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A Journal of Science for Development

Commission on Science and Technology for Sustainable Development in the South

COMSATS Secretariat: 4th Floor, Shahrah-e-Jamhuriat,
Sector G-5/2, Islamabad, Pakistan.
Tel : (+92-51) 921 4515-7 Fax : (+92-51) 921 6539
Email: info@sciencevision.org.pk, Website: www.sciencevision.org.pk

SCIENCE VISION

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EDITORIAL

Shortly after the inception of COMSATS in 1994, it was decided to launch a multi-disciplinary scientific journal that could promote the objectives of COMSATS by publishing scholarly articles on a broad range of topics in Science and Technology. The publication of this journal has been a useful source of information on latest developments in the areas of S&T that are most relevant to the socio-economic development. The free-of-cost distribution of the journal among the scientific community of COMSATS member countries and partner institutions is based on the policy of advancing and supporting scientific capacity-building.

The initiative has been steadfastly continued over the years in spite of some formidable challenges. A particularly lean period occurred during 2004 2007 when the publication of the journal was suspended. The re-consideration of that decision in 2009 necessitated to fill the gap of publications by bringing out two joint volumes for the period 2005 2008, containing a limited number of articles and abstracts/indexes of COMSATS conferences/seminars proceedings. The matter of revival of the journal was also raised in the 12th Coordinating Council meeting held in Nigeria, in 2009. On that occasion, the following three important decisions were made:

I) COMSATS Secretariat will continue its efforts to publish the journal by tapping the intellectual resources of COMSATS Centres of Excellence;
ii) The journal will be published bi-annually rather than on quarterly basis; and
iii) The focus of journal s publication will shift from purely technical articles to those that review a particular scientific theme of research or discuss issues relevant to the interrelationship of science and society.

Thus far, the publication of the journal has been an uphill task. However, despite the challenges, two thematic issues (Volumes 15 - 1&2) were brought out containing papers on environment and renewable energy, respectively. The present edition of the journal, comprising its Volumes 16 and 17, is an attempt to bridge-up the gap in the publication due to a few missing issues and to move towards re-defined focus of the journal with respect to the contents of the published articles. Other mechanisms adopted to successfully negotiate the transition period are the inclusion of book reviews, re-printed articles, and inclusion of articles presented during COMSATS supported international conferences and symposia. It is hoped that ultimately the journal s publication schedule will get in step with the calendar year and sufficient number of articles addressing the impact of science on society will be available for publication.

It is worth mentioning that this journal is specifically dedicated to such issues that have a direct bearing on the socio-economic development of COMSATS Member States. The scope of these issues are further restricted to the ones that are amenable to solutions through scientific research or technology applications. Thus, some of the areas of interest to COMSATS and hence suitable for coverage in the journal are; wider use of renewable technology, mitigation of the climate change effects, adequate food supplies, improved health conditions and access to information resources through affordable broad-band Internet connectivity. The present edition of the journal comprises 15 entries, presented under three broad categories: Energy Options for the Developing World; Science Education and Capacity-Building; and Role of S&T for Sustainable Development.

As a necessary conditionality required for all prestigious journals, the articles published are refereed to ensure their quality and originality. The Editorial Board remains vigilant during the scrutiny stage to avoid any compromise on publication standards. We are extremely grateful to all authors for submitting their valuable articles and for bearing with us during the lengthy review process.

Clearly, the success of this venture would continue to critically depend on the extent to which the COMSATS Centres of Excellence manage the support of the journal. Considering that all Heads of Centres of Excellence are members of Editorial Advisory Committee of the journal, it is earnestly hoped that the journal will emerge as a strong voice in the discourse on international sustainable development issues. Senior scientists from all over the world are also urged to share their experiences, foresight and broad perspectives through their intellectual contributions to Science Vision that could benefit the developing world.

Dr. I. E. Qureshi
Executive Director COMSATS
Patron & Editor-in-Chief, Science Vision

SCIENCE VISION

Patron and Editor-in-Chief: Dr. Imtinan Elahi Qureshi

Vol. 16 and Vol. 17 (January 2010 to December 2011)

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NANOTECHNOLOGY FOR SUSTAINABLE ENERGY

*Mohamed Ali Alsayed Ali**

ABSTRACT

Nanotechnology and its applications have captured a worldwide market. Nanomaterials that have been developed using this technology can be incorporated into the devices so that renewable energy can be converted or generated more efficiently. Nanomaterials have the potential to change the way we generate, deliver and use energy.

Hydrogen cells are used in auto industry as a viable power source. Compressed hydrogen tanks are used to supply Hydrogen, and Oxygen is used from the air directly. There is no pollution caused by hydrogen fuel cell autos since the only emission is water.

Organic dyes (dye sensitizers), which are sensitive to light, can absorb a broader range of the sun's spectrum. A dye-sensitized solar cell has three primary parts. On top is a transparent anode made of fluoride-doped tin dioxide (SnO_2:F) deposited on the back typically of a glass plate. On the back of this conductive plate is a thin layer of titanium dioxide (TiO_2), which forms into a highly nanoporous structure with an extremely large surface-area. After soaking the film in the dye solution, a thin layer of the dye is left covalently bonded to the surface of the TiO_2.

Computational material science and nanoscience can play many critical roles in renewable energy research. These include: finding the right materials for hydrogen storage; finding the most reliable and efficient catalyst for water dissociation in hydrogen production; finding a cheap, environmentally benign, and stable material for efficient solar cell applications; and understanding the photo-electron process in a nanosystem, and hence helping design efficient nanostructure solar cells.

Keywords: *Sustainable energy, Nanotechnology, Hydrogen cell, Dye solar cell, Computational nano sciences for renewable energy.*

1. INTRODUCTION

In today's world economy, acquiring reliable, efficient, pollution free, abundant energy is a major challenge. Major energy needs for economic development pertain to transportation, residential and commercial sectors. The World is heavily dependent on the non-renewable resources for our energy needs. Not only will these resources deplete over time, but they are also the major source of pollution, which is another key issue faced by the world economy. To address these challenges, there is a need to devise new technology that helps in reducing the problems and improving the economy.

With the advancement of S&T in the modern world, technology has been reduced and compressed to a nano-scale – to the order of 10^{-9} – in various applications.

Growing energy needs of the world call for increased measures to conserve energy, as well as to optimally utilize the alternative energy resources. This would not only reduce total dependence on fast-depleting fossil-fuels (oil, coal, gas, etc), but will also reduce the toll they take on environment in the form of green house gas emissions. Hence, the use of renewable energy resources (solar, hydro and wind) needs to be encouraged due to their economical viability, environment-friendliness and long-term availability.

2. THE ENERGY RESOURCES OF EARTH

Most of the energy currently used in the world comes from non-renewable sources. Disappointingly, the contribution of solar and wind energy has been very small, even lesser than geothermal. Most of the renewable energy comes from hydro-electric plants and some from biomass.

Increasing efforts and aspirations of the developing countries to come at par with the developed parts of the world in terms of socio-economic growth have resulted in increased energy demands. Figure-1 shows the uneven distribution of energy utilization rate throughout the world. It shows that 72 % of the world population uses less than 2 kW/capita, whereas 6 % of the population uses more than 7 kW/capita (Aldo, 2005).

There is a reasonable correlation between the total energy utilization rate of a country and its corresponding annual gross national production. About 2.2 W are used per dollar of yearly GNP. Thus, to generate each dollar, 69 MJ are needed. These figures, which are based on 1980 dollar rates, vary with time, owing partially to the devaluation of the currency, and partially due to changing economic circumstances. In fact, it has been demonstrated that during an energy crisis, the number of mega joules per dollar decreases, while the opposite trend occurs

* Higher Institute for Applied Sciences and Technology (HIAST), Damascus, Syria. E-mail: mhdcv.com@gmail.com

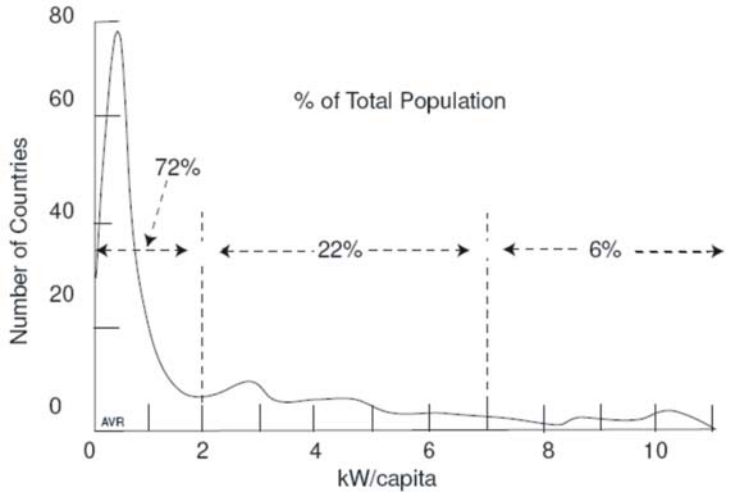


Figure-1: Most Countries use Little Energy Per Capita while a few Developed Ones Use a Lot. (Aldo, 2005)

during financial crises.

Further industrialization of the developed countries may not necessarily translate into an increase of the per capita energy utilization rate; the trend towards higher efficiency in energy use may have a compensating effect. Technological innovation has resulted in more efficient use of energy. Examples of this include better insulation in houses and better mileage in cars. Alternate energy sources have somewhat alleviated the demand of fossil fuels. Such is the case of using ethanol from sugarcane for the propulsion of automobiles. It is possible that the development of fusion reactors will, one day, bring back the times of abundant energy.

Introduction of a more efficient device does not immediately result in energy economy because it takes a considerable time for a new device to be widely accepted. The reaction time of the economy tends to be long. For example, in case of a privately owned fleet of cars, a sudden rise in gasoline price has little effect on travel, but it increases the demand for fuel-efficiency. However, car owners do not rush to buy new vehicles while their old ones are still usable. Thus, the overall fuel-consumption will only drop many years later, after a significant fraction of the fleet has been updated. Large investments in obsolete technologies substantially delay the introduction of more desirable and efficient systems. A feeling for the time constants involved can be obtained from the study of the market penetration function.

If, in 2050, all the estimated 11 billion inhabitants of Earth were to use energy at the present day USA level (11 kW/capita), the world energy utilization rate would reach 122 TW, which is a 16-fold increase over the present 7.6 TW. Such a rate is probably one order of magnitude higher than can be supplied unless fusion energy becomes practical and inexpensive.

3. EMERGING TECHNOLOGY

To identify and conserve the new renewable sources, many countries are trying hard to develop new projects to harness the new renewable forms of energy. Nanomaterials and hydrogen fuel cells have the advantage of being smaller and portable. Therefore, they have many more applications.

Today, solar cell technology is in limited use due to the relatively high manufacturing cost of silicon-based technology, and the low power efficiency of organic polymer-based technology. However, research is being done on hybrid cells based on dye-sensitizing organic polymers and a thin transparent conducting oxide layer comprised of nanoparticles. These cells could offer the same ease of manufacturing as organic cells, with improved efficiency.

Currently, although the improved efficiency is promising, it is still far below silicon-based solar cells. This paper also explores the role of nanomaterials in this flexible solar cell technology.

4. NANOMATERIALS

Nanomaterials, which are of the size of a 10^{-9} of a

meter, offer different chemical and physical properties of the same materials in normal form. They can be adopted in new technologies (Alsayed-Ali, M. A, 2010). Nanomaterials have the potential use in making more efficient solar cells and catalysts that can be used in hydrogen-powered fuel-cells. In this regard, the utilization and modification of the carbon nanotubes systems to enhance and tune the hydrogen storage capabilities of the nanotubes is important. The introduction of transition metals and hydrogen bonding clusters inside tubes undoubtedly increases their relevance.

Formation and modification of metal-organic frameworks (MOFs), three-dimensional nano-porous constructions made up of carbon atoms, is imperative, so that they can hold as much hydrogen as possible.

Due to small size and excellent conductivity, CNTs (carbon nanotubes), can be used as a foundation of future electronic devices. CNT cables could be used to make electricity transmission lines, giving huge performance improvement over present day power lines.

5. HYDROGEN FUEL-CELL

Hydrogen can be used in a fuel-cell, which basically operates like a battery. The fuel-cell consists of two electrodes and an electrolyte. Hydrogen and oxygen are passed over the electrodes to generate electricity and water. Hydrogen cells are mostly used in automotive-industry. Hydrogen vehicles include hydrogen fuelled space rockets, as well as automobiles and other transportation vehicles. The power plants of such vehicles convert the chemical energy of hydrogen to mechanical energy, to run electric motors, either by burning hydrogen in an internal combustion engine, or by reacting hydrogen with oxygen in a fuel cell. Widespread use of hydrogen for fueling transportation is a key element of a proposed hydrogen economy. Compressed hydrogen tanks are used to supply the hydrogen, and oxygen is used from the air directly. There is no pollution caused by hydrogen fuel cell autos, and the only emission is water. If the hydrogen fuel cell autos become mainstream instead of exception, autos can cease to be a part of the global pollution problem.

Hydrogen fuel does not occur naturally on Earth and thus is not an energy source, but is an energy carrier. At present, it is most frequently made from methane or other fossil fuels. However, it can be produced from a wide range of sources (such as wind, solar, or nuclear) that are sporadic, too diffuse or too cumbersome to directly propel vehicles. Electrolysis of water, integrated wind-to-hydrogen plants, etc. are technologies being explored to deliver low costs and high quantities to compete with traditional energy sources. Earlier research and development on hydrogen energy pertains to auto-thermal steam reforming catalysis of gas and alcohols, gasification, pyrolysis, thermo-chemical cycle, solar PV-electrolyser splitting of water, photo-electrochemical and photo-biological splitting of water and carbon nano-tube hydrogen storage. Previous research and development of fuel cells relates to proton exchange membrane fuel cell (PEMFC) materials, such as alternative electrolyte membranes, low-Pt electrodes, manufacturable bipolar plates and prototyping of PEMFC systems of 200 W to 5 kW portable power generator and fuel-cell motorcycles. PEMFC are promising devices for decentralized energy production, both in stationary and automotive fields, thanks to high compactness, low weight (high power-to-weight ratio), high modularity and efficiency, fast start-up, and response to load changes. The fuel-cell research groups are: fuel-cell process system engineering, fuel-cell electrochemical processes, fuel-cell material and manufacturing, micro direct methanol fuel-cell (DMFC), solid oxide fuel-cells (SOFC), and biofuel cell (BFC). The alkaline fuel-cell (AFC), phosphoric acid fuel-cell (PAFC) and molten carbonate fuel-cell (MCFC) have all been fully developed but were not fully commercialized due to technical and economic reasons. On the other hand, the PEMFC, DMFC and SOFC are still being intensively researched all over the world.

A new type of fuel cell, the microbial fuel cell (MFC) is also now being explored as a sustainable way of providing power. The ideal fuel for PEMFC is hydrogen with low carbon monoxide content to avoid poisoning of the fuel cell; in this way, PEMFC can achieve efficiency of up to 60 %, far higher than the 20-35 % efficiency of an internal combustion engine. The main thrust in PEMFC research is cost reduction of fuel cells by reduction of membrane and electrocatalyst costs; lowering electrocatalyst loading, reducing system complexity; and, by using CO tolerant anodes. PEMFC, system efficiency can be further enhanced through better designing of flow field in bipolar plates, and fuel/air in the stack, as well as through process optimization. The main thrust of SOFC R&D is reduction of the operational temperature by replacement with low temperature electrolytes, anodes and cathodes. Future DMFC R&D will focus on reduction of methanol crossover, water-

management and reduction in manufacturing costs. The main thrusts of R&D in hydrogen production from fossil-fuels are towards the development of low temperature auto-thermal steam reforming catalysts of alcohols, purification of reformed hydrogen through pressure swing adsorption and membrane processes, as well as membrane reactors, and higher hydrogen storage in carbon nano-tubes.

6. HYDROGEN ECONOMY

There is always a need for clean, efficient, convenient forms of energy, which the user can easily access. Hydrogen is one of the many convenient forms of energy, which have the potential to make an energy system and satisfy the human energy needs (Figure-2).

The hydrogen economy would be an energy system of the coming generations in the near future. Hydrogen, being most demanded, needs technologies for its production, storage, distribution, and utilization.

Hydrogen can be generated using the renewable energy sources which are readily available. One such source is wind energy that is playing the major role in the generation of hydrogen. The hydrogen economy is capable of fulfilling the human needs of the coming generations (Sherif, Barbir and Veziroglu, 2005).

6.1 Characteristics of Hydrogen

Hydrogen in chemistry has the following properties (Veziroglu and Babir, 1992):

- Available in huge quantity;
- Can be stored in solid, liquid or gaseous form;
- Can be converted into other forms of energy efficiently;
- Renewable source made from the product of water or water vapour;
- Easily transportable;
- Hydrogen as an energy carrier is environmentally compatible.

6.2 Hydrogen Production

Several technologies have been developed to produce hydrogen. Some of them have been analyzed to describe the process of hydrogen production. Hydrogen is mainly being produced from fossil-fuels in refineries or industries. The fossil-fuels that are used for hydrogen production are in the form of coal, crude oil or natural gas. These fuels produce carbon-dioxide gas during their combustion. The processes involved are hydro-treating and hydro-cracking. To avoid emission of carbon-dioxide gas, many other technologies are being developed to produce cost-effective hydrogen. Water electrolysis is one of the most efficient methods to produce hydrogen but it needs electricity, which is expensive (Veziroglu and Babir, 1992).

More suitable and effective method of water electrolysis would be with the use of photovoltaics; but photovoltaic cells are costly to produce and install. Thus, even though highly efficient, photovoltaics do not make a good alternative.

Wind energy is the other way to produce hydrogen at a low cost but this energy can be utilized only in the areas where the wind energy is easily and abundantly available. The energy required to produce hydrogen is more than what it is capable of releasing during its utilization as a fuel.

6.3 Hydrogen Storage

Hydrogen can be stored as solid, liquid or gas in the form of glass micro-spheres, chemical hydrides, or cryo-adsorbers.

Liquid hydrogen storage is being used only when there is a high need of hydrogen. Metal hydride storage system has an advantage in terms of storage safety. This process requires system set up and release of heat during the process is another important factor to make this storage system more popular.

In particular, one potential use of hydrogen lies in powering zero-emission vehicles via a proton exchange membrane fuel-cell to reduce atmospheric pollution. The recent discovery of high and reversible hydrogen storage capacity of carbon nanotubes makes such a system very promising. Due to its high surface area and abundant pore volume, porous carbon is considered a good adsorbent. For conventional porous carbon, the hydrogen uptake is proportional to its surface area and pore volume, while a high hydrogen adsorption capacity (4~6 higher wt.%) can be only obtained at very low temperatures, such as liquid nitrogen temperature. The important matters include:

a) How do structural characteristics influence the physical/chemical process?
b) Where does the adsorption occur, in inner hollow cavities and/or other pore space?

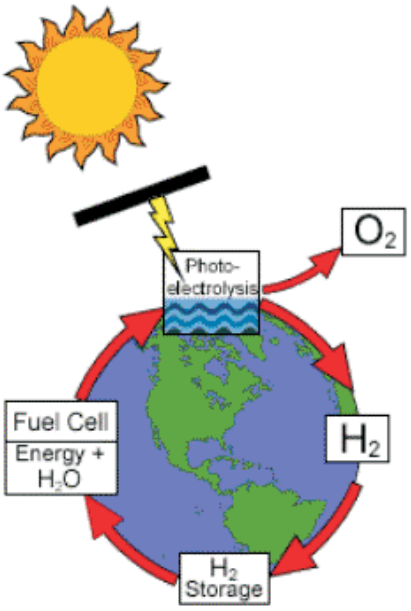


Figure-2: Clean, Cyclic Process of Generation of Hydrogen

c) In the adsorption of hydrogen onto carbon nanotubes, what interaction, chemical or physical occurs between the hydrogen and the carbon?
d) What are the adsorption mechanism and capacity?

Methods of hydrogen storage for subsequent use involve many approaches, including high pressures, cryogenics, and chemical compounds that reversibly release H_2 upon heating. Metal-organic framework (MOF) compounds consist of metal-oxide clusters connected by organic linkers. MOFs are a relatively new class of nano-porous material that show promise for hydrogen storage applications because of their tunable pore size and functionality.

6.4 Hydrogen Transport and Distribution

Hydrogen transportation by pipeline can be done up to 200 km from production to utilization sites but for effective transportation, high-capacity reciprocating compressors are used. The pipelines used for hydrogen transportation require large diameters and more compression power. Due to low volume of hydrogen and lower pressure losses, less recompression stations are required that need to be placed far apart. It has been estimated that transportation of hydrogen is cheaper compared to transportation of electricity. However, hydrogen distribution from industrial production plants to small-scale users has some limitations related to difficulties in hydrogen storage and transport. For its chemical and physical properties, indeed, the development of a hydrogen infrastructure seems to be not feasible in short term, while the concept of decentralized hydrogen production seems to be more reasonable; in this way, a hydrogen source, such as methane, is distributed through pipelines to the small-scale plants, placed near the users. The in-situ produced hydrogen is fed directly to the energy production system, avoiding hydrogen storage and transportation. In this sense, a compact fuel processor, capable of generating a hydrogen rich stream from an easily transportable fuel, may widely be used in the future.

6.5 Hydrogen Utilization

Hydrogen is being greatly used as a fuel in the internal combustion engines. The greater advantage is that it is cleaner and its use causes less pollution compared to gasoline. Hydrogen-use in jet engines and turbines produces only one pollutant, nitrogen oxides. Use of hydrogen in biomedical technology is becoming popular in the form of micro steam generator. Catalytic burners in household appliances are coming up with the use of combustion of hydrogen only.

6.6 Hydrogen Safety

Every process has its own risks and benefits. Similarly, hydrogen can be a risk if proper care is not taken from the beginning of the process of production till the

process of utilization. Hydrogen has the smallest molecule and so has a higher tendency to leak through small openings. Also, due to low ignition energy of hydrogen, the flame becomes nearly invisible that could be a dangerous issue, as it becomes hard to detect if there is a fire. Liquid hydrogen also creates the risk of cold burns. In spite of all the safety hazards, hydrogen has a very good safety record and is actually a safer fuel than any other gas.

7. DYE-SENSITIZED SOLAR CELLS BASED ON TiO_2 NANOPARTICLES

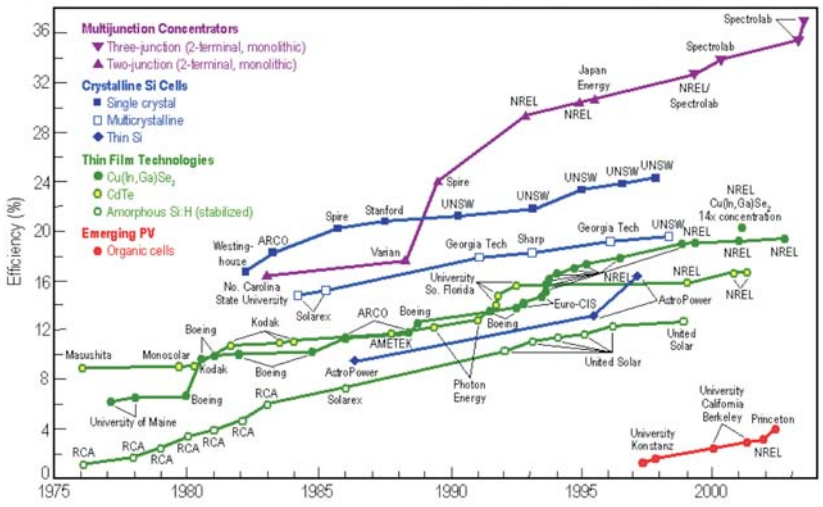
Today, due to the increasing global demands on energy, it is imperative that a renewable energy source be determined that is cost-effective and reliable. Solar cell technology has shown much promise over the years to replace the use of fossil-fuels. However, with the current technology, the cost per watt is rather high due to the high cost of manufacturing of silicon-based solar cells. The cost per watt can be lowered in two ways: i) lower the manufacturing cost; or ii) increase the amount of power output for the same cost. The latter is related to efficiency of the device. In other words, energy efficiency is the amount of energy output vs. the amount of energy coming in. In Figure-3, we can see the timeline of energy efficiencies of different types of solar cell technology. The current best is around thirty-six per cent. Clearly, a more efficient way of converting sunlight into energy needs to be researched in order to make solar cell technology economically viable.

Most traditional solar cells rely on a semi-conductor (typically silicon) for both light absorption, and charge transport. A fairly new, promising method separates these functions. Organic dyes (dye sensitizers), which are sensitive to light, can absorb a broader range of the sun's spectrum. When a photon hits the dye, an electron in the dye becomes excited and is injected into the conduction band of a nano-crystalline semiconductor oxide, where charge transport takes place. Electrons lost from the dye are regenerated by a redox electrolyte, usually an inorganic solvent. These components are sandwiched between substrates of transparent conducting oxide. It appears that the enormous surface area per unit volume of nanoparticles can increase the photon-to-current ratio.

Future studies are focusing on controlling the order and shape of the particles to increase the photon-to-current ratio even more. Although the mechanisms and processes of the dye sensitizer, electrolyte, and conducting substrate are worthy of study, we have tried to review the material properties of TiO_2 nanoparticles, and explore the mechanisms that make it a promising material in improving the efficiency of dye sensitized solar cells (DSC) (Michael Grätzel, 2004).

7.1 Theory of Operation for Dye-Sensitized Solar Cells

Dye-sensitized Solar Cells (DSCs) shown in Figure-4, rely on processes similar to photosynthesis. In



Source: *NREL: www.nrel.gov/ncpv/thin_film/docs/kaz_best_research_cells.ppt*

Figure-3: Timeline of Solar Cell-Efficiency according to Different Methodology (Kazmerski L., 2006)

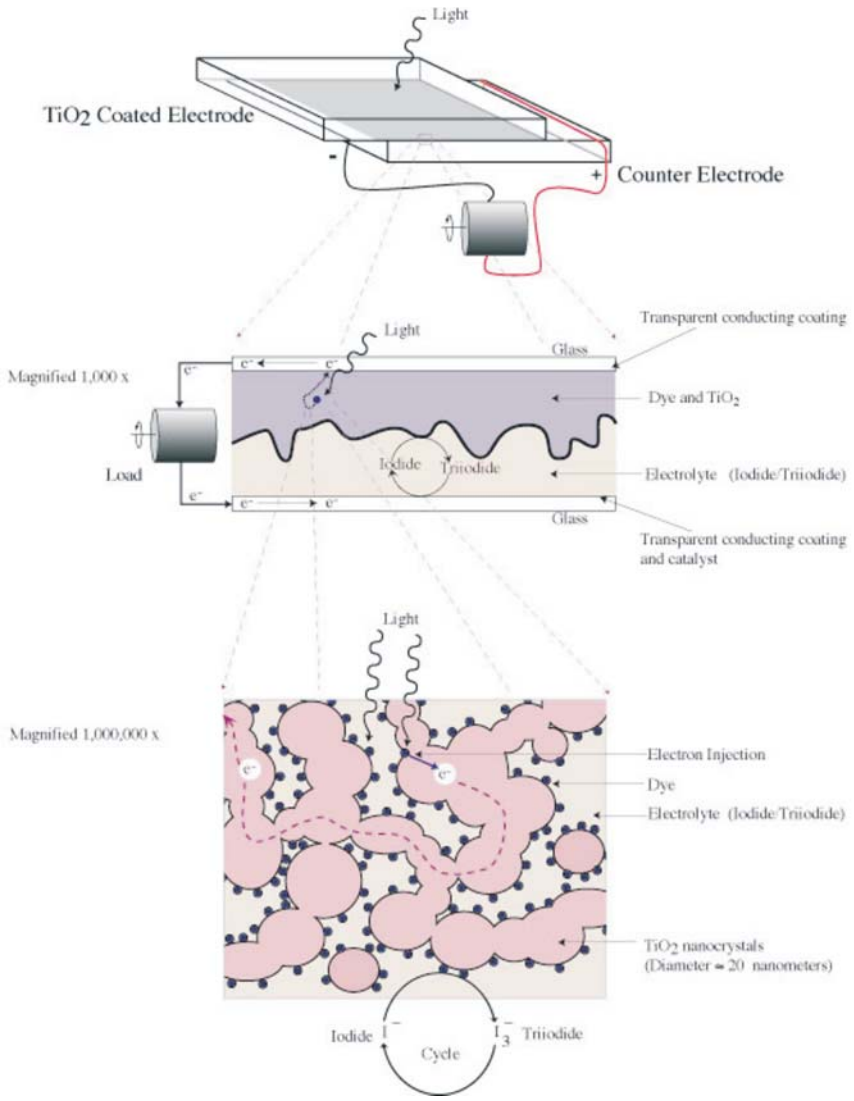


Figure-4: Schematic Diagram of a Dye-Sensitized Solar Cell (Wikipedia, 2006)

photosynthesis, light is converted into chemical energy. Chlorophyll and other pigments can eject electrons through photo-induced charge separation when struck by photons. The main component of a DSC is a semi-conducting material with a wide band gap. One such material is titanium dioxide (TiO_2). This is deposited as a thin layer onto a transparent conducting oxide (TCO) substrate using a sol-gel technique. The TiO_2 layer is also in contact with a monolayer of polymer dye, which has commonly been a ruthenium complex, also known as N3 (Kazmerski L., 2005). Exposure to sunlight causes electrons in the dye to become excited. This phenomenon is called photoexcitation. The electrons are then ejected from the dye and into the conduction band of the semi-conducting oxide layer. Regeneration of the lost electrons is handled by a redox process within an electrolyte, commonly an iodide and tri-iodide couple, which is in contact with the dye. The final component is a layer of TCO. The voltage generated is related to the difference between the redox potential of the electrolyte and the Fermi level of the electron within the solid. The electron that was ejected from the dye diffuses through the TiO_2 layer and into the conductive oxide electrode where it can be used as current.

