cost of production, docile technological base, almost non-existent entrepreneurs' culture, lack of commitment to society and extraordinary thrust for inflated profit-margins.

The firm foundation of science, research and innovation is a vision of vital importance to Pakistan's future, if it has to safeguard the economic growth for the welfare and security of it's people. As a result, a national research-strategy must be designed to reflect this vision. Such a strategy will require more financial resources, clearer priorities and lines of action by the organization, broader cooperation among various research communities and more interaction intended to benefit from the country's research and development efforts.

Man is basically a "curious" being. We have a deep-seated need to understand ourselves, to find meaning in our existence and to be an integral part of our surroundings. Scientific research contributes to the evolution of such knowledge. Research also has a high degree of utility value i.e research results are useful for development. Research-based knowledge plays an important role in the development of new technology, products, services and forms of organization. Both in the public and private sectors, knowledge- based innovation is crucial to quality and competitiveness. Moreover, emerging global environmental challenges are posing new demands in respect of research efforts.

We must never lose sight of the close link between the intrinsic value and the utility value of research. Basic and applied research must be viewed as two separate, but similar, aspects of the country's national research-strategy, as well as in connection with international research cooperation. Research is a long-term social investment and prerequisite if Pakistan aspires to be a nation of knowledge. Yet, the country is falling behind in important areas.

Due importance has not been given to R&D activities in Pakistan. As a result, per capita R&D spending is very low in Pakistan. Similarly, the number of scientists engaged in R&D per million inhabitants, the number of technicians in R&D, the number of scientific and technical journals per million inhabitants, also indicate the same pathetic situation. Pakistan's total allocations to research and development are lower than in those countries with which she is usually compared. The country spends less on the average on R&D and considerably lesser than the countries that give high priority to R & D. This reflects the fact that Pakistan's industry is dominated by enterprises that have not traditionally been particularly knowledge-intensive. However, the Government is gradually recognizing the importance of R&D; in the 2004-05 budget, basic research has been allocated Rs.566 million and the expenditure on R&D general services is estimated at Rs.2453 million.

Pakistan is characterized by political instability, not very efficient business enterprises and industrial establishments, uneven distribution of wealth and social insecurity. The country faces major challenges, and changes are needed both in the public and private sectors to ensure the integrity of its economy. Success will require a better foundation of knowledge and more widespread expertise at every level of society.

World trade is being deregulated, bringing greater challenges as well as new opportunities to Pakistan's business and industry. We are moving into a new era, led by rapid innovations in information-technology, materials-technology and biotechnology. The gap is narrowing between research and development, on the one hand, and application, on the other. Consequently, business and industry have no choice but to accept and embrace changes if they want to increase their value-added productivity and further develop their competitive position. Thus, the industrialists, chambers of industry and trade associations should take up the task of preparing the local industry for the challenges arising out of globalization and WTO. There is a need to pool resources for research and development for enhancing the competitiveness of the products and services. Recently, the foreign countries, who are giving us a tough time in international and local markets, are investing heavily in research and development. As a result, the quality of their products is improving and they are getting lion's share.

It is the responsibility of the business community to make R&D a part of their cost-of-production, as it is bound to pay them in return. The major problem that is hindering our progress at all levels is poor governance. The governance is the result of inefficient governmental functionaries, inactive private sector which needs a lot of improvement. The Government realizes that the traditional economic advantage (provided by its natural resources and cheap labor) is no longer sufficient to ensure a market for the production of SME's. Services for the modernization of small-scale enterprises have to be provided, particularly for areas where productivity, product- quality and cost-competitiveness are major factors for survival and growth.

The same path has been taken by many developing and developed nations in Asia. SME's, no doubt, are the aggressive partners in many stages of economic development in Asian nations. It is interesting to note that developed countries in Asia, have successfully adopted SME development policies and measures that were complemented by intensified technology-development and utilization drive.

Irrespective of the country of origin, the technological absorption-capability issue appears to be more critical in the small and medium-scale enterprise sector. A small businessman has to compete to at least maintain, if not to increase, his market-share. To improve his competitiveness, the small businessman has to upgrade his product-quality and increase his productivity. This is only possible through the introduction of newer and better technologies.

A small entrepreneur encounters several difficulties in trying to improve his operations (through the application of new technologies). First, the entrepreneur lacks the expertise in determining his technological needs. Second, the small entrepreneurs throughout the country, have limited access to information and developments concerning better technologies that are available. In evaluating the present level of technology, one major factor which is commonly disregarded by a small businessman, is the size of his market. A number of small firms (e.g. automotive sector) have acquired new technology/machinery without considering their markets.

The difficulty of a small businessman in evaluating applicable technologies, and adapting them to local conditions, is also a major impediment to technology-utilization among SME's.

Lastly, the small entrepreneur has limited access to funds available for financing the acquisition of new technologies and the production of prototype machinery. Evidently, the development of SMEs, through the application of better technologies, will require varied resources and support-services. These include technical information, consultancy services, training, funding and sectoral support. Government, in the last few years, has either revived such institutions or has set up new ones for the delivery of these services.

INNOVATION & PRODUCTIVITY

Productivity is a key factor for competitiveness. For much of the past decade, economists seriously questioned the economic payoff in improved productivity from growing investment in information-technology. Prof Robert Solow, a Nobel Prize winner from MIT, has said, “you can see the computer-age everywhere but in productivity statistics, productivity has been advancing at a rate of around 1% a year until 1996, when inflation began to drop significantly. Since then, the percentage change in non-farm productivity has more than doubled and came closer to 3%”. These strong increases in productivity, concurrent with rising wages and low inflation, now have made some economic experts believe that rising investment in information-technology is finally producing real returns.

Research and development is generally funded by the government, with appreciable support from the industry. Unfortunately in Pakistan, neither government nor industry has paid attention to this essentially important field. The function of university department or research institutes is to support local industry, first of all, in order to solve their production and development problems.

This support is strongly linked with highly qualified and trained persons in the relevant field. The question arises as to why mutual cooperation between industry and research institutes/departments is necessary. The answer is that solving many problems today requires specialists and special costly equipment. A single department can hardly keep up with the state of technology in every field, a fact which dictates cooperation. Here an attempt is made to highlight the methodology of mutual cooperation between the universities/ institutes and the industry.

COOPERATION

The industry needs creativity, innovations, future-oriented strategies and transfer of know how. Institutes or departments should have freedom to carry out basic research. Apart from the government, industry should also cooperate with the university departments for research projects. Applied research has become very expensive and, without the active support of industry, an institute can hardly continue to pursue active research. For this reason alone, close cooperation between industry and departments is necessary. In other words, fundamental activities related to knowledge and infrastructure involves basic research, highly qualified personnel and mutual research cooperation. There are some prerequisites for all research and development efforts. Conditions for basic research must be improved, particularly at the universities, to enable them to improve and develop the knowledge-base needed to meet the challenges of tomorrow. Educational base for basic research is indispensable for high-quality applied research. Highly qualified personnel can bring scientific expertise and insight to every segment of society. It is particularly important to (a) ensure good recruitments for research activities, and (b) increase the mobility of researchers towards industry. The inter-research partnership is essential for professional development, as well as for individual and institutional cooperation in the industrial sector.

Although the research work of most of the faculty-members in the universities and research institutions, in Pakistan, is heavily biased towards basic research i.e. generating knowledge, the importance of applied research has also been recognized lately. In the case of most developing countries, it really becomes difficult to decide whether to give more importance to basic or applied research. Since industrialized countries are reluctant in the transfer of technology, one might like to go for basic research. But, when we look at the wide gap that exists between the performances of economies of developed vs developing world, it seems more appropriate to make use of the knowledge already generated and go for the applied research focusing on problem-solving and result-oriented approach. A balanced approach is needed. So, Government-industry-academia collaboration has become increasingly important, in response to changing market-needs and priorities. The promotion of such tripartite collaboration often forms an intellectual creation cycle.

United States of America (USA) is a leader in putting forth the concept of tripartite collaboration into reality, followed by Europe, Japan and, more recently, many Asian countries. In USA, the case of Stanford University is well known for creating a number of venture-businesses. In Europe, the AT&T research institute at Cambridge University is claimed to be one of the most active examples.

Small & medium enterprises are usually the starting point of the development in countries seeking industrialization. They are required for shift to modern technology and large- scale production, and can even manage to evolve into large enterprises, provided help is extended their way.

GOVERNMENT–UNIVERSITY–INDUSTRY RESEARCH ROUNDTABLE CONFERENCE (GUIRRC)

GUIRRC will provide a platform for dialogue among policy-makers of the federal government, universities and industry in the field of science and technology. It will facilitate exchange of ideas on issues, problems and provide new opportunities. A council will be established that will set the agenda for future deliberations.

Unlike the developed world, where big industrial establishments not only have highly equipped research laboratories and R&D Departments of their own, but they also have strong liaison with the academic and research institutions, no such facilities and linkages worth the name exist in Pakistan. Thus there was urgent need to develop such linkages to promote the cause of basic as well as applied research.

National Productivity Organization has taken the initiative and is involved in undertaking both basic and applied research.

In the area of basic research, we have completed a Benchmarking study in the spinning sector, wherein eighty (80) best-practices have been identified, which, if adopted, could result in savings of as much as Rs.7.5 million per annum by an average firm. We have also published a report on productivity and cost-indices, besides various productivity- indicators like sales-value per employee, labor-cost per employee, unit labor cost and index of value-addition. A brief overview of these studies would be in order.

BENCHMARKING STUDY IN COTTON SPINNING IN PAKISTAN

Benchmarking refers to a continuous learning process, which helps in improving one's own performance by learning from the best practices of other enterprises in the same industry. National Productivity Organization has the unique honor of being the pioneer in introducing this concept in Pakistan.

The study was done on the basis of a concept-paper prepared by NPO after taking All Pakistan Textile Mills Association (APTMA), Punjab Zone, into confidence. There were in all 11 participating mills, the data for which was collected through a field survey, conducted during April-July 2002 with the help of a structured questionnaire. The analysis of the data was done by the NPO research-team with the assistance and guidance of Dr. Hafizur Rehaman Sheikh, a local expert.An APO (Asian Productivity Organization) expert, Mr. Greet.de Clercq, was also involved in the data-analyses and finalization of the report.

The main objective of the study was to identify functions and processes in each department of a spinning unit and the related results being obtained, in order to establish linkages between the two and identify the practices which result in the performance-gaps in various mills. It was ascertained that there is, as such, no technique or relevant information to assess productivity of individual mills for making comparisons with other mills in the same sector. Accordingly, a technique to assess the productivity of a mill was also established, which entailed the calculation of labor and machine productivity of each mill, based on a formal set of comparable data, thus established. The main outcome of this study was the identification of eighty best practices, the adoption of which, by an average mill, could result in annual savings of Rs 7.5 million by way of reduction in material handling and conversion costs. Additionally, overall productivity of the spinning sector will go up by 2 to 5%. It was also established that good performance, in the mills, depends on the efficient use of available resources, like raw material, finance, manpower, producing superior-quality products through implementation of Total Quality Management (TQM) System, besides effective marketing, continuous modernization and up-gradation of production- facilities and customer-oriented manufacturing.

PERFORMANCE OF THE MANUFACTURING SECTOR IN PAKISTAN (1990-91 TO 1995-96)

The performance of the manufacturing sector, especially the large-scale manufacturing, has recently picked up. In order to retain this momentum properly monitoring of the performance of this sector has to be done. Using CMI data for 1995-96(which came out in June 2001), the NPO conducted a disaggregated study of the manufacturing-sector. Productivity-indicators, like Sales-Value per Employee (SVE), Labor Cost per Employee (LCE), Unit labor-cost (ULC) and productivity indices of value-addition, productivity /output, input and various cost-components were computed. Moreover, on the basis of data obtained from UNIDO, these indicators and indices for a few other countries, like Sri Lanka, India, Malaysia and Germany, were also computed for the purpose of comparison with those of Pakistan. Our conclusion was that: (a) sports, handicrafts, scientific instruments and (to some extent), other manufacturing are common in the category of best performers, in terms of SVE, LCE and ULC; (b) leather and leather-products, glass and glass-products and wood were the common ones amongst the category of malfunctioning, in terms of all these indicators. The highest positive difference between the growth of SVE and LCE, is an indication of competitiveness of an industry. Sports, handicrafts, ginning and baling of fibers, transport-equipment and non-ferrous metal industries fall in this category. While comparing the value of SVE, LCE and Value-addition, it was found that, as expected, Germany had much higher values of these indicators. Pakistan did well as compared to Sri Lanka, but it was overtaken by Malaysia and India in most of the cases.

Sumarizing, one can say that, although Pakistan's industrial sector has shown a reasonable growth-pattern in terms of some specific indicators, the situation is not satisfactory. For example, sales-value per employee, a measure that gives the value generated by each employee is low in most of the industries. This could, as well, be due to the use of relatively outdated technology and not paying much attention to Balancing and Modernization (BMR). In the majority of cases, the industries have not been able to reduce their unit labor-cost. This may be attributed to lack of training and appropriate skills for a particular job. Another important factor is the lack of proper training on scientific lines, for the activities of each department in an industry.

As far as applied research is concerned, NPO is also working on a unique concept of establishment of Centers of Quality and Productivity Research in various educational institutions and other allied organizations. These centers are to facilitate demand-driven research, focusing on result-oriented and problem-solving approach on the issues being confronted by the industrialists. Role of NPO's is to promote tripartite partnership and act as a bridge between the academia and the industry. The centers would also help to promote the quality and productivity culture among the future work-force.

SUMMARY & CONCLUSION

Basic research i.e., generating new knowledge and applied research, which focuses on finding the solution of particular problems, are both important elements of any R&D activity. Unfortunately, developing countries in general and Pakistan in particular have been lagging far behind in promoting such activities, which are fundamental for economic development. Now, one thing is quite clear; that the developed countries and the new emerging economies have attainted this position because of having very strong R&D base. It is high time for sincere and serious efforts to be made to develop our R&D infrastructure, both in terms of men and material.

In the global context, most of the industries have similar requirements as far as their machinery and other production-processes are concerned. Nevertheless, where such requirements vary, basic research would be needed. However, the requirements for finding solutions to particular problems may have wide variations across the globe. Each country, and province/region within the same country, may have to adopt different approaches, depending upon their specific environment. Therefore, more emphasis will have to be given to applied research. In order to achieve tangible results, very close coordination among the research institutions, the academia and industries is a must if we have to reduce the yawning gap between the developed and the developing world.

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INITIATIVES OF PCSIR LABORATORIES, PESHAWAR, FOR TECHNOLOGY-TRANSFER THROUGH TECHNOLOGY-BUSINESS INCUBATORS

Jehangir Shah
Senior Scientific Officer PCSIR Laboratories Peshawar
Muhammad Tariq
Director General, PCSIR Laboratories Peshawar

ABSTRACT

The province (NWFP) is bestowed with rich natural resources, a hardworking population and immense opportunities for investment. However, industrially the province is backward and its share in the total installed industrial units is just 7.5 percent. Majority of these industrial units are not working, for one or the other reason. The overall percentage of closed units in the province is about 62%.

PCSIR Laboratories, Peshawar, which is a premier research and development organization in the field of industrial development for many years, developed a number of processes in the field of herbal medicines, minerals and food sectors, for small and medium Enterprises. However, no significant number of these processes has so far been leased out for commercialization. Most of the developed processes are still lying unutilized on the shelves of PCSIR. For example, PCSIR Laboratories, Peshawar, has created 23 different products from a medicinally important plant, seabucktorn; despite the efforts of MAINFAL and Chairman Security and Exchange Commission for its commercialization, none of these processes has been leased out for the last few years.

The existing as well as the new potential entrepreneurs are hesitant to invest, due to a number of reasons, such as lack of technical know-how, lack of pilot-plant and semi-commercial production facilities, infrastructure facilities, quality-control laboratories, managerial and marketing facilities, etc. Realizing this situation, the PCSIR Laboratories Peshawar started work on the idea of establishing Technology Business Incubators to commercialize its products. The objectives are to reduce the risk of business-failure by incubating the young firms: helping them to survive and grow during the startup period when they are most vulnerable.

Presently, PCSIR have involved five to six potentially progressive entrepreneurs for this program: PCSIR laboratories have provided its production-facilities to these entrepreneurs; they are marketing their own products and providing a nominal fee to PCSIR. When they establish their market and reduce the risk of business-failure, they will establish their own production facilities.

The present paper discusses this new approach of technology-transfer through

Technology Business Incubation and presents a case-study (in detail) for commercialization of its products. This approach has already been adopted successfully by a number of advanced countries of the world, like Japan, Korea and China.

INTRODUCTION

The province of NWFP is bestowed with rich natural resources, a hard working population, and immense opportunities for investment. However, industrially the province is backward and its share in the total installed industrial units in Pakistan is just 7.5%. Majority of the industrial units are not working for one or the other reason. The overall percentage of closed units in the province is about 62%.

The Scientists and Technologists of Pakistan Council of Scientific and Industrial Research (PCSIR) over the years have developed a number of processes for herbal medicines, minerals and food-sector for small and medium-sized enterprises. At PCSIR Laboratories Peshawar alone, more than two hundred processes were developed, but, no significant number of these were so far leased out to the SMEs. Despite the efforts of MAINFALL and Chairman Securities and Exchange Commission for its commercialization, none of the processes has been leased out for the last few years. These developed processes are still lying unutilized on the shelves of the PCSIR. The existing SME, as well as new Entrepreneurs, in one way or the other, are shy of investing, due to various risk factors.