7.2 Properties of TiO_2 Nanoparticles

The crystal structure of common forms of TiO_2 is tetragonal. Initially, mesoporous films of fractal dye

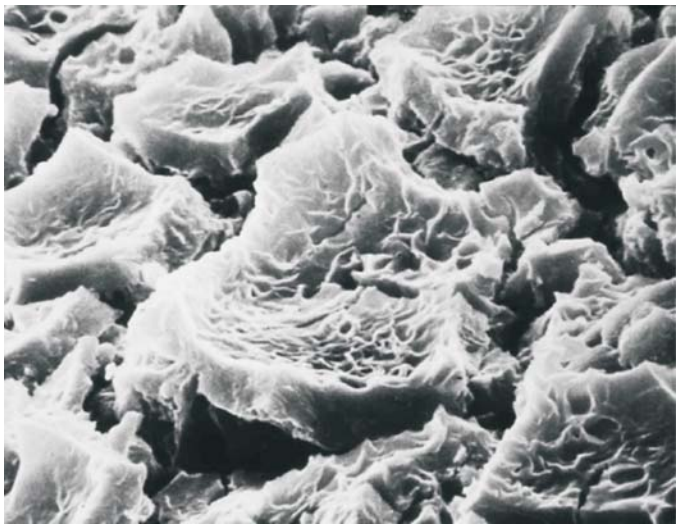


Figure-5: Scanning Electron Micrograph of a Mesoporous TiO_2 Film (Wikipedia, 2006)

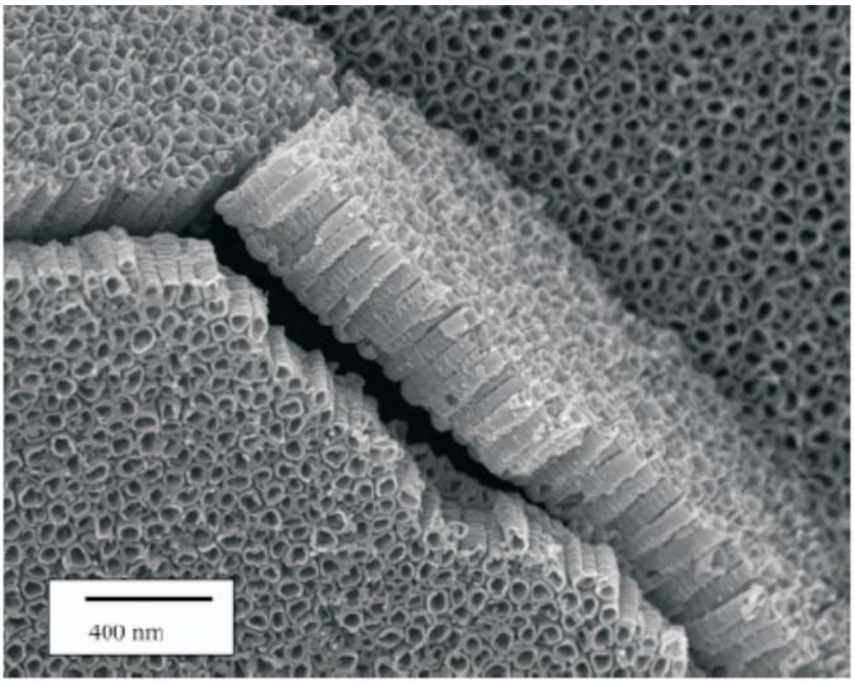


Figure-6: FESEM Images of Highly Ordered TiO_2 Nanotube Arrays (Gopal K. M., et al., 2006)

derivatized TiO_2 (Figure-5), with a surface roughness factor of 150, were used as the semi-conducting material in contact with the polymer dye. As seen in the micrograph, there is more surface area as compared to a flat surface. Adsorption of the mono layer dye sensitizer on a flat surface will result in a limited amount of coverage. By increasing the contact area between the semi-conductor and the dye, the amount of light harvesting is increased. The increased injection of electrons from the dye to the semi-conductor film improved the efficiency but more was needed. In order to further improve the efficiency of light harvesting, nanoparticles of TiO_2 were utilized. Nanoscale properties can be exploited to increase the amount of electrons captured. One very important property of nanomaterials is the morphology. The size

and shape of the nanocrystallites, as well as the surface topography is a key to increasing the efficiency of capturing electrons, as can be seen in Figure-5. Continuing studies are looking at controlling the size and shapes of these nanocrystallites. Control of the morphology of nanomaterials primarily takes place during synthesis.

8. WHAT IS NEXT?

A lot of investigation is being done on each component of dye-sensitized solar-cells these days. Increasing the efficiency of light harvesting, finding a more stable electrolyte, and improving the performance of the dye sensitizer are key topics. With regard to the semi-conducting oxide and light harvesting, researchers are trying to create more ordered rod-like crystallites. It is thought that a way to increase the amount of light harvesting is to have the rods aligned parallel to each other creating channels (Wikipedia, 2006). These channels would be perpendicular to the TCO electrodes. Highly ordered TiO_2 Nanotube arrays integrated into the DSC design (Gopal, et al., 2006) have been studied. Figure-6 shows images of the nanotube arrays from different angles. By assembling in this fashion, the nanotubes provide an excellent path for electron percolation, and thus increase the electron lifetime, and efficiency of charge carrier transport. The fabrication process begins with an Radio Frequency (RF) sputtering process of Titanium. This film is deposited on a glass substrate coated with a fluorine-doped tin oxide. An anodic oxidation step is next, followed by a 450ºC anneal in oxygen ambient. Prior to the annealing step, the nanotube arrays are not fully transparent. The resulting films show superior electrical performance as compared to nanoparticles. For example, open circuit voltage decay measurements were performed to look at the recombination effects. Figure-7 shows the response-time versus open-circuit voltage. The plot for the nanotubes clearly show longer response times, which correlate to longer electron lifetimes, which means less recombination of electron-hole pairs. This will ultimately translate to higher energy output. These results are very promising, and it is predicted that photocurrent efficiencies could approach the ideal limit of 31 % by lengthening the nanotube length (Gopal, et al., 2006). Although this is very encouraging, when dealing with structures that have a high contact area, the interface dynamics between the dye and the oxide must also be well understood.

Continued investigation into the interface dynamics of highly ordered nanotube arrays, as well as optimization of the other components are the focus of relevant future endeavours. The studies mentioned herein show that researchers are close to creating a DSC with viable cost-efficiency.

9. COMPUTATIONAL NANOSCIENCE AND MATERIAL SCIENCE FOR RENEWABLE ENERGY

Computational material science and nanoscience can

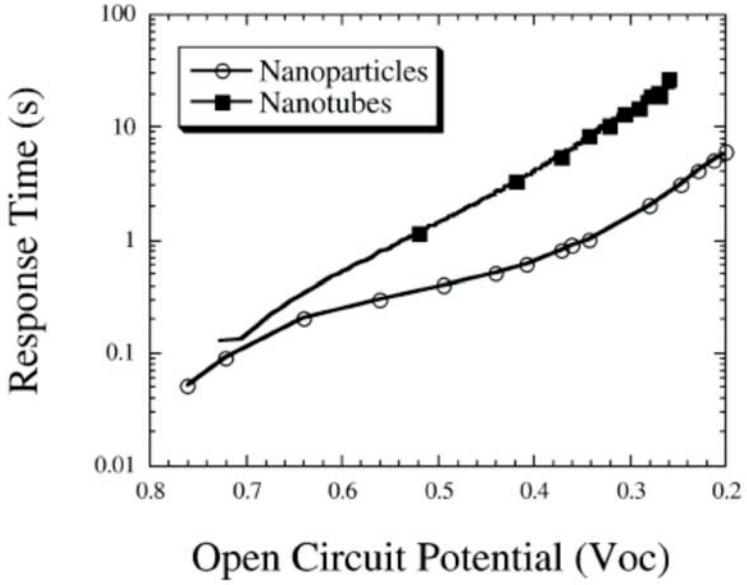


Figure-7: Response Time vs. Open Circuit Voltage for Nanoparticles and Nanotubes (Gopal K. M., et al., 2006)

play many critical roles in renewable energy research. These involve finding the right materials for hydrogen storage, a reliable and efficient catalyst for water dissociation in hydrogen production, cheap, environmentally benign and stable material for efficient solar cell application; and understanding of the photo-electron process in a nanosystem to help design efficient nanostructure solar cell. In all these areas, the possible exploratory parameter spaces are huge. This, at one hand, provides ample opportunity and potential for device-improvement, but on the other hand presents a tremendous challenge to find the best material and design. Exa-scale computation can thus help this optimization process, by either doing a direct numerical material by design search, or by understanding some fundamental processes in nanosystems.

In computational material science and nanoscience, there are three major challenges:

i) to develop the appropriate numerical approximation and model for accurate calculation of the corresponding physics properties;
ii) to integrate the diverse models and computational approaches and programmes to calculate different parts and aspects of a complex system, hence to enable the simulation of the whole system and process; and
iii) to calculate the large-scale systems (nanosystems containing tens of thousands of atoms) and dynamically for a long period of time (nanoseconds or microseconds).

The computational physics and chemistry community have been making efforts to address the fresh challenge since the invention of quantum mechanics. Although the many-body Schrodinger's equation is well known and describes exactly almost all the phenomena in material science; the direct accurate solution of that equation is almost impossible. This is because a system with N electrons needs to be described by a many-body wave function in N dimensional space (Alsayed-Ali and Zakaria, 2010). That makes the needed numerical co-efficients scale as N^N. A direct solution of such a problem might only be possible by future quantum computer. The most common approximation is to re-describe the 'many-body' wave function and the Schrodinger's equation with N single particle wave function. This is exemplified by the currently popular density functional theory (DFT), where a direction calculation scales as N^3, instead of N^N. DFT can describe many properties accurately, including atomic structures and binding energies. Thus, it is very useful in the search of hydrogen storage material and catalysis. Although it gives the approximate value of band gap with some corrections, it still can be used to study the optical properties and electron-phonon interactions. Thus, it can also be used for solar cell simulations. Other methods, like the couple cluster method in quantum chemistry, and GW method in material science can provide more accurate calculations for chemical binding and band structures, respectively. The search for more accurate and fast ways to calculating approximations will never end. But the continuation of search and the need for better methods/numerical models should not prevent us from using the models we already have. Actually, the current approximations (e.g., DFT) are already useful to carry out the simulations listed above for renewable energy research.

For the second challenge, the main focus should be on software development and integration. It also presents a computational hardware requirement more on capacity side than on capability side. Most experimentally measured physical properties are results of combinations of different physical processes (e.g. the solar cell efficiency and a nanosystem synthesis). At present, there are different methods and codes to calculate each individual property and process. But there lacks to a flexible tool to integrate them together, or to easily replace one model/algorithm in one part of a calculation by another.

For the third challenge, it calls both for algorithm development and for exa-scale computer. Due to the $O(N^3)$ scaling for DFT, even with petascale computers, one can probably only calculate the electronic structures of a system with 50,000 atoms for a given atomic configuration. If many time steps are needed to simulate a process, this direct approach will become unfeasible. Thus, linear scale approaches (to the size of the system) become necessary. Fortunately, due to the near-sight feature of quantum mechanical effects, such linear-scaling algorithms based on domain decomposition are possible, and effective for the large systems discussed here. With the linear-scale algorithm and the exa-scale computer, we should be able to simulate a whole nanostructure device, e.g. from photon-absorption exciton generation, to exciton-dissociation and carrier collection in a nanosize solar cell. This simulation can be done by following a time-dependent Schrodinger's equation (e.g. time-dependent density functional theory, TDDFT), and, at the same time, doing a Newtonian

dynamics for the atoms. Although there are still some uncertainties as to how exactly this may be done (for quantum state collapsing), such a simultaneous dynamical simulation for the electrons and atoms will help to reveal the electron-phonon interaction, the non-radiative carrier decay and cooling, as well as the under carrier transport and collection. These processes are critical for solar cell applications, and are poorly understood so far. To carry out such a simulation for an experimental sized nanosystem is a tremendous challenge. First is the size scale as described above and the second is the long-time scale. The typical carrier dynamics takes tens of nanoseconds, while the typical time step needed for a TDDFT is usually in the order of 10^{-3} fs (which is a thousand times shorter than a time step for atomic molecular dynamics due to the small mass of an electron). Thus, the number of time-steps is in the order of 10^{10}. Right now, one can do tens of fs simulations for small systems containing about a hundred atoms (e.g. on the Earth Simulator) based on the direct TDDFT formalism. Thus, there is a gap of about 10^5 in time scale and 10^2 in size scale. It is likely that both algorithm development (both in the linear-size scaling and in accelerating or approximating the dynamics) and larger exa-scale computer are needed to close this gap. But the benefit will be tremendous for understanding the photon-electron process in solar cell applications. The lack of such understanding is the current bottleneck in developing more efficient nanostructure solar cells.

10. CONCLUSIONS

The hydrogen fuel cell system is a green advanced power system for the future that is green, sustainable, clean and very environment-friendly. Priorities in energy research are the cheaper fuel-cell technology and renewable hydrogen production using water splitting photo-electrochemical cell. The main focus of R&D for sustainable hydrogen-production after fossil-fuel depletion is biomass pyrolysis, biohydrogen and photolysis of water into hydrogen and oxygen in solar photovoltaic-electrolyser system, direct solar photoelectrochemical reactors and solar photo-biological fermentors.

The increased injection of electrons from the dye to the semi-conductor film improved the efficiency, yet further improvement was needed. In order to further improve the efficiency of light harvesting, nanoparticles of TiO_2 were utilized. Nanoscale properties can be exploited to increase the amount of electrons captured. One very important property of nanomaterials is the morphology. The size and shape of the nanocrystallites, as well as the surface topography is a key to increasing the efficiency of capturing electrons.

Computational material science and nanoscience can play many critical roles in renewable energy research. An important prospect is to find the right materials for hydrogen storage. More and more experimental and theoretical results continue to appear, and more and more reproducible evidence proves that carbon nanotubes and MOFs (nano-porous materials) are potential hydrogen storage carriers. In order to use carbon nanotubes as a practical hydrogen storage medium, the mass production and utilization of carbon nanotubes are of current interest. Controlling the type and size of the tubes is expected to allow tuning the material for hydrogen sorption at desired temperatures and pressures. Nanoscience research also involves finding the most reliable and efficient catalysis for water dissociation in hydrogen production; the cheap, environmentally benign and stable material for efficient solar cell application; and understanding of the photo-electron process in a nanosystem to help design efficient nanostructure solar cell. In all these areas, the possible exploratory parameter spaces are huge.

The conclusion obtained from the above discussion is that we should increase the use of renewable energy sources and reduce the use of non-renewable resources. Existing renewable resources are well-established and proven. It has been seen that available renewable energy resources are helping in the production of the other forms of energy that makes energy system stronger and economical. The new upcoming technologies in renewable energy resources are very promising but a lot more research and infrastructure is required before they can be adopted.

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RENEWABLE ENERGY IN PAKISTAN: OPPORTUNITIES AND CHALLENGES

Irfan Afzal Mirza, Sana Ahmed** and M. Shahid Khalil****

ABSTRACT

Most of the countries around the world have realized that the key to attaining and maintaining prosperity and sovereignty is having independence and self-reliance in access to and subsequent use of energy. To address the global challenges, the energy system needs to undergo a transformation from fossil-fuels to renewable energy and energy efficient technologies. Pakistan has a huge potential for harnessing renewable energy and its share in the electricity mix has to be increased to achieve energy security. Security issues and circular debt in the country are the key challenges that need to be addressed to promote on-grid renewable energy through private sector. Around 38 % of the total Pakistani population remains without access to electricity. Fifty four per cent of the rural population currently has no access to electricity, forcing them to live a sub-standard life of poverty and social inequity. Microfinance and other innovative financial tools need to be evolved to promote rural electrification through renewable energies.

1. INTRODUCTION

Economies around the world are facing challenges of high energy demand to sustain the economic growth and development. This comes with a dire fact that the conventional sources of energy the fossil fuels are depleting. The environmental impacts of these conventional energy sources are also alarming. The large gap between demand and supply of electricity, increasing costs of imported fossil-fuels and worsening air pollution, demand an urgent search for energy sources that are cost-effective, reliable and environment-friendly. Consequently, there has been a lot of recent interest worldwide in developing renewable energy sources.

The current energy crisis in the country has taught us many lessons and one of the keys is to utilize indigenous sources of energy. Pakistan s electricity mix is heavily tilted towards thermal and the country is making 33.6 % of the total electricity from oil (HDIP, 2011). Through this paper, renewable energy is highlighted as a potential resource that can be tapped immediately to overcome the current energy crises and warrants energy security. Ninety-seven million people live in rural areas, comprising 7 million households. According to a report published by the International Energy Agency, 38 % of the Pakistani population remain without access to electricity (IEA, 2011). Fifty four per cent of the rural population currently has no access to electricity, forcing them to live a sub-standard life of poverty and social inequity. As a result, development of the country is suffering as these areas possess abundance of resources and workforce that is currently disengaged from the mainstream. Use of renewable energy, due to its manifold advantages of having positive cross-cutting effects and impact over various strata of the economy and society can play a vital role in mainstreaming this large resource and help provide sustainability, and social and economic equity among the targeted rural population.

2. CURRENT SITUATION OF ENERGY IN PAKISTAN

At this juncture, we are encountering the worst electricity crisis in the history of Pakistan resulting in extended load-shedding to an extent that it virtually suspends social life. The situation has further forced the Government of Pakistan to take decisions like early market shutdowns, power cut-off to industry, and two holidays per week thus affecting all business activities. In the short term, we put all our eggs in the oil based rental power projects. It is nearly impossible at this time to bear the cost of electricity both by the consumers and the government (circular debt issue) because of the existing oil-based projects, which could lead to further complications after rental projects with a little price hike of oil in the international market. The country needs to have an out-of-the-box thinking to utilize its indigenous resources, like hydro, coal and renewable energies.

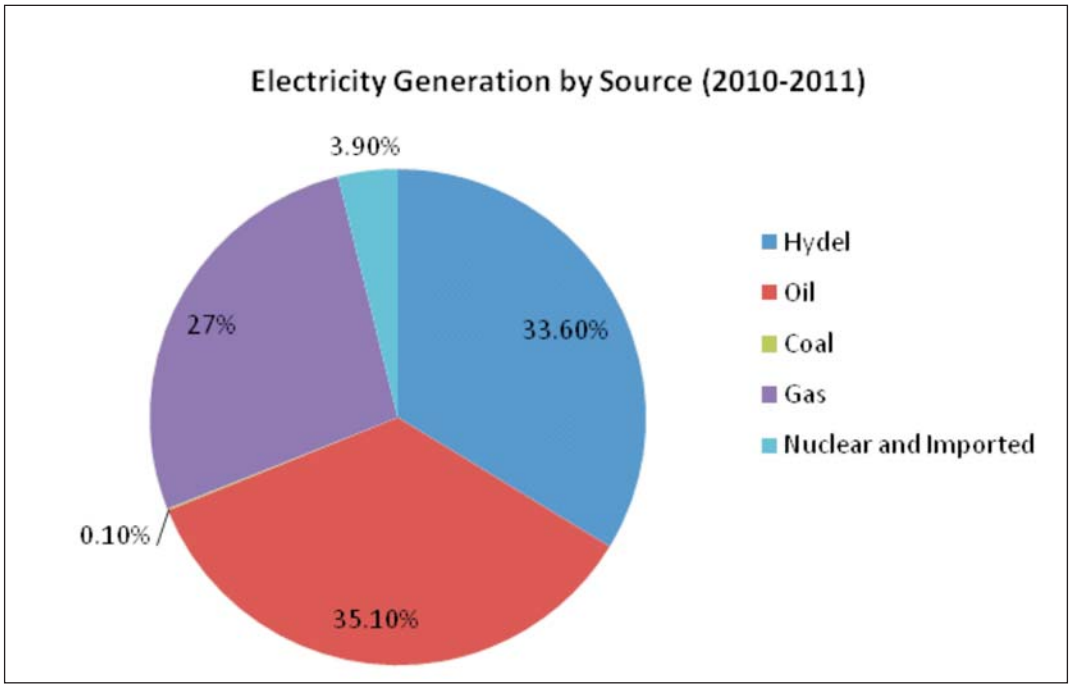
2.1 Electricity Mix of Pakistan

Unlike India, with an electricity mix based on indigenous sources and the share of oil-based generation of electricity is less than one per cent. The electricity mix of Pakistan is heavily tilted towards imported oil (Figure-1). Any oil price-hike in the international market badly impacts Pakistan s electricity generation rendering current circular debt issue even more critical.

3. GLOBAL PERSPECTIVE

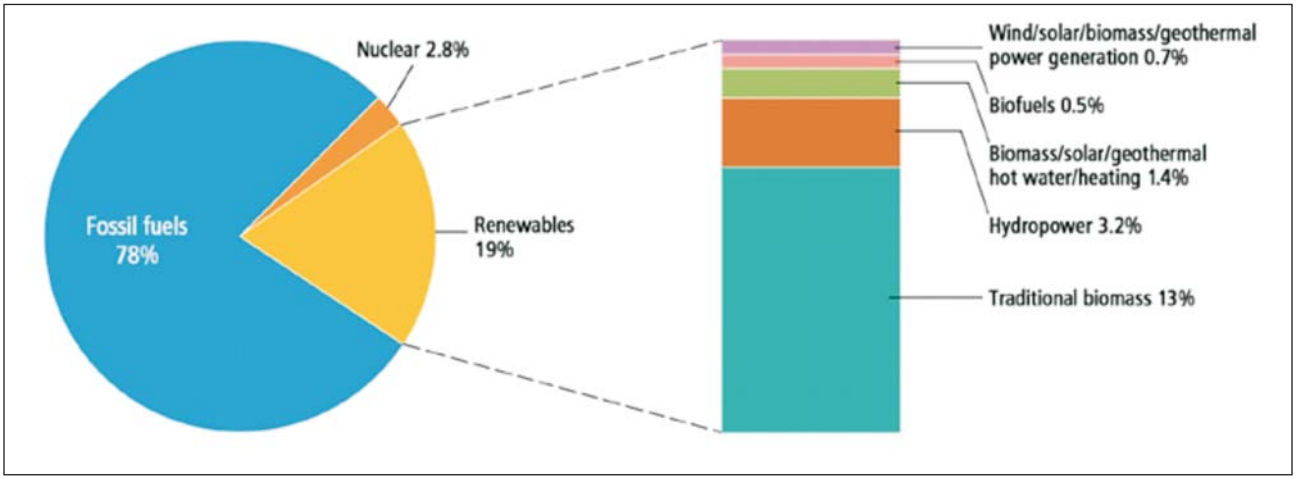
Since the advent of the new millennium, the world has transformed in a lot of ways; important among them are the menace of climate-change and the ever-

* Director / CEO, Renewable Resources (Pvt.) Ltd., Islamabad, Pakistan. Email: irfanmirza@renewableresources.com.pk
** Manager Project, Renewable Resources (Pvt.) Ltd., Islamabad, Pakistan. *** University of Engineering and Technology, Taxila



Source: *Pakistan Energy Yearbook by HDIP, 2011*

Figure-1: Electricity Mix of Pakistan



Source: *Global Status Report by REN21, 2010*

Figure-2: Renewable Energy Share of Global Final Energy Consumption, 2008

changing energy scenario in an increasingly volatile geo-political environment. Both the developed and the developing countries have realized that the key to attaining and maintaining prosperity and sovereignty is having independence and self-reliance in access to and subsequent use of energy. Coupled with the responsibility of keeping the climate-change under check for the sake of the future of our world, this has led to an all-time high emphasis on utilization of renewable energy resources world over. Global share of renewable energy in the energy consumption of the world is shown in Figure-2 (REN21, 2010).

By early 2010, policy targets for renewable energy at the national level existed in at least 85 countries worldwide, including all 27 European Union Member States. Many national targets are for shares of electricity production, typically 5 to 30 per cent, but range from 2 per cent to 90 per cent. Other targets are for shares of total primary or final energy supply, specific installed capacities of various technologies, or total amounts of energy-production, including heat, from renewable energy resources. Targets also exist for biofuels in many countries. Many historical targets have aimed for the 2010 2012 timeframe, although targets aiming for 2020 and beyond have emerged in increasing numbers in recent years. In 2008, all the 27 EU countries confirmed national targets for 2020, following a 2007 EU-wide target of 20 per cent of final energy by 2020.

Examples of new national targets among developed countries include Australia (20 per cent of electricity by 2020), Ireland (500 MW of ocean power by 2020), Japan (14 GW of solar PV by 2020), South Korea (11 per cent of primary energy by 2030) and the USA (25 per cent by 2025). An increasing number of developing countries have prescribed energy related targets, and as a group, now account for over half the countries worldwide with such targets.

The Renewables 2007 Global Status Report counted 22 developing countries with targets, and this figure expanded to 45 countries by early 2010. The national plans of developing countries also reflect increasing ambition in targeted amounts. China aims for 15 per cent of final energy consumption from renewables by 2020, even as total energy demand continues to grow at nearly double-digit annual rates. China met its 2010 renewable energy target of 10 per cent of primary energy two years early, in 2008. The country s most recent draft development plan targets 300 GW of hydro, 150 GW of wind, 30 GW of biomass, and 20 GW of solar PV by 2020.

In 2009, India set a target of 20 GW for solar power production by 2022 (including 1 GW of off-grid solar PV by 2017). Brazil aims to maintain or increase its existing shares of total energy (48 per cent) and electricity (85 per cent) from renewable through 2030.

4. FORMATION OF IRENA

To address the challenges mentioned above, the energy system needs to undergo a transformation, from fossil-fuels to renewable energy and energy efficient technologies. The critical need for a powerful, international actor that provides support and assistance to transform the energy system has been heralded worldwide. Thus, in January 2009, IRENA the International Renewable Energy Agency was established to bridge the institutional gap. Mandated by governments worldwide, IRENA aims at becoming the driving force in promoting a rapid transition towards the widespread and sustainable use of renewable energy. Acting as a global voice for renewable energies, IRENA will provide practical advice and support for both industrialized and developing countries. Since its creation, IRENA has been recognized as a viable global organization. IRENA must fulfill high expectations, as more countries are expected to join and support its work to meet the challenges that lie ahead (www.irena.org).

5. POTENTIAL OF RENEWABLE ENERGIES IN PAKISTAN

5.1 Solar Energy

Located in the sunny belt, Pakistan is lucky to have long sunshine hours and high insolation levels and is ideally located to take advantage of solar energy technologies. Solar mapping conducted by National Renewable Energy Laboratory (NREL), USA, in collaboration with USAID, has indicated a potential of 2.9 million MW in Pakistan (NREL, 2012), as shown in Figure-3.

This energy source is widely distributed and abundantly available in the country. The mean global irradiation falling on horizontal surface is about 200-250 watt per m^2 per day. This amounts to about 1500-3,000 sunshine hours and 1.9 - 2.3 MWh per m^2 per year. Balochistan province of Pakistan is particularly rich in solar energy. It has an average daily global insolation of 19 to 20 MJ/m^2 per day with annual mean sunshine duration of 8 to 8.5 hours a day and these values are among the highest in the world (Khalil, Khan and Mirza, 2005). For daily global radiation up to 23 MJ/m^2, 24 (80%) consecutive days are available in this area. Such conditions are ideal for PV and other solar energy applications.

Pakistan can make use of this abudant and widely distributed solar energy for improving the socio-economic conditions of the people living in remote areas and to reduce the poverty level. It is calculated that approx. 40,000 remote villages will be electrified through solar energy. The provinces of Sindh and Balochistan are ideal for utilization of solar energy. In Balochistan, 77 % of the population is living in the rural

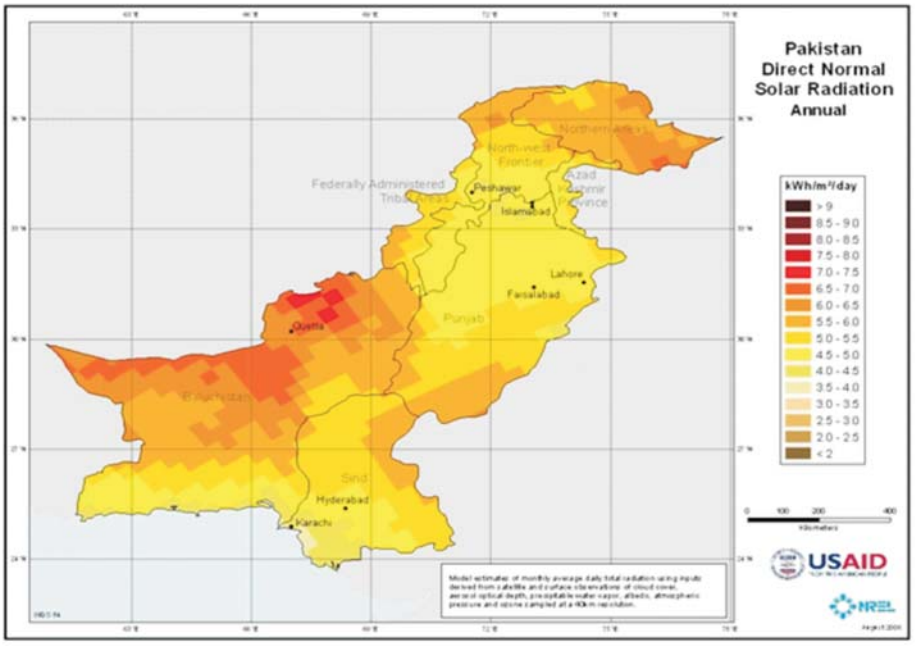


Figure-3: Pakistan Solar Energy Potential

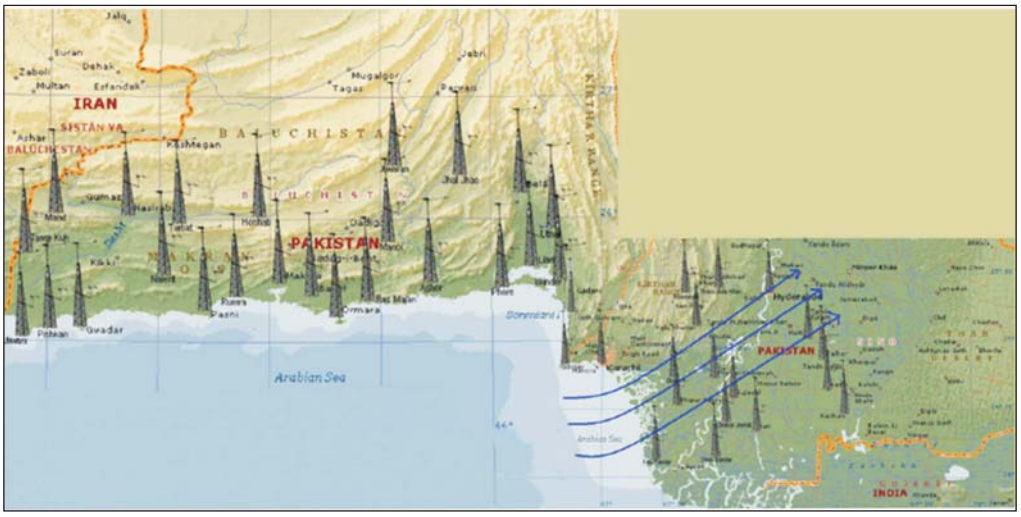


Figure-4: Wind Meteorology Masts Installed by PMD

areas and the population density is very thin. About 90 % of the villages are yet to be electrified. These villages are separated by large distances with absolutely no connecitng roads. Transmission lines are very expensive in this area and there is no chance of grid connection in the near future.