RISK FACTORS FOR THE EXISTING AS WELL AS NEW SMALL & MEDIUM ENTERPRISES:

i. A young Techno-Entrepreneur (highly qualified specialist), with new ideas or innovations, may be willing to set up an enterprise and take the risk; but, he has limited financial resources, limited or practically no management or marketing and organizational experience.

ii. Senior professionals and executives who are well qualified and have long management, marketing or organizational experiences, and have left their jobs due to privatization, industrial restructuring, down-sizing or right-sizing or otherwise, may have some capital assets, but they need technological and financial support.

iii. Existing SME or family business, including traders, etc., planning to diversify into technology-based production-enterprises, may have financial resources as well as organizational experience, but they need technological inputs and support.

iv. Large Corporations and multinational organizations that have their own R & D facilities, but nevertheless look for competitive advantage factor, such as knowledge and skills, technological capabilities, infrastructure facilities, policy framework, and market potential in the host country.

v Last, but not the least, the process of globalization, establishment of World Trade Organization (WTO), rapid scientific and technological advancements, newer developments and applications of information-technologies, emergence of knowledge-based and capital-intensive industries, stricter quality-standards and system including ISO 9000 and ISO 14000 systems, environment and pollution-control and energy considerations, direct and indirect trade-barriers by advanced countries, etc., are all eroding the traditional competitive advantages of industries in developing countries like Pakistan, particularly of Small and Medium Enterprises (SMEs), which significantly contribute to the overall industrial and economic development at national level.

ESTABLISHING TECHNOLOGY-BUSINESS INCUBATORS FOR RAPID INDUSTRIALIZATION

There is a clear need to overcome the above - mentioned problems of Industries, as well as to equip them in such a way as to face the future international challenges. The successful experience of the developed and industrialized world, in establishing TBIs, indicates a viable option for the revival of the sick/close units, as well as rapid industrialization in NWFP.

Technology Business Incubators (TBI's) are business-assistance programs that nurture young firms, helping them to survive and grow during the start-up period when they are most vulnerable. These programs facilitate business-enterprise development, and provide the essential support for startup firms. The primary goal of business incubation is to produce financially viable businesses within 2 or 3 years.

In general, Technology Business Incubators provide the following set of services:

- Production facilities (pilot plant and semi- production facilities);
- Training facilities;
- Technology and operations;
- Office space and conference room;
- Secretariat services and office equipment;
- Business strategy, planning and technical support;
- Direct marketing, trade show, media relations, event management;
- Introduction to investors, venture-capital firms and joint-venture partners;
- Legal and accounting assistance;
- Access to financing.

INITIATIVES OF PCSIR LABORATORIES FOR ESTABLISHING TBIs

The PCSIR Laboratories, Peshawar, took the initiatives of adopting this new innovative approach for commercialization of its products through Technology Business Incubators. This new approach has been successfully adopted in a number of Industrialized and developed countries of the world. Many of the facilities offered in the Technology Business Incubators, are already available.

The approach is being designed to attract such SMEs who are either shy of investing in technologies or do not have sufficient venture-capital resources of their own. On successful completion of this endeavor, PCSIR hopes to spearhead a new wave of small and cottage-scale industrial entrepreneurship in the country. This would create a large volume of job-opportunities, generate several spin-off industries, and make a valuable contribution to the growth of national economy.

One such successful case-study of promoting local economy through Technology Business Incubators is given below.

A SUCCESSFUL CASE-STUDY

Background

In the northern hilly areas (Skardu, Gilgit, and Baltistan) of Pakistan, lying at a height of 1700 ft from the sea level, fruits and vegetables are abundantly produced. More than 90% of the population, directly or indirectly, depends on agriculture. Fruit production has been the only source of income and sustenance of these people and the agricultural practices followed are primitive. Due to lack of technical know-how, difficult transportation, absence of market and storage-facilities, large quantities of fruits are wasted. The wastage of fruits may be assessed from the fact that, during the fruit-season, the abundantly available apricots are heaped in the fields or macerated in running water to get rid of the fleshy part and obtained the seeds. The kernels of the seeds are either sold as such, or used for extracting oil. Moreover, the apricot-pulp is often mixed with mud to plaster the walls and roofs of their houses. Actual loss was estimated at about 70% of the total crop for some major fruits.

Realizing this situation, Pakistan Council for Scientific and Industrial Research Laboratories established a Business Incubators station at Skardu in 1996.

Objective of the Skardu Business Incubator

The overall objective was to enhance socio-economic conditions of the locals by providing skilled training in fruit-preservation, processing, enhancing and establishing cottage-industries and creating job-opportunities.

Cost of Business Incubators

This project was approved at a cost of Rs. 9.4 million (U$ 0.16 million) in1996.

Available Facilities in the Business Incubator

The following common facilities were provided to the local people, as well as to the cottage-industries of the area through the TBIs:

i. Demonstrated the small-scale appropriate technologies, related to agricultural produce, for handling, fruit preservation, packing, and storage;
ii. Provided training to the locals and cottage-industries in fruit-processing, preservation, proper storage of fruits, besides provided training on skin-preservation of fruits, and hide;
iii. Provided Common Facilities for fruit-processing to the local people and cottage-industries at nominal fee;
iv. Developed new value-added products from fruits and vegetables, enabling the farmers to obtain additional income from marketing of these products;
v. Provided market-information to the farmers, for the value-added products in Pakistan, as well as abroad;
vi. Provided solar-energy facilities in the preservation of fruits and vegetables;
vii. Provided Research and Development facilities to the locals and cottage industries;
viii. Established Linkages of the cottage-industries and potential entrepreneurs with Banks and NGOs, who are active in socio-economic development of the area, such as AKRSP etc.

Strategy

The above-mentioned facilities, services and information, were provided both at a stationary station, as well as at a Mobile Training Unit.

Achievements

434 people (including males and females) were trained for scientific drying of apricot and apple, preparation of jams, jellies, and squashes, etc. Information about the potential market, sources of financial assistance /funding were also provided. After getting this advanced training, the selling-rate of apricot jumped from Rs. 5 /kg to Rs. 46 / kg. Now, hundreds of farmers are drying apricots and earning millions of rupees yearly. Exports from District Baltistan to Middle East and European Markets have also started.

CONCLUSIONS

The experience of the developed and industrialized nations of the world shows that, in a knowledge-based economy, technology-venturing is a key factor for internationally comparative advantage in industry. Recently, technology-venturing through incubator-activity is emerging and has become a useful strategy to improve international competitiveness. Business incubator, which breed and nurture enterprises, has become an important instrument in the creation of new enterprises and jobs. In particular, technology-incubator, which plays a role of accelerating commercialization of R&D outputs and transfer of technology, has contributed to start-ups of several enterprises based on high technology in the newly industrialized economies.

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SPECTROSCOPIC OPTIMIZATION OF DISCHARGE-PARAMETERS FOR SURFACE IONITRIDING OF STAINLESS STEEL 304

M. Zakaullah*, A.Qayyum* and A. Waheed**
**Department of Physics, Quaid-i-Azam University, Islamabad, Pakistan*
***PINSTECH, PO Box 2151, Islamabad, Pakistan*

ABSTRACT

Emission spectroscopy is used to study the concentration of molecular and atomic species (N_2, N_2^+, NH, H and Fe) of nitrogen-hydrogen mixture plasma, as a function of discharge-parameters, such as volumetric gas composition (40-90 % H_2), source power (200-400 watts) and filling pressure (3-7 mbar), to find optimum discharge conditions for species of interest required in plasma-ionitriding of SS 304. The emission-intensity ratios of the first negative band-head $N_2^+(B^2\Sigma_u^+ \Longrightarrow X^2\Sigma_g^+(0,0))$ and the second positive band-head $N_2(C^3\Pi_u \Longrightarrow B^3\Pi_g(0,0))$ are used to estimate N_2^+/N_2 ratios (relative occurrence of N_2^+ and N_2 species) under different discharge-conditions and to extract information on behavior of middle-energy and high-energy electrons. It is found that the relative occurrence of N_2^+ and N_2 species is strongly dependent on the discharge-parameters and can be optimized by appropriate selection of the discharge-conditions. The stainless steel 304 samples are nitrided under optimum discharge-conditions for 4, 8, 12 and 16 hours, and the hardness values are found to increase five times for 16 hours treatment time.

1. INTRODUCTION

Glow-discharge ionitriding is a surface-modification technique, which is primarily used to increase the fatigue-strength, wear and corrosion-resistance and surface-hardness of materials, especially iron-based alloys [1,2]. This technique has recently aroused considerable industrial interest, owing to its characteristic of faster nitrogen-penetration without causing any change in bulk-properties of the substrate, simplicity in application, economic and easier control of compound and diffusion-layers formation. The treatment-parameters can be arbitrarily selected within a wide range, to produce specific surface-structures and properties, which make it attractive, compared with other conventional ionitriding methods [3,4]. The addition of hydrogen with nitrogen enhances the case-depth and surface-hardness by removing the surface-oxides during the surface-ionitriding process. Therefore the compound layer-thickness and surface-hardness is usually controlled by the concentration of hydrogen in the gas mixture [5]. During the ionitriding process, the active species of nitrogen are generated by an electric discharge and are diffused into the bulk, making the surface hard. The generation of these active species rely on the ability of the plasma to produce a high concentration of excited states of the plasma-species. These electronically excited atomic species, as well as electronically and vibrationally excited molecular species, carry several electron-volts of energy above their ground-states and can affect the surface and, thus, deposition chemistry [6]. The addition of hydrogen with nitrogen plays an important role in the ionitriding process, by increasing the concentration of the active nitriding species in the plasma [7].

Owing to the long-distance diffusion of the nitrogen atoms from the surface toward the subsurface region of the substrate core, two different structures occur in the nitriding process. The outermost layer, which is a few micrometers thick, consists of an intermetallic compound of iron plus nitrogen (-$Fe_{2-3}N$, -Fe_4N) is referred to as the compound layer. Underneath this layer is a significantly thicker diffusion layer, where the nitrogen has mainly been incorporated into the existing iron-lattice as interstitial atoms [8].

The glow discharges used as processing plasma for surface-treatment can be established and sustained in various ways, such as by using pulsed DC discharges, RF and microwave discharges. However, the latter operation-modes are not so advantageous for up-scaling to large reactors (which is a new tendency in materials technology) due to high cost of RF and microwave generators. Therefore, the pulsing DC generated discharges are attracting increasing interest, due their simplicity and cost-effectiveness.

In this paper, plasma diagnostics by means of optical emission spectroscopy is carried out to obtain insight into the species that affect the plasma-reactivity and to gain a better understanding of the mechanisms leading to the production of these active species (radicals, atoms and molecular ions), whose occurrence determines the nitridation process. In particular, the influence of discharge-parameters, such as gas mixture ratio, source power and filling pressure, on the occurrence of these active species is studied. The main aim of this work is to find optimum discharge-conditions (gas composition, source power and filling pressure) for the desired treatment of the samples in a simple and cost-effective manner. Section 1 reviews the effect of hydrogen admixture with nitrogen on the concentration of the active species of N_2 H_2 mixture plasma and their excited states and, consequently, the dependence of the surface-properties of the treated samples. Section 2 contains the details of the experimental setup, along with the diagnostic procedure, whereas section 3 describes the mechanisms of the excitation of the N_2^+ and N_2 species and the evaluation of the emission-intensity of the selected electronic transitions of significant molecular and atomic species, using emission spectroscopic technique. Results are presented in section 4, whereas some concluding remarks are summarized in section 5.

2. EXPERIMENTAL SETUP

The experiment is carried out in a parallel-plate electrode-configuration, consisting of stainless-steel electrodes with diameter of 7.5-cm and a spacing of 6.0-cm. The side and back of the electrodes are covered with Ceramic casing, to prevent additional discharge. The electrode-assembly is housed in a cylindrical stainless-steel vacuum chamber of 40-cm diameter and height. The experimental setup is shown schematically in Figure-1. Prior to filling with working gases, the chamber is evacuated down to 10^{-5} mbar, using a rotary-vane pump and oil-diffusion pump. The flow of nitrogen and hydrogen gases is monitored with mass flow-meters for the desired composition of nitrogen and hydrogen mixture, and the pressure in the chamber is recorded by using capsule-type dial gauge. A pulsing DC power, which is obtained from a 50 Hz AC power-source through the step-up transformer and the diode chain (in half-wave rectifier arrangement), is applied to the top electrode through the inductive load, which limits the current during the discharge. The bottom electrode is grounded. By powering the top electrode with pulsing DC, N_2H_2 mixture glow-discharge is generated in abnormal region and optical emission spectroscopy is carried out, using a computer-controlled system comprising a McPherson2061 monochromator having 1200 grooves/mm and spectral resolution of 0.01 nm, coupled with a side-window photomultiplier tube (PMT- 9781B) and auto-ranging Pico-ammeter (Keithley-485). The system is calibrated with a mercury lamp. The emission from the N_2-H_2 mixture glow-discharge excited in the abnormal region is recorded as a function of gas-composition (40-90% H_2) at a constant source-power of 200 watts and filling pressure of 5-mbar, and the emission intensity of the selected spectral lines of plasma-species is evaluated to optimize the gas composition (H_2 concentration in the mixture) for the occurrence of the N_2^+ species mainly responsible for the heating of the

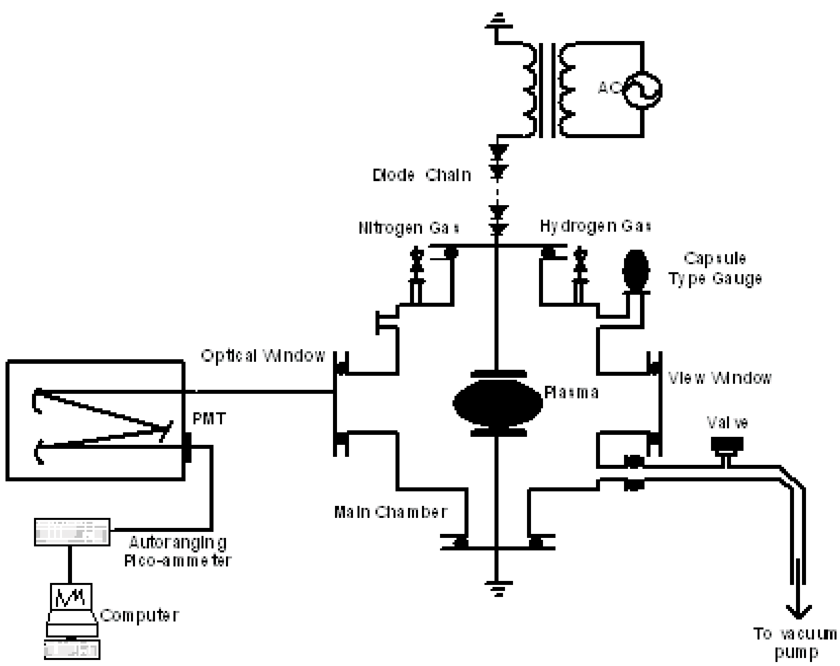

Figure - 1: Schematic Illustration of the Experimental Set up

Table - I: Data Characterizing the Spectral Lines of the Selected Species of Atoms, Molecules, Radicals and Ions Investigated in the Article

Species	Wavelength (nm)	Transitions	Excitation energy (eV)
N_2	337.1	$C^3\Pi u \Longrightarrow B^3\Pi g$ (0,0)	11.1
N_2^+	391.4	$B^2\Sigma_u^+ \Longrightarrow X^2\Sigma_g^+$(0,0)	18.7
NH	336.0	$A^3\Pi \Longrightarrow X3\Sigma^-$(0,0)	3.7
H	486.1	Balmer series (4,2)	12.7
F_e	372.0	$z\,^5F \Longrightarrow a\,^5D$	3.3

substrate surface, due to cathodic bombardment. Emission spectra are also recorded as a function of source-power (200-400 watts) by keeping the filling pressure at 5-mbar for optimum gas-compositions (60 80% H_2), to study the dependence of selected species. The effect of filling pressure on the concentration of the active species is also investigated by recording the spectra for different filling pressures (3-7 mbar) at constant power-level of 200 watts and optimum gas compositions (60 80% H_2). The SS304 samples are also nitrided under optimum discharge-conditions of 70% H_2 in the mixture, at a filling pressure of 5 mbar, for different durations of time and surface-hardness is measured by using Vickers hardness-testing system.

A typical spectrum recorded at a filling pressure of 5.0-mbar, source power of 200 watts and gas composition of 60% H_2 admixed with 40% N_2, is shown in Figure-2. The emission lines are identified and labeled by using compiled data [9].

3. OPTICAL-EMISSION SPECTROSCOPY

Optical-emission spectroscopy (OES) is the most popular technique to investigate the glow-discharges, since it can be employed quite simply to obtain information such as concentration of the species forming the plasma and their excited states. The basic premise of this technique is that the emission-intensity of a particular wavelength from an excited state is proportional to the concentration of species in that excited state [10]. In the glow-discharge, the plasma species are subjected to collisions with electrons and with other plasma species. The excitation collisions, and the subsequent radiative decays, emit characteristic photons of the plasma-species [11], which can be detected

Table - II: Ionization Processes of N_2 and H_2 Plasma Species, Along with their Ionization Energies

Species	Ionization process	Ionization energy (eV)
N_2	$N_2 + e^-$ $N_2^+ + 2e^-$	15.57
N_2	$N_2 + e^-$ $N^+ + N + 2e^-$	24.5
N	$N + e^-$ $N^+ + 2e^-$	14.5
H_2	$H_2 + e^-$ $H_2^+ + 2e^-$	15.37
H_2	$H_2 + e^-$ $H^+ + H + 2e^-$	18
H	$H + e^-$ $H^+ + 2e^-$	13.6

and analyzed by recording the spectrum. The emission-intensity of these emitted photons of characteristic wavelength provides information on the concentration of the plasma-species and their excited states. The spectral lines used in the study of selected species of atoms, molecules and ions are given in Table-I, whereas the ionization processes of N_2 and H_2 species, along with their ionization energies, is given in Table-II.

The population of the $N_2\,(C\,^3\Pi_u)$ excited state is mainly caused by the direct electron-impact (having energies above the excitation threshold) excitation from the ground state of $N_2\,(X\,^1{}_g\Sigma^+)$.

$$N_2\,(X\,^1\Sigma g^+)_{v=0} + e \Longrightarrow N_2\,(B\,^3\Pi_u)_{v'=0} + e\ (\Delta E = 11.1\ \text{eV})$$

The subsequent radiative decays emit characteristic photons of second positive band-head, having wavelength of 337.1 nm

$$N_2(C^3\Pi_u)_{v'=0}\ \ N_2\,(B\,^3\Pi_g)_{v''=0} + h\nu$$

Consequently, the emission intensity of this molecular electronic transition is proportional to the N_2 concentration [12,13].

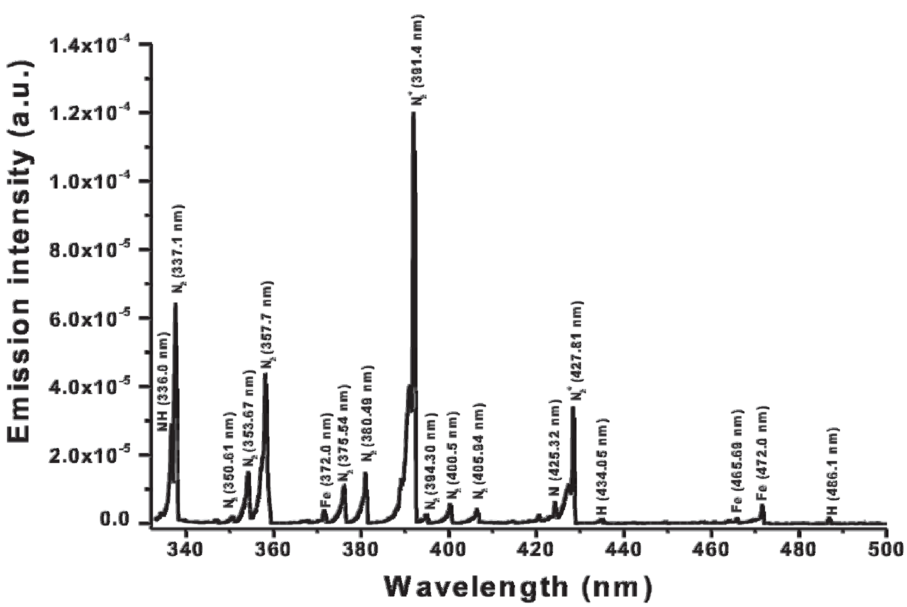

Figure - 2: Emission Spectrum Recorded from a Mixture of 60%H_2 + 40%N_2 Plasma at a Filling Pressure of 5.0-mbar and Source Power of 200 Watts

$$I(N_2) \propto [N_2] \int_{\varepsilon\, thr}^{\varepsilon max} n_e(\varepsilon)\sigma_{N2}(\varepsilon)d\varepsilon$$

Where $n_e(\varepsilon)$ is the electron-energy distribution-function, σ_{N2} is the electron excitation collision cross-section at energy ε;ε_{thr} is the threshold energy for the excitation process and $[N_2]$ is the concentration of the N_2 molecules.

The N_2^+ ($B\ ^2\Sigma_u^+$) excited state can be populated either by direct electron-impact excitation from the ground state of the molecule N_2 ($X\ ^1\Sigma_g^+$) via

$$N_2\ (X\ ^1\Sigma_g^+)_{\nu=0} + e \Rightarrow N_2^+(B\ ^2\Sigma_u^+)_{\nu'=0}\ + 2e\ \ (\Delta E = 18.7\ eV),$$

or stepwise via electron-impact ionization of the N_2 molecule and then subsequent electron-impact excitation of the molecular ion:

$$N_2\ (X\ ^1\Sigma_g^+)_{\nu=0} + e \Rightarrow N_2^+(X\ ^2\Sigma_g^+)_{\nu'=0}\ + 2e$$
$$N_2^+(X\ ^2\Sigma_g^+)_{\nu=0} + e \Rightarrow N_2^+(B\ ^2\Sigma_u^+)_{\nu'=0}\ + e$$

The subsequent radiative decays emit characteristic photons of first negative band-head, having wavelength of 391.4 nm:

$$N_2^+(B\ ^2\Sigma_u^+)_{\nu'=0}\ \ N_2^+(X\ ^2\Sigma_g^+)_{\nu=0} + h\nu$$

Again, the emission intensity is

$$I(N_2) \propto [N_2] \int_{\varepsilon\, thr}^{\varepsilon max} n_e(\varepsilon)\sigma_{N2}(\varepsilon)d\varepsilon$$

The cross section for excitation of 337.1 nm (second positive band-head) has a sharp peak near the threshold excitation-energy (11.1 eV) and is small above 20 eV. The cross section for 391.4 nm (first negative band-head) has a threshold above 18 eV and reaches maximum near 100 eV [12]. Thus the emission-intensity of second positive band head may be used to estimate electrons of energy around 15 eV, while the emission-intensity of the first negative band head gives information of the electrons well above 20 eV and relative band-head intensities of these systems are very sensitive to the N_2^+/N_2 ratios and electron-temperature [14]. Therefore, intensity measurements of a band-head of the first negative $B^2\Sigma_u^+ \Rightarrow X^2\Sigma_g^+(0,0)$ situated at a wavelength 391.4 nm and the second positive $C^3\Pi_u B^3\Pi_g$ (0,0) situated at 337.1 nm, may be used to estimate N_2^+/N_2 ratios under different discharge-conditions and to extract information on the behavior of middle-energy and high-energy electrons and also the shape of electron-energy distribution function (EEDF) [12].

The emission of the N_2-H_2 glow-discharge is mainly produced from the negative-glow region around the cathode. Therefore, to study the concentration of the selected species of N_2-H_2 mixture plasma in the negative-glow region, the emission spectra are recorded as a function of gas-composition (40-90% H_2), source-power (200-400 watts) and filling-pressure (3-7 mbar), and the emission-intensity of the selected electronic transitions is evaluated to investigate the effect of these discharge-parameters on the occurrence of the N_2, N_2^+, NH, H and Fe species. The variation in the emission-intensity of the selected species of atoms, molecules, ions and radicals with the gas-composition is presented in Figure-3. The effects of source-power and filling-pressure on the occurrence of these species are shown in Figure-4 and Figure-5. Relative band-head intensities of first negative system $B^2\Sigma_u^+ \Rightarrow X\ ^2\Sigma_g^+(0,0)$ and second positive system $C^3\Pi_u B^3\Pi_g$ (0,0) are evaluated under different discharge conditions to extract information on the N_2^+/N_2 ratios, electron temperature and electron-energy distribution-function (EEDF). The variation in the emission intensity ratio $N_2^+(B^2\Sigma_u^+ \Rightarrow X\ ^2\Sigma_g^+(0,0))$ / N_2 $C^3\Pi_u B^3\Pi_g$ (0,0)) is also investigated for various gas-compositions, as a function of source power and filling-pressure to investigate the relative dependence of N_2^+ and N_2 species.

4. RESULTS AND DISCUSSIONS

The measurements of the emission-intensities of the selected spectral lines of plasma-species give information on the concentration of the active species and their excited states. These active species carry several electron-volts of energy above their ground-states and can affect the surface of the substrate and, thus, the deposition chemistry. Moreover, the emission-intensity of the band-head of first negative system $N_2^+(B^2\Sigma_u^+ \Rightarrow X\ ^2\Sigma_g^+(0,0)$ at 391.4 nm)) provides the quantitative knowledge of the occurrence of N_2^+ ions bombarding the cathode-surface and offers the possibility of choosing the optimum discharge-conditions for the ionitriding process. Figure-2 shows that the most intense peak in the emission spectra comes from the first negative system, corresponding to the electronic transition from the ground vibrational level of the $B^2\Sigma_u^+$ state to the ground vibrational level of the $X\ ^2\Sigma_g^+$ state. Another intense peak comes from the second positive system, corresponding to the electronic transition from the ground vibrational level of the $C^3\Pi_u$ state to the ground vibrational level of the $B^3\Pi_g$ state. Together with these peaks, an intense peak corresponding to the emission of the NH molecules is present. This peak is due to electronic transition from the ground vibrational level of the $A\Pi^3$ state to the ground vibrational level of the $X\ ^3\Sigma$ state. These peaks are the most important, because the emission intensity of these peaks gives the concentration of the respective species.

4.1 Effect of H_2 Percentage in the Mixture

The results presented in Figure-3 indicate that the percentage of H_2 in the mixture affects the intensity of the selected emission lines of molecular and atomic species and, consequently, the occurrence of these species. The addition of hydrogen with nitrogen up to 70%, enhances the population of the $N_2^+(B^2\Sigma_u^+)$ state, which is mainly caused by direct electron-impact excitation from the ground state of the N_2^+ resulting from the electron-impact ionization of the N_2 molecule. Therefore increased emission-intensity of first negative band-head $N_2^+(B^2\Sigma_u^+ \Rightarrow X\ ^2\Sigma_g^+(0,0))$ with increase in hydrogen concentration from 40 to 70% illustrates the strong dependence of N_2^+ occurrence on the gas-mixture ratio and suggests the optimal hydrogen percentage ranging from 60 to 70% for the occurrence of maximum N_2^+ species in the plasma. Furthermore, the concentration of the N_2^+ species in the plasma can be controlled by the H_2 percentage in the mixture. This effect is probably caused by a substantial change in ionization mechanisms of the gas mixture, and by possible larger nitrogen-hydrogen ion-flux at the cathode, or else a rise in the secondary-electron emission due to interactions of hydrogen with the cathode-surface [15]. The emission-intensity of second positive band-head $N_2\ C^3\Pi_u \Rightarrow B^3\Pi_g\ (0,0))$ decreases with hydrogen-concentration in the mixture, indicating the decreased occurrence of N_2 molecular species in the mixture.

The emission-intensity of the selected Fe line characterizes the sputtering of the cathode material, which is caused mainly by the bombardment of positive ions. The sputtered Fe atoms arrive in the glow-discharge and are subjected to collisions with

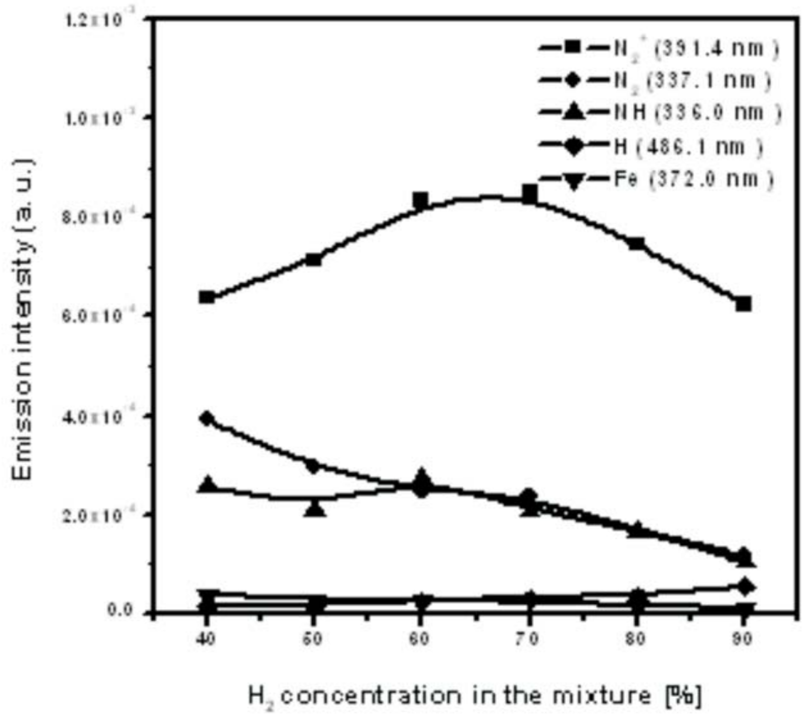

Figure - 3: Variation of Emission Intensity of Selected Spectral Lines of Plasma Species with H_2 Percentage in the Mixture Plasma

electrons and with other plasma species. The excitation-collisions, and the subsequent radiative decays, emit characteristic photons of the Fe atoms [11]. The intensity of these emitted photons of characteristic wavelength gives the concentration of the Fe atoms in the discharge. The emission intensity of hydrogen Balmer line shows the increasing trend with H_2 concentration in the mixture.

4.2 Effect of Electrical Power

The results illustrated in Figure-4 predict that the electrical power affects the emission-intensity of the selected spectral lines. For three optimized gas compositions, the emission intensity of $N_2^+(B^2\Sigma_u^+)$ state increases more rapidly than the emission-intensity of $N_2\,(C^3\Pi_u)$ state, up to a power of 250 watts and then decreases. This fact may be explained as follows: The bombardment of positive ions at the cathode not only releases secondary electrons, but also atoms of the cathode material, which is called "sputtering". With increase in power, the energy of the secondary electrons ejected from the cathode-material, due to bombardment of positive ions, increases and the excitation cross-section of $N_2\,(C^3\Pi_u)$ state decreases with increase in electron's energy

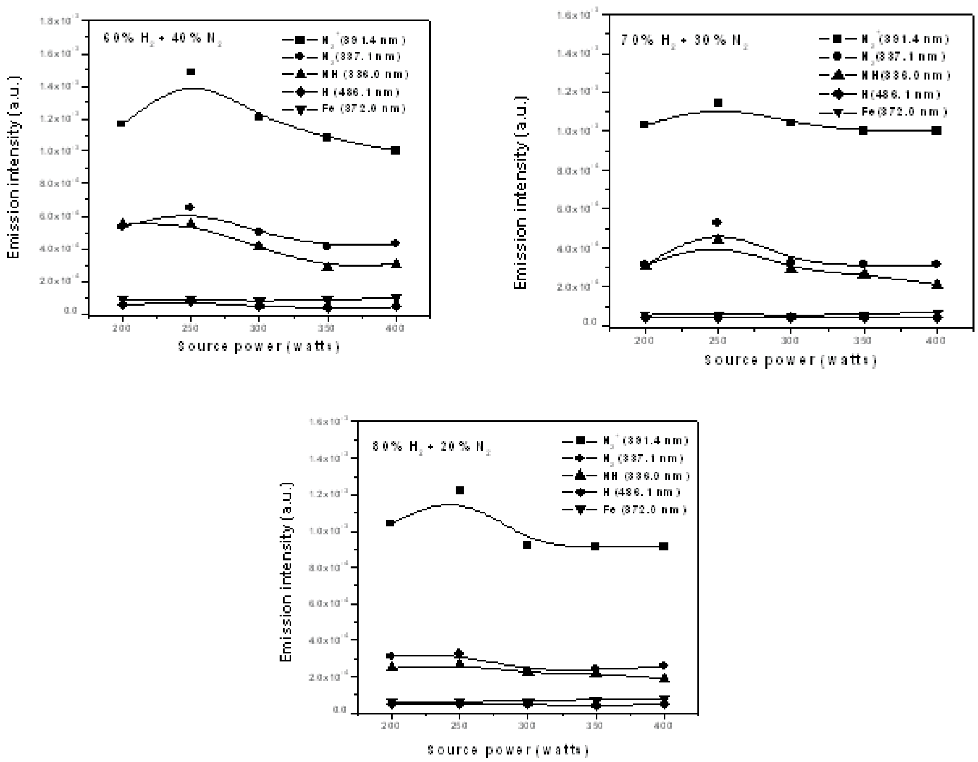

Figure - 4: Variation of Emission Intensity of Selected Spectral Lines with Source Power for Various H_2N_2 Mixture Compositions

above the excitation threshold of N_2 ($C^3\Pi_u$) state. The excitation cross-section of $N_2^+(B^2\Sigma_u^+)$ state extends to larger degree, because the excitation of $N_2^+(B^2\Sigma_u^+)$ state is more sensitive to high-energy electrons than the excitation of N_2 ($C^3\Pi_u$) state. When power is increased above 250 watts, the sputtering of the cathode increases, which is characterized by the increased emission intensity of the selected Fe line with electrical power, since the atoms of the cathode-material arrive in the glow region and are subjected to collisions with electrons and other plasma species. The excitation and ionization cross-sections of Fe atoms are higher for low-energy electrons, due to lower excitation and ionization threshold energies of metal atoms, compared with plasma species [16]. Due to ionization and excitation collisions, the electrons are cooled down thus affecting the emission of $N_2^+(B^2\Sigma_u^+)$ and N_2 ($C^3\Pi_u$) states. The emission intensity of hydrogen Balmer line shows weak dependence on the electrical power.