Within the broad scope of Solar Power Technologies, following concrete opportunities are available in both on-grid and off-grid applications:

i. Village electrification;
ii. Solar water pumps;
iii. Solar water heating and space heating solutions;
iv. Outdoor lighting (Solar/LEDs);
v. On-grid solar power projects using solar PV and solar thermal technologies;
vi. Net metering applications.

There are other options available but it is believed that fast-track development in solar energy for immediate

impact can be obtained by exploiting the above-mentioned segments.

5.2 Wind Energy

In the year 2002, Pakistan Meteorological Department (PMD) launched a campaign for the assessment of wind resources in the south of Pakistan. Meteorological masts were installed with anemometers at 10 m and 30 m heights (Figure-4). Analysis of the data gathered through these masts confirmed the presence of a logical wind corridor in coastal belt of Sindh province with wind speeds averaging more than 7 m/s at a height of 80 m. Further analysis of this wind regime showed a promising exploitable wind potential of more than 50,000 MW only at Gharo Keti Bandar corridor of Sindh Province (Qamar, 2009).

National Renewable Energy Laboratories (NREL) of USA under the USAID assistance programme in 2007 has carried out the wind resource study of Pakistan and developed a meso-scale map of Pakistan, showing the wind speed potential available at 50 m height. NREL study has also confirmed the availability of wind resource in Sindh. As per the wind resource map of Pakistan developed by NREL of USA, in collaboration with Alternative Energy Development Board (AEDB) and USAID, Pakistan has a potential of more than 300,000 MW of wind energy in whole of the country (Mirza, Khan and Memon, 2010) (Figure-5).

As mentioned above, more than 40,000 villages in Pakistan are not connected with the national grid and most of the remote villages in the south can be electrified through micro wind turbines. It is estimated that more than 5,000 villages can be electrified through wind energy in Sindh, Balochistan and Northern Areas. So far, 5 villages have been electrified using micro wind turbines by AEDB, Pakistan Council for Renewable Energy Technologies (PCRET) and other governmental and non-governmental organizations in Pakistan*.

5.3 Hydropower

The potential of only micro-hydro is discussed in this paper. The northern part of the country is rich in hydro power resources. Other than small hydro power plants (capacity greater than 1 MW), there is a large number of sites in the high terrain, where natural and manageable waterfalls are abundantly available. The recoverable potential in micro-hydropower (MHP) up to 100 kW is roughly estimated to be 300 MW on perennial water falls in northern Pakistan. The population in these areas is distributed in thin clusters

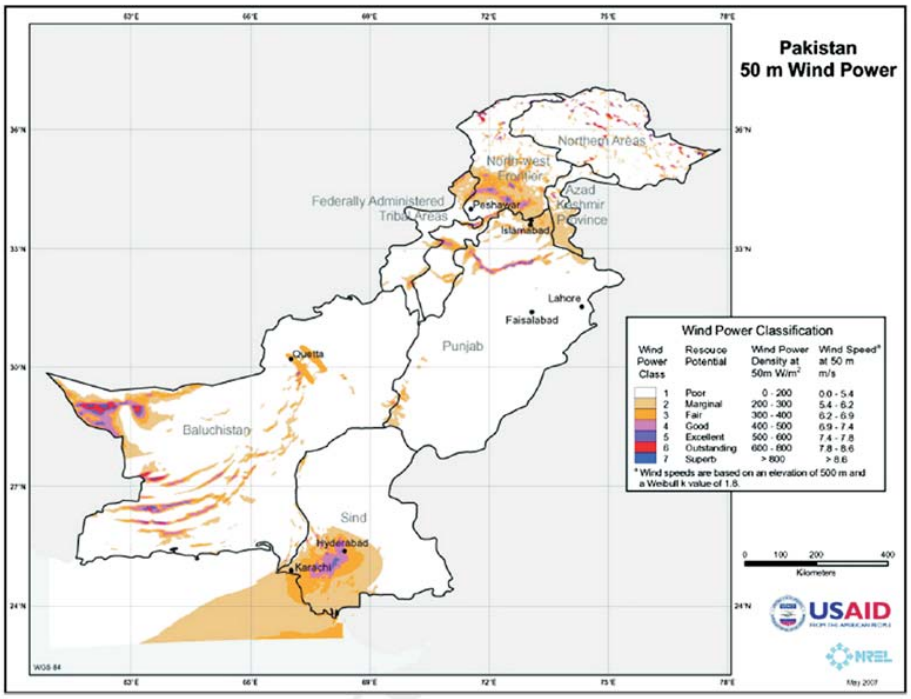


Figure-5: Wind Map of Pakistan

* The author has not been able to get the data as to whether these wind turbines are still producing electricity or not.

and is located far from physical infrastructures. Such remote population can greatly benefit from renewable energy sources. Besides, there is an immense potential for exploiting water falls in the canal networks, particularly in the Punjab province of Pakistan, where low head high discharge exists on many canals. The potential is estimated to be around 350 MW. The Government of Punjab has recently started exploiting this potential through the private sector. Punjab Power Development Board (PPDB) has started facilitating various projects of around 100 MWs in Punjab.

Pakistan also has commenced development of Micro Hydro Kaplan Turbine in a local industry for beneficial utilization of available low head in the canal system of Pakistan. A total of 228 run-of-river type plants with a total capacity of 3 MW have so far been installed in the Khyber Pakhtunkhwa Province of Pakistan. These plants not only provide electricity for light at night but are also used to run small industrial units, such as flour mills for wheat and maize thrashing, and cotton ginning during the day time when electricity is not required for lighting.

5.4 Biomass

Millions of tons of solid biomass comprised of cotton and wheat stalks, rice husk, corn cobs and other crop residues are produced in Pakistan annually. Wheat stalk is used as feed for the livestock. Except for use of this resource by rural households, mainly for cooking, the biomass is not being used for power-generation on a wide scale. Some companies use solid biomass residues to burn in boilers to generate steam for power generation. Burning biomass is not efficient from an energy conversion point of view. World is now using new technologies like gasification that uses controlled conditions of temperature and oxygen level to convert the original biomass feedstock into producer gas or wood gas (if the feedstock is wood) and more heat content of the biomass is captured.

There is a huge potential of generating electricity from biomass in Pakistan. Only the sugar industry has a potential of producing more than 1,000 MWs of electricity from bagasse. Private Power Infrastructure Board (PPIB) of Government of Pakistan has already announced a cogeneration policy for the fast track development of electricity from bagasse. Experts suggest that biomass can also play a vital role in reviving SMEs for fulfilling their requirements of electricity and heat if they start installing their own biomass projects in the 500 kW to 5 MW range (PPIB, 2008). Moreover, being clean and renewable, it will also contribute towards environmental protection, sustenance of ecosystem and conservation of the biodiversity.

5.5 Other Renewable Energy Sources

In addition to the sources mentioned above, Pakistan is also blessed with the following other renewable energy sources:

- Biogas;
- Geo-thermal;
- Tidal / wave; and
- Bio-fuels Biodiesel and Ethanol.

6. ISSUES AND CHALLENGES

Introduction of renewable energies at a large scale for both on-grid and off-grid applications in Pakistan have many issues and challenges. These are listed below:

6.1 On-Grid

- Success stories need to be created which can be replicated.
- Integrated policy and attractive FITs feed in tariffs are required for each technology to be exploited, like wind, solar, hydro, etc.
- Circular debt and the ability of the utility to pay is one of the biggest challenges at this time.
- Investment capacity of the local banks to lend the projects is also a big issue as the foreign lenders are reluctant to come to Pakistan in the current geo-political scenario.
- Security situation of the country is also a key threat at this time. Foreign investors are reluctant to come to Pakistan.
- R&D and adoption of appropriate technology is also a key challenge under the current circumstances. No university is geared up to take this role.
- Capacity issues are there in public sector institutions, private sector and also among financial institutions.

6.2 Off-Grid

According to a report published by the International Energy Agency (IEA, 2011), 38 % people in Pakistan remain without access to electricity. More than half of the rural population currently has no access to electricity, forcing them to live a sub-standard life of poverty and social inequity.

Water and Power Development Authority (WAPDA) of

Pakistan estimates indicate that there are over 40,000 villages across the country that cannot be provided electricity as it would not be technically and economically viable to extend the national grid to the rural areas. Out of these 40,000 villages, 6,968 have been identified in Balochistan. Renewable energy can be effectively used for sustainable development and poverty alleviation in these areas by enhancing sustainable livelihood opportunities. Rural demands for electricity pertain to, and are not limited to, lighting, heating & cooking, clean drinking water, agro-industries, small commercial and manufacturing establishments and production uses, e.g., water/irrigation pumping, crop processing, refrigeration, and motive power.

Following key challenges are there for introduction of renewable energy in off-grid areas:

- Lack of information prevents the outreach in rural areas in Pakistan. There is very limited information available on both demand and supply. Base-line information about the energy needs assessment of people living in the rural off-grid areas is not available. There is limited knowledge available to the potential investors/technology suppliers/microfinance institutions about the potential clients and their needs, which is required to take initiatives to serve in these areas. Also, the people living in these areas or the clients are unaware of the resources where they can tap into solve their energy-related problems due to poor physical and social infrastructure.
- Operations & Maintenance issues as well as unavailability of trained technicians in such remote areas.
- Risk Perception because it is a new product for a new market alongwith the high cost of renewable energy equipment is also a concern. Most of the people living in the off-grid areas are at or below the poverty borderline and have insufficient capacities to pay their electricity bills.
- Unstable, volatile and explosive law and order situation in both Khyber Pakhtoon Khawa and Balochistan poses a serious challenge.

7. CONCLUSIONS

Both the developed and the developing countries have realized that the key to attaining and maintaining prosperity and sovereignty is having independence and self-reliance in access to and subsequent use of energy. Coupled with the responsibility of keeping the climate change under check for the sake of the future of our world; this has led to an all-time high emphasis on utilization of renewable energy resources world wide.

Perhaps one of the most relevant and unique application of renewable energy is its cross-cutting relevance with the Millennium Development Goals (MDGs). In particular, the following MDGs link the role of Renewable Energy to social equity and sustainable development:

MDG 1: Eradicate Extreme Poverty and Hunger
MDG 7: Ensure Environmental Sustainability

Target: Integrate the principles of sustainable development into country policies and programmes; reverse loss of environmental resources.

Pakistan is currently facing a two-pronged crisis of threat to its Energy Security and an alarmingly low Human Development Index (HDI). Effective use of renewable energy can successfully address both these issues by improving the quality of life of the under-developed population, economic empowerment of the socially deprived and contribute to achieving the MDGs.

Opportunities exist for investors, developers, manufacturers, lenders and other players to exploit the Pakistani renewable energy market. The Government has the opportunity to use renewable energies to overcome the existing energy crises and create job opportunities. The key challenge for the government is to give confidence to investors under the current security scenario, along with an assurance to address the circular debt issue for on-grid power projects.

Pakistan s government has to create an enabling environment for off-grid electrification of villages and needs to create success stories. Microfinance models used in Bangladesh for renewable energy village electrification can be replicated to create success stories. Renewable energy can be effectively used for sustainable development and poverty alleviation in these areas by enhancing sustainable livelihood opportunities.

The potential is huge and renewable energy can play a vital role to achieve energy security, supplement the on-grid electricity and change the lives of people living in rural areas. Out-of-the-box thinking and innovative solutions need to be evolved to create success stories.

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BIOETHANOL: A SUSTAINABLE AND ENVIRONMENT FRIENDLY SOLUTION FOR PAKISTAN

*Muhammad Arshad**

ABSTRACT

Ethanol has the potential to reduce total dependence on fossil fuels for energy needs and mitigate environmental pollution. Presently, it is substituting approximately 3 % of the fossil-based gasoline consumed world over. In Pakistan, bioethanol is produced through fermentation of sugarcane molasses. Petrol consumption in Pakistan is approximately 1.6 million tons, and 10 % blending of ethanol can give rise to 160,000 tons of fuel ethanol consumption. Pakistan has the capacity to produce this quantity of ethanol from sugarcane molasses. By implementing an ethanol blending programme, the environmental benefits, particularly reduced emission of greenhouse gases, can be achieved. This will also help to meet the future energy needs as well as save the national exchequer.

1. INTRODUCTION

Lately, there has been a universal consensus that global warming is predominantly due to greenhouse gases (GHG), including nitrous oxide (N_2O) and, especially, carbon dioxide (CO_2) and methane (CH_4). This distress forced many nations to reach agreement on Kyoto Protocol (1997). Pakistan ratified the Kyoto Protocol on Climate Change in 2004 and weighted the scientific innovation's potential as a way to tackle GHG emissions (Daily Times, 2004). Kyoto targets have not been met so far. The reality is that the situation is likely to become more complicated in the next few years.

About 27 % of primary energy worldwide is used for transportation (EIA, 2006). Approximately 28 % of the energy in the EU25 countries is consumed by transportation, of which, more than 80 % is for road transport (Eurostat, 2007). Transportation fuels are thus promising targets for reduction in GHG emissions. Existing requirement of oil is about 12 million tons a day (Qin, et al., 2007) with a projection to increase to 16 million tons per day by 2030. While 30 % of the global oil consumption accounts for transport; a striking 60 % of the rising demand is expected till 2030.

The share of petroleum products is about 40 per cent in the current energy-mix in Pakistan. Its consumption has grown sharply, dominated by gasoline and fuel oil. Gasoline is mainly consumed by transport sector by public and private sectors (Business Recorder, 2011).

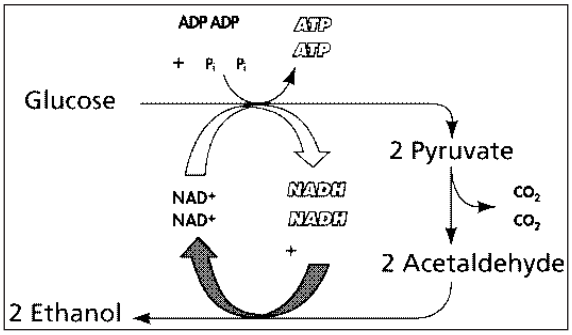
The availability of conventional oil is geographically restricted and a general agreement now is that the era of cheap and secure oil (cheap energy) is over.

In an attempt to replace natural gas and oil in the transport sector, numerous substitutes are currently being explored (photovoltaics, wind and nuclear power). However, there is bioethanol that emerged as a real alternative to the use of gasoline and conventional diesel used in transportation. An exponential increase in consumption of such biofuels has taken place in the last few years.

2. PROCESS FOR BIOETHANOL PRODUCTION

Saccharomyces cerevisiae is the principal organism for bioethanol production, capable of metabolizing glucose, fructose, mannose, galactose, sucrose, maltose, and maltotriose. Embden-Myerhof-Parnas (EMP) pathway (Figure-1) is utilized for ethanol production by *S. cerevisiae.*

In the simplest form, ethanol formation from glucose can be shown as following:



The theoretical yield is 0.511 g ethanol produced per gram glucose consumed. Practically, this yield can never be attained because not all of the glucose consumed is converted to ethanol but part of it is used for cell mass synthesis, cell maintenance, and production of by-products, such as glycerol, acetic acid, lactic acid, and succinic acid. However, at industrial scale, it remains 90 to 95 per cent of the theoretical yield under ideal conditions.

3. SUBSTRATE

Molasses, a byproduct remainant after the formation of raw-cane sugar from sugarcane juice (Hugot and Jenkins, 1986) containing some high value

* Assistant Professor, Department of Biochemistry & Biotechnology, The Islamia University of Bahawalpur, Bahawalpur, Pakistan.
Email: chauhdary.arshad@gmail.com

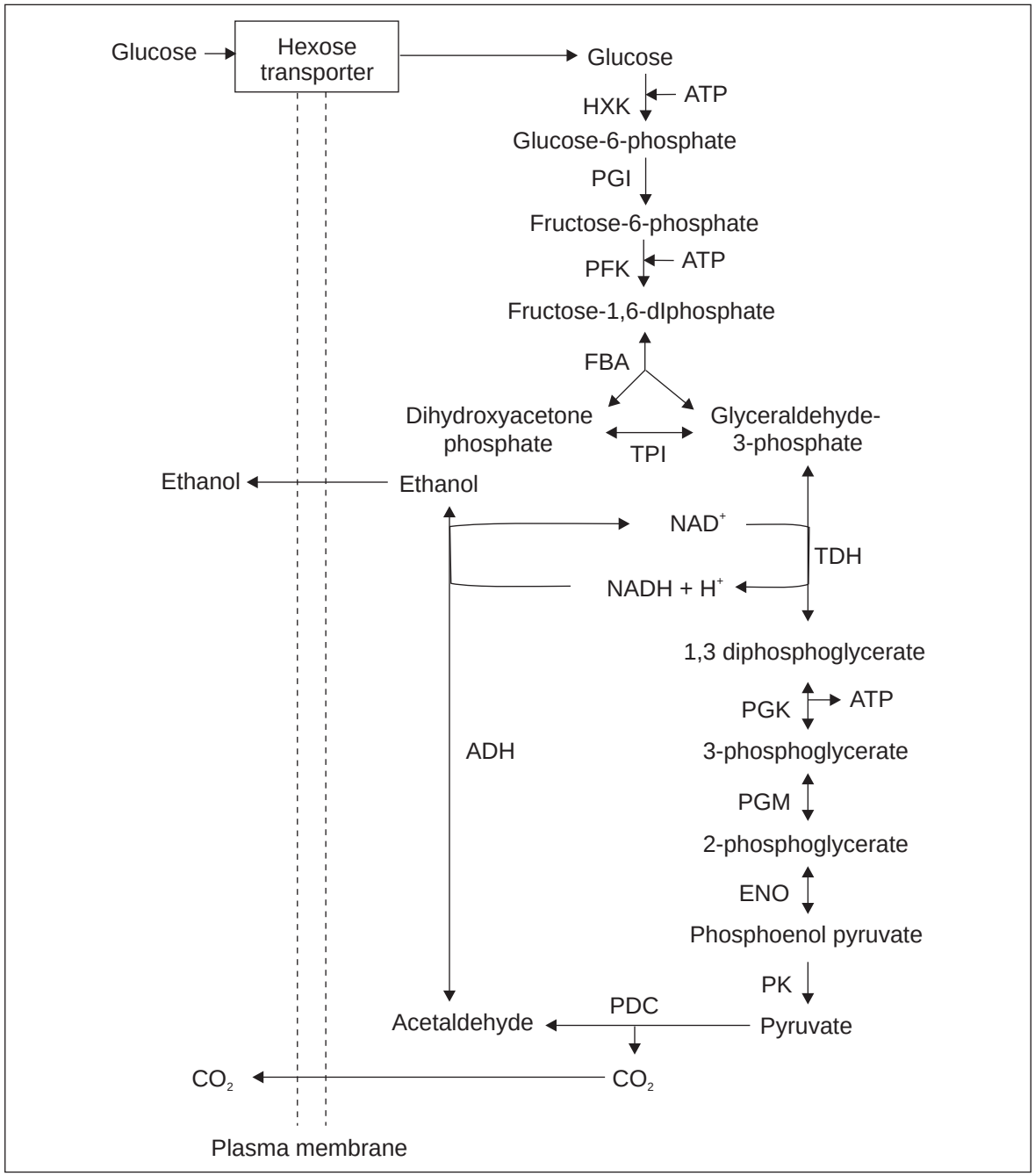


Figure-1: The Glycolytic Pathway for Ethanol Production in *S. cerevisiae*
Note: *(HXK: hexokinase; PGI: phosphoglucose insomerase; PFK: phosphofructokinase; FBA: fructose bisphosphate aldolase; TDI: triose phosphate isomerase; TD: triose phosphate dehydrogenase; PGK: 3-phosphoglycerate kinase; PGM: phosphoglycerate mutase; ENO: enolase; PK: pyruvate kinase; PDC: pyruvate decarboxylase; ADH: alcohol dehydrogenase)*

disaccharides and monosaccharides with minerals that are regarded as impurities in raw sugar. The fermentable sugar content of molasses varies inversely with the purity of the raw sugar produced at the factory. Molasses is a low value product that is used as cattle feed supplement, in specialized yeast propagation or as a flavoring agent in some foods (Troiani, 2008).

4. POSSIBLE BENEFITS FROM THE USE OF BIOETHANOL IN PAKISTAN

4.1 Reduced Emissions

Ethanol contains oxygen while the amount of carbon monoxide (CO) and unburnt hydrocarbons in the exhaust is reduced considerably. With introduction of ethanol in fuel-mix for transportation in Brazil, CO emission from automobiles decreased from 50 g/km in 1980 to 5.8 g/km in 1995 (Goldemberg, 2008).

One of the disadvantages in using pure ethanol is that aldehyde emissions are higher than those of gasoline, but it must be observed that these aldehyde emissions are predominantly acetaldehydes. Acetaldehydes emissions generate less adverse health effects when compared to formaldehydes emitted from gasoline engines.

4.2 Reduction in Greenhouse Gas Emissions

The net CO_2 emission of burning a biofuel, like ethanol, is zero since the CO_2 emitted on combustion is equal to that absorbed from the atmosphere by photosynthesis during the growth of the plant (sugarcane) used to manufacture ethanol. This is illustrated by the following equations:

$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6$ (plant sugar) $+ 6O_2$ (photosynthesis)

$C_6H_{12}O_6 + 3H_2O \rightarrow 3C_2H_5OH$ (ethanol) $+ 3O_2$ (hydrolysis and fermentation) of glucose

$3C_2H_5OH + 9O_2 \rightarrow 6CO_2 + 9H_2O$ (combustion of ethanol)

Life cycle analysis from well to wheels shows that ethanol has the lowest CO_2 emission among the major transportation fuels. Ethanol can thus contribute significantly to climate change mitigation by reducing CO_2 emissions.

4.3 Increased Employment

The bioethanol sector has the potential to serve as a source of substantial employment opportunities. A programme that generates employment is always particularly welcome in countries like Pakistan. The investment in ethanol industry in terms of job creation is significantly less than the job in the petroleum field. In Pakistan, the sugar industry, which is the backbone of ethanol production, is the biggest agro-industry. The sugar industry is the source of the livelihood of farmers and their dependants, comprising 70 per cent of the population. A few others are employed as skilled or semi-skilled labourers in sugarcane cultivation. Distilleries are the source of additional employment (Arshad, 2009). Direct employment in a distillery unit is approximately 60 persons. Persons having different backgrounds like biochemistry, microbiology and chemical engineering are required for the operation. Undoubtedly, Pakistan is an agricultural country due to which it has an immense potential to produce ethanol as a fuel. The existing production capacity of fuel-grade ethanol in the country is 270,000 tonnes per annum, which can be easily increased to 400,000 tonnes per annum with the increase in jobs. However, the bulk of raw molasses is exported, and only minor quantities are converted into industrial alcohol for domestic use and exports. This results in the loss of foreign exchange and employment opportunities.

4.4 Energy Security and Decreased Dependence on Oil Imports

Pakistan's energy demand is expected to grow exponentially each year. Pakistan's domestic production of crude oil currently satisfies only about 25 per cent of the country's consumption. Dependence on imported fuels leaves Pakistan's economy vulnerable to possible disruptions in supplies, which may result in physical hardships and economic burdens. The volatility of oil prices poses great risks for the world's economic and political stability, with unusually dramatic effects on energy-importing developing nations. Renewable energy, including biofuels, can help diversify energy supply and increase energy security, offering a favourable trade balance with saving of foreign exchange.

4.5 Good Fuel Properties

Due to high heat of vaporization, high octane number/rating and low flame temperatures, ethanol becomes an excellent fuel for transportation. Ethanol has an octane number of 120, much higher than that of petrol which is approximately 108.6. Thus, ethanol blending increases the octane number without having to add a carcinogenic substance like benzene or a health-risk posing chemical like methyl tertiary butyl ether (MTBE). The energy content of ethanol is only

26.9 MJ/kg compared to 44.0 MJ/kg for petrol. This would suggest that the fuel economy (km/litre) of a petrol-powered engine would be 38.9 per cent higher than that of an ethanol-powered engine. In actuality, this difference is 30 per cent since ethanol engines can run more efficiently (at a higher compression ratio) because of the higher octane rating. For a 10 per cent ethanol blend, the fuel economy advantage of a petrol engine is only 3 per cent. The flammability limit of ethanol (19 per cent in air) is higher than that of petrol (7.6 per cent), and similarly the auto-ignition temperature of ethanol is higher than that of petrol (363° vs. 280°). Thus, ethanol is safer than petrol due to the lower likelihood of catching fire. Further advantages of ethanol usage is that it:

- requires no change in existing engines (E-10);
- yields good engine performance;
- burns clean and more efficiently;
- is more biodegradable; as well as
- consistent with the global focus on biofuel.

List of some of the countries that are implementing biofuel programmes is given in Table-1.

5. ETHANOL INDUSTRY IN PAKISTAN

Molasses fermentation is done for ethanol production in Pakistan. The yield of sugar on average is approximately 85-95 kg per ton of cane. About 40 kg of molasses is produced per ton of cane from which about 10 litres of ethanol can be obtained. If the sugarcane is directly and fully used in ethanol manufacture, the yield of ethanol is 70 litres per ton. Currently, 21 distilleries produce industrial alcohol in the country. As many as eight distilleries have so far installed the molecular sieve technology to process industrial ethanol into fuel ethanol. Most of these distilleries are a part of sugar mills and are situated on-site, making the production cycle an integrated one.

6. ECONOMICS/COST OF ETHANOL PRODUCTION

By exporting molasses, only US$100 million can be earned, while by using raw molasses to produce blended ethanol fuel, Pakistan can save precious foreign exchange of about $600 million (Sibtain, 2009). Assuming an ethanol yield of 250 litres/ton of molasses, the raw material cost of ethanol is Rs. 9000/250 = Rs. 36/litre ($0.40/litre). After adding salary and wages of operational staff, capital related charges of investment, energy cost of producing anhydrous alcohol, the cost of transport and marketing, the cost of producing ethanol directly from sugarcane molasses is Rs. 45/litre ($0.53/litre). This compares favorably with the current world price of petrol. By using the spent wash more efficiently, ethanol price can be brought down further. Produced in large quantity (about 15 litres per litre of ethanol produced), can be subjected to anaerobic digestion that not only removes its BOD and COD but also

Table-1: List of Some of the Countries Implementing Biofuel Programmes

Country	Blending	Since		Country	Blending	Since
Brazil	E 24-26	1970		Costa Rica	E –07	2008
Thailand	E-10 E-20	2000 2008		EU	E-02 E-10	2003 2005
China	E-10	2004		Ireland	E-05	2007
Japan	E-03	2007		Bulgaria	E-05	2008
Australia	E-02	2002		Philippines	E-05	200
India	E-05 E-10	2003 2008		Colombia	E-05 E-10	2003 2008
Taiwan	E-03	2007		USA	E-10	2004
Netherland	E-02	2006		Canada	E-7.5	2005
Sweden	E-05			Pakistan	E-10	2006 & 2009

Source: *Antoni, D., Zverlov, V.V., and Schwarz, W.H., 2007.*

provides valuable biogas (60 per cent methane). This biogas can be used to offset 67 per cent of the energy cost of making anhydrous alcohol through distillation.

7. GASOLINE VS. ETHANOL

Ethanol is an oxygenate fuel, which means it has a more complete combustion than gasoline. Also, ethanol is a much slower burning fuel; it has an octane rating of 110, whereas regular unleaded gasoline has a rating of 87. The production and distribution of one cubic meter of ethanol results in emissions of 457 kg of CO_2 equivalent, which is very less as compared to gasoline (Oliveira, 2008).

8. A WAY FORWARD FOR PAKISTAN

Pakistan State Oil (PSO) has launched E-10 gasoline pilot project at designated retail outlets in Karachi, Lahore and Islamabad. It is based on a detailed feasibility study conducted by the Hydrocarbon Development Institute of Pakistan (HDIP). The new fuel —10 % ethanol blended with motor gasoline — is being introduced experimentally as part of government's strategy to promote alternative energy resources. The pilot project was conducted for 6 months, with 25 pre-identified vehicles using ethanol-blended gasoline in each city. The monitoring of these vehicles was carried out by HDIP. Based on the results of the project, the blended fuel would be made available throughout the country. Pakistan's sugar industry has a capacity of producing four billion liters of ethanol annually (Umar, Nasir and Tariq, 2008)

In July 2006, PSO took the initiative to launch the pilot project of ethanol filling station in Pakistan. Although PSO in collaboration with Hydrocarbon Development Institute of Pakistan (HDIP), initiated a pilot project to introduce ethanol fuel blended with gasoline in a 1:9 ratio (E10) at three petrol pumps in Karachi, Lahore and Islamabad, this venture failed due to lack of coordination among various stakeholders, and gaps at planning and implementation stages.
The Economic Coordination Committee (ECC) of the Federal Cabinet of Pakistan has decided to allow marketing of Ethanol-10 as motor vehicle fuel on trial basis at PSO stations.