4.3 Effect of Filling Pressure

The results presented in Figure-5 indicate that, for the gas composition 60% H_2 + 40% N_2, the emission intensity of N_2^+ ($B^2\Sigma_u^+ \Rightarrow X\,^2\Sigma_g^+(0,0)$) band-head increases more rapidly

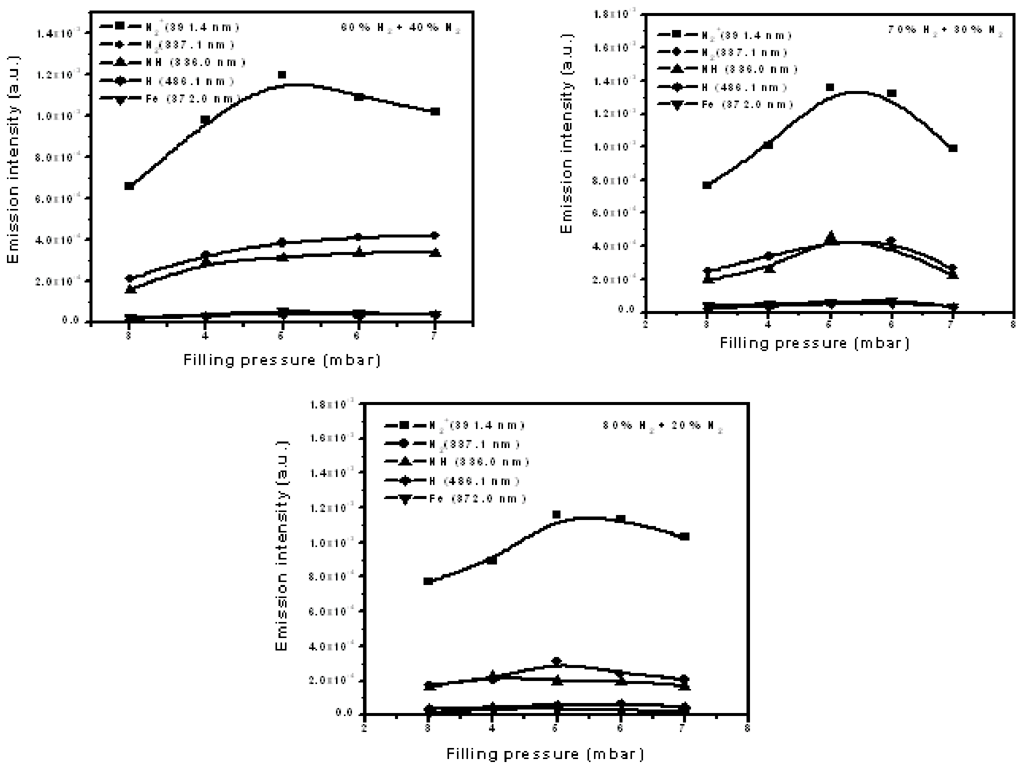

Figure - 5: Variation of Emission Intensity of Selected Spectral Lines with Filling Pressure for Various H_2N_2 Mixture Compositions

than the emission intensity of N_2 ($C^3\Pi_u \Rightarrow B^3\Pi_g$ (0,0)) band-head, up to filling pressure of 5-mbar, which suggests the increased population of the N_2^+ ($B^2\Sigma_u^+$) state as against the N_2 ($C^3\Pi_u$) state. Since the emission of N_2^+($B^2\Sigma_u^+$) state is more sensitive to high-energy electrons compared with the emission of N_2 ($C^3\Pi_u$) state, therefore this effect may be explained by the increased number of energetic electrons with rise in filling pressure up to 5-mbar. Above this pressure the emission intensity of N_2^+($B^2\Sigma_u^+$) state decreases, whereas the emission intensity of N_2 ($C^3\Pi_u$) state continues its previous trend. Almost the same trends are observed for other two gas-compositions (70% H_2 + 30% N_2, 80% H_2 + 20% N_2), suggesting the 5 mbar is an optimum pressure for the maximum N_2^+ molecular ions hitting the substrate. It is observed that filling-pressure has a weak effect on the emission-intensity of Fe spectral-line intensity, in comparison with power.

4.4 Comparison Between the N_2^+ and N_2 Species

As stated earlier, the emission-intensity of the first negative band head N_2^+ ($B^2\Sigma_u^+ \Rightarrow X\ ^2\Sigma_g^+$(0,0)) and second positive band-head N_2($C^3\Pi_u \Rightarrow B^3\Pi_g$ (0,0)) is proportional to the electron-density whose energy is greater than excitation threshold of the corresponding excitation processes and their concentration. Therefore the evaluation of the emission-intensity of these band-heads not only provides information of the concentration of the N_2^+ and N_2 species, but also helps to extract information on the behavior of middle-energy and high-energy electrons and also the shape of electron-energy distribution function (EEDF) [12].

Figure-6 (a) shows that the emission intensity ratio N_2^+ ($B^2\Sigma_u^+ \Rightarrow X\ ^2\Sigma_g^+$(0,0))/$N_2$($C^3\Pi_u \Rightarrow B^3\Pi_g$ (0,0)) increases with filling pressure for the gas-composition (80% H_2 + 20% N_2), whereas it decreases with filling pressure for the other two gas-

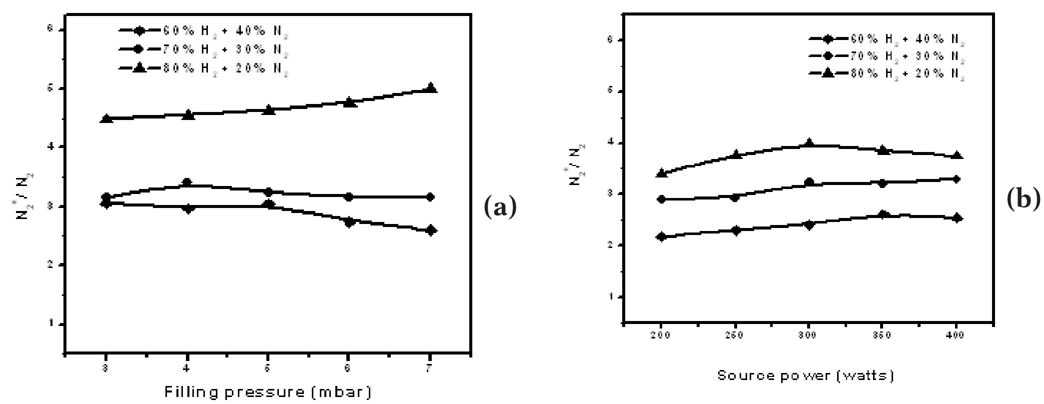

Figure – 6: Variation of Emission Intensity Ratio of First Negative Band Head N_2^+ (B^2 $_u^+$ X ^{2} $_g^+$(0,0)) and Second Positive Band Head N_2^+(C^3 $_u$ B^3 $_g$ (0,0)) for Various H_2–N_2 Mixture Compositions with: (a) Filling Pressure, (b) Source Power

compositions (70%H_2 +30% N_2, 60% H_2 + 40 % N_2). These results suggest an increased occurrence of N_2^+ molecular ions, in comparison with N_2 molecules with filling pressure for gas composition (80% H + 20% N) whereas decreased occurrence of N_2^+ ions in comparison with N_2 molecules for the other two gas compositions.

Figure - 6(b) presents the variation of the emission-intensity ratios with source-power and suggests an increased occurrence of N_2^+ ions, in comparison with N_2 molecules for all three gas-compositions. Since the cross section for excitation of 337.1 nm (second positive band-head) has a sharp peak near the threshold excitation energy (11.1 eV) and is small above 20 eV, and the cross section for 391.40 nm (first negative band-head) has a threshold above 18 eV and reaches maximum near 100 eV [12], therefore an increase in the emission-intensity ratios with power also suggests an increase in the number of energetic electrons in the plasma.

4.5 Ionitriding of SS 304 Samples Under Optimum Discharge Conditions

Optical emission spectroscopy of active species of N_2-H_2 mixture plasma reveals that 70% hydrogen at 5 mbar filling pressure may be the optimum for ionitriding of SS 304. The SS 304 samples are nitrided under these optimum conditions for different durations. The surface hardness of the treated samples is measured by using Vickers hardness testing system. It is found that the surface hardness of SS 304 increases linearly with treatment-time and is enhanced up to five times for a treatment time of 16 hours. The results are presented in Figure-7.

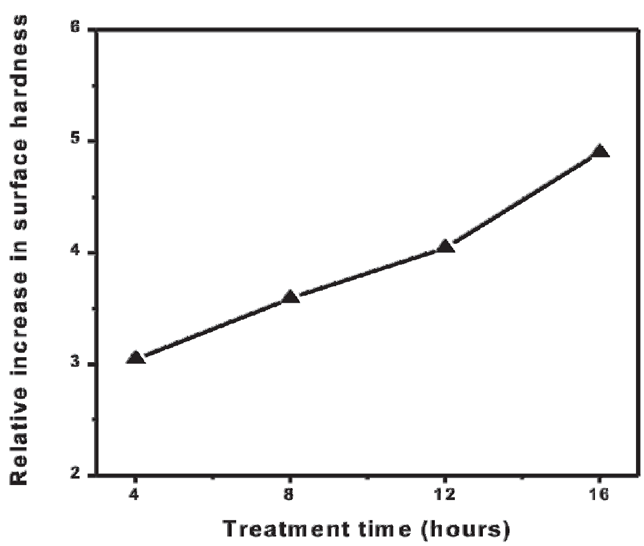

Figure - 7: Variation of Relative Increase in Surface Hardness with the Treatment Time (Hardness of Treated Samples/Hardness of Untreated Sample)

5 CONCLUSIONS

Plasma analysis, using optical emission spectroscopy, has been carried out in abnormal glow regime, to determine the optimum discharge-conditions for plasma nitriding. The emission-intensity of the selected spectral lines of significant molecular and atomic species has been evaluated, in terms of their dependence on the discharge parameters such as gas-composition, source-power and filling-pressure of the plasma-processing reactor. The measurements of the intensities of selected spectral lines provide information on the concentration of the active species and their excited states. It is observed that the concentration of the active species of the N_2-H_2 mixture plasma is dependent on the gas-composition, source-power and filling-pressure, and can be optimized by appropriate selection of the discharge conditions. The emission intensity ratio N_2^+ $(B^2\Sigma_u^+ \Rightarrow X\ ^2\Sigma_g^+(0,0))/N_2(C^3\Pi_u \Rightarrow B^3\Pi_g\ (0,0))$ of the first negative band-head and second positive band head provides information of the relative occurrence of N_2^+ and N_2 species and their excited states. An increased occurrence of N_2^+ molecular ions, in comparison with N_2 molecules, is observed with source-power for all three gas-compositions, whereas decreased occurrence of N_2^+ molecular ions, in comparison with N_2 molecules, is observed with filling-pressure except for the gas composition (80%H_2 + 20% N_2) where increased occurrence of N_2^+ is observed. The optimized discharge conditions are found favorable for ionitriding of stainless steel 304.

ACKNOWLEDGMENTS

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BASIC RESEARCH AND LARGE-SCALE PRODUCTION OF RADIO-PHARMACEUTICALS

M. Jehangir and A. Mushtaq
Isotope Production Division
Pakistan Institute of Nuclear Science & Technology (PINSTECH)
P.O. Nilore, Islamabad, Pakistan

ABSTRACT

The linear model of relationship between research and innovation suggests that research contributes knowledge for the innovation process. Scientific information is used in the creation of new technologies, which are then used in economic activities. This is specially true in the pharmaceutical industry where 1% increase in the stock of basic research ultimately leads to 2 - 2.4% increase in the number of commercially available ethical drugs. Despite an increasing number of non-radioactive tracer-techniques developed during the last decades, such as luminescent, fluorescent, enzyme-linked immunoassay/ELISA, functional MRI, or the use of stable isotopes in various fields, the major applications of radioactive tracers in medicine will remain or even increase, because of their sensitivity combined with ease of imaging from outside a closed system (such as the human body).

Radioisotopes and radiopharmaceuticals play a key role both in diagnostic investigations and therapy. Emission tomography (PET and SPECT), which uses short-lived tracers, is a rapidly proliferating technology. Rapid, efficient remotely controlled, automated and computerized methods of radionuclide and precursor production, labeling of biomolecules, and quality-control procedures need to be developed. In this paper, the role of PINSTECH and other research organizations (in developed and developing countries) for expanding nuclear medicine practices in their respective countries is described.

1. THE ECONOMIC RETURNS TO BASIC RESEARCH

The relationships between public research and innovation are recognised to be an increasingly significant aspect in the emerging knowledge-economy. However, this is an area beset by high level of complexity and a surprisingly small amount of empirical research.

1.1 An Intuitive Approach

In the context of limited resources for supporting basic research, and the need to justify the expenditure of these resources, a growing number of policy-makers and academic-analysts have become interested in understanding the relationship between basic-research and economic activity. Much of this analysis has been underpinned by an attractive intuitive approach to understand these relationships. This approach is characterised by several logical and sequential steps:

- First, science is mainly seen as a source of new information about how the world works.
- Second, because this information is published openly in the usual academic way, it is 'free to all comers' – a low-cost input into economic processes.
- Third, the link between science and technology is obvious: scientific information is used in the creation of new technologies, which are then used in economic activities.
- Finally, given this role of science in the creation of economic returns, it becomes attractive to try to quantify the amount of economic benefit that can be attributed to the basic-science elements.

1.2 Overview

Table-1 shows the latest available information from peer-reviewed journals on the rate-of-return from publicly funded R&D, starting with the original contribution from Griliches. It should be noted that only one recent paper has attempted to calculate a rate-of-return: other papers reviewed below do not provide an estimate of this measure, so these are not included in this table.

The Strategic Planning and Economic Analysis Group of the US National Institute of Standards and Technology (NIST) has more recently become a large source of economic-returns assessments. They have been conducting economic impact assessments of their research-funding programmes since 1992. The studies cited in the literature are recent economic-impact assessments of projects undertaken by NIST Measurement and Standards Laboratories. Tassey (Tassey 1999) provides an overview of their assessment-programme and a discussion of the lessons learned about the methodology of their economic-impact studies.

They claim that 'Collectively, the entire set of economic-impact studies conducted, to date, demonstrates that the rates of return on NIST infratechnologies consistently match or exceed rates-of-return to private investment in technology' (Tassey 2001).

As indicated above, there is a range of problems associated with measuring comprehensive economic returns to public R&D. The academic debate about these problems has encouraged researchers to adopt a more modest approach, focussing on measuring the relationship between public-funding and specific desirable outcomes, such as the level of business R&D and innovation. Table-2 provides a summary of two recent papers providing estimates of partial-indicator elasticities: other papers reviewed in this section do not provide comparable data, so are not included in this table. While the figures in Table-1 are average values, Table-2 provides elasticity measures that are of greater use when deciding about increasing or decreasing

Table - 1: Published Estimates of Rate-of-Return to Publicly Funded R&D

Studies	**Subject**	**Rate of return to public R&D**
Griliches (1958)	Hybrid corn	20-40%
Peterson (1967)	Poultry	21-25%
Schmitz-Seckler (1979)	Tomato harvester	37-46%
Griliches (1968)	Agricultural research	35-40%
Evenson (1968)	Agricultural research	28-47%
Davis (1979)	Agricultural research	37%
Evenson (1979)	Agricultural research	45%
Davis and Peterson (1981)	Agricultural research	37%
Mansfield (1991)	All academic science Research	28%
Huffman and Evenson (1993)	Agricultural research	43-67%
Cockburn and Henderson (2000)	Pharmaceuticals	30% +

Taken from Alister Scott, Grové Steyn, Aldo Geuna*, Stefano Brusoni, Ed Steinmueller. *The Economic Returns to Basic Research and the Benefits of University-Industry Relationships A literature review and update of findings Report for the Office of Science and Technology By SPRU - Science and Technology Policy Research, the Stationery Office, UK.*

Table - 2: Estimates of Partial-Indicator Elasticities

Studies	**Subject**	**Finding**
Toole (2000)	Pharmaceuticals	Estimate that 1% increase in the stock of public basic research ultimately leads to 2-2.4% increase in the number of commercially available new compounds.
Guellec and Van Pottelsberghe (2000)	All sectors	One dollar of public funding for R&D (Including defence) leads to additional business R&D as follows: +$0.70, when allocated to business -$0.44, when allocated to government labs -$0.18, when allocated to universities (The effect is approximately zero when defence-spending is removed. See the review in section 4.1.2 below for further explanation of the role of defence spending)

resource (funding) for public research.

1.3 Toole (2000)

Working in the pharmaceutical industry, Toole investigated the impact of public basic research on industrial innovation. He used a production-function framework to model the number of new products as a function of research-investment in seven technology classes over the period 1978 –1994 for federally funded basic research conducted in the USA. He found that a 1% increase in the stock of basic research ultimately leads to a 2-2.4% increase in the number of commercially available ethical drugs. His estimates also suggest that the lag between funding and commercialisation is seventeen to nineteen years. He further finds that (for the pharmaceutical sector) the marginal product of basic research is larger than the marginal product of applied R&D.

1.4 Science and the Economy: Scoping the Benefits

Previous SPRU reviews found seven benefits from public research for innovation. Rather than re-rehearse the evidence for each here, we refer the reader to those reviews (Martin, Salter et al. 1996; Salter, d'Este et al. 2000; and also Salter and Martin 2001). The benefits are:

i. Producing new scientific information;
ii. Training skilled graduates;
iii. Supporting new scientific networks and stimulating interaction;
iv. Expanding the capacity for problem-solving;
v. Producing new instrumentation and methodologies/techniques;
vi. Creating new firms;
vii. Providing social knowledge.

Recent work has continued to confirm the existence of these benefits. For example, over 20% of industrial R&D managers report using instruments and techniques generated by public research in their own projects, within the previous three years (Cohen, Nelson et al. 2001). On university spin-offs, Pfirrmann adds data about Germany (Pfirrmann 1999) , while Chiesa adds data from a survey in Italy and reviews recent literature (Chiesa and Piccaluga 2000). Several other benefits have also been cited by firms in recent research, such as enhanced credibility for firms using independent test-facilities at universities, and enhanced commercial credibility through being linked with a university (Rappert, Webster et al. 1999). Similarly, analysts in Germany have concluded, on the basis of a large survey of firms, that collaborations with universities stimulate or enable firms to introduce more advance innovations … 'pure' science seems to be more effective in stimulating advanced innovations than applied research focusing on commercialization' (Kaufmann and Todtling 2001). Basic research is a public good, for which social returns may greatly exceed private ones.