The ECC met under the chairmanship of Shaukat Tareen, Adviser to PM on Finance and Economic Affairs at the Prime Minister's Secretariat. The decision to allow marketing of E-10 was taken to reduce reliance on imported petroleum products, to the extent possible through use of appropriate indigenous blendable substitutes. Anhydrous Ethanol (Ethanol with less than 1 % water) is one such product, which can be blended with gasoline in varying proportions. Most gasoline vehicle engines operate well with mixtures having 10 percent Ethanol E-10. The ECC further decided that Ethanol-10 would be treated as motor vehicle fuel (Sajid, 2010).

Government of Pakistan imposed a 15 % duty on molasses export to favour the use of molasses for ethanol production rather than export. Achievement of cheap and renewable energy has become an important issue in energy management and economic development in all the countries.

If all molasses produced is converted to ethanol, it can replace 5-7 % of gasoline. It will be a significant contribution to the overloaded economy. Pakistani government should formulate policy to implement the initiative of blending ethanol in transportation fuels as soon as possible.

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ENERGY-EFFICIENT BUILDINGS IN PAKISTAN

Ahmed Sohail and*
*Moin ud Din Qureshi**†*

ABSTRACT

Pakistan is one of the countries with the highest energy consumption for domestic use. Annual energy consumption by the domestic sector is 45.9 % of the total, while the industrial sector, consumes about 27.5 %. About half of the total energy consumed is used in buildings and/or heating, ventilation and air-conditioning (HVAC) and lighting appliances. The energy consumed for the same purposes in China and UK is 25 to 30 % and 40 %, respectively, even in extreme weather conditions.

Energy deficiency in Pakistan is approximately 5,000 MWe, which results in worst load-shedding in summers and, lately, even in winters. Building new energy sources like dams, coal power plants and renewable energy power projects are some possible solutions, but these are time taking and need at least 2 to 6 years to complete, depending upon the nature of the project.

Fast development of energy-efficient buildings is, therefore, necessary to deal with exacerbating energy-crisis and related environmental impact in Pakistan. Innovations in the prevailing building-design will help the country in reducing the energy burden. These innovations may include improved architectural designs, energy-efficient building materials, electrical appliances and implementation of building energy-efficiency codes. In 1987, the National Energy Conservation Centre (ENERCON), Pakistan, was established under Ministry of Environment, Government of Pakistan, with the aim to build awareness among the masses for energy-conservation, and to make policies regarding energy-conservation structures in the country. But no policy regarding building energy codes has been introduced by ENERCON till now.

In collaboration with Pakistan Engineering Council (PEC), ENERCON has recently finalized the Building Energy Code of Pakistan Energy Provisions 2011 for which statutory notification is under process for necessary amendment in the building by-laws. The implementation of this Energy Code will result in 25 to 30 % of energy savings in the new buildings. This paper discusses important aspects of energy-conservation through building of energy-efficient structures, while taking into account their geographic location, cost-effectiveness, trade-offs and aesthetics.

1. INTRODUCTION

Pakistan is a highly energy-deficient country. The energy consumption per capita for Pakistan is 475 kWh/annum and is 164th on world ranking, while USA is at number 9 with per capita consumption of 12,924 kWh/year. Whereas, world's average consumption per capita is 2,500 kWh/year. Pakistan's installed energy capacity is approximately 19,500 MWe, out of which only about 13,500 MWe is being produced. It is one of those countries in the world that generate its maximum share of electricity from thermal source. The share of thermal energy in Pakistan's energy mix is approximately 70 % and its efficiency is merely 35 to 40 % (Haleel, 2009).

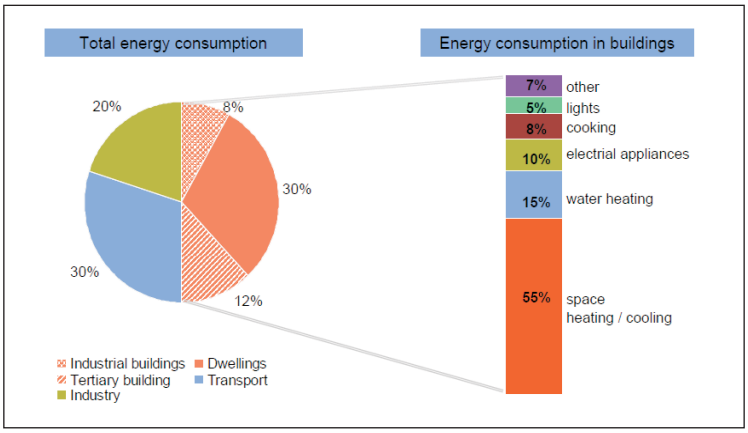
Under this scenario, energy-conservation seems to be the only way out. Pakistan is situated on latitudes between 24^{o}N and 35^{o}N, which means that 70 % of the country remains in sunny and hot climate throughout the year. Thus the major energy use is for cooling and should be the main concern while designing buildings. But, unfortunately, after consuming 55 % of the national energy resources, buildings in the country are still unable to provide a comfortable living atmosphere.

More than one-thirds of the world's energy is used in buildings; the majority of that energy is used in houses and apartments (Clarke and Maver, 1991). A lot of money can be saved to deal with the prevalent energy-crisis by building energy-efficient houses and buildings. Such buildings would conserve a lot of energy that is normally wasted in ordinary dwellings. An energy-efficient new house uses only 10 % to 30 % of the energy used by a house of similar size that is built according to usual contemporary standards. The small additional costs of thermal design may be recovered quickly, and the energy-efficient homes will reduce dependence on expensive and unreliable energy resources.

2. WORLD SCENARIOS

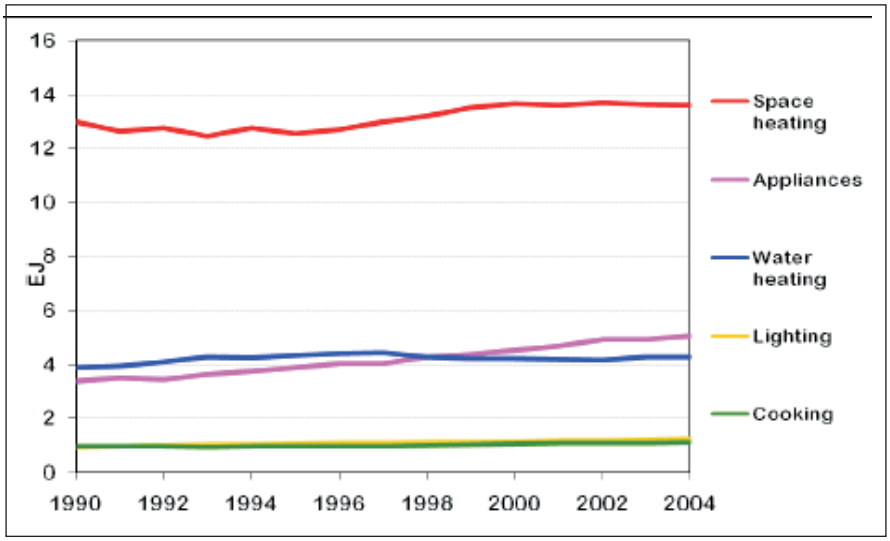
Earlier, energy-efficiency measures for buildings resulted in poor insulation levels, which could lead to health problems because of humidity or air-infiltration. Before the oil crisis in 1973/74, most regulations for energy-efficiency in buildings came from the northern regions (European countries) that are cold enough to considerably influence public health (Figure-1). Requirements on specific constructions, with some thermal characteristics in these regions, first appeared

* College of Electrical & Mechanical Engg., National University of Sciences and Technology (NUST), Rawalpindi, Pakistan.
** College of E&ME, NUST, Rawalpindi, Pakistan. †Email: engrmoinqureshi@gmail.com



Source: *DG TREN, European Commission*

Figure-1: Total Energy Consumption by Buildings in Non-Energy Efficient Scenario



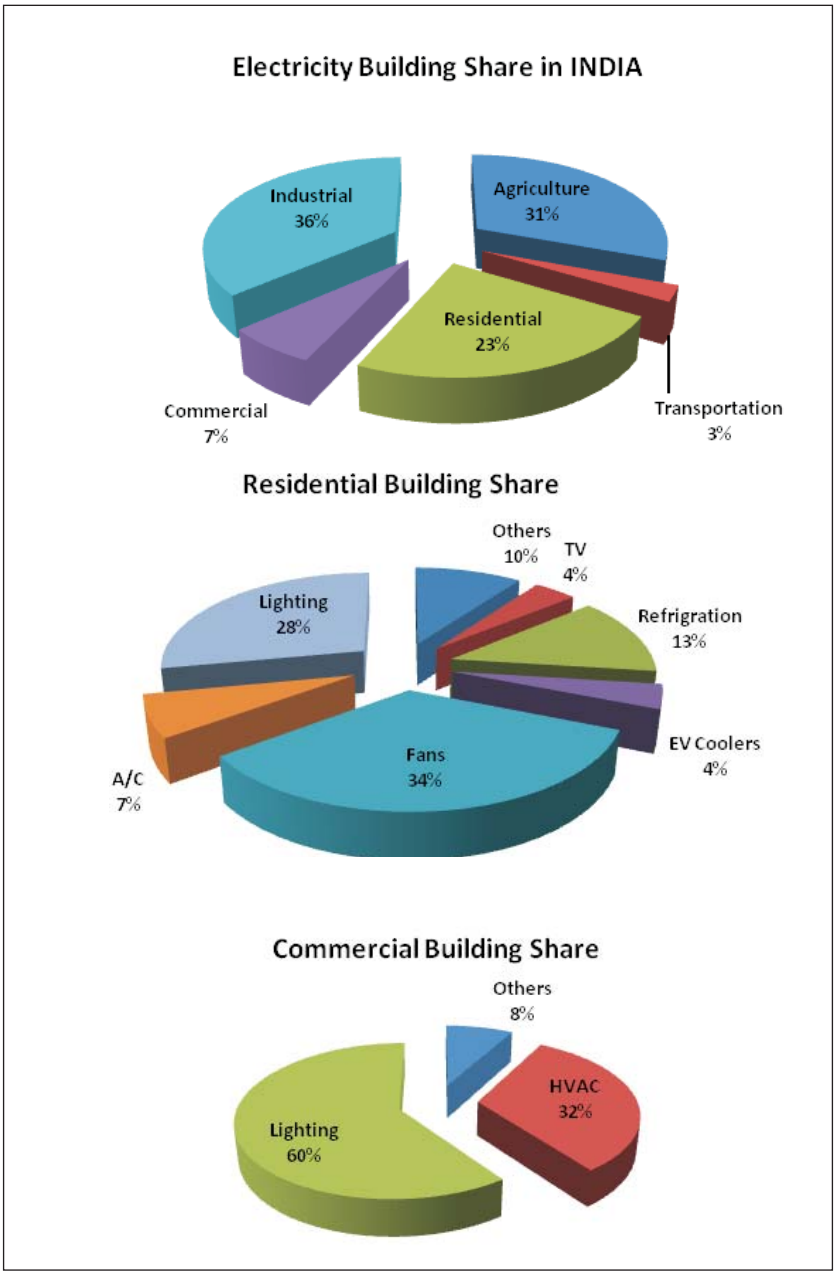
Source: *30 Years of Energy use in IEA Countries (Lausten, 2008)*

Figure-2: Energy Usage Proportion in IEA Countries

during the period between the two World Wars, when some countries regulated the introduction of simple insulation in the form of air layers in cavity walls or double layer floors of timber beam.

The first real insulation requirements for the U-values 10, R-values and specific insulation materials or multi-glazing, date back to the late 1950s and the early 1960s in Scandinavian countries. These insulation requirements were developed to improve energy-efficiency and comfort in buildings. Comfort was the prime motivation for raising the requirements – in view of increasing standard of living, people demanded better and improved living conditions.

In many countries, the oil supply crisis of the early 1970s catalysed the development of energy-efficiency requirements for buildings. These countries already enforcing efficiency-regulations generally raised their requirements during the early 1970s to further reduce energy-consumption and decrease dependence on oil. During the 1980s and 1990s, the energy-efficiency requirements were set or increased in most of the member countries of International Energy Agency (IEA) and Organisation for Economic Cooperation and Development (OECD). The reason for focusing on

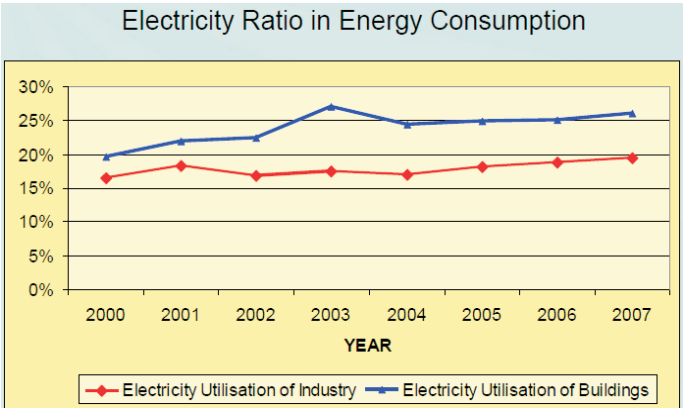


Source: *The Bureau of Energy Efficiency (BEE), 2008*

Figure-3: Total Energy Consumption by Buildings in India

OECD countries is that these nations are among the highest per-capita electricity consumers. The graph of electricity consumption in IEA member countries from 1990 to 2004 (Figure-2), shows that more than 50 % of the share was used for space heating and cooling (Lausten, 2008).

Rapidly developing countries having the economic capacity to install cooling or heating systems, such as India and China, seek to improve comfort and reduce the dramatic increase in energy-consumption by regulating energy-efficiency in buildings. Examples of India and Turkey are elucidated below:



Source: *Electrical Power Resources Survey and Development Administration (EIE),Turkey*

Figure-4: Electricity Ratio in Industry and Buildings, Turkey

2.1 India

The Bureau of Energy Efficiency (BEE) was set up in March 2002, under the provisions of the Energy Conservation Act (2001), to provide a legal framework for the government's energy-efficiency initiatives in the country.

Being the emerging economic giant in Asia, India has raised its electricity consumption per capita from 402 kWh/year in the year 2000 to 571 kWh/year in 2009. The Indian government is striving hard to harness the demand vs. production ratio. In this regard, the Energy Conservation Act (2001) was constituted (BEE, 2008).

Having the primary objective of reducing energy intensity of the Indian economy, the Bureau's mission is to develop policies and strategies with a thrust on self-regulation and market-principles.

2.1.1 Energy Conservation Building Code (ECBC) Development Process

An extensive data collection was carried out for construction types and materials, glass types, insulation materials, lighting and HVAC equipment (see Figure-3). Furthermore,

- base-case simulation models were developed;
- stringency analysis was done through detailed energy and life-cycle cost analysis;
- a stringency-level for each code component was established;
- a code was finalized.

The code was launched on 27th May 2007 with focus on commercial buildings and new construction. The code on building components included:

- Building envelope (walls, roofs, windows);
- Lighting (indoor and outdoor);
- Heating ventilation and air-conditioning (HVAC) System;
- Solar-water heating and pumping;
- Electrical systems (power factor, transformers).

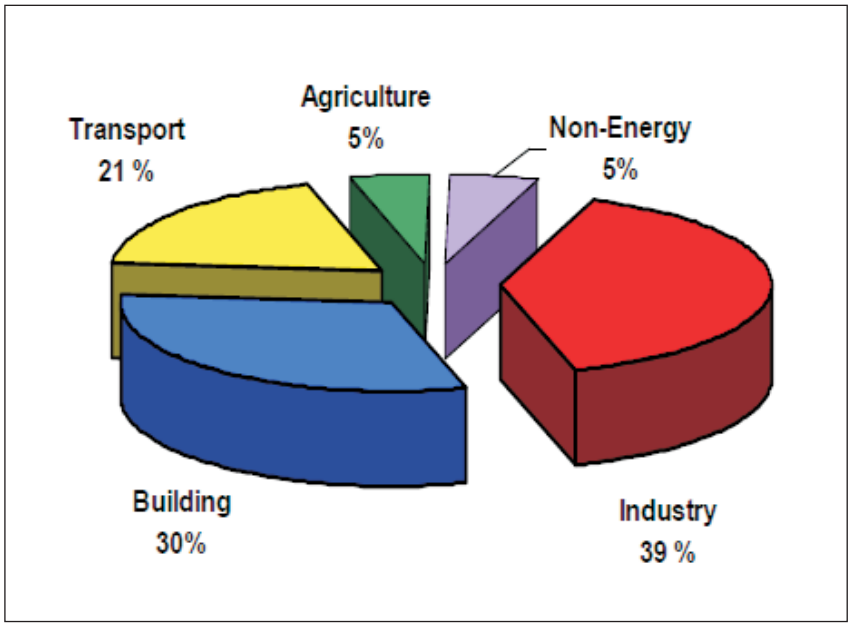
2.2 Turkey

Due to its effective energy-efficiency policies for buildings, electricity consumption in Turkey was reduced to 25 to 30 %, against the average of 50 % as seen earlier (Figure-4). The total population of Turkey is 70.5 million and per capita electricity consumption is 2,692 kWh/yr (Keskin, 2008).

2.2.1 Energy-efficiency Activities

An Energy Efficiency Policy was prepared by Turkish Ministry of Energy and Natural Resources (MENR), followed by:

- Energy-efficiency implementation by the General Directorate of Electrical Power Resources Survey and Development Administration;
- Some energy-efficiency projects supported by international donors, such as UNIDO, the World Bank, JICA, GTZ, and the European Union;
- The goals of capacity-building and awareness raising was achieved to some extent although big-scale energy-efficiency enhancement was not ensured in all sectors;
- Preparation and adoption of 'Energy Efficiency Strategy' by MENR for Turkey in June 2004.



Source: *Electrical Power Resources Survey and Development Administration (EIE), Turkey*

Figure-5: Electricity Ratio (by Sectors), Turkey

Turkey's industry has one of the best energy management system that can serve as a good example for other countries (Figure-5). Almost 1,000 energy managers were trained and certified in a programme comprising lectures and practical applications on energy-management methods (Buyukmihci and Calikoglu, 2009). With this programme in industrial plants, which consume more than 2,000 TOE energy, a perceptible energy-efficiency increase was achieved. Under the Energy Audit Scheme, more than 100 plants were audited. The mandatory regulation for heat insulation in new buildings, labeling of household equipment, air conditioners and lamps are some other effectively implemented programmes.

2.2.2 How it Works

The Ministry of Public Works and Settlement (MPWS) is the body responsible for enforcing the regulatory framework of the building sector in Turkey.

- The Building Standard (TS-825), sets thermal insulation standards for new buildings and at renovations of existing buildings with 15 % ratio or more (mandatory since 2000).
- Regulation on heating insulation in buildings was last revised in October 2008. After the 1999 earthquake, building inspection agencies were established in 19 provinces in 2001 to carry out inspection of buildings. These agencies are also authorized to control new buildings' heat-insulation.

3. TYPES OF REGULATIONS

Energy-efficiency requirements can be set in different ways and methods as referred by the IEA. These are:

3.1 Prescriptive Method

When using the prescriptive method, energy-efficiency requirements are set for each component of the building. This could be a thermal value (U-value) for windows, roofs or walls. The prescriptive method can include efficiency values for technical installation, ventilation, orientation of buildings, solar gains, and the number and size of windows. To comply with a prescriptive standard, each part of a building must meet its specific prescribed value.

A simple version of a prescriptive building-code set thermal values for the essential 5 to 10 building parts. In the most complicated systems, energy-efficiency requirements are set for all parts of the building and installations, including heating installation, cooling units, pumps, fans, and lighting. In some cases, these requirements are even adjusted according to the size of the equipment/the size or the percentage of windows based on floor area/ the outer wall.

In general, instructions for the prescriptive method are easy to implement. U-values can be followed by descriptions of typical constructions that fulfill the needs, and the requirements for equipment can be combined with the labelling of products. A prescriptive method could require an appliance to be labelled 'A' or 'B', or rated with energy stars. Every product being used in the building has its green-star rating termed as 'labels' and it can be matched with the building specifications.

3.2 Trade-off Method

Trade-off method sets values for individual building parts and/or for parts of the installations, akin to the prescriptive method. However, in meeting a general standard for efficiency, a trade-off can be made between the efficiency of some parts and installations such that some values are exceeded while others are not met.

The trade-off is generally made in simple terms. Trade-off can be made between U-values for the building shell, or between the building shell and the energy-efficiency requirements for heating and cooling installations. The trade-off model provides more freedom and flexibility than the prescriptive method. The calculations are simple and can be done by hand or using a simple spreadsheet.

3.3 Model-building Method

In the model-building method, values are set for each building part and/or for the parts of the technical installations. Based on the values and the characteristics of the actual building, a model-building value is calculated with all the set values for losses and efficiency. This calculation follows a clearly defined method. The actual building is then calculated by the same method using the actual values for the individual building parts, heating, cooling, and ventilation systems. The total result of the calculation is compared with the model-building value and the actual building value must be better than that of the model-building.

The most complicated models take into account all parts of the technical systems in these calculations, including heating systems, ventilation, cooling, lighting, built-in equipment. Renewable energy can be included in the calculations to make a solar collector, for instance, reduce the general energy-efficiency requirements for the heating system or even the insulation level.

The model-building method gives more freedom and flexibility to architects and constructors than a prescriptive model. Expensive systems can be changed with improved efficiency in parts of the building or installations, where efficiency will be more cost-effective.

3.4 Energy-Frame Method

The energy-frame method for a building sets a maximum limit on energy-loss from the building. This is usually set as a total frame for the building, a value per square meter of the building area or as a combination. The energy-frame will then be followed by a procedure on how to calculate the energy losses from simple values, such as the U-values, temperature, surface and heat gains from sunlight. Values for the individual parts are not set in this model but only for total loss or use of energy.

This method enables the constructor to build parts of the buildings that are less energy-efficient when other parts are made better than typical constructions. For example, this method can, also help avoid limiting the size of the window area, as improved windows or increased insulation can adjust for the additional heat losses or larger sun gains by having a larger surface for windows. As long as the overall value is met, the building plan is approved.

The energy-frame method can also be defined as an overall thermal value (adjusted U-value), per square meter of building floor area. Again, it will be the constructor's decision to document that the building is built on the standard of the model-building given by the overall values.

Similar to the model-building method, the energy-frame method gives more flexibility in fulfilling the requirements and this can easily be adapted to the most economic solution. On the other hand, it increases the need for making complicated calculations.

3.5 Energy-performance Method

With the energy-performance method, a total requirement for the building is set based on the supply of energy or the resulting environmental impact, for instance, in form of CO_2 emissions. This method requires comprehensive calculations of the energy-performance of a building, with standard values for climate and use in different types of buildings. Constructors are required to use an advanced

computer-based model for the calculations, which integrates the values of all the different parts and installations of the building.

Values for energy-performance are set on the basis of an overall value – consumption per square meter or a mixture of the two – for different types of use or different types of buildings. Installations using renewable energy in the building will usually be calculated as improvement in performance. The energy-performance model requires handling multiple factors, such as solar gains, recovery of energy losses, shading and efficiency in installations.

In energy-performance method, comparing the use of different energy forms, such as heating (gas, oil or diesel) with the use of electricity is necessary. Depending on local energy conditions, there may be adjustments where some kWhs or GJ are valued higher than others or the comparison can be based on energy costs. In performance calculations, the maximum value is often set for the use of fossil fuels – primary energy use or as a maximum CO_2 emission. Free trade-offs can be made between insulation and installation of efficient equipment, but this trade-off should be based on the selection of fuels, the use of renewable energy, the primary design (form) of the building, use of daylight, and intelligent installations or automatics. Windows with better thermal values can be used to increase the window area or negative losses can be balanced out with positive gains as passive heating.

Energy-performance standards give optimal freedom to constructors or designers to reduce energy consumption within the frame. If efficient boilers or air conditioners are more cost-effective than improved insulation, the constructors can choose this alternative to improve performance. Similarly, it will be possible to substitute more expensive solutions in the building envelope with efficient renewable energy systems or by heat recovery. The model adapts to a change in prices, technical development and allows new solutions and products. There is a need to develop and maintain sophisticated calculation methods and computer tools that take all these important factors into account.

3.6 Mixed Models (Hybrids)

Some countries use a mix of all the afore-mentioned models. For example, an energy-frame for the building might be combined with prescriptive values for installed products. Another typical mixture is when building codes allow a choice between the simple approach with prescriptive values, an energy-performance or an energy-frame. The designers can, therefore, use a model that is simple to calculate, or choose a more complicated model that offers more freedom and flexibility. Sometimes both performance values and prescriptive values are set, whereby the prescriptive values are tighter than the value for the overall calculation. This ensures that buildings constructed after the prescriptive values, automatically fulfill the energy-frame or energy-performance requirements.

Some countries/states have two or more models that have to be followed at the same time. In this case, energy-efficiency requirements will grow from the prescriptive models over the energy-frame to energy-performance. The target is to ensure that no building part or component of the heating or cooling system is too poor to base the overall calculation on a model that gives more flexibility. The aim may also be to avoid moisture problems if building parts without insulation result in condensation, or to compensate for different lifetimes of components.

4. DEVELOPMENT

Most countries had started with prescriptive values. When energy-efficiency requirements increased and more elements were included, trade-offs or an overall frame allowing adjustments of the individual values was required. Today, energy-performance models and computer tools are being developed in many regions. International standardisation has been introduced with the aim of developing and harmonising models to calculate energy-performance.

At the same time, countries have decided to have several methods for compliance with regulations, which allow builders and constructors the flexibility to choose from a number of options. This is especially the case for small residential buildings where there is a general effort to make simple and comprehensive rules.

5. SCOPE OF BUILDING EFFICIENCY IN PAKISTAN

The biggest consumers of energy in housing are air-conditioning and heating (in extreme weather), while next in importance are refrigeration and water heating. The smallest energy uses in typical dwellings are for lighting, cooking, laundry and running miscellaneous electronics.

Optimization of a building, as per its usage and location, is the most important factor for energy-conservation. Buildings in southern parts of Pakistan, like Multan or Karachi, will require more cooling than heating. Similarly, requirements of lighting of building and most importantly their control (manual or automatic/timer based) will curtail the energy bill.

Todate, there is no Building Energy Efficiency Code in practice in Pakistan. Some suggestions and recommendations from different case studies, existing building codes and research for energy-conservation are given below:

6. THE LAYOUT AND STRUCTURE OF BUILDINGS

According to Donald (2003), the following measures can help make buildings energy-efficient:

6.1 Design a Layout Tailored to Energy-Usage

The primary purpose of a building layout is to provide pleasant living environment. A good layout allows convenient movement between rooms/ compartments, provides easy access to outside areas, exploits views, isolates noise, keeps one comfortable under all conditions, and does all this with elegance. For example, orientation of the living-room windows toward the waterfront or the mountains, and putting bedrooms on the quiet side of the house. At the same time, the layout should be used to minimize the energy requirements. One should create a core area that consists of the cluster of rooms more often used. Rooms that are occupied less frequently should be located outside the daily traffic pattern so that they do not need to be heated, cooled, or lighted most of the time. For example, locate guest bedrooms and storage rooms in a separate wing. In general, large spaces should be kept out of the daily traffic pattern.

Large rooms that are used occasionally may be thermally isolated from the rest of the house. For example, big halls that are occasionally used should be parted from the rest of the house with glass doors and partitions, to save cooling and heating costs. These allow to merge the large room with connected spaces when needed. If the temperature in an unoccupied space rises or falls a lot, it should be thermally isolated from the rest of the house by using doors and insulated interior walls.

If the house/building has more than one storey, provide convenient doors at the top or bottom of the stairs. The doors prevent uncomfortable temperature stratification and energy waste. The doors should be made as wide as the stairs to provide ample manoeuvring space near the stairs.

6.2 Installation of Insulation in the Walls, Roof, and Exposed Floors

Insulation is the primary tool to slash two biggest energy costs, heating and cooling. Unfortunately, there is not much awareness on this issue in Pakistan. In typical Pakistani weather, to install 12" of insulation in the walls and 16" to 20" of insulation in ceilings will be of good use. The contemporary building structure made of concrete and cement or baked clay blocks has no place to accommodate the above-mentioned insulation techniques. This calls for a big change in construction practices. Walls that are thick enough to accommodate adequate insulation require studs of the same width, which should be rigid and strong. Increasing the wall thickness does not greatly increase materials cost. Generally, conventional non-flammable glass or mineral fibre insulation is used for the walls, roof, and floors.

6.3 Rationalization of Windows and Skylight Areas

Windows and skylights create a large fraction of the total heating and cooling costs. Unfortunately, glazing remains a weak link in the energy-performance of the houses. Even the best windows have poor insulation value compared to insulated walls. Also, windows and skylights account for most cooling cost by allowing sunlight to enter the house directly. If the house has too much glass, no other improvement to the structure can compensate for this. It is like a boat that has a big hole in the hull. So, the use of glass should be planned wisely. The sight lines from inside the daytime rooms should be planned to get the best view in relation to the glass area. In bedrooms and bathrooms, the window sills should be high enough to provide privacy, as well as allowing the use of windows for lighting.

Glass allows good use of daylighting, which is pleasant if it is well-planned. However, lighting cost in houses is small, whereas heating and cooling costs are large. For commercial buildings, on the other hand, lighting may cost more than heating or cooling. Windows and skylights are light fixtures that cost a lot of money to install and operate, and should be planned accordingly.

6.4 Installation of Windows/Doors with Good Insulation and Excellent Weather Sealing

The insulation value of windows depends mainly on number of panes. For the windows that can be opened the models that close very tightly should be selected and stay tight for as long as the house stands. Slider and hinged windows are available in tight-sealing models. Windows also serve as the inlet for outside ventilation air that could be used for cooling.

Daylighting uses relatively small skylights and clerestories to provide daylight in addition to the light that comes through regular windows. Well-designed daylighting provides a pleasant ambiance while also saving a relatively small amount of energy. Passive solar heating is the use of direct sunlight through large windows and skylights to provide heating. In many locations, passive solar heating could eliminate the cost of heating energy almost completely, e.g. in northern areas of Khyber Pakhtunkhwa and Balochistan provinces of Pakistan. However, it is expensive to build and is much more complex in use than it appears to be. Most passive solar installations have generally been failures, wasting energy, causing discomfort and moisture problems, and ruining the appearance of the house.

6.5 Shading Windows to Minimize Air-Conditioning Cost

Most home air-conditioning cost is due to sunlight that enters through windows. Entrance of direct sunlight from windows during warm weather should be contained. Deep roof overhangs are a great feature for this purpose. They also prevent basement moisture problems and extend the life of exterior wall surfaces. Where roof overhangs are not sufficient, soffits and other architectural features should be considered for shading. Awnings are an effective alternative, but they tend to become shabby with age. All exterior shading requires careful orientation with respect to the Sun's motion. Interior shading is inexpensive, but it is less effective and it interferes with views. Ordinary venetian blinds and roller shades work well, but only if used properly.

6.6 Ventilating Near Ceiling Air

The space above the roof insulation should be open to air flow. The roof surface should work like an umbrella or a parasol, not like a tight fitting raincoat. Good ventilation of the underside of the roof surface reduces air-conditioning cost, prevents moisture condensation and ice dams during cold weather. A continuous row of large openings should be installed completely around the bottom edges of the roof to feed air to the underside of the roof surface.

6.7 Tree Plantation to Optimize Shading

In a climate that can be warm for extended periods, trees should be made an integral part of building designs.

7. THE ENERGY-USING EQUIPMENT OF THE BUILDING

The most important principles for energy using equipment are discussed below:

7.1 Select High-Efficiency Models of All Energy-Using Equipment

All the equipment in the building that uses energy – including air-conditioners, water heaters, refrigerators, freezers, washing machines, cloth dryers, television sets, computers, light bulbs, etc – is available in a wide range of high-efficiency versions. Select high-efficiency appliances. This requires no special skills, and it adds very little to the cost construction of the house.

7.2 Turn off Heating, Cooling, Lighting, and Other Energy-using Equipment when not Needed

All electric appliances should be turned off when not needed. Electronic equipment that is operating in 'standby' mode uses very little energy.

8. EFFECTIVE HEATING AND COOLING

8.1 Heating and Cooling Systems that are Tailored to Individual Spaces

Equipment that can heat and cool rooms individually only when occupied should be used. Separate systems for heating and cooling should be used. This avoids big compromises in efficiency and comfort. Heating and cooling systems that need ducts for air distribution should be avoided. Ducts leak badly and control temperature unevenly and also collect dirt and cause health problems.

Hydronic heating is a favoured heating method in most advanced countries. Convectors are completely silent. It is easier to install pipes or wiring for convectors than to install ducts. High-efficiency gas

boiler may be used to heat water. This system is now being introduced in Pakistan and is economical to install during new constructions. For cooling, one gets the best combination of efficiency and comfort by using a number of split system air-conditioners, each serving an individual room or a group of rooms that are used at the same time.

8.2 Programmable Thermostats

Programmable thermostats turn off heating and cooling automatically and help conserve energy.

8.3 Placement of Condensing Units of Air-conditioning Equipment in Cool and Clean Locations

The condensing unit is the outside metal box that makes all the noise. Its location is critical, and should be installed in a cool location, such as a shaded side of the house. It needs wide open air flow and should be installed somewhere it is not fouled by debris, such as leaves and dirt.

8.4 Quiet, High-volume Ventilation Fan fo Provide Outside Air Cooling

A quiet whole-house ventilation fan should be installed for use when it is cool outside and air-conditioning is not needed. The fan exhausts warm air from the house and cool air enters through windows. This works well for cooling bedrooms at night. In houses, the most common method is to install the fan above an opening near the ceiling.

8.5 Management of Windows and Ventilation

Opening a window very slightly will provide enough ventilation to avoid indoor air quality problems in a room. Even a small window opening admits a lot of air.

8.6 Energy Efficient Cooking Area

- Refrigerators and freezers should be installed in cool areas that isolate them from heat producing equipment, including the cooking range, water heater, and dishwasher.
- Keeping lids on pots and pans while cooking saves cooking time and energy.
- Frozen food should be thawed in the refrigerator.

8.7 Saving Water and Water Heating Energy

- Separate hot and cold water faucets should be installed for all basins, tubs, and showers.
- Efficient flushing toilets should be installed .
- Efficient washing machines should be uised.
- Geysers should be turned off if the house is being vacated for longer period.

8.8 Efficient Lighting

- Reflective interior colours should be used to reduce lighting costs.
- Fluorescent lighting should be installed in rooms where lights stay on for long periods.
- All light fixtures should be made as efficient as possible.
- Motion sensors can help control lighting in appropriate locations.

9. CONCLUSIONS

Energy-conservation is a long and time-taking process but is very beneficial in the long run. It is the right time for Pakistan to adopt energy-conservation techniques and equipment like developed world has. Fast development of energy-efficient buildings is, therefore, necessary to deal with growing energy-crisis and related environmental impacts in Pakistan. Innovations in the prevailing building-design will help the country in reducing the energy crisis.

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BOOK REVIEW: ENERGY CRISIS IN PAKISTAN

Authored by Muhammad Asif[†]

Reviewer:
Syed Hussain Shaheed
*Soherwordi**

* The reviewer is Senior Lecturer at Department of International Relations, University of Peshawar, Peshawar, Pakistan
Email: syedshaheed@hotmail.co.uk

The review has also been published earlier in International Journal of Law and Management
published by London Emerald and a daily edition of The News, a leading English Language newspaper of Pakistan

Muhammad Asif is a leading figure among Pakistani scientists. In previous works, Asif has written about Hydro-energy and Kalabagh Dam, the contemporary phenomenon that can provide the country with substantial economic growth but is understood locally (in Khyber Pakhtunkhwa and Sindh, provinces of Pakistan) as an overwhelming social tragedy by few time-servers.

This book is a welcome addition to the already scare literature on energy crisis in Pakistan. By taking up broad conceptual issues, this book moves beyond straight thoughts about Pakistan's social and economic areas of studies. It is divided into seven chapters with a sequence of themes focusing energy, institutional framework, recent surge of energy crisis in Pakistan and sustainable energy options.

The first two chapters, entitled: 'Energy and its Wider Dimensions', open with interesting parallels elaborated by Asif as energy and sustainable development, fossil fuels, nuclear energy and renewable energy resources. The author points out the successive culmination of development in energy resources from coal to oil reserves and their depletion (p. 14).

After highlighting depletion of oil reserves and global warming, the author proposes that to safeguard the future of coming generations, the world thus has to move towards low-carbon energy systems (p. 22).

The author gives a full and detailed account of oil-driven foreign policy of global actors and geo-strategic conflicts in the twentieth century. He says the geo-politics of the present day has been increasingly influenced by pursuit for energy resources (p. 31).

Asif gives a detailed background of energy as a historical source of influencing foreign policy by the British. He says that 'one of the main motives behind Nazi Germany's invasion of Poland and the Soviet Union was also to control their oilfields' (p. 45). He links this co-relation with the post Second World War and post Cold War eras by highlighting the US policies to dominate the oil-rich areas of the world, especially Middle East.

In chapter three and four, Dr. Asif describes Pakistan's energy agencies, its framework and the energy crisis. He begins with a brief discussion of the poor policies and reckless attitude on the part of concerned energy authorities (p. 81). He talks about integrative functions of energy resources, and in particular the bonds that people construct when creating energy alternates like hand fans, steeling electricity by different cable wires and so on.

But this is little more than a cursory review, and Asif is more interested to describe ritualistic and performative nature of energy culture adopted by the successive governments in Pakistan.

The book explores at greater length how people construct socially acceptable and unacceptable expressions of energy and power generation and how the domestic political economy of energy consumption is experienced by, and leads to disputes between the government and the governed.

This he highlights not only with text but also by few but very important pictures showing public expression of frustration. Text as well as pictures give a very serious situation of energy crisis in Pakistan (pp. 100, 107-111).

Chapter five argues for changes that include promoting policy and decision-making process of energy and natural resources in Pakistan and the

[†] Senior Lecturer, School of Engineering & Built Environment, Glasgow Caledonian University, Glasgow, UK. Email: dr.m.asif@gmail.com

role of the relevant stakeholders.

After giving details on practical difficulty of dealing with energy issues, Dr Asif analyses the role of academia, industry and energy departments in Pakistan. He says that lack of vision, corruption and nepotism are responsible factors in hampering the development of the energy sector. He specifically mentioned corrupt practices in privatization of energy departments like KESC, the hasty deal on Independent Power Producers (IPPs), and politically motivated snatching of power projects from WAPDA.

Asif says that energy discussion in Pakistan cannot be complete without mentioning Kalabagh Dam. He quotes ex-WAPDA chairman Shamsul Mulk who believes: "The greatest beneficiaries of the Kalabagh Dam project will be NWFP (present day Khyber Pakhtunkhwa) and denying the project is denying the fruits of the Indus Basin. Kalabagh is also going to benefit Sindh by supporting its agriculture with increased level of water.'

The last chapter is focused on solutions to the energy problems facing Pakistan. Asif highlights coal as alternate source of energy in Pakistan and its huge reserves which remained untapped. He further goes on by mentioning nuclear energy, hydropower, solar energy, and solar thermal power.

While this is a highly commendable volume, a chapter on India-Pakistan-Iran gas and oil pipeline project and Caspian Sea Oil politics would have been a great addition. However, it should still be said that it would be difficult to produce a more comprehensive and impressive book with such minute details from a single author in this field.

It will be counted as an important and pioneering contribution to the energy sector and crisis in Pakistan. This book will appeal to scholars and practitioners belonging to energy and renewable resources and the masses affected by the energy shortage in Pakistan to know what caused such a great crisis in their country. Postgraduate students and activists would like to acquaint themselves with the complexities of energy praxis and activism in Pakistan.

About the book

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REINFORCING S&T CAPACITY-BUILDING IN DEVELOPING COUNTRIES

*Lu Yongxiang**

ABSTRACT

Science and technology have long been seen as a key for sustainable development. Facing rapid scientific development in the world, many developing countries are facing tremendous challenges in S&T development. S&T innovation and capacity-building in the developing countries may be affected by many factors, but the most important one is talent fostering and cooperation among the talent. This paper presents arguments on how to foster talent, encourage women's participation in science and technology, and strengthen international cooperation for addressing the common concerns over S&T innovation capacity-building in the developing countries.

Keywords: *Capacity-building, Talent training, Sustainable development, S&T lagging countries.*

1. INTRODUCTION

Science and technology have long been recognized as the primary driving force behind economic and social development, and is a key factor in ensuring national and public security. In the history of human civilization, the dependence of economic and social development on S&T progress has never been as strong as it is today. The energy revolution, marked by green and low-carbon technologies, will play an important role in promoting energy structure change, improving energy-efficiency and tackling climate change. ICT and relevant industries are a major driving force for the recovery of world's economy. Development of life-science and biotechnology will significantly improve agricultural production and human health, and the related industry will be one of the pillars for sustainable development.

The world is now witnessing new profound changes in the pattern of social and economic development mostly because of S&T progress and innovation. In view of the rapid scientific development in the world, most developing countries have exerted themselves during recent years to promoting development of science and technology and improving their capacities for innovation. In doing so, they are confronted with tremendous challenges, including shortage of talent, poor infrastructure, weak capacity in exploration and exploitation of natural resources, environmental deterioration, lack of knowledge of global climate change, and related mitigation and adaptation methodology, etc., which further endanger their sustainable development. In this context, it is imperative for the developing countries to build or enhance the innovation capacity, most importantly, to cultivate and maintain an innovative talented team, and to build a strong force in S&T and application.

2. FOSTERING TALENTS AND RESEARCH TEAMS

In the process of modernization, the developing countries, including China, cannot maintain their conventional modes of economic development, nor can they follow the existing models of the developed countries. Rather, it has been a major strategic issue and a matter of great concern for the developing countries to find new roads to industrialization, which take into account their ground realities and location conditions, and will lead to green, smart, sustainable and shared development, featured by cost-effective production, low-emission and highly efficient resource utilization.

The S&T community shoulders great responsibilities in addressing the future challenges. The urgent demand in a new round of industrial development calls for the readiness of scientists to take up important tasks and achieve more contributions. No efforts should be spared to deepen our understanding on the nature of S&T breakthroughs, enhancing people's qualities through popularization of science and education, and providing momentum for the development of newly emerging industries, through technology innovation and transfer.

S&T innovation has supported China's development strategies, which are based on science, education, innovation and talent. Recognizing this fact, the Chinese Government has set up a series of policies and programmes to encourage the young people studying S&T, even in foreign countries, since 1979 when China officially began to adopt Opening and Reform Policy. In 1996, the China Scholarship Council was founded to provide financial assistance to students and scholars studying aboard. In 2003, a fellowship programme was launched to support self-funded students studying abroad. In the recent years, for reversing brain-drain, the Chinese government and relevant organizations have implemented a lot of programmes to encourage overseas Chinese scholars to return to China, and work in Chinese Academy of Sciences (CAS), universities, and

* Former President, Chinese Academy of Sciences and Co-chair, InterAcademy Council, Amsterdam, Netherlands
Email: yxlu@cashq.ac.cn

enterprises. For example:

- 'Fund for Returnees to get S&T Research Started', was initiated in 1990;
- 'Programme for Training Talents toward the 21st Century', started in 1993, targeting outstanding young teachers returning from overseas studies;
- 'Hundred Talents Programme', launched in 1994 by CAS, has attracted outstanding young scientists with over four years of overseas experience to return and work at CAS institutes;
- 'Chunhui (Spring Bud) Programme', started in 1996, targeting returnees with doctoral degree and outstanding achievements for short-term cooperation;
- 'Changjiang Scholar Incentive Programme', has been providing financial support for young and middle-aged leading scholars who have studied abroad and are invited by Chinese universities as Distinguished Professors;
- 'Programme of Academic Short-return for Scholars and Research Overseas', providing financial support for outstanding Chinese scholars studying or doing research abroad to give lectures or do research in 28 key Chinese universities during their short holidays or return to China;
- 'Fund for Returnees to Start Enterprises in China' and favorable policies for running an enterprise;
- 'National Overseas Eminent Scholar Fund' launched by NSFC, and 'CAS Overseas Eminent Scholar Fund' launched by CAS, to support overseas scholars to conduct research in China and CAS institutes; and
- 'Thousand Talents Programme' for attracting elite scientists to work in China and so on.

As the national supreme academic institution in natural sciences and advanced technology research and development in China, CAS has set up a plan for talent training & recruitment for implementing the Academy's long and mid-term development programme. The programme aims at building up CAS into a base for scientific research and technology innovation that conforms to international standards, to become a centre for training highly innovative researchers and incubating high-tech industries. This would develop CAS into a quality national research institution having first-class research conditions, high-standard management and highly professional staff that could provide strong support for implementing China's national innovation strategy by delivering qualified human resources and generating new knowledge. The package plan includes High-level Talent Recruitment Scheme, Excellent Young Talent Training Scheme, Technical and Administrative Talent Training Scheme, and Overseas Brains Recruiting & Talent Training through International Exchange Scheme.

The Package Plan also encourages young and middle-aged scientists to take an active part in international exchange and cooperation projects, thus broadening their international vision and enhancing their innovation capability. The CAS-sponsored 'Study-Abroad' Program shall be readjusted to focus on bringing up the next-generation of leading scientists and young researchers. The Senior Research Fellowship is designed for strategic scientists and technologists to conduct clearly-targeted international collaborations and return visits focusing on key areas and national priorities; international training opportunities are also made available for excellent young researchers, technical support staff, backbone administrators and tech-transfer personnel through the implementation of international exchange programmes, such as the Visiting Scholarship and Joint Postgraduate Training Agreements. All these programmes should be adapted to the needs for the readjustment of the disciplinary layout and the advancement of S&T innovation in CAS.

In terms of research capacity, more attention needs to be paid to basic and frontier research and strategic high technology development. Without perseverance, it is impossible to make major achievements in this kind of research that requires a lot of hard work. Key strategic high technologies will not be obtained through technology-transfer or import. Original and key technology innovations are sources of national and industrial competitiveness. In order to take a lead in economy and technology development in the future, self-reliance is needed to make original innovative achievements instead of following the path of others or depending on technology transfer from abroad.

3. ENCOURAGING WOMEN S PARTICIPATION

Women as mothers are role models for their children. Empowering women in science and technology innovation is of great significance for future generations. Even though women's engagement in S&T innovation, economic and social development has been expanded with the progress of human society, there are restraints and obstacles to larger participation of women in these fields. In some developing countries, there is still an inadequacy of opportunities for women in S&T, and the potential of

women in making discoveries and inventions are far from being fully tapped, as evident from the low percentage of their women scientists. With majority of them playing dual roles (family/career), women scientists have to take care of their families and nurture their children while dedicating themselves to scientific research, which negatively impacts women in fully developing their creativity to some degree. Despite facing this challenge, women scientists in the developing countries have made important contributions to S&T and innovation, with particularly outstanding performances in medicine, biology, chemistry, interdisciplinary fields between natural and social sciences as well as innovation management.

In order to get more women involved in research, development and innovation, a better legislation and policy environment is needed, coupled with a conducive research and education environment, as well as better social and cultural encouragement.

In this regard, better legislation and policy measure include:

(i) eliminating social prejudice and gender discrimination, making gender equality enforceable by law;
(ii) ensuring equal rights for women in receiving higher education and applying for positions or grants in research and development;
(iii) ensuring equal rights for women scientists to vote, participate, supervise and evaluate; and
(iv) taking into full account the needs, interests, opinions and suggestions of women scientists in making policies law and regulations.

A better research and education environment for women calls for:

(i) setting up special funds for research applicable to women scientists;
(ii) establishing special organizations or institutions that provide assistance, support and guidance to women scientists;
(iii) setting up special funds for education and training of professional women scientists; and
(iv) making sure that all existing research funds and award systems take women participation in ful consideration.

A better social and cultural environment includes:

(i) enhancing the efforts of public media in characterizing the figures of women scientists so as to raise the public recognition of contributions made by women scientists and increase in social support and their respect for their work;
(ii) improving the social service system for mothers and children; and
(iii) increasing self-awareness of women scientists to be equal, independent, confident and creative in thinking, to take full advantage of the social environment to improve their professional skills and innovation capability, to participate in academic exchanges and collaboration, to achieve a balance between the roles of being a wife, a mother and a scientist, to realize their values by taking an active part in S&T innovation activities.

4. STRENGTHENING INTERNATIONAL COOPERATION

We live in a world faced with grave global challenges, such as food security, energy shortage, environmental pollution and climate change. Only with acceleration of institutional and science and technology innovation, can we fundamentally overcome negative effects of the global financial crisis and address these challenges. All the issues cannot be solved by one country or one nation alone. More important now than ever before, international cooperation provides us the best approach for systematic solutions to the complicated problems humankind is faced with. International cooperation may help the world recover from financial crisis and global economic shrinkage through building an improved finance monitoring and warning system; promoting global economic restructuring; protecting international trade and investment, and generating a new and essential driving force through S&T innovation.

Science has become a culture and treasure of the world created by all the nations together, especially for the fundamental science based on big science facilities. From concept formation, preparatory research, components design and development to facility construction, international cooperation is embed in the whole process for big science facility development. Science is beyond the borders, which is flowing within or among all the countries. International cooperation can help the developing countries to improve their scientific capabilities, train their young scientists, and build their research teams.

CAS has given considerable importance to exchanges and cooperation in science and technology with the

developed and developing countries. Based on an equal, mutually beneficial and win-win basis, as well as with clear targets in different countries, international cooperation has diversified in terms of formats, including personnel exchange, data exchange and sharing, bilateral workshops, international conferences, joint centers, project-based scientists groups, joint laboratories, or partnership between institutes. It has been extended from bottom-level scientist cooperation to high-level strategic communication, from bilateral agreements between scientific institutions to multilateral research programmes, and from pure science research to partnership with industries for translational research and technology transfer.

Some of these initiatives are carried out in partnership with The World Academy of Sciences (TWAS). For example, CAS launched the CAS-TWAS Fellowship in 2004. With the establishment of the 'training bases for developing countries' in some CAS Institutes, the fellowship has funded scholars from more than 30 developing countries and regions, such as Bangladesh, Egypt, India, Nigeria, Pakistan and Sudan, to conduct their research in the CAS. A total of 79 Ph.D students, 77 post-docs and 84 visiting scholars have been enrolled under the programme so far. Another noted programme is the CAS-TWAS-WMO Forum (CTWF) on climate sciences, which was incepted in 2000. CTWF provides a platform for scientists (mostly from developing countries) to communicate and gear up the cooperation within developing countries on climate related issues. Since its establishment, CTWF has organized nine international conferences (workshops) with different themes, which are all hot topics related to the climate sciences.

CAS is the founding member of the InterAcademy Council (IAC), a multinational organization of science academies. The IAC produces reports on scientific, technological, and health issues as great global challenges of the time. At the United Nations in February 2004, the IAC released its first report 'Inventing a Better Future – A Strategy for Building Worldwide Capacities in Science and Technology'. This report has been widely adopted within developing countries for enhancing science and technology capacities. The second IAC report, commissioned by the U.N. Secretary-General and published in June 2004, was titled 'Realizing the Promise and Potential of African Agriculture – Science and Technology Strategies for Improving Agricultural Productivity and Food Security in Africa'. The recommendations of this report are being addressed by key agricultural institutions in Africa. The third report was published in June 2006, 'Women for Science'. Academies of sciences within developing countries have sponsored significant workshops on this topic. The fourth report was published in October 2007, 'Lighting the Way: Toward a Sustainable Energy Future', which outlined sustainable energy strategies for developing countries. A fifth report was published in fall 2010: a review of the Intergovernmental Panel on Climate Change (IPCC) as requested by the UN Secretary-General and Chair of the IPCC. The IPCC has adopted key recommendations of this report.

Being one of its founding members, CAS has been working closely with Commission on Science and Technology for Sustainable Development in the South (COMSATS) for capacity-building of developing countries. For example, in 2011, in collaboration with COMSATS and United Nations Educational, Scientific and Cultural Organization (UNESCO), CAS-TWAS-WMO forum (CTWF) organized a joint international training workshop aimed at reinforcing the capacity-building of young research scientists from developing countries.

International cooperation contributes significantly to talent training, and attracting and accumulating talent. Through young scientist groups, partnership groups, bilateral or multilateral workshops on frontiers of sciences, or other kinds of practical cooperation, international scientists work together on the research areas of common interest, jointly conduct experiments, publish papers in internationally peer-reviewed journals, and supervise graduate students or post-doctorate researchers. It is greatly beneficial for the students and young scientists to grow and evolve in an international atmosphere, nurture their interests in science, build their capacity for conducting scientific research, and create a focus on science for their careers.

5. CONCLUSIONS

Self-reliance should be given top priority for S&T capacity-building in developing countries. Strengthening science and technology cooperation and exchanges among developing countries will benefit the overall development of all developing countries. Opportunities should be created for promoting academic exchanges and increasing avenues for education and training, and collaborative research among the scientists, especially for women and young scientists from the developing world. The

rights and interests of women and young scientists should be safeguarded in participating in S&T innovations, and more women and young scientists should be empowered through professional education and participation in scientific research, development and innovation. All the scientists, engineers, and academicians have to work together on building global capacity and assume responsibility for addressing the common challenges, and cooperate on building science and innovation capacity of all nations and regions.

GENDER AND HEALTH ISSUES IN SCIENCE EDUCATION

*Haseena Khan**

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ABSTRACT

Recognizing the complexity of the economic and social determinants of health, it is necessary to provide a resource of health knowledge and information on healthcare for individuals. In Bangladesh, population growth and the associated pressures of development are increasing the difficulties associated with sustaining effective public health practices and policies. The interrelationships among science, technology, society, politics, environment, and all of the specific contexts of human health and welfare are a complex web. It is not possible to extract any one area without having to examine the connections to others. However, the unifying factor can be a good quality education on the health issues of the country. It is, therefore, necessary to integrate world health issues into a live science classroom.

Due to some positive actions undertaken during the past few years, gender gap has been considerably reduced from the primary and secondary education. The net enrollment rate of girls is higher than that of boys at the primary level, yet there are still some social practices (i.e. behavioral treatment) that favour boys over girls in Bangladeshi institutes. However, this gap widens at the tertiary level education system due to inadequate budgetary provisions. This is so because the study of science is becoming more and more expensive, and the axe falls on females. The women of developing countries like Bangladesh, lucky enough to have pursued science education, will find discrimination at the work place.

1. INTRODUCTION

Owing to the complex inter-relationship between economic and social determinants of health, it is necessary to provide a resource of health knowledge and information about healthcare for individuals. In Bangladesh, population growth and the related pressures of development are increasing the difficulties associated with sustaining effective public health practices and policies. The connections among science, technology, society, politics, the environment, and all of the specific contexts of human health and welfare are a complex web. It is not possible to extract any one area without examining its connections to others. However, the unifying factor can be a good quality education on the health issues of the country. It is therefore necessary to integrate world health issues into a life science classroom.

2. WOMEN AND SCIENCE IN BANGLADESH

Gender is about men and women and not males and females. It is not synonymous with sex. Sex refers only to the biological and physiological process. Men and women are not equal; nor will they ever be in terms of sex. Gender, however, does not only refer to the biological differences, but also to the social and cultural structure in a given society and its cultural setting. Gender is a multi-dimensional concept of social knowledge that helps to regulate socially defined sexually differentiated roles and relationships, particularly power relations between women and men , said Jayawickramarajah, in 2001 at Regional Health Forum, WHO South-East Asia Region.

In Bangladesh, many talented and committed women are bypassed where it comes to science education and career because of their gender. However, progress of 21st century will be appraised and reviewed on the basis of human development, that also includes the development of women in the developing countries. In Bangladesh, almost 49 % of the total population are women, of whom nearly 86 % live in rural areas. The adult literacy rates are 59 % for men and 48 % for women. But in the rural population, only 30 % men and 16 % women are literate. However, it is gratifying to note that the female literacy rate among young Bangladeshis is actually higher than the literacy rate for males.

3. HEALTH IN SCIENCE EDUCATION

An educated and healthy population is essential for sustainable economic development and eradication of poverty. Although men and women have a basic right to health, education and well-being, the global information shows some serious violation and inequalities in health status and access to healthcare and education services. Global consensus supports gender equality in health and education as a policy objective. It is considered to be the most important

* Professor, Department of Biochemistry and Molecular Biology, University of Dhaka, Bangladesh. Email: haseena@univdhaka.edu

measures for bringing the women in the mainstream.

The WHO Gender Policy integrating gender perspectives in the work of WHO was announced in the year 2002 to contribute to better health for women and men through health research, policies and programmes which give due attention to gender considerations and promote equity and equality between men and women [*].

The development challenges of Bangladesh with include poor quality health and education services, unequal access to those services not just for the poor only but female population. For many involved in such processes, fulfilling a child s right to education ends in the provision of school buildings, teachers and learning materials that equip the child to read and write. The fact that a congenial learning environment goes beyond mere provision of these, is often overlooked. The importance of educating girls about health and hygiene during primary education, and providing such facilities in schools is crucial, as many of them become mothers at very young ages.

There are many schools in the country with deplorable sanitary conditions, and, in most cases, with absolutely no considerations for the special needs of girls. Thus, in most schools one will find a serious lack of adequate water supply and functional sanitation facilities. Girls have also reported the absence of privacy, which causes them embarrassment and fear of using the toilets. Under such circumstances, many girls shy away from attending classes for certain days of the month. Poor sanitary conditions also cause frequent illnesses and under nourishment. Irregular attendance of school negatively impacts their academic performance. All the absentees in a particular year add up to a substantial sum. Such a scenario leads to fewer enrollments by girls into science subjects, which not only require longer hours because of the practical classes but regular attendance as well. Ensuring gender equality for girls and boys means that they have equal opportunities in school (Qumrun and Rokaya, 2006).

Although the Government is promoting higher education for girls by providing special incentives and stipends, and is often allocating funds to pay the salaries of teachers; construct new classrooms; and purchase textbooks. There is enough evidence to suggest that these attempts will bear little fruit unless accompanied by improvements in the water and sanitary conditions. However, helping girls to successfully complete primary education and move on to secondary education requires more than just water and sanitation at schools, these two are critical inputs into better schools. At a school hundred of children can be reached out each day at one place in order to provide them better healthcare. Healthier students learn better; become productive members of society; and can share the importance of basic public health measures in their own homes and communities.

Health programme in its broadest sense is a multi-sectoral intervention, focusing on the physical, social, economic, and spiritual dimensions that can bring total health to individuals, their families and communities. There is, therefore, a paradigm shift from curative action to health promotion and the prevention of ill-health. Since government is the key player when it comes to creating provisions for facilities, it has a significant role in ensuring that the special needs of adolescent girls become an integral part of any intervention to ensure higher attendance of girls at school.

Programmes for advancing women s health must also involve policy makers and civil society, ensuring that government policies are in effect that benefit women s health and increase their access to vital health services and products.

Government-funded initiatives are required to: i) reduce pressure on women to sacrifice their own health in order to care for children, elderly, and the infirm; ii) promote gender equality in unpaid family care work; iii) formulate industrial relations policies that are family friendly for both men and women. One needs to prioritize the pursuit of safe public spaces and transport systems in order to increase the mobility and access to services of individuals of both genders.

In addition to relevant government policies, from commitment by practitioners and implementors is also needed to reduce institutional biases. Because of such biases women and men are not on a level playing ground in terms of their access to health services as consumers, as producers or even as decision-makers. There is a need to recognize that gender bias in health sector institutions damages the effectiveness and sustainability of any health programme.

4. GENDER IN SCIENCE EDUCATION

Many of the science curricula, examination systems and teaching methods in Bangladesh and other

[*] Women and men in this document, refers to women and men of all ages.

developing countries have been borrowed from western countries and have failed miserably to address their current challenges. This has resulted in a science education that is characterized by irrelevant, de-contextualized knowledge being transferred by poorly trained teachers in overcrowded and under-resourced educational institutions.

However, there is no denying that one of the clearest signs of a society s intellectual health is the strength of science and mathematics education. Science and mathematics facilitate developments in scientific research and industrial technology, and ultimately lead to a more diverse, robust economy. Science, mathematics and technology education constitute the areas within the educational system where the gender disparity, in several of the poorest countries of the world, is greatest. Unfortunately, these are also the areas of the educational system where many of the skills resulting from such an education, stimulate development. Securing good health, fighting diseases, protecting the environment, farming and developing agriculture, and developing new industries and technologies, are all activities that require skills in science and technology. A proper science education is also considered crucial to empower pupils and equip them with skills necessary to play a constructive role in the future. Science education in several developing countries however has been found ill-suited to equip pupils with such skills.