2. PHARMACEUTICAL INDUSTRY

The modern drug-industry can be said to have started in 1935 with the introduction of the sulfonamide antibacterial. Prior to 1935, it was unusual for a physician to be able to prescribe a drug to cure a specific disease. In 1999, the research-based pharmaceutical companies in the United States sold $134.1 billion of pharmaceuticals, $91.8 billion inside the United States and $42.3 billion by United States-owned companies abroad. United states is the world's most important pharmaceutical manufacturer and produces about one-third of world-output. Although many countries produce pharmaceutical intermediates, and even active substances, only four countries joined the United States in being major innovators. They were the United Kingdom, Switzerland, Germany and France. Research expenditures are very high, amounting for United States based companies to about 17% of sales. Put another way, a typical drug firm spends more than four times the proportion of its sale-revenue on research and development than does a chemical company. The reason is not hard to find. At every stage in the development of a new drug, failure is the norm. Only 1 out of every 2500 compounds examined by Japanese firms is actually introduced to the market. In Europe, the figure is 1 in 4300 and in the United States, 1 in 6200. Even then, only 30% are commercially successful. High research-expenditure leads to a high level of innovation and high rates of change. The American industry has grown since 1950, typically at 7.5% per year. More than 95% of

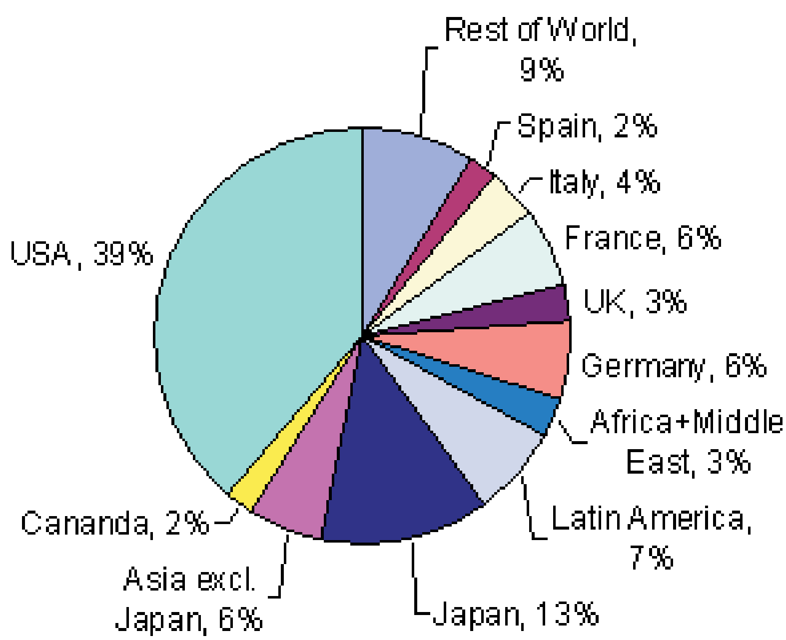

Figure - 1: World Pharmaceutical Market. Total 1999 Sales: $338 bn drugs available originated after that date. World pharmaceutical-market scenario is shown in Figure-1.

Artificially produced radionuclides, for medical use, have a relatively short history. Reactor-produced radionuclides for public distribution was first announced in Science, June 14, 1946. Subsequently, the first radionuclide for clinical use was shipped on August 2, 1946. During the ensuing decades, since this modest beginning, radioactive drugs, or as they are now called, radiopharmaceuticals, have been increasingly applied to the diagnosis and treatment of disease in medical practice. Radiopharmaceuticals now play a vital role in patient-management and have significantly expanded the physician's armamentarium. These provides unique methodology that includes a varied group of radionuclide techniques. Most of these techniques may be characterized as diagnostic screening procedures and, as such, are singularly atraumatic and innocuous, representing some of the most powerful diagnostic tools of modern medicine. Interest in employing unsealed radiotherapeutic agents for treatment of cancer has increased in the past 2 decades., primarily due to the emergence of sophisticated molecular carriers (monoclonal antibodies, peptides) that may provide vehicles for selective deposition of radioactivity in the vicinity of cancer cells. In order to develop effective radiopharmaceuticals for therapy, it is essential to carefully consider the choices of appropriate radionuclides in conjunction with the in-vivo localization and pharmacokinetic properties of the radiotracer. Each radiotherapeutic agent (The Magic Bullet) will, in most cases, be used for a specific application that requires balancing in-vivo targeting and clearance characteristics of the carrier-molecules with decay properties of the attached radionuclide.

3. RADIO-PHARMACEUTICALS

Radiopharmaceuticals have been defined as radioactive drugs that, when used for the purpose of diagnosis or therapy, typically elicit no physiological response from the patient. This definition is strongly supported by the Nuclear Medicine community's collective experience in administering radiopharmaceuticals: most practitioners, in their entire careers, have not observed a physiological response or an adverse reaction following administration of a radiopharmaceutical. The design of these compounds is based solely upon physiological function of the target organ. Unlike radiographic procedures, which depend almost entirely upon tissue-density differences, external imaging of radiopharmaceuticals is essentially independent of the density of the target organ. The mechanism of localization of a radiopharmaceutical in a particular target organ can be as simple as the physical trapping of particles or as sophisticated as an antigen-antibody reaction or chemisorption of an inorganic phosphate on the hydroxyapatite crystals deposited in an acute myocardial infarction. There is a significant difference between a radioisotope (a radionuclide whose chemical form is unknown) and a radiopharmaceutical whose chemical form is usually precisely known. For example, I-123 is a radioisotope with a characteristic physical half-life. Reference to a biological half-life or an effective half-life for I-123 is meaningless since we don't know the chemical form. On the other hand, I-123 NaI is a compound with

Table - 3: Characteristics of An Ideal Radio-pharmaceutical for Organ Imaging

Radionuclide	
Radiations	• pure emitter
	• no particulate emissions (or)
	• ray energy of 100-300 keV
Half-life	• similar to length of investigation
	• facilitates waste disposal
Chemistry	• versatile
	• stable radiolabeling
Toxicity	• non-toxic to body organs and systems
Availability	• readily available at all times
Cost	• reactor-produced radionuclides cost less than cyclotron-produced radionuclides
Radio-pharmaceuticals	
	• high target-to-background ratio
	• no adverse reactions
	• no unwanted pharmacological responses
	• stable for *in vitro* and *in vivo* studies
	• residence time in target-organ should be long enough to complete the study
	• cheap and easy to produce
	• quality easily assayed by simple techniques

known biodistribution and clearance-rates and is associated with both biological and effective half-lives. Criteria for selection of radiopharmaceutical for imaging and radiotherapy are presented in Table-3 and Table-4, respectively.

4. LARGE-SCALE PRODUCTION OF RADIO-PHARMACEUTICALS AND DISTRIBUTION CONSIDERATIONS

In undertaking a program for the large-scale production and supply of radiopharmaceuticals, the following factors have to be considered in detail.

i. The pattern of demand for the different products;
ii. The requirements of purity;
iii. Stability and shelf-life of the products;
iv. Special requirements of quality control;
v. Availability of facilities and raw materials;
vi. Cost of production;
vii. Requirements of radiological protection and other special requirements for the production of radiopharmaceuticals;
viii. Research and development program for new radiopharmaceuticals.

Table - 4: Characteristics of An Ideal Radiopharmaceutical for Therapy

• Delivers its radiation exclusively to target-organ, sparing healthy tissues • Pure alpha, beta , Auger electron emitter or Coster-Kronig electron emitter • Ratio of non-penetrating (particle) to penetrating radiation as high as possible • Half-life between some hours and about 70 days are adequate • High specific-activity or no-carrier added • Available as radionuclide generator • Decay-product should be stable • Appropriate particle-size, in case of colloids and particulate pharmaceuticals • Stable *in vivo* and *in vitro* • Coordination chemistry of metal radionuclides and pharmacology of biological molecule should be well established. • Cost-effective

4.1 Pattern of Demand

The schedule for the production of various radiopharmaceuticals must be drawn up, keeping in view the pattern of demand for the individual products. Preparations containing short-lived radionuclides, such as 24Na, 64Cu, etc, are processed frequently. Preparation of long half-life, such as 131I and 99Mo/99mTc, generators are processed weekly or fortnightly.

4.2 Requirements of Purity

There are four aspects of purity for radiopharmaceuticals. The radionuclidic purity is defined as the percentage of the total radioactivity that is due to the stated radionuclide, daughter activities being excluded. Radionuclidic purity of the product should be greater than 99%. The radiochemical purity of a product is defined as the percentage of the stated radionuclide in the stated chemical form. High radiochemical purity, greater than 95%, is usually desired. The chemical purity of the product may be defined as the percentage of active ingredient in the preparation, vehicles preservatives and additives being excluded, while toxic elements are undesirable. Injectable products must be sterile and apyrogenic. The procedures adopted for the production and purification of radiopharmaceuticals should be carefully standardized, so that the product obtained satisfies the above purity-requirement. Clean-room facility is employed for production of radiopharmaceuticals to maintain sterility and apyrogenicity.

4.3 Stability and Shelf-Life of Radio-pharmaceuticals

Optimum specification and shelf-life of radiopharmaceuticals must be known. All multidose consignments should be delivered to the customer well before the expiration date of the product. Thermolabile product, such as high-activity 131I-MIBG preparations, should be packed in refrigerated containers to ensure that these are not damaged during transit.

4.4 Special Requirements of Quality-Control

It consists of: (a) analysis and quality-control of raw materials; (b) control of production-processes and facilities; (c) analysis and quality-control of individual batches and consignments; (d) supervision of packaging and dispatch.

Analysis and quality-control of raw materials consists essentially of the purity and suitability of these for production and dispensing operations. Water, which is the vehicle in most of the radiopharmaceutical injections, should be examined for sterility and absence of pyrogens. It is essential to control the environmental bacterial contamination in the production-laboratory and in the production and dispensing plants where injectable is prepared. All the equipments used must be periodically calibrated. The quality-control (physical, radiochemical and biological) and analysis of the individual batches must be recorded. A careful supervision by personnel is required at the packaging and dispatch stages in order to insure that the products are not incorrectly labeled, handled, or dispatched. Double checks are needed to prevent any fault. Containers must be checked for proper shielding, closure, leakage and safe shipment.

4.5 Cost of Production

Various production-routes may be available for production of different isotopes. A careful evaluation should be made of the practical and economic feasibility of the different routes.

4.6 Radiation Protection

The essential requisites to minimize radiation-hazard in radiopharmaceuticl laboratory are: controlled ventilation, , adequate shielding, and remote-handling equipment for the plants employed for the processing, dispensing and analysis of different products. It is essential to maintain a high degree of cleanliness in the laboratory, and asepsis in the areas where non-heat-sterilizable products are prepared and dispensed.

4.7 Research and Development

With the advent of emission tomography (Positron Emission Tomography and Single Photon Emission Tomography, PET and SPET), new vistas for probing biochemistry in-vivo have been opened. Endoradiotherapy (ERT) is also becoming a widely used tool for cancer-treatment. The radiochemist faces an ever-increasing challenge of designing new radiotracer for diagnostic and therapeutic applications. Rapid, efficient and automated methods of radionuclide and precursor production, labeling of biomolecules and simple quality-control methods need to be developed.

5. CURRENT ACTIVITIES OF ISOTOPE-PRODUCTION DIVISION

Isotope-Production Division (IPD) is one of the few laboratories of the Pakistan Institute of Nuclear Science and Technology (PINSTECH), Islamabad, that has achieved a unique status through the distribution of its products and services all over Pakistan, Production of radioisotopes started when Pakistan Research Reactor (PARR-I) went critical in December 1965. Pakistan Atomic Energy Commission (PAEC) is helping the government in the health-sector by operating thirteen medical centers in Pakistan, while a few more are expected to begin functioning shortly. Various medical centers in private sector are also using IPD manufactured radiopharmaceuticals. In these medical centres, more than 350,000 patients are treated every year. For many years, Isotope Production laboratories are meeting almost all the demands of Sodium Iodide (131I) and cold kits for ^{99}mTc radiopharmaceuticals for these centres. Sterile PAKGEN ^{99}mTc generators are also being fabricated in a 99Mo loading clean-room facility created under an International Atomic Energy Agency Technical Cooperation Project. Nowadays, IPD is also providing its products to various private and government hospitals, for treating patients with nuclear medicine. With the constant support of PAEC/PINSTECH, the

Table - 5: Radioactive Products

S#	Radionuclide	Chemical form	Maximum activity / Batch	Application
01.	Iodine-131	Sodium Iodide (^{131}I) ^{131}I-MIBG	~7Ci/259 GBq 20mCi/0.74GBq	Diagnosis/ Therapy Diagnosis
02.	Molybdenum-99	^{99m}Tc-Generator (PAKGEN)	~1Ci / 37 GBq	Diagnosis
03.	Sodium-24	Sodium carbonate (^{24}Na)	35mCi/ 1.3GBq	(R & D)
04.	Phosphorus-32	Sodium phosphate (^{32}P)	>1Ci/ 37GBq	Therapy, Agriculture
05.	Sulphur-35	Sodium sulphate (^{35}S)	10mCi/0.37GBq	$^{-}$ source (R&D)
06.	Chromium-51	Sodium chromate (^{51}Cr) EDTA-^{51}Cr Complex	100 mCi / 3.7 GBq 100mCi / 3.7 GBq	Diagnosis, Hydrology Diagnosis
07.	Iron-59	Ferric chloride (^{59}Fe)	5mCi / 0.185 GBq	R & D
08.	Cobalt-60	Metal (^{60}Co)	10mCi / 0.37 GBq	source (Educational)
09.	Selenium-75	L-Selenomethionine (^{75}Se)	10mCi / 0.37 GBq	Diagnosis
10.	Bromine-82	Potassium bromide (^{82}Br) Ammonium bromide (^{82}Br) Dibromobenzene (^{82}Br)	~1Ci / 37 GBq ~1Ci / 37 GBq ~1Ci / 37 GBq	Industry, Hydrology Industry, Hydrology Industry, Hydrology

continues...

...continued

11.	Silver-111	Silver chloride (^{111}Ag)	5mCi / 0.037GBq	R & D
12.	Antimony-125	Antimony chloride (^{125}Sb)	1mCi / 0.037GBq	Educational sealed-source
13.	Cesium-134	Cesium chloride (^{134}Cs)	100mCi / 37GBq	R&D
14.	Cesium-137	Cesium Chloride (^{137}Cs)	2mCi / 0.074GBq	Educational sealed-source
15.	Barium-133	Barium chloride (^{133}Ba)	In Ci / KBq	Educational sealed-source
16.	Lanthanum-140	Lanthanum chloride (^{140}La)	~ 1Ci / 37GBq	Hydrology
17.	Samarium-153	^{153}Sm-EDTMP	~ 1Ci / 37GBq	Therapy
18.	Europium-152/ 154	Metal	~10mCi / 0.37GBq	Calibration source
19.	Holmium-166m	Holmium oxide (^{166m}Ho)	Ci/KBq	Calibration source
20.	Holmium-166	Particles	>100 mCi / 3.7 GBq	Therapy
21.	Rhenium-186/188	^{186,188}Re-EHDP	>100 mCi / 3.7 GBq	Therapy
22.	Tungsten-188	Generator of ^{188}Re(^{188}W - ^{188}Re)	5mCi	R&D
23.	Gold-198	Colloidal (^{198}Au)	~ 1 Ci	Therapy
24.	Gold-199	Gold chloride(^{199}Au)	~ 10mCi	R&D
25.	Mercury-197	Neohydrin- ^{197}Hg	100 mCi	Diagnosis
26.	Mercury-203	Neohydrin- ^{203}Hg	10 mCi	Diagnosis

IPD has upgraded its production and quality-control installations with technologically advanced equipments, aiming towards maximum automation and standardization, while strictly following the methodologies of Good Manufacturing Practices (GMP) and the protocols of International Atomic Energy Agency (IAEA), Vienna, Austria.

The main goal of Isotope Production Division (IPD) is to maintain uninterrupted supply of radioisotopes/radiopharmaceuticals and in-vivo kits for ^{99}mTc-radiopharmaceuticals to their users. Radioisotopes find applications in various fields, such as nuclear medicine, diagnosis and cure of diseases, hydrology, sedimentology, agriculture and industry.

5.1 Goals

- Regular production and supply of radioisotopes/radiopharmaceuticals, such as Sodium Iodide (131I),
- Regular Production and supply of ^{99}mTc-radiopharmaceuticals cold-kits for diagnosis.
- Regular Production and supply of PAKGEN-^{99}mTc-generators.
- Cold-welding of Aluminum capsule for reactor-irradiation to all users in

PAEC.

- Research and development of new radiopharmaceuticals for in-vivo applications.
- Production of therapeutic radiopharmaceuticals.
- Automation and standardization of production-procedures and methodologies for increasing production-volume.
- National and International scientific collaboration.
- National and International promotion of the IPD products.

5.2 Research and Development Programme

Most routinely used technetium radiopharmaceuticals are prepared by adding sodium pertechnetate to a pre-packaged 'kit' of sterile, lyophilized ingredients. The radiopharmaceutical, thus obtained, represents the culmination of extensive development work and enables the pharmacist to obtain a reliable and efficacious product for the ultimate benefit of the patient.

The current research-activities of the IPD are oriented towards the development of new radiopharmaceuticals and radiodiagnostic products and cover some specialized topics: Radiochemistry and radiopharmacology of Technetium and Rhenium complexes, peptide radiolabelling techniques and, ß-emitting, radionuclides-based therapeutic radiopharmaceuticals. At the same time, educational programmes are also planned for the technical staff of hospitals and laboratories. Collaborations are in progress with the nuclear medical centres and Pakistan Institute of Engineering and Applied Sciences, that enable the transfer of technical know-how.