5. GENERAL PERCEPTION: SCIENCE EDUCATION IS FOR MEN

There is a general perception that science education is for men, which gives science a masculine image and does not accommodate female participation. Despite the documented evidence of the benefits of female education, for economic and social development, relatively fewer girls are given opportunities to acquire science education in many of the developing countries of the world. Approaches have been taken for female-friendly , gender-neutral and gender-sensitive science education. However, these labels are widely used without a clear explication on what constitutes these concepts and what action is required to be taken in order to achieve their goal. In Bangladesh, besides the public sector institutions, non-governmental organizations, are involved in such efforts. But one will hardly find any thrust towards seriously redressing gender inequity in science education. In spite of the increased focus on female education, few seem to realize that much of what is expected as outcomes of education for all, actually presupposes a high-quality science education for all.

There is a tendency, starting right from preschool level, for educators to choose classroom activities that appeal to boys' interests and to select teaching strategies in which boys excel (Ho, Tomlinson and Whipple, 2011). Hence, girls are usually less enthusiastic towards science education; this is not because they think that they are not competent enough to pursue a career in science. Girls say that teachers encouragement is a big factor in their pursuit of advanced mathematics and science courses. This perception of science as masculine subject is still persistent in many developed countries; however, the message is not communicated as clearly to pupils here in Bangladesh as is in the developed countries. Girls in the country are often told by their parents, teachers and peers that science is not suitable for them. Choosing to pursue a career in science in many of these countries is, therefore, regarded as masculine. Females who choose this career path are often looked upon as less feminine and, thus, regarded as less attractive on the marriage scale . It is this mindset of the parents/guardians and also the teachers that needs to be changed. The under representation of female science teachers, and hence lack of female role models, particularly in secondary schools have also been shown to have a negative impact on girls. It is therefore desirable that education policy should focus on ways to encourage girls to be interested in science education and break the stigma attached to science education of girls.

Research has also generally supported the conclusion that there are no biological, neurological, or genetic factors at work in the creation of scientific gender disparity. However, since gender differences in performance and participation in science education is still persistent in many countries; this can, therefore, indicate that the problem of poor performance and participation among girls in science education is more of a pedagogical and cultural in nature than a problem caused by gender differences to learn science. A combination of elements come together to make it difficult for girls to train for and maintain a career in science. These factors, as indicated earlier, include social stigma of the sciences as masculine and also the institutional biases in the scientific community.

Due to some positive measures included in National Education Policy of Bangladesh, and its implementation in the past few years, gender gap has apparently been reduced at the primary and secondary education levels. The net enrolment of girls

is higher than that of boys at the primary level, but there are still some social practices (i.e. behavioral treatment) that favor boys over girls in the country s educational institutions. Moreover, basic infrastructural facilities in educational institutions for girls (i.e. girls toilets, science labs) are not sufficient either, due to which girls withdraw from science education.

While girls generally express positive attitudes towards science at primary education levels, they tend to lose interests in science and develop negative attitudes towards the subject as they move to secondary school. This gap further widens at the tertiary level education, where not many financial commitments have been made to remove the biases. The problem is accentuated because the study of science is becoming more and more expensive, and the axe falls on females. Parents would rather allow and often coax their sons, even those not interested in science, to study science than allow a yearning daughter to do the same. Since their daughters leave after marriage, their education is also tailored to the opportunity of finding suitable husbands rather than what they may want to do. For those lucky enough to have pursued a path in science, will find discrimination at the work places. Therefore, in countries with high unemployment rates, this makes it even less attractive for parents to pay for an expensive science education for the girls.

It is thought that science disparity has its most profound effects on students at the university level, but addressing the issue requires a mix of approaches at every stage of education. Younger students must be exposed to the subjects of mathematics and science in a way that makes it clear that they can, and should, do their utmost to attain excellence. In high school, a greater range of science subjects, along with a broad range of associated requirements for all students and higher availability of after-school tutoring, will help to eliminate the stigma of mathematics and science as being too difficult, irrelevant or masculine for that matter. At the college level, a well-designed curriculum with emphasis on the scientific components of a general education will help students of all backgrounds to explore their interests in the scientific world while deciding on their future careers.

After having acquired a degree in science, most Bangladeshi women would either become teachers or follow some other career. Hardly any woman would contemplate a career as a researcher in science. In general, this is true for many developing countries. The world as a whole is failing to take advantage of an available resource: the brainpower of women scientists. It is no longer a question of convincing people that women can do well in science, it is a question of whether work environments are made conducive for female scientists, who traditionally face gender discrimination and often have a harder time balancing work and family.

The competitive nature of funding research endeavours drives the typical 50 to 60 hour work week of most scientists and poses a daunting challenge for many women. Their careers are a constant gamble, as it is hard to strike the right balance between three things:

i) how much they must commit to their career in order to remain a competitive scientist;
ii) how much time they should devote to their households and to meet the traditional social demands; and
iii) how much time and effort to give to their children to help in their growth and development.

These women usually have a deep passion for science, but they have to combine it with the willingness to compromise their marriage, their career, or the happiness and well-being of their children. It is easy to see why many women would choose not to confront those risks on a daily basis.

Science is passion, vision, and a way of life, but it is almost synonymous with sacrifice or compromise or even misery for many women from the developing countries. When the choices women make in life are choices they are willing to make, then these should be the choices that make them satisfied and happy. And today science requires content and balanced men and women to carry out research and development in the field. Many female scientists are making significant personal sacrifices to achieve professional goals. Female researchers are struggling to balance their personal lives and their careers in science, technology, engineering, and mathematics (STEM).

There are many strong women who would want other women to muster super-human levels of self-assurance in order to change the way they are perceived and treated. This seems less of a solution to the problems women face in the workplace and more of a coping mechanism - one that may avert male prejudice but not address its root causes. It implies that if women get emotional, say, or falter for a moment in their resolute belief that they are capable and

deserving, the consequences are their responsibility.

One will find many talented young female scientists in the country who are very worried about their careers and they have every right to be worried. They are competent women, who understand their worth and are convinced of their potential to contribute. But these are women in disciplines populated by people who may, subconsciously, believe in women s inferiority, which brings about a gender-biased system that makes it difficult for female scientists to have a career and a family and to succeed at both. Unless the government and academic institutions take action to make it easier for them to balance work and private life, women are forced to choose between the two.

Using biology as a field for the analysis, it can be pointed out that over the years, there may have been an increase in the number of women scientists in biology, but gender-based disadvantages continue to be the order of the day even in academic institutions of Bangladesh (Beede, 2011). Many science departments will not recruit women faculty beyond a certain number despite being equally or more qualified.

Most M.Sc courses and Ph.D programmes in the country s national institutions have a large proportion of women students. In biology, women even outnumber men. However, if the available data on scientists and academic faculty members, in diverse institutions is inspected, it would reveal that very few women continue to struggle up the scientific ladder. This erosion is undoubtedly a result of the difficulty in pursuing a career that demands an excessive investment of time, in the face of increasing family demands. Even though we now see families allowing their female members to work but they would be happy to see they pursue a 9 to 5 job rather than work as researchers, which requires putting in longer hours.

Research requires a quick mind that should be free from stress and calls for an environment that is supporting and encouraging. Many women are not fortunate enough to find such support and encouragement either from the society or their families. Many women lose interest in the pursuit of their profession at a very early stage. Even for those who cross this hurdle successfully, find a path crisscrossed with endless obstacles impeding them to work and excel.

Contrary to common belief, a female researcher works as hard as a man if not harder, and is intellectually as equipped for the job as her male counterpart. Science requires one to have patience and perseverance. These attributes are found more often in females than in male scientists. Despite all, sometimes having male researchers seems like the best choice. This is especially so because most institutions, including the reputed institution, like Dhaka University, do not have a separate section to cater to the needs of researchers like having an officer to look into the import of chemicals, or getting perishable research items released quickly from the airport. Since a project will not allow recruiting people other than researchers, therefore, it is convenient to employ male research associates so that would come in handy when dealing with such matters.

Following are some of the problems in Bangladesh due to which one does not find many women in science: (i) security for working women (when working until late hours measures have to be taken to ensure that she is not alone and to have someone to escort her home after work); and (ii) discrimination in recruitment, harassment at the workplace, problems of reconciling the demands of families, with the sometimes impossible demands of a research career.

Being asked to perform maximally at jobs at a time in their lives when other needs compete for their energy and time, such as family care, can often be a big obstruction for women scientists. Some opine that if women had the flexibility to move slower at first until their family needs (at early career level when family life is also stabilizing and children are still too young) were met, they could be very productive later in their scientific careers. There is evidence showing that mid-career and older female scientists produce articles that are cited more highly than articles by their male colleagues (Jaschik, 2007). This leads to the argument that women would excel, if only they could be allowed delayed start-ups. As can be seen, there is no straightforward solution to this situation, and if delayed start-ups were permitted, it would raise a host of other serious issues having to do with gender equity, and ensuring and evaluating progress in professional fields. Studies have shown that many very talented women are far more likely to put their own careers on hold to facilitate the careers of their partners.

Many men and women alike think that it hardly matters whether the practice of science is being done by a man or a woman. But hardly ever are any steps taken either at the workplace or at home to make a woman prove her worth as a scientist. Science is science, and gender has very little to do with it. By pursuing science

education, women like men attain intellectual growth; it provides tremendous confidence, mental maturity and happiness. It definitely helps other women stand up and gain confidence, and encourages other women to join the field.

Not only science, women have little access to information technology and are barely equipped with business education. Therefore, they lag far behind in all professions requiring IT and business knowledge.

6. CONCLUSIONS

Twenty first century is ushering an era of new hopes and aspirations for the women folk, as the women of Bangladesh can now look forward with pride and hope for achieving significant improvements in education. Active cooperation between men and women is a must to clear the pathway to decent work environment for women.

As for the gender issues in science education, Bangladeshi women like other women of any developing country of the world to whom science is passion, vision, and a way of life, are making significant personal sacrifices to study science in universities far away from home among many adversities in order to achieve professional growth. They are struggling to balance their personal lives and their careers in science, technology, engineering, and mathematics. They we salute!

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THE ROLE OF SCIENCE EDUCATION FOR COMBATING AND PREVENTING DISEASES

Abdul Ghaffar[*†], Shahina Tariq[**] and Gul Muhammad[***]*

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ABSTRACT

In most developing countries, the role of science education for combating and preventing diseases is both minimal and impracticable. There are two main reasons to this: i) lack of medical knowledge; and ii) lack of practical knowledge. These consequences may be a result of exclusion of medically trained people in the education system, e.g. in our education systems, there is no established trend of medical doctors to teach at school, college or even at university levels. There is a provision of medical education at teaching hospitals, but they still lack the right educationists and latest trainings at par with global standards.

In order to consolidate the concept and promotion of science education in the field of health and medicine, this paper discusses four diseases commonly found in developing countries like Pakistan. These diseases are Poliomyelitis, Malaria, Rabies and Typhoid. The disability/mortality due to Poliomyelitis; the morbidity and mortality as a result of Malaria and Typhoid fever, and a very high death rate (up to 5000/year) as a result of dog bites (Rabies) are reported in Pakistan. The study takes into account myths and mysteries related to these diseases and their consequences/ complications leading to mortality. This study is focused on the prophylactic measures (prophylaxis), as an ounce of prevention is worth a pound of cure. Prophytactic measures can only be taken by creating awareness about these diseases and re-evaluation of the role of science education in all sectors.

Keywords: *Medical knowledge, Education system, Different diseases, Mortality, Pakistan.*

1. INTRODUCTION

Public Health (PH) is the science and art of preventing disease, prolonging life and promoting health through organized efforts and informed choices of society, organizations, public and private, communities and individuals (Winslow, Charles-Edward Amory, 1920). Public Health plays an important role in disease prevention efforts in both the developing world and developed countries. It is a modern concept although it has roots in antiquity. The main focus of PH intervention is to improve health and quality of life through the prevention and treatment of diseases and other physical and mental health conditions (Ali, 2000; Heymann, 2006). The other main focus of PH intervention is to prevent and manage diseases and the promotion of healthy behaviours, communities and environments. Many diseases are preventable through simple, non medical methods and this is the main focus of PH. In developing countries like Pakistan, health problems are not addressed on priority basis. Poor hygiene conditions and malnutrition in addition to poor economic condition exposing the mankind to different severe diseases. Although the vaccination for different diseases is excellent preventive measure but to administer these vaccinations and to maintain their cold chains is impossible especially when the vaccines have to be delivered to different communities far away (EPI, 2003; WHO, 2002). The maintenance and promotion of health is achieved through different combinations of physical, mental, and social well-being, together sometimes referred to as the 'health triangle'.

2. SCIENCE EDUCATION FOR COMBATING DISEASES

Epidemics and high endemic disease rates have occurred in the Central Asian Republics, the Indian subcontinent, and across Asia and the Pacific Islands. Another main characteristic of a supply of fresh water is its quality and here the link with health is very direct. One of the most significant improvements in public health came about in the 19th century with the discovery that much illness was caused by polluted water supplies.

To study and evaluate the role of science education for combating and preventing diseases in Pakistan, four diseases have been selected. These are Poliomyelitis, Typhoid, Malaria and Rabies. Out of these four two are viral (Poliomyelitis & Rabies), one is bacterial (Typhoid) and one is a vector-borne disease (Malaria). The details of these diseases are as follows:

2.1 Poliomyelitis

Poliomyelitis, generally known as polio or infantile paralysis, is a highly infectious viral disease that

*[†] Department of Meteorology, COMSATS Institute of Information Technology (CIIT), Islamabad, Pakistan. Email: aghaffar@comsats.edu.pk
** Chairperson, Department of Meteorology, CIIT Islamabad, Pakistan. *** Advisor, Department of Meteorology, CIIT Islamabad, Pakistan.

attacks the central nervous system (CNS) and is characterized by symptoms that range from a mild nonparalytic infection to total paralysis in a matter of hours. There are three known types of polioviruses (called 1, 2, and 3), each level causes a different kind of the disease. These types are members of the family of enteroviruses (Heymann, 2006; Mueller, Wimmer and Cello, 2005). Type 1 is the leads to epidemics and many cases of paralysis, which is the most severe manifestation of its infection. The virus is usually a harmless parasite, using human beings as its hosts. Some statistics quote that one in 200 infections leads to paralysis, while others state that one in 1,000 cases reach the central nervous system (CNS). When it reaches the CNS, inflammation and destruction of the spinal cord motor cells (anterior horn cells) occurs, which prevents them from sending out impulses to muscles. This causes the muscles to become limp or soft and they cannot contract. This is referred to as flaccid paralysis and is the type found in Polio. The extent of the paralysis depends on where the virus strikes and the number of cells that it destroys. Usually, some of the limb muscles are paralyzed; the abdominal muscles or muscles of the back may also be paralyzed, affecting posture (Figure-1). The neck muscles may become too weak for the head to be lifted. Paralysis of the face muscles may cause the mouth to twist or the eyelids to droop. Life may be threatened if paralysis of the throat or of the breathing muscles occurs (Aylward, 2006; Fine, 2009).

Source: *UNICEF/NYHQ2011-0198/Zaidi*

Figure-1: Children are Still being Disabled by Polio in Pakistan Despite Years of Efforts to Eradicate the Disease

Humans are the only natural host for polioviruses that most commonly infect younger children, although older children and adults can be infected as well. Crowded living conditions and poor hygienic conditions spur the spread of poliovirus. Poliovirus can spread by direct exposure to droplets (respiratory or saliva), and more commonly, by contact or eating foods contaminated with viruses from waste products from the intestines and droplets of moisture (saliva) from an infected person. Thus, the major route of transmission is feco-oral, which occurs primarily due to poor sanitary conditions. The infection is passed on to others when poor hand washing allows the virus to remain on the hands after eating or using the bathroom. The virus is believed to enter the body through the mouth with primary multiplication occurring in the lymphoid tissues in the throat, where it can persist for about one week. During this time, it is absorbed into the blood and lymphatics from the gastrointestinal tract where it can reside and multiply, sometimes for as long as 17 weeks (Falconer and Bollenbach, 2000). Once absorbed, it is widely distributed throughout the body until it ultimately reaches the CNS (the brain and spinal cord). Transmission from infected person is possible while the virus is being excreted from gestro-intestinal/ respiratory tracks and it can be transmitted till the source is disposed of. The incubation period ranges from 3 to 21 days, but cases are most infectious from 7 to 10 days before and after the onset of symptoms (Paul, 1971; Pearce, 2005).

There are two basic patterns to the virus: the minor illness (abortive type); and the major illness (which may be paralytic or nonparalytic). The minor illness accounts for 80-90 % of clinical infections and is found mostly in young children. It is mild and does not involve the CNS. Symptoms include a slight fever, fatigue, headache, sore throat, and vomiting, which generally develop three to five days after exposure. Recovery from the minor illness occurs within 24 to 72 hours. The symptoms of the major illness usually appear without a previous minor illness and generally affect older children and adults (Trojan and Cashman, 2005).

About 10 % of the people infected with polio-virus develop severe headache, pain and stiffness of the neck and back. This is due to an inflammation of the meninges (tissues which cover the spinal cord and brain). This syndrome is called "aseptic meningitis." The term "aseptic" is used to differentiate this type of meningitis from those caused by bacteria. The patient usually recovers completely from this illness within a few days.

About 1 % of the people infected with poliovirus develop the most severe form of Polio. Some of these patients may have two to three symptom-free days between the minor illness and the major illness but the

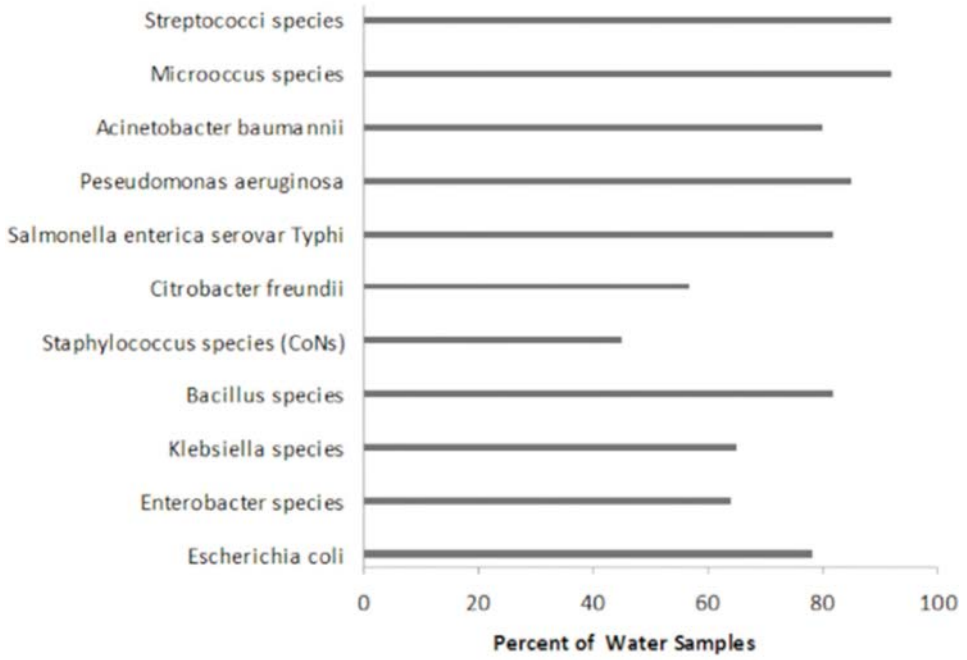


Figure-2: Different Bacterial Species Responsible for Outbreak of Typhoid Fever Associated with Drinking Water (Farooqi, Khan and Kazmi, 2009)

symptoms often also appear without any previous minor illness. The symptoms again include headache, and back and neck pain (Trevelyan, Smallman Raynor and Cliff, 2005). The major symptoms, however, are due to invasion of the motor nerves, which are responsible for movement of the muscles. This viral invasion causes inflammation, and then destruction of these nerves. The muscles, therefore, no longer receive any messages from the brain or spinal cord. All muscle tone is lost in the affected limb and the muscle becomes soft (flaccid), floppy and paralyzed within a few days, and begins to decrease in size (atrophy). The affected muscles may be on both sides of the body (symmetric paralysis), but are often unbalanced within the body (asymmetric paralysis). Sensation or the ability to feel is not affected in these paralyzed limbs (Richard, 2002; Paul, 1971).

2.2 Typhoid

Typhoid fever is the clinical disease caused by *Salmonella typhi*. This infection is endemic in developing countries where sanitation is poor. Unlike dengue or rickettsial infections, typhoid fever can evolve insidiously. According to World Health Organization (WHO), more than one billion people in low and middle income countries lack access to safe water for drinking, personal hygiene and domestic use (Figure-2). These numbers represent more than 20% of the world's population. In addition, almost 2 billion people do not have access to adequate sanitation facilities. Water-borne diseases, according to the WHO, are those generally arising from contamination of water by feces or urine infected by pathogenic viruses or bacteria. These are directly transmitted to new hosts when such contaminated water is ingested or used in the preparation of food. Worldwide, typhoid fever affects roughly 17 million people annually, causing nearly 600,000 deaths (Crump, Luby and Mintz, 2004; Acosta, et al., 2004; Bahl, et al., 2004). The causative agent, *Salmonella typhi*, is an obligate parasite that has no known natural host except humans. This gram-negative enteric bacillus belongs to the family Enterobacteriaceae. It is a motile, facultative anaerobe that is susceptible to various antibiotics. Currently, 107 strains of this organism have been isolated; many containing varying metabolic characteristics, levels of virulence, and multi-drug resistance genes that complicate treatment in areas where much resistance is prevalent (Farooqi, et al., 1991; DeRoek, et al., 2005).

Infection of *S. typhi* leads to the development of typhoid, or enteric fever. This disease is characterized by the sudden onset of a sustained and systemic fever, severe headache, nausea, and loss of appetite. Other

symptoms include constipation or diarrhea, enlargement of the spleen, possible development of meningitis and general malaise (Robbins, et al., 1996). Untreated typhoid fever cases result in mortality rates ranging from 12-30 %.

The encounter of humans with *S. typhi* occurs via fecal-oral route from infected individuals to healthy ones. Poor hygiene of patients shedding the organism as well as consumption of shellfish from polluted water bodies can lead to secondary infection. The most common source of infection, is drinking water and food tainted by urine and feces of the infected individuals. The estimated inoculum size necessary for infection is 100,000 bacteria. Typhoid fever also represents the second most commonly reported laboratory infection. Once ingested, the organism multiplies in the small intestine over the period of 1 to 3 weeks, breech the intestinal wall and spread to other organ systems and tissues. Transmission of *S. typhi* has only been shown to occur by fecal-oral route, often from asymptomatic individuals. Two to five of previously infected individuals become chronic carriers who show no signs of the disease, but actively shed organisms capable of infecting others (Parry, et al., 2002; Bahl, et al., 2004). The key to avoiding infection by S. typhi is prevention of fecal contamination in drinking water and food supplies. Since the only source of this agent is infected humans, it is possible to control transmission through measures, such as proper hygiene, waste management, water purification, and careful treatment of the sick. These measures are suitably taken in developed societies, resulting in the lower incidence of the disease (WHO, 1986).

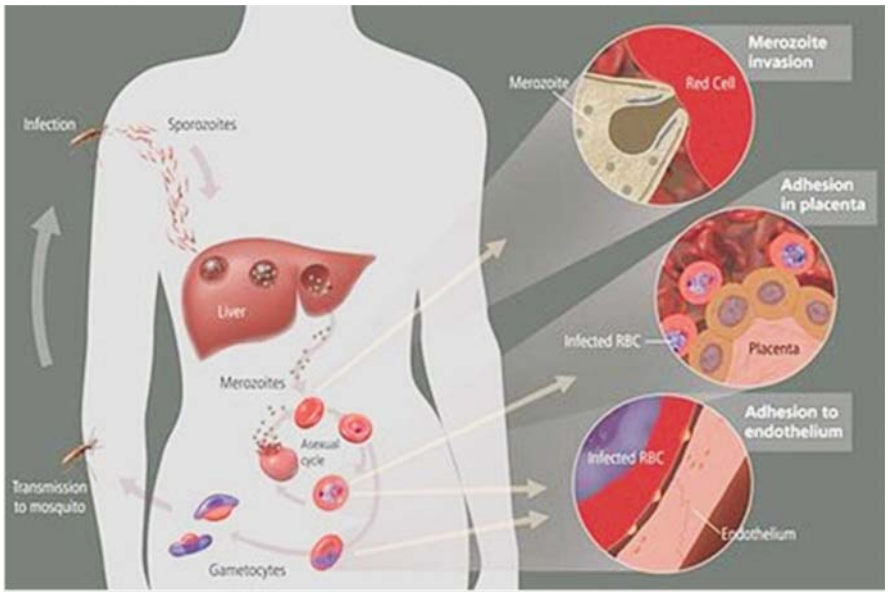
2.3 Malaria

Malaria is a mosquito-borne infectious disease caused by eukaryotic protista of the genus Plasmodium. It is widespread in tropical and sub-tropical regions, including much of Sub-Saharan Africa, Asia and the Americas. Malaria is prevalent in these regions because of the significant amounts of rain-fall and consistent hot temperatures. This warm humid climate provides mosquitoes with perfect environment to breed continuously. The disease results from multiplication of the malaria parasite within red blood cells (Figure-3), causing symptoms that typically include fever and headache, in severe cases progressing to coma and death (Andrej, et al., 2003; Hoffman, Goh and Luke, 2002). Four species of Plasmodium can infect and be transmitted by humans. Severe disease is largely caused by Plasmodium falciparum. Malaria caused by Plasmodium vivax, Plasmodium ovale and Plasmodium malariae is generally milder and rarely fatal. Fifth sub-species is Plasmodium knowlesi, which causes malaria in macaques but can also infect humans (Hanscheid and Grobusch, 2002).

In developing countries, outbreaks of malaria can be contained by preventing mosquito bites through distribution inexpensive mosquito nets and insect repellents, and taking mosquito-control measures, such as spraying insecticides inside the houses and draining stagnant water that facilitates mosquito breeding. Although many vaccines are under development, the challenge of producing a widely available vaccine that provides a high level of protection for a sustained period is still to be met. Two prophylactic drugs are also available that can prevent malaria while traveling to malaria-endemic countries (Humphreys, 2001; Lin, et al., 2001). Pakistan's Roll Back Malaria (RBM) strategy has been undermined by the country's weak health infrastructure, poverty, shortage of qualified doctors and inadequate data for monitoring the high mortality rate of the infection. For the RBM initiative, the Government of Punjab the largest province of Pakistan, approved Rs. 39.750 million for 2003-2008 and increased this to Rs. 185.680 million for the years 2009-2014.

The Malaria parasite's secondary (intermediate) hosts are humans and other vertebrates. Female mosquitoes of the genus Anopheles are primary hosts and transmission vectors. A mosquito becomes infected when it takes a blood meal from an infected human (Pattanasin, et al., 2003; Moody, 2002). Once ingested, the parasite gametocytes taken up in the blood will further differentiate into male or female gametes and then fuse in the mosquito's gut. This produces an ookinete that penetrates the gut lining and produces an oocyst in the gut wall. When the oocyst ruptures, it releases sporozoites that migrate through the mosquito's body to the salivary glands, where they are then ready to infect a new human host. This type of transmission is occasionally referred to as ‘anterior station transfer’. The sporozoites are injected into the skin, alongside saliva, when the mosquito takes a subsequent blood meal (Lee, et al., 2002; Meis, et al., 1983; Moody and Chiodini, 2000).

Only female Anopheles mosquitoes feed on blood while male mosquitoes of the genus feed on plant nectar. Thus, the male Anopheles do not transmit the disease. The females of the Anopheles genus of mosquito prefer to feed at night. They usually start searching for a meal at dusk, and will continue



Source: *wikipedia.org*

Figure-3: The Life Cycle of Malaria Parasites

throughout night. Malaria parasites can also be transmitted by blood transfusions, although this is rare (Lon, Tsuiuoka and Phanourong, 2006; Nguyen, et al., 1995).

2.4 Rabies

Rabies virus is neurotropic virus that can be fatal to humans and animals. Rabies transmission can occur through the saliva of animals. The rabies virus has a cylindrical morphology and is the typical species of the Lyssavirus genus of the Rhabdoviridae family. These viruses are enveloped and have a single stranded RNA genome (WHO, 2006).

From the wound of entry, the rabies virus travels quickly along the neural pathways to the CNS. The retrograde axonal transport of the rabies virus to the CNS is the key step of pathogenesis during natural infection. The exact molecular mechanism of this transport is unknown, although binding of the P protein from rabies virus to the dynein light chain protein DYNLL1 has been established. P protein also acts as an interferon antagonist, thus decreasing the immune response of the host (Hong and Banta, 2005).

From the CNS, the virus further spreads to other organs. The salivary glands located in the tissues of the mouth and cheeks receive high concentrations of the virus, thus allowing it to be further transmitted (McEwen, 2006). Fatality can occur from two days to five years from the time of initial infection. This however, depends largely on the species of animal acting as a host. Most infected mammals die within weeks, while strains of a species such as the African Yellow Mongoose (Cynictis penicillata) might survive an infection asymptomatically for years (Badrane, et al., 2001; Hong and Banta, 2005). Rabies is a serious and long neglected disease, mainly affecting the poorer strata of our society.

3. MATERIALS AND METHODS

This study is based on the data collection from 2001-2005. The following institutions of Lahore (one of the most populous cities of Pakistan), were selected for this purpose;

i. Institute of Public Health (IPH), 63 Shadman;
ii. Sir Ganga Ram Hospital, Queen Road; and
iii. The University of the Punjab.

For Rabies, all day-to-day matters at IPH and the cases of Rabies during 2001-2005 all over the Punjab province were discussed with the Punjab Medico-legal Officer because IPH was overseeing with the whole Province. For Malaria and Typhoid cases, patients as well the duty doctors were interviewed. A total of 500 indoor patients (100/year) and 2,000 out-door patients (400/year) were interviewed. The University of the Punjab was selected for studying 110 disabled persons and different Polio campaigns in the periphery

of Lahore city. In addition to this, 70 general practitioners (GPs) in Lahore city were interviewed. Moreover, the latest information about the current trends was also gathered from the people serving in different vaccination companies in the countries, such as Aventis, Amson, Berna and Galaxo Welcome.

4. RESULTS AND DISCUSSIONS

It has been established that contaminated water is one of the biggest source of spreading commendable diseases. All except the most carefully protected sources of fresh water must therefore be treated before they are considered fit for human consumption (Sinha, et al., 1999). It is important to know the quality and characteristics of any water source so as to design appropriate treatment, and also monitor the quality of the supply continuously for immediate response to any unexpected pollution. Wastewater draining from urban and industrial areas must also be treated before it is returned to the environment so that it does not become a threat to human health (Wain, et al., 1997; Wain, et al., 2001). Again, there is a need to monitor, not only the wastewater, but also the quality of the waters into which it drains, because reduced water levels can concentrate pollutants and pathogens in both surface-water and groundwater.

According to discussion in National Assembly of Pakistan (2010), out of the total 150 cases of Polio reported in the country, 107 were the children who were given the Polio drops. The Health Minister stated that polio drops given to children suffering from diarrhea were ineffective. The other issue identified was the maintenance of cold temperature required for preserving the vaccine, while delivering it to far-off areas. The third most important reason behind the vaccine's ineffectiveness as found to be its direct exposure to sunlight. However, the staff administering the vaccine did not know the specification that Polio drops given in sunlight activates Poliovirus in the vaccine causing the disease instead of eradicating it. For this purpose, 110 people affiliated with the University of the Punjab and affected by polio virus were interviewed, including enrolled students of different departments under the age of 30 years; they all admitted that they had been given the Polio drops two to three times under the age of five years but they got infected anyway.

According to WHO, 50,000 cases of Malaria are reported every year in Pakistan. Malaria eradication campaign was launched in 1961 yet Malaria continues to be a major public health problem in Pakistan. Extensive agriculture practices, a vast irrigation network and monsoon rains have considerably added to malariogenic potential in many areas. Moreover, more manifestations of mosquito-borne diseases are seen in the form of dengue fever. Secondly, there is no difference in the symptoms of Malaria and Typhoid fever. Severe and sometimes wrong medication for Malaria, if a person having malaria is given treatment for and vice versa, causes further complications.

More than 70 % doctors do not use the lab. facility at the beginning of treatment, rather they only rely on medication that leads to more complications. Moreover, most general practitioners use the medicines both for Malaria and Typhoid at the same time as the apparent symptoms of Malaria and Typhoid are the same (i.e. high fever and shivering) in both cases. This overdose of medication results in many post-treatment complications. Similarly, there is no availability of laboratory facility in OPDs, at government hospitals, and doctors only recommend lab. tests to indoor patients, which do not account for more than 5 % of the total patients.

The reported dog bite cases do not give the exact and real picture of the Rabies infection. Only the reported cases i.e., that visit different big hospitals, are around 30,000-50,000 annually. In most hospitals, dog bite cases are treated with first aid (washing the wound with spirit) and administration of tetanus vaccine to satisfy the patients coming from far-flung areas. A very limited number of patients is given the Rabies vaccine prepared by National Institute of Health (NIH) and its efficacy is doubtful. Patients have to visit hospitals fourteen times as 14 injections are administered subcutaneously, which is a very painful, time-consuming and inconvenient process. A meagre ratio of 1 out of 500 patients very influential are given the privately marketed vaccine that is originally purchased by the Government to support and save the lives of the poor people. These results and discussions show that more has to be done for combating and preventing even the common diseases in the country.

5. CONCLUSIONS

The Public Health programme should be re-evaluated according to the new trends of public demand. In Pakistan, only the diploma courses have been initiated but the higher degrees like Ph.D in public health are in progress and the minimum number of trained staff is insufficient to create the desired level of awareness. The most important point in this regard is that a person lacking enough information should not make

suggestions of any sort. In developing countries, however, complications start from self medication – non-medical personnel, uncertified and less certified doctor. A degree programme in biometeorology at university level can help address many public health problems if the university has a trained and well-informed faculty for teaching and research in the relevant field, addressing the new and contemporary health challenges.

6. RECOMMENDATIONS

- The subject of science at school levels should be revised according to new demands of public health.
- The subject of biology at high school levels should include a satisfactory portion regarding the public health.
- The subject of biometeorology should be included in colleges and universities addressing the common health problems with the help of applied research at community levels.
- Extensive trainings on public health policies must be initiated.
- Public Health departments at hospital should be sensitized and made responsible to provide services at the door steps of even the farthest communities.
- A patient must be made aware about common diseases and encouraged to consult a well qualified doctor only.

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TEACHING SCIENTIFIC CONCEPTS THROUGH SIMPLE MODELS AND SOCIAL COMMUNICATION TECHNIQUES

*Kumari Tilakaratne**

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ABSTRACT

For science education, it is important to demonstrate to students the relevance of scientific concepts in every-day life experiences. Although there are methods available for achieving this goal, it is more effective if cultural flavor is also added to the teaching techniques and thereby the teacher and students can easily relate the subject matter to their surroundings. Furthermore, this would bridge the gap between science and day-to-day experiences in an effective manner. It could also help students to use science as a tool to solve problems faced by them and consequently they would feel science is a part of their lives.

In this paper, it has been described how simple models and cultural communication techniques can be used effectively in demonstrating important scientific concepts to the students of secondary and higher secondary levels by using two consecutive activities carried out at the Institute of Fundamental Studies (IFS), Sri Lanka.

1. INTRODUCTION

In Sri Lanka, general attitude of students towards science distracts them from studying in science stream. They believe science is a very boring and difficult subject. Present trend of Sri Lankan school students is to pursue commerce or arts education. According to the Ministry of Education, only 22 % of the General Certificate of Education (G.C.E.) Advance Level (A/L) students study the science subjects, while 25 % follow commerce stream and the rest (53 %) follow arts stream. According to the published statistics of the Department of Examinations of Sri Lanka, science knowledge of Sri Lankan students at G.C.E. Ordinary Level (O/L) is not adequate. The percentage of students passing with science subject at G.C.E. (O/L) in the year 2009 was 48.3 %.

Science Technology & Innovation Strategy Report of Sri Lanka (2011-2015) states that "The low number of students opting for science careers and a high failure rate in science and mathematics at G.C.E O/L examination need to be addressed through focusing on science and mathematics education at schools and career development programmes. The lack of trained teachers in science, particularly in rural areas, makes this challenge more difficult. This needs to be addressed by a well coordinated, concerted effort by state institutions, universities, professional organizations and the private sector."

2. METHODOLOGY

Introducing new ways to study science in interesting manner is important. One way of doing this is to show students the relationship of science with nature, and show them how to use science in day-to-day life.

The following two activities were held at IFS that can be considered as examples of interactive and interesting ways of teaching science.

2.1 Activity-1

In order to highlight the importance of relevance of scientific concepts with students' day-to-day experiences, a review was carried out through an island wide competition for students. Objectives of this activity were to gather information regarding students' knowledge and ability to explain the basic concepts of science in a simple non-scientific language, as well as to train them how to apply scientific knowledge in analyzing the occurrences in day-to-day life.

In this competition, students were given options to express their capabilities in their native language (in Sinhala and Tamil languages). The activity was conducted for two age categories; 12-14 years & 15-16 years (i.e. grades 7-9 & grades 10-11). In this exercise, six topics were specified and students were given the option of selecting three topics among them. They needed to find the scientific concept relevant to each topic and to explain it. The topics are given in Box-1.

One of the major challenges of this activity was that students had to explain all the scientific words and concepts in a very simple way where a person with non-scientific background could understand. The standard target audience chosen for the students to

* Head of the Science Dissemination Unit, Institute of Fundamental Studies, Kandy, Sri Lanka. Email: chantikiri@yahoo.com

Box-1: Topics that Students were Required to Find the Relevant Science Concept

Topics for age category 12-14 years

- Electrical/Telephone wires sag in the summer.
- A well grown tree can be considered as an ecosystem.
- Watery liquid ooze from chopped tree trunk.
- Footprints of pointed heels are deeper than those of shoes with flat soles.
- Hopper batter (a special type of local bread) will not rise when old baking soda is used.
- A gas was emitted when lime was added to ash of the kitchen hearth.

Topics for age category 15-16 years

- It is dangerous to leave a car engine running when the car is in a closed garage.
- Damaged Tin plated iron get rusted quickly, but damaged galvanized iron is rust resistant.
- Gasoline transport trucks have chains that hang down and drag on the road at the rear end of the truck.
- Closing a window by pulling window lock is easier than pulling from the window hook near the hinge.
- If you shine a flashlight or headlights into dogs/cats eyes at night, their eyes glow but this will not happen with humans. However people have red eyes in flash photographs.
- If you get a chance to go to the deep sea, you will see tiny blue-green lights appearing and disappearing. Explain the incident.

address for the activity was nine years old children.

A total of 1,562 students of the age group 12-14 years (1,007 Sinhala-medium and 562 Tamil-medium students) and 684 students of the age group 15-16 years (384 Sinhala-medium and 300 Tamil-medium students) participated in this activity. An island wide participation was experienced for this activity and the district-wise distribution is given in Figure-1.

2.1.1 *Observations*

The following observations were made:

- Students had used different instruments of communication such as posters, drama scripts,

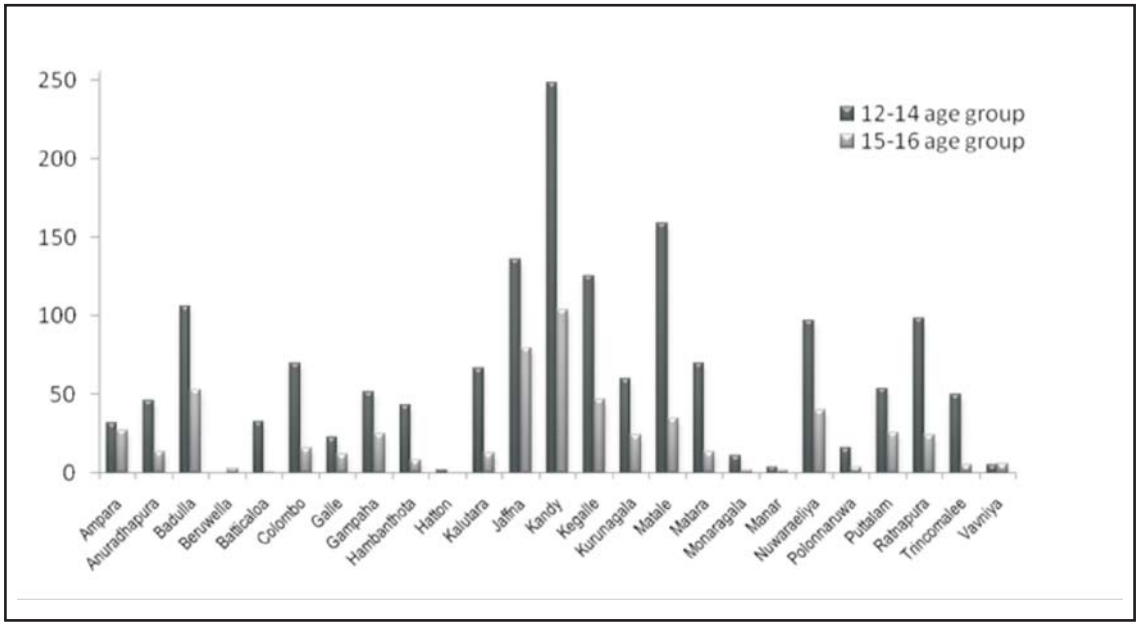

Figure-1: District-wise Distribution of Participants (Black Colour Columns Represents the 12-14 Age Category and Ash Colour Columns Represents The 15-16 Age Category)

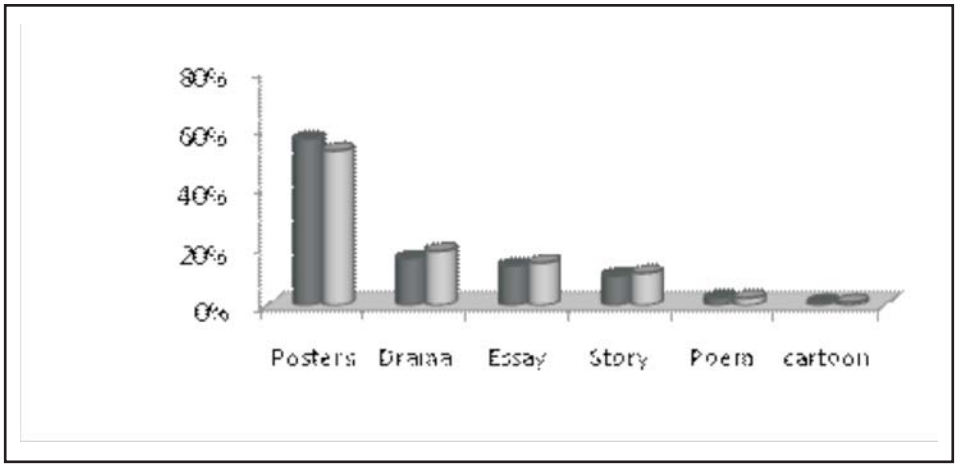

Figure-2: Distribution of the Instruments of Communication that Students used to Explain the Topics (Black Colour Columns Represent the 12-14 Year Age Category and Ash Colour Columns Represent the 15-16 Year Age Category)

essays, stories, poetry, and cartoons to explain their topics (Figure-2).

- Students added cultural flavour to illustrate science concepts in a simple and attractive manner.
- Although students had the option of selecting three topics out of six, only a few selected all three topics. Some selected two topics and most took up only one subject.
- Contrary to what was expected, it was surprising that some of the schools having best facilities and opportunities failed to perform up to their standard.
- It was evident from the presentations made by the students that have good imagination and creative abilities, but poor presentation skills. Their presentation skills were poorer as compared to their writing capabilities.
- Despite the fact that they had learnt the science concepts at school, it was difficult for them to relate those concepts with their daily activities and surroundings. In this competition, students easily gave text book examples to describe scientific concepts but they had a hard time using real life examples (other than what is found in text books) for describing them.

2.1.2 *Feedback*

Last part of this activity was to gather feedback from students who participated in this activity. Following is some of the feedback received from the participants.

a. After taking part in this activity, students realized that they have become interested in finding the science concepts in daily events and occurrences in their surroundings.
b. Some of them informed that they had used heavy scientific words to describe scientific concepts in the past, but now they realize the importance and beauty of explaining things in simple words and with simple examples.
c. Students felt that science is closer to them and they can now look at science in a different angle.

2.2 Activity-2

In the second activity, simple models were created to explain various scientific concepts. For example, to familiarize students with the periodic table: wall clock with elements of the periodic table, card games, desk calendar, etc., were introduced. Similarly, to teach the electrochemical series/reactivity series: snakes and ladders game, wind chimes, and posters, etc., were used as simple models. Flip-flop and origami was used as easy ways to memorize science concepts.

All of these models were introduced to the students. About 90 % percent of the students responded positively towards the models and desired to use those with their fellow students at school. Five percent of the students stated that the models were good. Rest were not keen to make any response. However, most of the students wanted ready-made models rather than making their own. They were reluctant to spend time in constructing even the simplest model using origami.

3. CONCLUSIONS

After reviewing the Activity-1, it was realized that using native communication techniques and adding cultural flavour to express the science concepts in a simple and attractive manner is not only important in improving science communication skills, but also making science more relatable.

Introducing simple models needs more attention, and mass scale survey is needed. Financial constrains limited the vast scale analysis of the applicability of simple models.

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THE USE OF SUGARCANE BAGASSE ASH AS AN ALTERNATIVE LOCAL POZZOLANIC MATERIAL: STUDY OF CHEMICAL COMPOSITION

Mohamed Eljack Suliman and Samah M. Fudl Almola***

ABSTRACT

The sugarcane bagasse ash is used as fuel in the boilers of the Kinana sugar factory in Sudan. The field observation and qualitative study of the ash revealed that it consisted of major amounts of carbon and organic materials; this is due to the incomplete combustion of bagasse fibers in boilers. Therefore, it became necessary to recondition the samples for use as pozzolana by re-ashing it. The study of chemical composition of the ash revealed that such byproducts are likely to be pozzolanic. Comparison between chemical compositions of Kinana sugarcane bagasse ash and the pulverized coal fly ashes (ASTM C 618 1999) shows that the composition of bagasse resembles that of Class F Coal Fly Ash, as the total of alumina, silica, and ferric oxide content is about 72 %. It may, therefore, behave like Class F Fly Ash, in its engineering properties.

Keywords: *Sugarcane, Bagasse ash, Pozzolana, Fly ash.*

1. INTRODUCTION

In the Republic of the Sudan, there are five operational sugar factories that utilize sugarcane. These factories are located at New Halfa in Kassala State; Guenied in Gezira State; Sinnar in Sinnar State, and Kinana and Assalaya in White Nile State. Some of these factories are generating electric power by using the sugarcane bagasse fibres. Bagasse is the fibrous leftover after sugarcane stalks are crushed to extract their juice. Bagasse is now used as a biofuel – as a renewable resource in the manufacture of pulp and paper products, and building materials. Bagasse is often used as a primary fuel source for sugar mills; when burned in quantity, it produces sufficient heat energy to supply all the needs of a typical sugar mill, with energy to spare. To this end, a secondary use for this waste product is in co-generation. The use of a fuel source to provide (i) heat energy, used in the mill, and (ii) electricity, which is typically sold to the consumer electricity grid. The combustion yields ashes containing high amounts of unburned matter, Silicon and Aluminum oxides as main components (Paya, J. et al., 2002).

The demand for building materials has been continuously rising with the increasing consumption of buildings, both in rural and urban areas. It has been seen that materials that were being used about a century back are still very popular. Commercial exploitation of traditional building materials by various industries has aggravated the situation. It has, therefore, become necessary to think over this problem seriously and to provide some sustainable solution to make the alternative materials available to solve this problem. Hence, the use of an alternative and cheaper local building material to substitute the ones being traditionally used may facilitate solving the acute problems relating to building materials (Ballerino, 2002).

Recently, a variety of alternative building materials are available. The use of these new materials may provide better, efficient, durable and cost-effective construction-material resources with reduced degradation of environment. Some of the materials are manufactured by using waste materials, such as fly ash (the ashen byproduct of burning coal), or agricultural waste ash as the raw material for their production (ASTM C 618, 1999).

Among other properties, pozzolanic activity is the main property that the researchers seek in industrial waste material of mineral nature. The pozzolanas are materials containing reactive silica and/or alumina, which on their own have little or no binding property, but when mixed with lime in the presence of water will set and harden like a cement (Lea, 1956). They are important ingredients in the production of an alternative cementing material to ordinary Portland cement. Nowadays, a wide variety of siliceous or aluminous materials of both natural and artificial origins are being used for producing pozzolanas, the common material being calcined clays; pulverized fly ash; volcanic ash; diatomaceous earth and ash from agricultural residues; such as rice husks (Oyetola, and Abdullahi, 2006); and sugarcane bagasse ash (Hernandez, Middendorf, Gehrke, and Budelmann, 1998). The industrial byproducts, including clays and wastes with an elevated silica content, are used as pozzolanas partially in place of Portland cement. This is due to their capacity for reacting with Calcium hydroxide ($Ca(OH)_2$), produced during the hydration of the Portland cement. Hydrated compounds formed during pozzolanic reactions commonly improve the performance of new cements (Massazza, 1976; Taylor, 1997; Metha, 1998; Frý´as, Sa´nchez de Rojas, and Urý´a, 2002; and Frý´as, and Sa´nchez de Rojas, 2004). The recycling of industrial wastes from

* Industrial Research & Consultancy Center, Khartoum, Sudan. Email: abueljack@yahoo.com
** Juba University, Khartoum, Sudan

the agricultural sector is increasingly encouraged, particularly in developing countries, e.g., Cuba, India and Brazil. For use as pozzolanas, the agricultural wastes need prior calcination but pozzolanic activation can vary substantially as a result of the calcining conditions and the nature of the source materials. However, there are contradictory reports about the pozzolanic effectiveness of agricultural waste ashes, possibly due to the use of different calcining temperatures (Martirena, Middendorf, and Budelman, 1998; Baguant, 1995; Paya, et al., 2002; and Singh, Singh, and Rai, 2000).

Since the beginning of the 20th century, sugarcane bagasse has been used as fuel in the boilers of the sugar factories. The sugarcane bagasse consists of approximately 50 % of cellulose, 25 % of hemicelluloses and 25 % of lignin. Each ton of sugarcane generates approximately 26 % of bagasse (at a moisture content of 50 %) and 0.62 % of residual ash. In 2003, approximately 95 % of the sugarcane bagasse produced in Brazil was burnt to generate energy resulting in about two million tons of residual ash (Cordiero, et al., 2004). Table-1 illustrates the basic composition of different bagasse fibres, studied by various authors.

can be used in many construction applications where they have advantages, e.g. as mortars, renders and non-structural concretes (Markopoulos, and Triantafyllon, 2004).

Pozzolanic cements additionally have numerous other technical advantages to the user, such as improved workability, water retention/reduced bleeding, sulphate resistance, resistance to alkali and lowered heat of hydration. Therefore, in many large civil engineering projects involving mass concrete works, Portland cement-pozzolana mixes are specified due to these technical advantages (Eljack, 2008).

The objective of this paper is to describe the chemical nature of some of these resources and to emphasize the fundamental properties of this class of material so that it can be best utilized in an appropriate manner.

2. MATERIALS AND METHODS

A total of six samples (three each from Kinana and Guenaid Sugar companies) of sugarcane bagasse ash obtained after combustion of the bagasse fibres, for power generation were chemically analyzed. The field observation and qualitative studies of sugarcane

Table-1: Basic Composition of Bagasse Fibres (% by mass)

Cellulose	Hemicellulose	Lignin	Ashes	Reference
37	28	21	unreported	Bon, E.S.B., 2007
26 - 47	19-33	14-23	1-5	Paturua, J.M., 1989
38	33	22	3	Trikett, R.C., and Neytzell-de Wilde F.G., 1982
50	25	25	0.62	Cordiero, G.C., et al., 2004

The residue after combustion presents a chemical composition dominated by Silicon dioxide (SiO_2), Aluminium oxide (Al_2O_3) and Ferric oxide (Fe_2O_3). In order to be used as a mineral admixture, the residual sugarcane ash must have appropriate physical and chemical properties. The research work of Hernandez, Middendorf, Gehrke, and Budelmann (1998), emphasizes the similarity between the chemical composition of the rice husk residual ash and the residual bagasse ash (Metha, 1998 and Malhotra, (Ed.), 1996). The study of the mineralogical composition of different wastes of sugar industry, mainly sugarcane bagasse ash and sugarcane straw ash, have shown that such byproducts are likely to be pozzolanic (Hernandez, Middendorf, Gehrke, and Budelmann, 1998); their use in lime-pozzolana binders could become an interesting alternative to Portland cement. The alternative cements are not capable of replacing Portland cement totally, but they

bagasse ash revealed that it consists of a major amount of carbon and organic materials. This is due to the incomplete combustion of bagasse fibres in boiler's system (Eljack, Mohamed and Ibrahim, 2009; and Scheetz, et al., 1997). Thereof, it became necessary to recondition the samples for use as pozzolanic material by re-ashing again at 700°C in the laboratory to exclude the high carbon content. It was then pulverized to pass 150-micron sieve and the resulting ash was chemically analyzed. Table-2 shows the results of chemical analysis of bagasse ash from Kinana and Guenaid sugar companies.

3. RESULTS AND DISCUSSION

The results of the chemical analyses are presented in Table-2, which shows that the amount of silicon dioxide varies from 56.70 % in Guenaid sugar factory bagasse ash to 58.03 % in Kinana bagasse ash; and

Table-2: Average Chemical Composition of Sugarcane Bagasse Ash from Kinana and Guenaid

Oxide	Guenaid sugar factory (%)	Kinana sugar factory (%)
SiO_2	56.70	58.03
Fe_2O_3	15.52	4.56
Al_2O_3	6.81	9.69
CaO	9.30	13.71
MgO	4.50	5.85
LOI	6.40	8.66

iron oxide content ranges between 15.52 % in Guenaid to 4.56 % in Kinana. Aluminum, Calcium and Magnesium oxides and loss on ignition (LOI) also showed significant variations in contents.

Those variations may be due to the difference in soil type from one area to another. The significant increments of CaO values from 9.30% in Guenaid sugarcane bagasse ash to13.71% Kinana bagasse ash may be due to the presence of the lime nodules that are very common in the sediments of the White Nile area, where Kinana sugar factory is situated. These nodules include various forms of calcium carbonate, like calcite nodules and crystals, fossil shells as well as Ankerite (mixed carbonate of Ca, Mg, Fe and Mn) (Eljack, 2008), due to the different fertilizer treatments applied, to improve the cane production.

The chemical composition of the sugarcane bagasse ash produced in the laboratory showed that it is a non-volatile, incombustible, thermally altered mineral matter that was contained in sugarcane. The principal component of those ashes is certain mineral oxides dominant mineral phase in sugarcane. These minerals will undergo dehydroxylation in a fluidized bed combustion facility and melt to form glass in a bagasse combustion unit (Howard, 1989).

When the chemical composition of the sugarcane bagasse ash is compared with the chemical composition of pulverized coal fly ashes, classified by ASTM (ASTM C 618, 1999) by their aggregate Alumina, Silica, and Ferric oxide content into Class F or C. Class F coal ashes are generally produced by higher rank coals and typically have lower calcium content. Class F contains a total of at least 70% of these three oxides and Class C contains greater than 50% of the three oxides (ASTM C 618, 1999). Table-3 summarizes the average bulk composition of a Class F ash based on some analyses (Scheetz, et al., 1997; and Scheetz, and Earl, 1998).

From Table-2, the chemical composition of the sugarcane bagasse ash from Kinana sugar factory is seen to resemble that of Class F coal fly ash (Table-3), especially in terms of the total of Alumina, Silica, and Ferric oxide content. Therefore, it may also behave like Class F fly ash in its engineering properties. Table-4 shows the range of chemical composition of fly ash and a comparison between chemical compositions of Kinana sugarcane bagasse ash and the pulverized coal fly ashes (ASTM C 618, 1999) classification.

The major advantages of the bagasse ash is that it is cheaper to produce, needs much lower or even negligible capital inputs to get started, and requires far fewer imported technological equipment because it is produced by already existing facilities. They can also be produced on a small scale to supply a local market resulting in greatly reduced transportation costs and a much greater degree of local accountability in the supply of building materials.

There are five sugar factories in the Republic of the Sudan. According to the estimates of the Sudan Sugar Company officials, they were delegated to produce a total of 7 million tons of sugarcane stems annually. Each ton of sugarcane stems yields 26% bagasse fibres, i.e. 1.82 million tons of bagasse fibres annually.

Table-3: Average Bulk Composition of a Class F Fly Ash

Oxide	Wt. %
SiO_2	52.5±9.6
Fe_2O_3	7.5±4.3
Al_2O_3	22.8±5.4
CaO	4.9±2.9
MgO	1.3±0.7
LOI	2.6±2.4

Table-4: Comparison between Chemical Compositions of Kinana Sugarcane Bagasse Ash, Guenaid Sugarcane Bagasse Ash and the Pulverized Coal Fly Ashes ASTM C 618 Classification

Oxide	Guenaid sugarcane bagasse ash (%)	Kinana sugarcane bagasse ash (%)	Class F fly ash (%)	Class C fly ash (%)
SiO_2	56.70	58.03	40 - 63	32 - 42
Al_2O_3	15.52	4.56	17 - 28	15 - 20
Fe_2O_3	6.81	9.69	3 - 12	5 - 7
MgO	9.30	13.71	0.6 - 2	4.1 - 6.1
CaO	4.50	5.85	2 - 8	15 - 35
LOI	6.40	8.66	0 - 5	0 - 0.5

Most of the factories are used to burning bagasse fibres for power generation; the burning of one ton of bagasse leads to the production of 0.62% of residual ash (Cordiero, et al., 2004). So, theoretically, the burning of 1.82 million tons of bagasse fibres is going to produce 11,284 tons of residual ash.

4. CONCLUSIONS AND RECOMMENDATIONS

The recent average results of the chemical analyses of the sugarcane bagasse ash from Kinana and Guenaid sugar factories revealed that sugarcane bagasse combustion products (ash) resembles pozzolana in chemical nature. Therefore, it should be considered as an important mineral resource in Sudan. It might be successfully used as an engineering material for a wide variety of applications. The chemical investigations on the bagasse ash carried in this study indicated that it has had more or less the same chemical composition of other artificial pozzolanic material, like fly ash or any other conventional pozzolana.

The author considers that the material may be used for preparing lime ash (pozzolana) mixture for local use as a mortar; and other low cost building material, such as blocks and bricks, especially in the sugar production areas where its availability is high. Therefore, more detailed work to explore the physical and mineralogical characteristics of these materials will enable expansion of engineering and useful applications for environment conservation.

As should be done for all mineral resources, it is strongly recommended to exercise the applications of bagasse ash to avoid potential replacing of one environmental problem with another.

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IDENTIFICATION OF GLACIAL FLOOD HAZARDS IN KARAKORAM RANGE USING REMOTE SENSING TECHNIQUE AND RISK ANALYSIS

Arshad Ashraf[†], Rakhshan Roohi*, Rozina Naz* and Naveed Mustafa**

ABSTRACT

Glacial Lake Outburst Floods (GLOFs) are great hazard for the downstream communities in context of changing climatic conditions in the glaciated region of Pakistan. The remote sensing data of Landsat ETM+ was utilized for the identification of glacial lakes susceptible to posing GLOF hazard in Karakoram Range. Overall, 887 glacial lakes are identified in different river-basins of Karakoram Range, out of which 16 lakes are characterized as potentially dangerous in terms of GLOF. The analysis of community's response to GLOF events of 2008 in the central Karakoram Range indicated gaps in coordination and capacity of the local communities to cope with such natural hazards. A regular monitoring of hot spots and potential GLOF lakes along with capacity-building of local communities and institutions in coping future disaster situation is necessary, especially in the context of changing climatic conditions in Himalayan region.