6. ECONOMIC SCALE OF UTILIZATION OF RADIATION IN MEDICINE: COMPARISON BETWEEN JAPAN AND USA

In Japan, use of radiological technology in medicine is increasing. For example, in 1997, the economic scale was about 10b$, corresponding to 4% of the national health expenditures (240b$) or 0.24% of the nominal GDP (gross domestic product, 4231b$). For the TDHE (total domestic health-expenditures) base, it was 987b$ in the USA, and 279b$ in Japan, implying that the American people spent rather a lot of money for their health. For the economic scale, estimated by studying parameters (ESP), approximately 49b$ for the USA and 12b$ for Japan, ESP in the former, is large in magnitude by a factor of 4, implying that in USA people do not hesitate to use radiological technologies for curing their disease. This tendency was clearly observed in the expenditures on prostate cancer and theFDG-PET and so on. The use of medical radiology may be enlarged in the future, due to the focus on high quality of life (QOL).

6.1 Radiation Imaging

Here the radiation-imaging is for X-ray diagnosis, CT and nuclear medicine. The revealed economic scales of these are summarized in Table-7 and Table-8. In the two

Table - 6: In-vivo Kits for ^{99m}Tc-Radiopharmaceuticals

Sr. #	Freeze-dried kits	Uses
1.	PINSCAN DTPA	Kidney Imaging
2.	PINSCAN MDP	Bone Imaging
3.	PINSCAN MIBI	Heart Imaging
4.	PINSCAN Ca Hepta Gluconate	Kidney Scanning
5.	PINSCAN Phytate	Liver / Spleen Imaging
6.	PINSCAN DMSA III	Renal Studies
7.	PINSCAN DMSA V	Head/ Neck Carcinoma
8.	PINSCAN DISIDA	Hepatobiliary Studies
9.	PINSCAN EHIDA	Hepatobiliany Studies
10.	PINSCAN PIPIDA	Hepatobiliany Studies
11.	PINSCAN BRIDA	Hepatobiliary Studies
12.	PINSCAN MAG-3	Kidney Scanning
13.	PINSCAN Pyrophosphate	RBC/ MUGA Studies
14.	PINSCAN ECD	Brain Scanning
15.	PINSCAN Sucralfate / Ulsanic	Stomach Scanning
16.	PINSCAN Dextran	Lymphoscintigraphy
17.	PINSCAN HMPAO	Brain Studies
18.	PINSCAN Ciprofloxacin	Infection imaging
19	PINSCAN Ubiquicidin	Infection imaging
20	PINSCAN EHDP	Bone, Transchelating agent

Table - 7: Radiation-Imaging Expenditures

Medicine	Japan	(%)	USA	(%)
X-ray diagnosis	4189	(49)	31893	(74)
Computed tomography (CT)	3286	(39)	8995	(21)
Nuclear medicine	1034	(12)	2099	(5)
Total (M$)	8509	(100)	43077	(100)

Table - 8: Radiopharmacy (Nuclear Medicine for Imaging)

Year	1998	1999
USA	736 M$	832 M$
Japan	366 M$	374 M$

Note: Utilization of ^{99m}Tc in USA >80%

Table - 9: Overall Comparison between Japan and USA

		USA	Japan	Ratio
General (i) Total Expenditure				
Personal and National Health Care (B$)		969	240	4
Total Domestic Health Expenditure (b$)		987	279	3.5
Specified (ii) Radiation imaging	(M$)	43077	8509	5.1
(iii) Prostate cancer	(M$)	576	0.6	996
Charged particle therapy				
(iv) FDG-PET	(M$)	50	2	21
(v) Cyclotron; RI Production	(M$)	19	6	3.2
PET	(M$)	47	25	2
(vi) Medical equipment	(M$)	3133	1844	1.7
(vii) Radioisotopes (RI)	(M$)	140	9	16.2
(viii) Radiopharmacy excluding in vivo Products	(M$)	832	374	2.2
(ix) Contrast media (X-ray/CT)	(M$)	1119	926	1.2
	Sum(M$)	48942	11666	4.2

countries, X-ray diagnosis is used frequently; that is, 49% in Japan and 74% in USA. The economic scale was 4189M$ for the former and 31983 M$ for latter. The latter is large in magnitude by a factor of about 8, implying that the USA uses radiation greatly. As a whole, radiation imaging expenditure in the USA is 5 times bigger than in Japan.

7. CONCLUSIONS

Basic research is a public good, for which social returns may greatly exceed private ones. No drug is 100% safe; in order to minimize the risk, basic research is essential. Basic research increases patent-activity, and countries spending more in basic research are more developed than countries spending less. Almost all sort of new radiopharmaceuticals are being developed at basic-research centers in the world. All radiopharmaceuticals produced in Pakistan are also developed in basic-research center(PINSTECH).

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R&D AND PRODUCTION OF NUCLEAR INSTRUMENTS IN PINSTECH AND THEIR APPLICATIONS

M. Tahir Khaleeq
Electronics Division, PINSTECH,
P. O. Nilore, Islamabad

ABSTRACT

R&D and production of nuclear instruments for nuclear industries is continuously being carried out at PINSTECH, to produce instruments according to our requirement and demand, such as instruments for 'environmental radiation monitoring' and 'reactor-power measurement and control'. The activities have also been extended for development of instrument-modules of NIM standard for research labs. Besides the activities on development of nuclear instruments, research and development activities are also being carried out on general-purpose instruments, which are useful for test and measurement of electronic signals, in the light of existing demand in local market. This paper presents the research activities on design and development of nuclear instruments and the relevant applications in nuclear industries and research labs.

I. INTRODUCTION

Basic research brings value to society today, by helping lay the foundation for tomorrow's technological breakthroughs. Basic science seeks answers to a wide variety of scientific challenges. This includes experimental and theoretical work in Materials Science, Physics, Chemistry, Biology, Electronics, and Computer Science. No one can deny that further advancement in basic research is not possible without the use of modern technology. Today, sophisticated instruments are used in basic research to analyze the data, record the results in a database, interpret the results, and then implement an appropriate line of action. These instruments are highly reliable, incredibly powerful and totally computer-controlled.

Research and development activities in the field of electronics began at PINSTECH, soon after the installation and commissioning of Pakistan Research Reactor (PARR-1) in 1965. At PINSTECH, its important role in scientific research and development is recognized and valuable service has been rendered to the scientific effort by maintaining scientific equipment and developing various electronic instruments for research and development projects. An outstanding achievement was the design and engineering of nuclear instrumentation for our research reactor (PARR-1), which required a very high degree of sophistication and reliability [1]. PARR-1 is currently a big facility for basic research activities at PINSTECH.

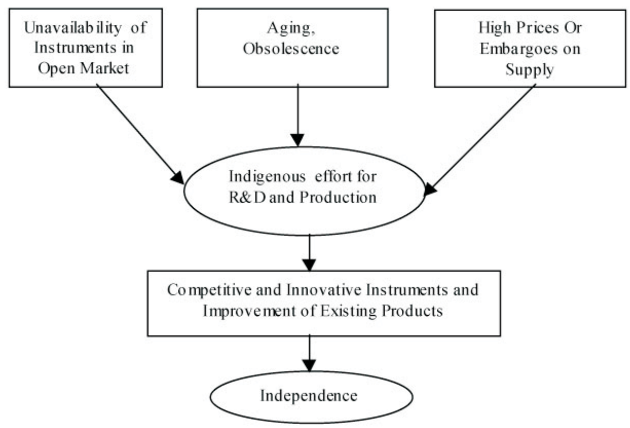

Figure - 1: Facts of R&D and Production on Nuclear Instruments at PINSTECH

After renovation of instrumentation and control systems of PARR-1, the indigenous efforts for R&D and production of nuclear instruments were promoted (see Figure-1) by the exorbitant prices of equipment and unavailability of instruments (for specific applications) in the open market and by embargoes imposed on their supply [2]. Research and development work on the nuclear instruments for nuclear industries is therefore continuously being carried out, to produce instruments according to our requirement and demand, such as instruments for 'environmental radiation monitoring' and 'reactor-power measurement and control'. PINSTECH also offers training-courses to technicians/engineers of R&D organizations, as well as internships and projects to students of universities, in Electronics, Instrumentation and Control. In the following sections, some new trends of electronic instruments and the research activities on design and development of nuclear instruments and their applications in nuclear industries and research labs are discussed.

II. NEW TRENDS OF ELECTRONIC INSTRUMENTS

A dramatic change has occurred in the electronics industry. Today, microelectronics has allowed the invention of instruments in small, totally computer-controlled packages. The computers have now become incredibly powerful and compact, and are being used for large-scale instrument-operations, and portable applications. This allows extremely sophisticated software to automatically and reliably operate the instrument, analyze the data, record the results in a database, interpret the results, and then implement an appropriate action. The most recent addition to this impressive evolution has been the ability to predict the performance of these instruments before they are built.

Modern technology allows the creation of a new class of tools to perform reliable and practical implementation of sophisticated devices for basic research. These devices can greatly reduce the need for sample-taking and laboratory analysis. This reduction, in reliance on the sampling process, can greatly increase the accuracy- rate for heterogeneous items. These new devices can provide more information, to document the decisions made about the analysis and results. These tools can accomplish this task in a manner that saves both time and money.

III. R&D ON ELECTRONIC INSTRUMENTS AT PINSTECH

Research and development on nuclear instruments was started about twenty years ago, after the renovation of instrumentation and control systems of PARR-1, due to the various facts shown in Figure-1.

PINSTECH laboratories carry out research and develops nuclear instruments for specific applications, used by nuclear and process industries and various research labs [3-4]. The instruments are supplied as integrated turnkey solutions. These instruments combine modern electronics and control-theory, making them available for researchers and industrial use. These instruments offer speed and precision, with designs that can adapt and expand to the demanding requirements of the future. The research and development in nuclear instruments, is now being applied to improve the safety and availability of nuclear reactors.

The activities have also been extended for development of instrument- modules of NIM standard for research labs. Besides the activities on development of nuclear instruments, R&D activities on general-purpose instruments, (which are useful for test and measurement of electronic signals), are also being carried out according to the

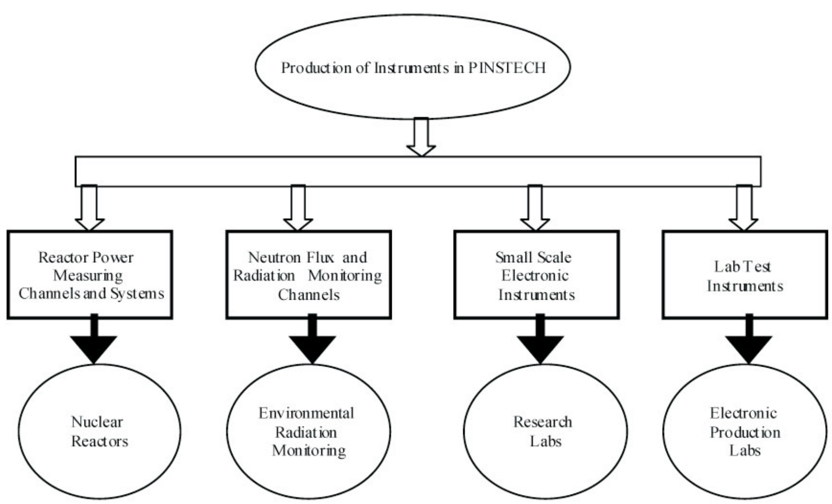

Figure - 2: Instruments Developed at PINSTECH

Figure - 3: Reactor Power Monitoring Channels

existing demand in local market. R&D efforts have also been started for improvements and modernization of existing monitoring systems of nuclear research and power reactors (see Figure-2). These activities will improve the standards of safety and availability of the nuclear power plants. PINSTECH also provides training and offers projects to university students in the fields of applied electronics, instrumentation and control for industrial applications.

IV. ELECTRONIC INSTRUMENTS DEVELOPED BY PINSTECH

Well equipped laboratories were established in PINSTECH for R&D and production of electronic instruments in (see Figure-2) the following areas:

- Instruments for nuclear reactors and process-industries for signal-monitoring and control (Figure-3);
- Health-physics instruments, like dosimeters, portable survey meters (Figure-4);
- Small-Scale Lab Test Instruments (Figure-5).

Instrument Modules for Nuclear Reactors

a. Amplifiers: Log-Linear Count-Rate Meters, Linear Amplifier, Logarithmic Amplifier, Programmable Wide-Range Amplifier, Instrumentation Amplifier, Isolation Amplifier, Differentiating Amplifier and Preamplifiers.
b. Voltage Supplies: Low-Voltage Supplies for Instrument Modules, High-Voltage Supplies for Nuclear Detectors and Magnetic-Clutch Current Supply.

Figure - 4: Area Monitoring Channels

Figure - 5(a): Modules for Research Labs

Figure - 5(b): Laboratory Test Instruments

c. Alarm Processing Units: Single, Dual and Triple Alarm Units, Fault Monitor, Logic Unit (1 of 2) and Logic Unit (2 of 3).
d. Test Units: Pulsars, Voltage and Current Signals Test Units.

Nuclear Channels

a. Reactor- Power Monitoring Channels: Logarithmic Pulse Channels, Logarithmic DC Channels, Linear DC Channels, Wide-Range Log-Linear Channel and Logic Alarm Channels.
b. Area Monitoring Channels: Neutron Dose-Rate Monitors, Gamma Radiation Monitors.

Instrument Modules for Research Labs

Amplifiers: Log-Linear Count-Rate Meters with discriminator, Logarithmic Amplifier, Linear Amplifier, Preamplifiers, High and Low-Voltage Supplies, Alarm-Processing Units etc.

Laboratory Test Instruments

Amplifiers, High and Low-Voltage Power Supplies, Function-Generators, etc.

V. REPAIR AND MAINTENANCE FACILITY OF NUCLEAR AND SCIENTIFIC INSTRUMENTS

At PINSTECH, the repair and maintenance facility is well equipped and engineers and technicians have a vast experience of maintaining electronic instruments, ranging from the nearly obsolete type to modern microprocessor-based instruments, and from nuclear-reactor instruments to scientific instruments of research labs. Some of the scientific instruments repaired are: different types of process-controllers, spectrometers, quantometers, analyzers, radiation-monitoring equipment, furnace controls, HIVAC plant controls, X-ray machines, etc. In this regards, PINSTECH is providing excellent services to other establishments of PAEC, universities, research institutions and industries. Furthermore, testing and calibration of numerous electrical equipments can also be performed. Repair and maintenance of instruments of PARR-1 and PARR-2 is also performed. Periodic calibration of instruments of PARR-1 &PARR-2 is carried out, in order to maintain their accuracy and reliability. A well equipped laboratory has been established with modern instruments for test and calibration of nuclear and other instruments.

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INVESTIGATION OF AIR-GASIFICATION PROCESS WITH A BUBBLING FLUIDISED BED GASIFIER FOR ELECTRICITY GENERATION

R. Avella, G. Braccio, P. Marzetti*, D. Matera and V.K. Sharma***
ENEA CR Trisaia, Biomass and Solar Thermal Section
75026 Rotondella (MT) – Italy
**ENEA CR Casaccia, Renewable Energy Division*
00060 S.M. di Galeria, Rome - Italy
***Visting Scientist, ENEA CR Trisaia*
75026 Rotondella (MT) Italy

ABSTRACT

Biogas production, its purification and maximum power-conversion using air-gasification process with bubbling fluidised bed gasifier (design, developed and experimented by researchers at PINSTECH) are discussed in the paper.

Key words: Biomass, gasification, thermal energy conversion, fluidised bed gasifier.

INTRODUCTION

Considering limited availability of conventional fuels worldwide, along with ever increasing energy-demand, especially in the developing world, it is imperative to search for new alternative sources to supplement or substitute the traditional ones. Due to its strategic role in the sustainable worldwide development, use of biomass for energy purpose has gained considerable attention during the last couple of years. Biomass-to-electricity schemes already provide over 9 GWe of world-wide generating capacity [1]. The technology to be used being relatively simple, as well as versatile, is of great interest for both underdeveloped and industrialised countries.

Although many biomass gasification processes have been developed commercially [2-6], only the fluid-bed configurations are being considered in applications that generate over 1 Mwe. Fluid-bed gasifiers are available from a number of manufactureres, in thermal capacities ranging from 2.5 to 150 MWth for operation at atmospheric or elevated pressures. Atmospheric bubbling-bed gasifiers manufactureres include EPI, PRM Energy Systems, Foster Wheeler, and TPS. Pressurized bubbling-bed systems are being developed by Enviropower and IGI. No doubt, electricity generation could be accomplished in a variety of ways, but the most interesting near-term opportunities involve internal combustion engines or highly efficient gas turbines.

It is true that the technology is quite mature for its commercialisation but the fact remains that to fully appreciate its real potential, optimisation of different technical parameters, along with quality of the gas produced, still needs to be investigated. It is in the above reference that an experimental station has been set up to investigate a process with air-bubbling fluidised bed gasifier of 1 MWt capacity. The size of the plant is suitable for decentralised power generation and employment in far-off areas. The results obtained will be discussed in the present paper.

DEVELOPMENT OF AIR GASIFICATION PROCESS WITH BUBBLING FLUIDISED BED GASIFIER

It is worthwhile to note that the characteristics of feedstock as they are found at harvest or collection, are often very different from the feed characteristics demanded by the conversion-reactor, and steps are usually required to match the feedstock to the process. In order to cope with the range of feed-constraints and system-capacities imposed by a fixed bed gasification plant, a multi-combustion gasification process, with air as gasifying agent, has been developed. An experimental gasification plant of capacity 1 MWt has been designed, installed and tested experimentally at ENEA Research Centre Trisaia (photo-1). The plant comprises a bubbling fluidised bed reactor. Producer gas is used to generate electric energy in a generator. The use of generators, based on reciprocating internal combustion engine, has been suggested essentially due to its size, efficiency, flexibility to use and, moreover, its easy coupling.

Photo - 1: Bubbling fluidised bed gasification plant (Italy)

Photo - 2: Bubbling fluidised bed gasification plant (China)

The project, financed in the framework of scientific exchange programme, signed between Italian Ministry of Foreign Affairs and Chinese Government, has been completed while working together in close collaboration between University of Aquila (Rome) and Lianoning Institute of Energy Resources (China). In view of the above-mentioned agreement, subsequently the plant was shipped to the experimental centre at LIER Yingkou, in China (photo-2).

Process Description: The gasification plant utilises biomass residues in a low pressurised gasification process, coupled with internal reciprocating combustion engine. The plant doesn't work in the cogeneration mode. It has a net electric efficiency in the range 15-20%. Principle technical characteristics of the plant are shown in Table-1.

In brief, the plant consists of the following four main sections:

- Feedstock preparation and its feeding ;
- Gasifier;
- Cooling and cleaning;
- gas storage and its utilisation.

Feedstock Preparation and its Feeding: Crushed and uniformly distributed fixed-size biomass material (stored in an open tank) is pushed towards the secondary tank (closed and weighted) at controlled flow-rate with the help of a screw conveyor and cup elevator. Screw conveyor and rotary valves permits gasifier-pressurisation and subsequent feeding. The biomass fed to the gasifier directly by falling, without injection screw conveyor.

Gasification Section: Gasifier is a bubbling fluidised bed reactor, connected directly to a cycle and ash discharge (Figure-1).

Alloy 800 HT (special chrome nickel-steel material) due to its inherent characteristics of optimal resistance at high temperature and reduced atmosphere, providing elimination of risks in connection to the refractory movement and elimination of thermal shock related to the repeated "ON/OFF" during experimentation, was employed as the constructional material of gasifier. The gasifier consists of both

Table - 1: Technical Characteristics of the Plant Under

Gasifier type	BFB
Power	0.9 1 MW
Fuel input	280 kg/h
Electric efficiency	16 – 20%
Gasification pressure	0.2 bar
Gasification temperature	800 °C
LHV gas	6000 MJ/Nm3

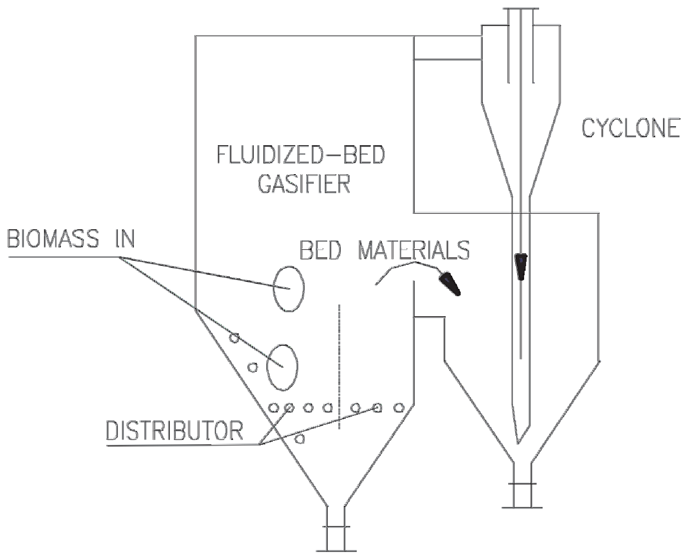

Figure - 1: BFB: Gasification Section

central (reactor) and a lateral body (photo-3).

Circulation of solid material is achieved by dividing the reactor into two different chambers (subject to different velocity of fluidisation) using an adjustable baffle. The feeding of biomass may be realised at different heights. Air is used for fluidisation and gasification. Biomass flow rate is of the order of 280 kg/h, whereas that of the produced combustible gas is nearly 520 Nm3/h. Burner has been provided in the reactor freeboard. Solid particles (ash and char) from the gasifier are separated, using a cyclone placed at the reactor exit. Discharge takes place through dip-leg in lateral chamber of the reactor, provided with-discharge rotary valve. Air for gasification, is provided from a distributor comprising a set of horizontal tubes. The main characteristics of the gasifier (dimensional and fluid dynamics) are presented in Table-2. Ash is discharged with the help of rotary valves and screw conveyor.

Cooling and Cleaning Section: The gas at 800°C is cooled to 600 °C in a tubular exchanger where fluidisation air is preheated in the counter-flow. Pre-heating air enters the exchanger at a temperature of nearly 70 °C and exits at a temperature of nearly 500 °C. Successively, the gas comes in contact with the scrubber (cooling section) and is thus cooled further. The scrubber is made to function with water in counter-current to gas (water tower) and, the dusts, tar, organic, nitrogen and chlorine compound contained in the gas are washed away with water. The gas produced then could either be stored or sent directly to the burner.

Gas Storage: Purified combustible gas is stored in a 50 m3 capacity gasholder at a temperature of nearly 30°C. The gasholder permits a regular coupling between

Table - 2: Principle Charateristics of gasifier

Minimum fluidisation velocity	0.133 m/s
Bed height	1200 mm
Expanded bed height	1500 mm
Height of gasifier	4200 mm
Minimum length	800 mm
Maximum length	2000
Braedth	500 mm
TDH	2.2 m
Distributor	Set of horizontal tubes of diameter 2 mm

gasification plant and the generating set at variable load. The storage tank and generator are placed externally, but in the vicinity of the gasification plant. The applied part comprises two electric generating sets based on 6-cylinder 13.2 litres reciprocating internal-combustion engine (Otto cycle), coupled to an electric generator.

Experimental Investigation:

During preliminary experimental tests, two types of biomass (almond shell and wood chips) were used. The engines were tested using both methane and gas from fixed-bed

Photo - 3: Gasifier and cyclone assembly

Table - 3: Operating conditions

Operating conditions	
Temperature	750 – 780 °C
Bed Material	Silica sand
Density	2650 kg/m^3
Mean diameter	0.5 mm
Voidage	0.43
Pressure	0.1 bar_g
Biomass	Spruce chips, almond shells
Flow rate	200 – 280 kg/h
Air/biomass ratio	0.8 - 1

down-draft gasification plant. The bed was realised using silica sand, and gas was burnt in the torch. The main process-conditions and characteristics of the sand used are given in Table-3.

The variations could be attributed to the type of biomass used, air/biomass ratio applied, reaction temperature, etc. In spite of high calorific value caused mainly due to notable methane content and presence of hydrocarbons C2-C3, the percentage of hydrogen (foreseen during the design phase), appears to be significantly lower. It is worthy of note that feeding of biomass in low fluidisation and near freeboard zone hinders its thorough mixing in the bed and, as such, is present at the pyrolytic phase, outside the bed. Hence, the products of pyrolysis try to have low residence-time at high bed-temperature. Also, this explains the high methane content and other hydrocarbons thermodynamically incompatible with real bed temperatures.

The plant tested in Italy demonstrated a few problems relevant to biomass feeding (in the formation of biomass bridges), thus creating serious difficulties concerning continuous/smooth biomass feeding. In order to solve this problem, air injectors were positioned that helped to break the biomass bridges thus enabling to conduct the tests with guarantee of regular biomass supply to the reactor.

Table - 4: Main Characteristics of Producer Gas

Composition of gas	
CO_2	12 – 18.5%vol
CO	14.7 – 17 %vol
CH_4	1.6 – 6.3% vol
C_2H_6	0.3 – 0.9% vol
C_3H_8	0 3.8% vol
H_2	5 – 8 %vol
N_2	50 – 60% vol.
LHV dry	3950 – 9340 kJ/Nm^3
Tar content	5 – 10 gr/Nm^3

Tests in China were conducted using rice-husk as the primary material, that being much lighter compared to the biomass used in Italy increased the problems. Successively, due to a series of difficulties, it was decided to place an exhaust fan on the top of the motor, along with an additional filter using saw-dust that enables gas-cleaning further for its possible use to run the motor along with smooth biomass feeding. In fact, thanks to the exhaust fan, the plant was slightly depressed and the above-mentioned problems were resolved, as well. In brief, the following main modifications were done on the plant:

- proper placement of air injectors (system for smooth biomass supply)
- Adjustment of a double rotary valve (system to discharge ash)
- Double dry filter, with saw dust (for gas cleaning and dehumidification)
- Variation of pressure inside the gasifier, through an exhaust fan.

It was only after the above-mentioned modifications that a series of experimental tests could be conducted at the experimental centre at LIER, Yingkou, in China, while coupling the plant gasifier to achieve a useful power of 169 kWe from the electric generator.

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^{13}C UREA BREATH-TEST RESEARCH AND FACILITY ESTABLISHED AT PAEC: CHALLENGES AND OPPORTUNITIES

Rakhshanda Bilal[*], Tanvir Ahmad, Sadia Yousuf, Zahid Latif and Nasir A. Zaidi

[*]Life Science Group, Radiation and Isotope Applications Division
Pakistan Institute for Nuclear Science and Technology
P.O. NILORE, PAECommission, Islamabad Pakistan

ABSTRACT

Helicobacter pylori is a common infection, especially in the developing-world. This infection may remain asymptomatic for a long time, but may cause conditions including abdominal pain and peptic ulcer disease. Of every 10 ulcer patients, 9 are because of H. pylori infection, while some other causes include use of NSAID. Not enough is known about H. pylori prevalence among our population, primarily due to lack of an appropriate diagnostic tool.

Conventional methods to diagnose H. pylori infection are mostly invasive, which require endoscopy or a blood sample (histopathology, quick urease, culture and serology). Until recently, the highly sensitive and specific non-invasive tools like Urea Breath test were not available in the country.

The ^{13}C UBT test has been validated and clinically applied for various research projects in the country by Pakistan Atomic Energy Commission (PAEC). Recently, a full fledged facility has been established by PAEC to make it available as a routine diagnostic tool, as well as to facilitate research studies on various aspects of H pylori, especially on children, which is ethically not possible using routine invasive methods.

The paper discussed the challenges and constraints of the research on Helicobacter pylori, in view of the opportunities that the established techniques offer.

Key words: helicobacter pylori. ^{13}C Urea Breath Test, diagnosis of infection, mass-spectrometry.

INTRODUCTION

Peptic ulcer is a common chronic condition of the stomach and duodenum. Almost 10% people in the developed countries have this condition at some time in their lives. H. pylori is the major cause of peptic ulcer disease. For those infected, the lifetime risk of developing H. pylori-associated peptic ulcer is estimated at 10-20%[1]. Of every 10 ulcer cases, 9 are because of Helicobacter pylori infection, while some other causes include frequent use of nonsteroidal anti-inflammatory drugs (NSAIDs)[2,3]. Peptic ulcers were always associated with stress and various eating habits till 1983[4], when Warren and Marshall showed that a bacterium Campylobacter, (now known as H. pylori), was the cause of these gastrointestinal problems. With later confirmation and recognition of H. pylori as the main causal agent of gastritis and ulcers, the whole scenario of diagnosis and treatment changed. In 1994, the NIH made a consensus statement stating that ulcers (because of H. pylori) should be treated with antibiotics, so that the organism could be eradicated[5]. Nowadays, peptic ulcer disease is regarded as an infectious condition that can be cured with a short course of antibiotics, in combination with bismuth compounds or acid suppressants[6]. Many studies have shown that the persistence of ulcers can lead to cancer[7].

Accurate diagnosis of the infection is, therefore, very important for deciding the modality of treatment. A number of tests available are discussed below, along with the pros and cons of each.

DIAGNOSTIC METHODS FOR H. PYLORI INFECTION

H. pylori infection can be diagnosed by several invasive and non-invasive tests[8,9]. If a gastroscopy is performed, biopsy-specimens can be taken to detect H. pylori by a rapid urease test, histological examination, polymerase chain reaction (PCR), or culture. The rapid urease test is based on the buffering capacity of H. pylori related to the large quantity of urease enzyme-the microorganism produces. For this test, the biopsy specimen is placed directly in a medium of urea and a pH indicator. The test is quick and can be read by the endoscopist shortly after the gastroscopy[10]. H. pylori can also be detected by histological examination of the biopsy specimen. The main advantage of histology is its ability to give information about the presence of gastritis, atrophy, and intestinal metaplasia. PCR on biopsy samples, for diagnosis of infection is not a method of choice because it can not deliver any additional information to that already provided by above mentioned tests. Although PCR has found its applications in studying the virulence of isolates, molecular testing for antibiotic resistance, finger printing and genotyping of local isolates and comparing with standard strains[11]. H. pylori being a microaerophilic organism, requires specific growth conditions and culture results are only available after several days. On the other hand, culture has the advantage that antibiotic susceptibility can be determined[8]. This test is not done routinely in any local lab.

Invasive testing for test-of-cure, is not reasonable in the primary care setting. Same information about H. pylori can be easily obtained by other non-invasive methods, avoiding the inconvenience of gastroscopy. These non-invasive tests include serology, breath tests using either ^{13}C or ^{14}C labeled urea and stool antigen test. Serology is cheap, but not very suitable since the antibody titers decrease very slowly after therapy[9,12-14]. For an IgG enzyme-linked immunosorbent assay (ELISA), commercial kits are also available[15]. Serologic testing cannot definitively evaluate post-treatment infection status, due to its lack of specificity, following treatment.

Recently the HpSA (H. pylori Stool Antigen) test has been introduced. It involves detecting the presence of H. pylori antigens in a stool specimen, using commercially developed and available antibodies against the bacterium[16]. However, validity of this test is still questionable; besides, handling stool samples requires a special setup. Potential risk of lab workers getting infected, through invasive procedures and also those requiring handling of infectious materials, should not be underestimated. UBT is by far, the most safe and accurate non-invasive test for the routine diagnosis of H. pylori infection. Some comparative data for invasive and non invasive tests is summarized in Table-1.

Urea Breath-Test

The principle of urea breath test is simple. Urea isotopically labeled with ^{13}C, is given orally and if H. pylori is present in the stomach, its urease enzyme hydrolyses the urea producing isotopically labeled carbon dioxide. This CO_2 diffuses into the blood and is

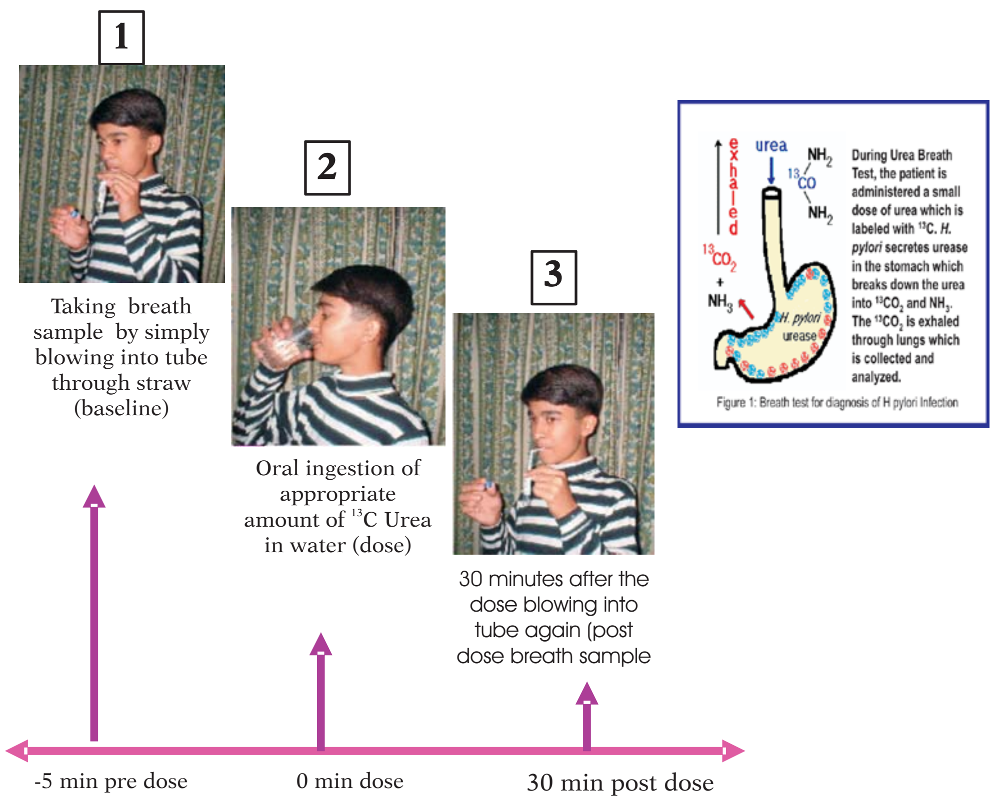

Figure - 1: Three Steps of the Urea Breath Test

Table - 1: Comparison of Invasive and Non-invasive tests used for *Helicobacter pylori* diagnosis

	Invasive (Biopsy)				**Non Invasive**		
Tests	**Culture**	**Histo-pathology**	**Urease**	**PCR**	**^{13}C UBT**	**Serology**	**HpSA**
Sensitivity% / Specificity%	98/100	93/97	90/100	96/100	99/1001	85/79[3]	93/93[2]
Availability	Indoor	Indoor	Indoor	Indoor	Outdoor	Out/Indoor	Indoor
Rapidity of Results	> 1 week	> 1 day	Immediate to 1 hour	a day	Immediate to 1 hour	immediate	2 hours
Advantages	Pathogenecity, strain typing, antibiotic susceptibility	Evaluation of the status of the mucosa by direct Visualization	Quick	Pathogen-ecity strain typing	Non invas-i've detects presence of active infection	retrospect-I've analysis cheap	Active infection
Disadvantages	Depends on The conditions In which the Specimen is Transported And processed	Requires expertise of the pathologist	Sensitivity decreases after treatment	Strict protocol to avoid cont-amination Not suitable As a routine diagnostic Test	Less well known	Antibody titer falls slowly, not suitable for follow-up	Requires stool handling

exhaled through lungs (Figure-1). The breath can be collected and the analysis of breath through appropriate instrument (Isotope-ratio mass spectrometer) can detect the ^{13}C in breath-sample.

Procedure: The procedure involves collecting a baseline breath-sample from an overnight fasting subject. Oral ingestion of appropriate amount of ^{13}C urea (Cambridge Isotope laboratories, Boston MA, USA) dissolved in tap water. Collecting a second breath-sample 30 minutes later.

The $^{13}CO2/^{12}CO_2$ abundance ratio is measured by gas isotopic ratio mass-spectrometry (BreathMAT plus, Finnigan, Germany), and the values are expressed as delta per mil (‰) versus PDB (Pee Dee Belemnite, the limestone standard). Positive values for H. pylori infection are defined as ≥5 δ‰ over baseline . The figure shows a 60 minute time-profile of a control (UBT –ive) and a UBT +ive subject. (Figure-2). For diagnostic purposes, only two samples are sufficient.

RESEARCH DONE AT PINSTECH

RIAD's mass spectrometry laboratory ranks as one of the best in the region and has an International reputation in precise isotopic analysis[17]. Before introducing any new test, this test needs to be established validated in the local population and then clinically certified. Following projects were completed at PINSTECH, before the urea breath-test was made available commercially.

- Establishment of general $^{13}CO_2$ Breath test methodology during 1990-1991
- Validation of $^{13}CO_2$ Urea Breath Test for detection of Helicobacter pylori in gastritis patients during 1995-1997 in collaboration with Rawalpindi Medical College.
- Clinical application of $^{13}CO_2$ Urea Breath for the diagnosis of Helicobacter pylori infection (1998-2000) in collaboration with Military Hospital Rawalpindi.
- ^{13}C Urea Breath test to compare the efficacy of drug-regimens used for Helicobacter pylori eradication (1998-2000), in collaboration with Military Hospital Rawalpindi.

After the establishment of basic breath test methodology; the ^{13}C urea breath-test was validated against the available conventional methods in the local population, for the diagnosis of H. pylori infection through collaboration with the local hospitals. In the next stage, the test was applied in clinical settings for the diagnosis of infection and confirmation of eradication after treatment, also in collaboration with local doctors[18]. During this stage, 122 patients were diagnosed for H. Pylori infection, using four available tests. Number of patients diagnosed positive by non-invasive UBT was highest (80) as compared to all other invasive tests used (Table-2).

Table - 2 : Comparison between Different Tests Performed for Diagnosis of *Helicobacter pylori* Infection

	Initial Diagnosis by			
	Clo*	**Histopath***	**Culture**	**UBT**
Positive	69	72	48	80
Negative	52	46	72	39
ND (Test Not Done)	1	4	2	3
Total	**122**	**122**	**122**	**122**

Note: * Clo= quick urease test; Histopath= Histopathology on a strained biopsy smear : UBT = ^{13}C Urea Breath Test

INTRODUCTION TO FACILITY ESTABLISHED BY PAEC

To provide the real benefits to both the clinicians and the patients, a facility has been established by PAEC at NORI Hospital, Islamabad, which makes available the test to local population.

The lab is equipped with state-of-the-art mass spectrometer from Thermo Finnigan, Germany. This instrument is fully automatic and requires only 10 ml of exhaled air sample. The test can be done while the patient is at the clinic of the prescribing physician. Patient can also come to the Breath MAT Lab NORI the test. In special cases, they are instructed appropriately and the test can be conducted at their home or office. The samples, which need to be analyzed, can be sent to the central analysis lab at NORI. The test results are then available within 24 hours of the receipt of samples in the BreathMAT lab. The results can be collected from the lab at NORI or can be conveyed through phone, Fax or email of the referring physician or the patient. The PAEC has setup many referral points throughout the country, where the kits are available for ^{13}C Urea Breath Test (Figure-3).

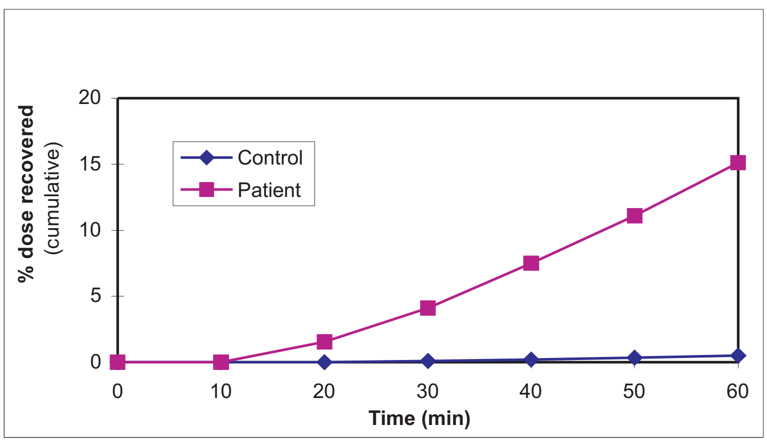

Figure - 2: Typical ^{13}CUBT Graph for a Negative and Positive Patient

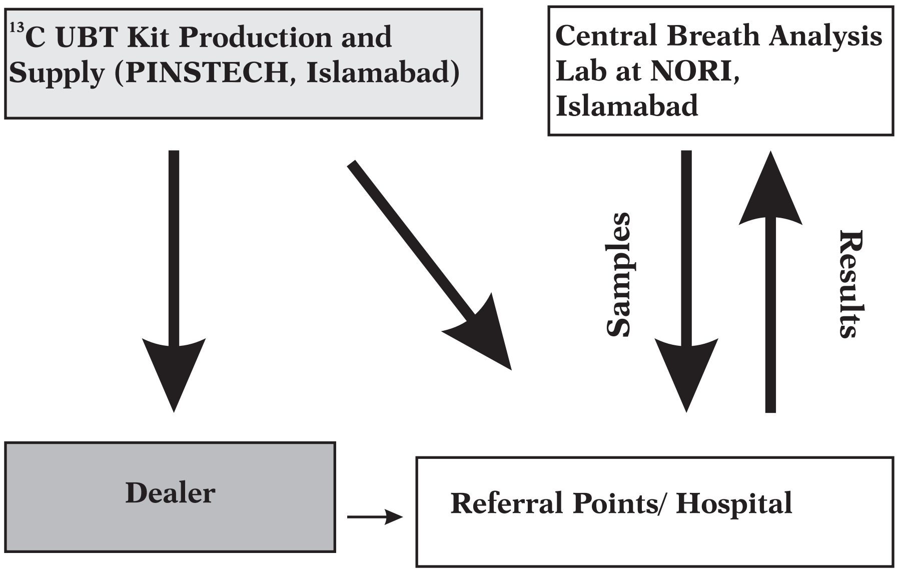

Figure - 3: The Set Up by PAEC to Provide ^{13}C UBT Services to End-Users

OPPORTUNITIES / ADVANTAGES OF ^{13}C UREA BREATH-TEST

The advantages that an established facility of PAEC offers, lies in its noninvasiveness and safety from even minutest of radiation effects, which are inherent in the use of radioactive isotopes of ^{14}C urea breath test. In the labeled breath-test, a positive reaction indicates the presence of live bacteria in the stomach. ^{13}C is a stable isotope,

Box - 1: Opportunities / Advantages offered by ^{13}C Urea Breath test

Advantages of the breath test	Who Benefits Most?
• Non radioactive • Non invasive/Circumvents the need for endoscopy • No waiting time • Patient-friendly/convenient to perform • Simple • Safe for all age-groups • Does not require any special setup	• Patients (initial diagnosis Follow up after the treatment) • Children with Recurrent Abdominal Pain • Pharmaceutical companies for testing the efficacy of drugs • Clinicians who are running clinics and do not have access to endoscopy facility • Remote areas where endoscopy specialist are not available • Researchers/epidemiologists

Box - 2: Constraints in Promoting the ^{13}C Urea Breath Test in the Country

- Marketing / promotion / creating awareness
- Patent
- Entrepreneurship
- Lack of awareness (both Industry and end user)
- Conflicts of interest
- Profit margin
- Involvement of Academia
- Involvement of Business Development Units (BDU)
- Maintaining the analytical lab/spare part and supplies
- Procurement and supplies

which means that no radiation is emitted and hence poses no danger for children and women of child-bearing age. With the introduction of ^{13}C-urea breath-test, it is now possible to investigate a large section of population including children. The ^{13}C UBT is accurate enough to assess the result of anti-H. pylori treatment and to confirm eradication.

The biggest advantage of this test is, that it does not require the pressure of patient at hospital. If prescribed by the doctor, the patient can carry it out on his/her own place of convenience, by simply following the instructions given in the breath-test kit. The samples then can be sent to the analytical laboratory in Islamabad.

For endoscopy, it requires a specialist, and a number of endoscopies are limited by the specialists time. Usually, there is a waiting time in most clinics, for endoscopy appointments. In case of breath test, there is no waiting time, as the capacity of the instrument is to analyze samples of at least 100 patients per day and no specialist is required for performing the breath test. Some further advantages are:

- UBT can be easily introduced to any existing clinical settings.
- This test is a non-invasive, sensitive and useful tool for initial diagnosis, as well as follow-up after eradication treatment.
- UBT is specially useful in confirmation of eradication, since it circumvents the invasive endoscopy procedure, which is quite inconvenient for the patients.
- The breath test is useful in diagnosing infection of H. pylori in symptomatic but endoscopically normal mucosae patients
- The UBT is cost-effective than endoscopy, along with any other conventional test.
- Currently, this test is considered gold standard. There is no known limitation except the maintenance of the analytical instruments.

SOME OTHER BREATH-TESTS

^{13}C breath-tests can also be used, for example, to: Measure gastric emptying rate, in order to evaluate its significance in appetite-control and to assess response to meal-size and composition; Measure pancreatic enzyme activity in health and disease (e.g. cystic fibrosis); Measure liver function pre- and post-transplantation; Quantify gastrointestinal transit times etc.,[19] [Figure-4].

CHALLENGES/CONSTRAINTS

The established breath-Mat Laboratory, by PAEC at NORI is engaged in both research and services involving ^{13}C Urea breath-test for diagnosing H pylori infection/status. There is a strong need to create awareness among end-users, which include both clinicians and the patients. Since the concept of stable isotope applications, though not very new for developed countries, is very new for the clinical community in Pakistan. Moreover, it is very difficult to change an existing practice and knowledge base. During the last two years, constraints faced in introducing the test are listed in Box-2.

The efforts undertaken so far, including a variety of seminars and courses, distribution of brochures and hand out, which show that there is a complete lack of awareness among doctors and end-users about the utility of this test. Involvement of academic institutions like universities and medical colleges, is therefore required, where students should be exposed to some theory and practice pertaining to the use of stable isotopes in nutrition and health research.

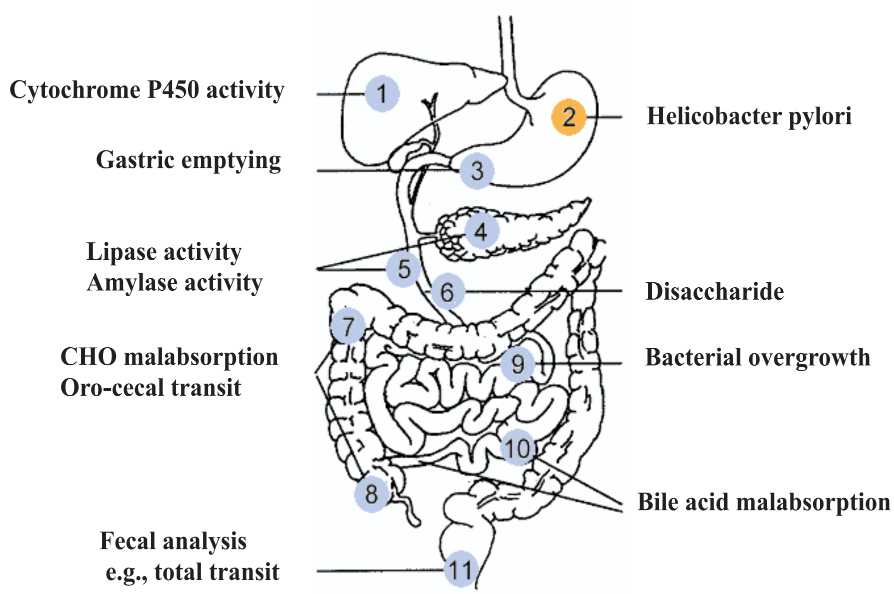

Figure - 4: Various investigative tools available to clinicians for studying gastrointestinal and metabolic functions

The concept of intellectual property rights and patenting is not very well developed in this country. Therefore, it is very difficult to find a mechanism to take the research results to its logical end-users.

The laboratories offering routine diagnostic test, when approached, seemed very keen to take up the test, but needed more profit-margin, than was agreed to by PAEC. Moreover, the clinicians who run private practice, and who have an endoscopy facility installed, do not want to prescribe this test, even though it is of definite use in certain situations, since it will deprive them of the endoscopy fee that they charge from their patients. So, there is a wide gap in developing an understanding between researchers in the country (who have validated and applied this test in the country) and clinicians who have to prescribe this test to the patients.

One general criticism about this test is the cost. Most of the clinicians, who reject this test on the basis that it is expensive, do not realize the fact that it is safe and cheaper, as compared to the cost of an endoscopy-based test (which most specialists charge), which requires biopsy specimen to be sent to a laboratory for further investigations. The inherent noninvasiveness of the procedure, makes it useful beyond simple cost-comparison, if one considers the infection caused by inadequate cleaning of the endoscopes used in this country.

This gap, in the knowledge among end-user and researchers, can be bridged by proper communication and Academia. This will facilitate the researchers in the country, who will then be spared the efforts of promoting the research. Instead, one would expect the business-development units to take care of promotion and leave the scientists to do their research in the country.

CONCLUSIONS

Based on the last ten yeas of research-effort for validation and clinical application of ^{13}C Urea Breath test, plus last two years efforts in promoting this test, the authors can confidently say, that this test has definite advantages over the conventional tests. It is only a matter of increasing the level of understanding, of both the patients and referring clinicians, that this test is an addition to all other tests available for the diagnosis of ulcer patients. Each test has its own merits and demerits. What is required is to put the test in appropriate perspective with the other tests, so that doctors should know which one is the best test to prescribe. This test can definitely help cut down on the number of endoscopies that are performed per day on ulcer-patients less than 40 years of age as on children.

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RECOMMENDATIONS FOR STRENGTHENING RELATIONSHIP BETWEEN ACADEMIA, GOVERNMENT AND UNIVERSITIES

The Conference on Basic Research and Industrial Applications brought some useful recommendations to strengthen the research base in the country and to promote stronger ties especially between academia and universities. Some of the important recommendations are given as follows:

A

- The government and the industry, as well as, the masses must be sensitized on the pivotal nature of science and technology. With a better awareness about the role of science and technology, greater benefits can be brought to all economic and social activities.

- The meeting called for equally emphasizing the basic as well as applied research and to focus on long term plans, and to develop strategies wherein basic and applied research can be done in parallel. The meeting resolved that long term plans for inducting science and technology in every sphere of life is a must, which was deemed to provide resources for the dignity to humanity. The need for the transfer of technology, based on 'science' was also stressed, and in order for transfer of technology the transfer of science was suggested.

- It is vital to incorporate new sciences into education and curricula, including material design to induce curiosity towards sciences and engage young minds in attempting to find answers to the unexplained. This is one of the prerequisites for the provision of a well-trained, knowledgeable and skilled human resource that would actively contribute to many fields of science, achieve technological breakthroughs and ultimately set the way to sustainable development.

- On the one hand, all nations must rethink their scientific and technological priorities in the face of growing economic constraints and new political and ethical realities, while on the other, they must strive to build the capacity necessary for effective research and its commercial applications. Education and research represent long-term investments in human capital that yield large returns in economic growth.

B

- The input of scientists along with industrialists, educationist and technologists, must be inculcated in the policy-making process, so that long-term strategies may include the scientific-benefit factor within them. Developing countries would simultaneously have to make a special effort to push science and technology to the forefront of their domestic policy agenda.

- The aspect of training, especially in the fields of natural sciences, and the provision of optimum funds government and non-governmental should be ensured through viable mechanism. The initiation of 'Innovation Development Fund' was also accentuated.

- R&D institutes, the industry and the universities must aim to adopt and support the promotion of indigenous technologies that are suited to indigenous peculiarities. If technologies would continue to be imported from abroad, developing countries would not be able to free their economies from the burden it causes.

- All proven performers should be supported by adequate funds. These funds may come from government sources, but it is important that funds also come from the industry and private sector. Once research shows promise for commercialization, it would be possible to attract private funds, but this requires developing good relations between R&D institutes, universities and the industry.

C

- The building of scientific capacity should be supported not only by the spirit of collaboration between stakeholders at the national level, but also by regional and international cooperation. This would help to ensure both equitable development and the spread and utilization of human creativity without discrimination of any kind against countries, groups or individuals. Assurance must be made that cooperation should be carried out in conformity with the principles of full and open access to information, equity and mutual benefit.

- Joint websites for R&D institutes, universities and the industry that have Online Question-and-Answer Forums could provide a quick and accessible platform that would not only encourage interaction, but would also provide assistance on specified problems, encourage flow of funds for direct projects and build the trust that is so evidently absent at present.

- Data collection is a necessary exercise in order to establish the true state of affairs for basic research and the industrial needs for science and technology. “Technology Audits”, “benchmarking” and “cataloguing” the needs of R&D institutes, universities and industry is the first and most important step towards encouraging sustainable interaction within these stakeholders.

- This effort must be strongly backed by policy and system channels that forge the spirit of knowledge sharing. System channels include “Technological Business Incubators” attached to the industry at one end, and universities at the other. Another channel is “Liaison Cells” at universities that facilitate contact of students with the industry, and “Liaison Cells” at industrial units that contact universities and R&D institutes with their specified needs. “Research Utilization Boards” that may be government entities could bridge the gap between these stakeholders by acting as the missing links in the chain of interaction.

AUTHOR INDEX

SUBJECT INDEX