Keywords: *Glacial lakes, GLOF hazard, Climate change, Remote sensing, Karakoram*

1. INTRODUCTION

The glacial lakes dammed by moraines and or ice core of retreating glaciers may breach suddenly due to unstable moraine 'dams', resulting in discharge of huge amounts of water and debris - known as 'Glacial Lake Outburst Flood'. The frequency of natural hazards like flash floods and GLOFs has increased in the Himalayan region of Pakistan due to increase in global warming in recent decades. They often have catastrophic effects in down country; even a small glacial lake associated with hanging glaciers poses high risk of GLOF event. According to Chaudhry, Mahmood, Rasul and Afzaal (2009), Pakistan experienced 0.76°C rise in temperature during the last 40 years. The frequency and persistence of heat waves in glaciated mountains has risen drastically causing rapid melting and sudden discharge of bulk of water to terminal lakes of glaciers increasing the risk of outburst.

According to Goudie (1981) and Miller (1984), among 339 disastrous incidents identified along Karakoram Highway (KKH) in Hunza valley in 1980, the most destructive ones were related to glacial movement that led to outburst floods of ice-dammed lakes. The importance of this situation has magnified over the past decades due to increase in numbers of glacial lakes that are formed at the glacier terminus. Thirty-five destructive out-burst floods have been recorded for the Karakoram Range during the past two hundred years (Hewitt, 1982). Some of the ice dams may have been the result of glacier surges. There is unambiguous evidence of large reservoirs ponded by 18 glaciers. Kelly (1988) outlines the historical development and disappearance of Virjerab lake in Hunza due to glacial motion. There occurred a series of GLOF events in upper Hunza valley, central Karakoram Range, within short time periods during 2008 that had a devastating effect on the nearby communities (Roohi, Ashraf, Mustafa and Mustafa, 2008). The people residing at considerable distances downstream from the unstable lakes are facing a serious threat to their lives and property. This situation calls for in-depth study on GLOF hazard in the Northern Himalayan region.

This paper describes the situation of glacial lakes and lakes susceptible to creating GLOF hazards in the Karakoram Range of Pakistan. A stepwise approach to assess the risk beginning with an extensive desk study of satellite images for the reconnaissance mapping of the glacial lakes was adopted. Also, community based risk and response analysis was carried out in the selected villages in the Karakoram range in order to provide basis for developing timely response and risk-management strategies for the area.

1.1 Glacial Environment of Karakoram Range

The Karakoram Range in Pakistan is bordered by Hindukush Range in the west, Afghanistan and China in the north, Indian held Kashmir in the east and gigantic Indus River flowing in the south. Overall, about 23 % of the Karakoram Range is found under extensive glacial cover. The range houses about 2,398 glaciers, which possess ice reserves of about 2,387 km^3. The biggest ice reserve is contributed by Shyok River basin (about 37 %) followed by Hunza (34 %) and Shigar river basin (24 %). Some of the largest glaciers outside Polar region are present in the Karakoram range, namely Siachen, Hispar, Biafo, Baltoro and Batura. It is ablation zones of these large glaciers that cause the bulk of glacial ice to melt. A large number of glaciers in the Karakoram Range are stable or even increasing (Hewitt, 2005 and 2007).

* Water Resources Research Institute, National Agricultural Research Centre, Islamabad, Pakistan.
† Email: mashr22@yahoo.com

High sliding velocities and isothermal ice produces abundant englacial and sub-glacial meltwater that leave the glacier through sub-glacial tunnels.

Although monsoon is the dominant source of precipitation in main Himalaya and Front Ranges, but in some years the monsoon is strong enough to break through the Front Ranges and can deliver substantial precipitation to the central Karakoram region (Mayewski and Jeschke, 1979; Mayewski, Pregent, Jeschke and Ahmad, 1980). The second source of precipitation is depression coming from the west, which provides dominant nourishment to the glacier systems of the Karakoram Range.

2. DATA AND METHODOLOGY

In the present study, remote sensing data of Landsat-7 Enhanced Thematic Mapper Plus of period 2000-2001 provided by ICIMOD, Nepal, was used for spatial data analysis of lakes. The Landsat-7 ETM+ sensor is a nadir-viewing, 7-band plus multi-spectral scanning radiometer that detects spectrally filtered radiation from several portions of the electromagnetic spectrum. The spatial resolution (pixel sizes) of the image data includes 30 m each for the six visible, near-infrared and short-wave infrared bands, 60 m for the thermal infrared band, and 15 m for the panchromatic band. A scene of a Landsat-7 data gives a synoptic view of an area of 183 km by 170 km of Earth's surface. The list of Landsat scenes covering the study area is given in Table-1. The topographic maps of the Survey of Pakistan available at variable scales and National Imagery and Mapping Agency (NIMA) U.S. (on half million scale) were utilized for image georectification, and acquiring topographic attributes and geographic details of the lakes and associated glaciers, infrastructure and settlements, in the target areas.

2.1 Mapping of Glacial Lakes

For mapping of glacial lakes, the Karakoram Range was divided into five draining basins, i.e. clockwise from the west: Gilgit, Hunza, Shigar, Shyok and part of the Indus basin (Figure-1). The spatial database of lakes of each river basin was systematically developed through on-screen digitization of the image data in ILWIS 3.2 software. The attributes used for the lakes in this study are similar to the lake inventories carried out by LIGG/WECS/NEA (1988), Mool, Bajracharya and Joshi (2001) and Roohi, et al. (2005).

In order to describe the lakes and identify their orientation in a basin, the basin and ridge lines were initially marked through visual interpretation of the panchromatic image. In the panchromatic band of Landsat ETM+ image, the lakes are visible in dark patches with distinct curvilinear boundaries. The land features like ridge and basin boundaries, drainage network, etc. become prominent using low range of digital numbers (DN), i.e. 0-150 of this band type. The cascading ice mass of the glaciers can be visualized distinctly in nearly full stretched pan image, exhibiting not only the orientation of the ice-flow pattern, but also of ridge boundaries hidden underneath thick ice mass over high mountains. In the image of May 2001 (Path-148: Row-36) containing limited snow cover, the glacial lakes were identified on the basis of their smooth texture of the overlying frozen surface.

After defining boundaries of the lakes, these were numbered using point identifiers, i.e. which start from the outlet of the major stream/river and proceeds clock-wise round the basin. Reference longitude and latitude were designated for the approximate centre of the glacial lake by creating a digital point map over the digitized glacial lakes. The area of the glacial lake was determined from the generated digital database. The drainage direction of the lake is specified as one of eight cardinal directions (N, NE, E, SE, S, SW, W, and

Table-1: List of Landsat-7 ETM + scenes Covering Study Area

S. No.	Path	Row	Bands	Date
1	148	035	7 plus	21 July 2001
2	148	036	"	18 May 2001
3	149	034	"	30 Sept. 2001
4	149	035	"	30 Sept. 2001
5	150	034	"	07 Oct. 2001
6	150	035	"	07 Oct. 2001
7	151	035	"	09 Sept. 2000

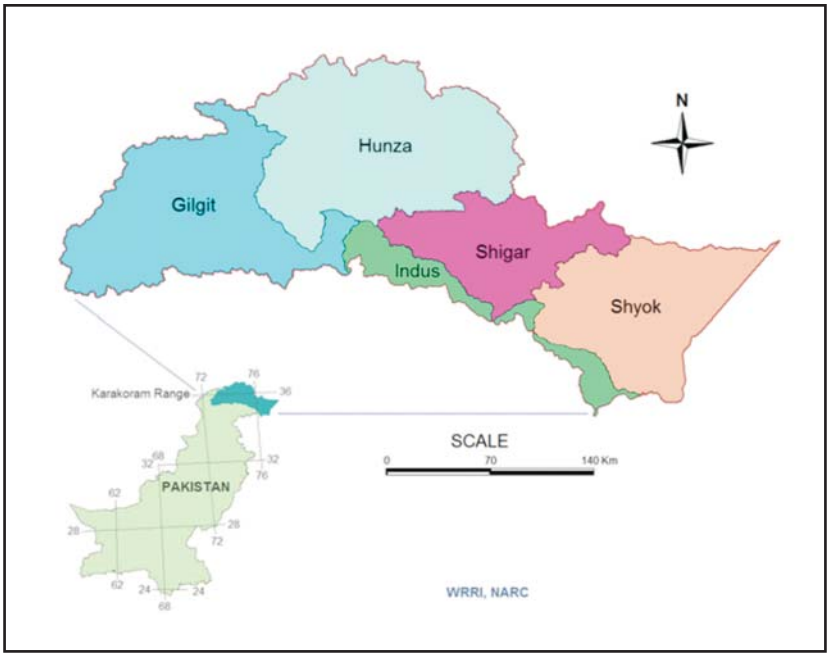

Figure-1: Karakoram Range and its Major River Basins in Pakistan

NW). Glacial lakes are divided into drained lakes and closed lakes according to their drainage condition. The former possess drainage system (Ds), i.e. water from lakes flows into the river; while the latter have closed system (Cs), i.e. water does not flow out from the lakes. For a closed lake, the orientation is specified according to the direction of its longer axis. The lakes were classified into various types according to their formations in the glacial environment. The attribute data of lakes was derived/entered and linked with spatial data in GIS. The glacial lakes with area larger than 0.02 km^2 were characterized as major glacial lakes.

2.2 Criteria for Identification of GLOF Lakes

Although a standard index to define a lake 'potentially dangerous' does not exist, the main factors considered for the study were its physical characteristics and association with its surrounding and nourishing glaciers. The criteria for identifying potentially dangerous glacial lakes are based on factors like processes and records of past events, geo-morphological and geo-technical characteristics. Mool, Bajaracharya and Joshi (2001), and Bajracharya, Mool and Shrestha (2007) identified the following physical conditions of the surrounding area of a lake that may be observed before declaring it to be potentially dangerous.

a. A group of closely spaced supraglacial lakes at glacier tongues merging and forming large lakes;
b. The conditions of the damming material in moraine dammed lakes;
c. The nature of the mother glaciers, i.e. presence of large mother glacier near the lake, debris cover and steep gradient at glacier snout area;
d. Presence of crevasses, ponds at the glacier tongue, collapses of glacier masses at the tongue and ice blocks draining to lake;
e. A moraine dammed lake that had breached and closed subsequently in the past and refilled again with water;
f. Physical conditions of the surrounding area, such as risk of rockfall, mass movements, hanging glacier, snow avalanche site around the lake that can fall into the lake suddenly; and
g. Neo-tectonic and earthquake activities.

The potentially dangerous lakes are generally at the lower parts of the ablation area of the glacier near the End moraine, and the mother glacier should be sufficiently large to create a potentially dangerous lake environment.

The communities' response to GLOF events of 2008 was studied during a survey conducted in selected villages, i.e. Ghulkin, Hussaini and Passu in Hunza valley of Central Karakoram (Questionnaire for the survey is given in Box-1). Ghulkin village is situated in

Box-1: Questionnaire for Community Based Risk and Response Analysis to GLOFs in Hunza Valley, Karakoram Range

1. Personal/Community information
2. What are the main livelihood options in your village?
3. Are these livelihood options seasonal in nature?
4. What is the institutional setup of your village?
5. What are the natural hazards that you have been exposed to in the past?
6. If your village were affected by the last flash floods during 2005, 2007 and 2008, what was the differential impact?
7. What has been the impact of any such event on the livelihood, agriculture, infrastructure, communication network, etc.?
8. Are women and children, elderly and disabled especially affected by such events?
9. Is there a need to train women for disaster preparedness and do they have a significant role to play?
10. How are community leaders, local medical practitioners/priests/teachers involved in any disaster preparedness programme?
11. Was there any loss of life/ other damages, what was the reason behind it?
12. What have been some of the risk reduction measures in the past, either at the community level or the ones initiated by the government?
13. What coping mechanisms do you adopt in the aftermath of an event?
14. How would you rate your access to facilities like healthcare, education, communications, electricity, transportation in connection with disaster preparedness?
15. Before and/or during sudden happening of flood event, what type of warning mechanism is adopted?
16. Who is responsible for rescue activities and selection of suitable sites for shelter?
17. How are the neighbouring villages involved in the rescue work?
18. Are there any redeeming factors of these floods?
19. In which time of the year flooding generally occurred?
20. What is the mechanism adopted for breaching the GLOF lake?
21. Any other comment/note.

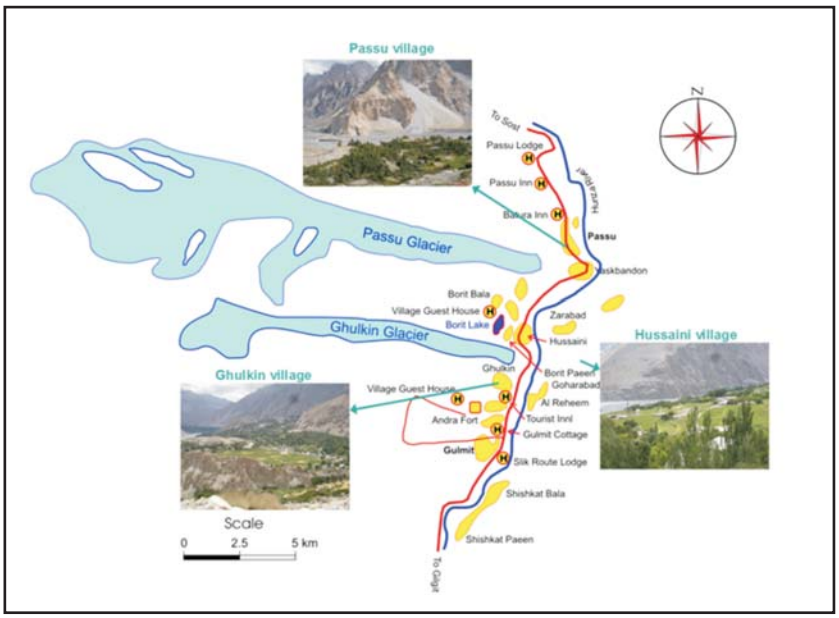

Figure-2: Location of the three Villages Surveyed in Hunza valley of Central Karakoram Range

Table-2: Summary of Glacial Lakes in Major River Basins of Karakoram Range

Basins	Total Lakes	Lakes Area (km^2)	Major Lakes	Potential GLOF Lakes
Gilgit	614	39.2	380	8
Hunza	110	3.2	47	1
Shigar	54	1.1	11	-
Shyok	66	2.7	31	6
Indus part	43	1.6	23	1
Total	887	47.7	492	16

the south of Ghulkin glacier, whereas Hussaini in the north east (Figure-2). Passu village lies in the east of Passu glacier. The village is the setting-off point for climbing expeditions up the Batura, Passu, Kurk and Lupgar groups of peaks, and for trekking trips up the Shimshal Valley and Batura Glacier (www.mountainleaders.com). The Ghulkin, Hussaini and Passu villages have 138, 83 and 117 households and populations of 1133, 621 and 863 persons, respectively (Focus, 2008).

3. RESULTS AND DISCUSSION

The systematic application of remote sensing in GIS environment has revealed about 887 glacial lakes that cover an aggregate area of about 48 sq. km in the Karakoram Range of Pakistan (Table-2 and Figure-3). These lakes can be seen in true color and contrast with the surrounding features using band combinations of 5, 4, 2 and Pan, 7, 6b (Red, Green, Blue) of Landsat ETM+ image. In false color composite (FCC) of 5, 4, 3 (RGB), the lakes in blue color can be differentiated from the black appearance of shadow areas. Majority of the glacial lakes belong to Erosion (39 %) and Valley (17 %) followed by End moraine dammed types (14 %). Most of these lakes lie in the Gilgit basin (Table-3). Supraglacial lakes (formed over glacier surface) are dominant in Hunza, Shigar and Shyok river basins due to prevalent glaciated environment. About 55 % lakes were characterized as major lakes (surface area greater than 0.02 sq. km).

3.1 GLOF Lakes in Karakoram Range

Out of the 887 glacial lakes, 492 were identified as major lakes in the Karakoram Range. Among these

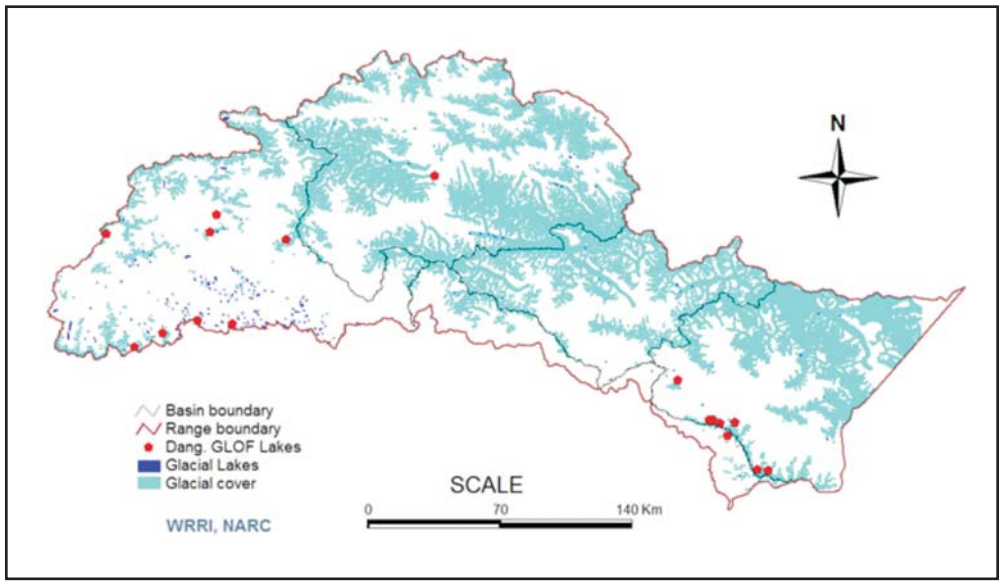

Figure-3: Glacial Environment Indicating Potential GLOF Lakes in Different Karakoram Basins

Table-3: Summary of Different Types of Glacial Lakes in Karakoram Range of Pakistan

Type	Gilgit	Hunza	Shigar	Shyok	Indus	Total
Cirque	53	-	-	2	-	55
End-moraine dammed	100	4	-	12	12	128
Lateral moraine dammed	49	3	1	3	6	62
Erosion	283	20	-	26	13	342
Supraglacial	2	55	30	11	4	102
Valley	125	24	2	8	6	165
Blocked	2	4	21	4	2	33
Total	**614**	**110**	**54**	**66**	**43**	**887**

major lakes, 16 were identified as potentially dangerous GLOF lakes. About 12 of these GLOF lakes belong to End-moraine dammed type, while the rest belong to Valley type. There may be some lakes beneath or within glaciers, but these are usually not visible on images and so cannot be mapped (ICIMOD, 2011). The majority of dangerous lakes are located at elevations between 4,000 and 5,000 metres above sea level, and are either near or in contact with large source glaciers, which make them potentially dangerous (Table-4). The End-moraine dammed lakes are usually in contact or very close to the snout of the glaciers. Some of the source glaciers are hanging in nature, the ice mass of which can fall any time in the lakes causing sudden outburst flooding. The lakes are mostly oriented towards NW, N and NE directions – the aspects that are relatively less exposed to solar radiations.

Among four river basins in the range, Gilgit basin has the maximum of 614 glacial lakes, out of which 380 lakes were characterized as major lakes. Among these, 283 were characterized as Erosion lakes and the largest lake of this type has an area of about 0.21 sq. km. Erosion lakes are usually formed in depressions eroded by the receding glaciers. Here, eight glacial lakes comprising of six End-moraine dammed and two Valley type lakes were identified as potentially dangerous GLOF lakes. Most of these dangerous lakes are associated with large size mountain glaciers of hanging nature, i.e. ice mass of glaciers can fall any time in the lakes creating outburst floods hazard. The settlements, agriculture and grazing land along the streams and Gilgit river are vulnerable to any extreme GLOF incidence in future. Although it is difficult to estimate the probability of occurrence of such flood hazards because of rapid changes in the nature of glacial systems, but effective monitoring of hot spots/glacial lakes and dissemination of early warnings could help in better risk mitigation.

In Hunza River basin, out of 110 glacial lakes, 47 lakes were characterized as major lakes. Majority of these belong to Supraglacial and Valley types. An End-moraine dammed lake (Hunza_gl 6) was identified as potential hazardous. This lake has a surface area of about 0.12 sq. km and is close to a large valley glacier - Passu which has length of about 26 km and average thickness of about 173 meters. The lake had caused heavy flooding in July 2007 and later in April 2008. This resulted in heavy damage to the Karakoram highway, nearby hotels and houses in the Passu village. According to the locals, this lake has breached several times in the past. Although this lake is hazardous for the nearby communities of the Passu village but with the creation of a large land-slide dammed lake at Attabad during February 2010, the villages along Hunza River upto Gilgit and downstream become highly vulnerable of lake outburst flood hazard. Proper monitoring of the lakes' behavior and installation of early warning system can reduce risk of any flood disaster in the downstream areas.

In Shigar River basin, out of 54 glacial lakes, 11 lakes were characterized as major lakes. As most of the northern part of the basin is glaciated, the lakes generally belong to the Supraglacial type. There was no lake identified as potentially hazardous, in this basin.

In Shyok River basin, out of 66 glacial lakes 31 were characterized as major lakes. Six glacial lakes comprising four End-moraine dammed and two Valley type lakes were identified as potentially dangerous GLOF lakes in this basin. The criteria used for characterizing these lakes potentially dangerous are their association with large valley type and mountain

Table-4: Potential GLOF Lakes in Karakoram Range of Pakistan Identified Using 2000 and 2001 Images

Lake Number	Elevation (masl)	Area (ha)	Length (m)	Drainage	Type	Situation
Gil_gl 336	4107	21.4	833	Cs	End Moraine	Near large glacier source
Gil_gl 399	4148	72.9	1569	Cs	End Moraine	In contact of large glacier of hanging nature
Gil_gl 469	4323	26.5	966	Cs	End Moraine	Near large glacier of hanging nature
Gil_gl 505	4375	21.2	690	Cs	End Moraine	Near large glacier of hanging nature
Gil_gl 550	4265	9.6	497	Ds	End Moraine	Near massive glacier
Gil_gl 589	4026	20.4	946	Ds	Valley	In contact of large glacier of hanging nature
Gil_gl 590	4413	19.2	905	Cs	End Moraine	Near several hanging glaciers
Gil_gl 611	3699	28.6	809	Cs	Valley	Near several hanging glaciers
Hunza_gl 6	2546	12.0	453	Ds	End Moraine	Near large glacier
Shyk_gl 45	5022	12.7	802	Cs	End Moraine	In contact of large glacier of hanging nature
Shyk_gl 51	4832	17.1	680	Ds	Valley	In contact of large glacier of hanging nature
Shyk_gl 60	4815	8.0	332	Ds	End Moraine	In contact with large glacier
Shyk_gl 62	4639	9.4	560	Ds	End Moraine	In contact with large glacier
Shyk_gl 64	4656	10.7	705	Cs	Valley	Large glacier source
Shyk_gl 65	4593	21.0	800	Ds	End Moraine	Preceded by a lake and large glacier
Ind_gl 290	4770	13.3	904	Ds	End Moraine	Large glacier source

Note: *Where Cs: Closed system, Ds: Drained system*

type glaciers of hanging nature (criteria c & f under section 2.2) besides End moraines damming and draining characteristics of the lakes. The two End moraine dammed lakes, i.e. Shyk_gl 64 and Shyk_gl 65 lie close to each other and are fed by large source glaciers, draining into a single stream, making the nearest town 'Bara' and further downward 'Shyok River' vulnerable to outburst floods. According to the local sources, the two lakes possess cyclic histories of breaching. Although the lake Shyk_gl 64 was identified being closed due to snow effect in the image, yet it was draining out at the time of survey in the year 2004, which shows misinterpretation of the image due to RS period limitation. It also highlights the importance of synchronization between the image period and time of survey because ground situation may sometime alter rapidly with time. Although maximum potential GLOF lakes lie in remote areas in the southern part of this basin, but in case of any flood event, their effect may reach to communities settled in valleys along main Shyok river. A community-based early warning system needs to be established in order to avoid consequences of any extreme GLOF incident in the basin. In Indus sub-basin part of the Karakoram Range, 43 glacial lakes were identified, among which 23 were characterized as major lakes and only an End-moraine dammed type lake, Ind_gl 290, was characterized as potentially hazardous (Table-4). The low and medium terraces of agriculture land and settlements along the main streams and River Indus in mountain valleys remain vulnerable to glacial flood hazard. The post flooding effects, like bank erosion, debris flows and landsliding may cause high sedimentation, besides other environmental problems.

3.2 Community-based Risk and Response Analysis

In order to provide basis for developing future strategies for timely response and risk-management in the area, a field survey was conducted in Ghulkin, Hussaini and Passu villages in Hunza valley of the Central Karakoram Range during August 2008. The information was mainly collected from about 32 households of the three villages through interaction with notables and elders of both genders. Population distribution in these villages is moderately uneven due to physical conditions of the area. According to most of the respondents, landslides, flash floods and glacier surges are the main natural hazards in this area. A few added earthquake and river erosion. Some of these

hazards, like floods, river erosion and landslides are interlinked, i.e. the intensity of flash floods may increase the process of river erosion and, in some cases cause, landsliding. Though rainfall is not a major hazard in the area, but it triggers mass movement and hazard of landslide. The Karakoram Highway is often blocked due to such events during the rainy season.

According to the respondents in Ghulkin and Hussaini, flash floods mostly occurred between spring and summer seasons but for the first time in January 2008. According to the locals, Ghulkin glacier had flooded at least four times in six months during 2008, causing huge damages to infrastructure and property besides loss of human lives. Two big lakes were formed inside the Ghulkin glacier, most likely due to rapid melting of huge glacial ice mass mixed with rock debris. The water level in one of the glacial lake called 'Sheri Baig' on Ghulkin glacier was rising dangerously (Figure-4), posing a great danger to life and property of the villagers downstream. The extent of Sheri Baig lake depression after the occurrence of GLOF event is shown in Figure-5. The depression formed from outburst of the Supraglacial lake was measured as 221 m in length; 12 m in width; and 7 m in depth.

Most of the communities of these villages are poor and belong to low-income category. The main sources of income are farming, animal rearing, home-making, business, and public service. In Hussaini village, floods had damaged the main irrigation channels that disturbed the livelihood of local community. As flood events had occurred mostly near the agricultural land and at a distance from the main village settlements that is why the loss of human lives was less. Reduced tourism and trade affect the livelihood and economy of the communities. The damage to main highway and bridge costs millions of rupees to repair. Due to floods, there was loss of crop, like wheat, potatoes, apricot, apple and popular trees. The livelihood insecurity due to agricultural losses is among the major concerns. The village people, especially the elderly, women and children are under great mental stress because of the shadowing disastrous effects. According to most of the respondents, the response of villagers to such events is on self-help basis. There exists no formal administrative setup in the villages. During the flood event of April 2008 at Passu, the nearby villagers helped people in evacuating their houses close to the glacier and shifting to safer places to avoid further damages. There exist gaps in coordination and capacity of the local communities of the area to cope with natural hazards like GLOFs.

4. CONCLUSIONS AND RECOMMENDATIONS

- The results of the study helped identify a total of about 887 glacial lakes in the Karakoram Range of Pakistan, out of which 16 were characterized as potentially dangerous GLOF lakes. Majority of these dangerous lakes belong to End-moraine dammed type.
- The less glaciated Gilgit river basin contains the highest numbers of glacial lakes and potential

Courtesy: *Asghar Khan*

Figure-4: Expansion of a Supraglacial Lake on Ghulkin Glacier on May 11, 2008

Figure-5: The Extent of Depression Developed over Ghulkin Glacier after Breaching of Supraglacial Lake. *A Surveyor is Shown in a Circle (Surveyed on August 16, 2008)*

GLOF lakes as compared to highly glaciated Hunza, Shigar and Shyok river basins.

- Most of the dangerous lakes in the Karakoram Range are associated with large valley and mountain type glaciers of hanging nature.
- The local communities are now more vulnerable to frequent glacial hazards probably due to global climate change in the recent decades. Capacity-building of the remote mountain communities of Gilgit, Hunza, Shigar and Shyok, need to be done for their disaster preparedness and survival as well as for issuance early warnings.
- Strategies for flood risk mitigation need to be developed at policy level with the involvement of district management and local communities so that these could be adopted and implemented effectively.
- In the face of increasing efforts of global warming in this region, regular monitoring of GLOF lakes behavior, using high-resolution RS data supported with frequent ground surveys and comprehensive GLOF risk assessment, is imperative to save lives and property of the downstream communities.

ACKNOWLEDGEMENTS

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STRUCTURAL CHARACTERIZATION OF PURE AND DOPED CALCIUM PHOSPHATE BIOCERAMICS PREPARED BY SIMPLE SOLID STATE METHOD

Samina Ahmed†, Md. Humayun Kabir*, Farah Nigar*, Sumaya F. Kabir**, Ahmad I. Mustafa* and Mainul Ahsan **

ABSTRACT

Calcium Phosphate based bioceramic materials, in pure and doped forms have been successfully synthesized from egg shells by using solid-state method for the first time. Considering the diverse role of zinc and fluoride in biological functions, these two ions were chosen to develop the substituted bioceramic materials. Structural characterizations of these developed bioceramics were performed by using FTIR, XRD, SEM and EDS techniques. The results revealed that the fluoride doped apatite was formed in single phase containing hydroxyapatite while pure and Zinc doped apatites contained β-TCP with hydroxyapatite. Experimental results and the crystallographic parameters matched well with the literature values indicating that the present experimental protocol favoured the formation of the desired bioceramics. However, to synthesize the ($Ca_3(PO_4)_2$) based bioceramic materials, such a simple solid-state approach would obviously be very helpful, not only in making the process economically feasible, but also in creating an effective material-recycling technology for waste-management.

Keywords: *Bioceramic, Hydroxyapatite, Synthesis, Egg shell, Solid state method.*

1. INTRODUCTION

Recently, synthetic bioceramic materials biocompatible, bioactive and osteoconductive-are extensively used for medical purposes, e.g. bone tissue engineering, bone substitution, and dentistry fields (Sinha, Misra and Ravishankar, 2008; Kabir, Ahmed, Ahsan and Mustafa, 2012). Among the bioceramic materials, Calcium Phosphate based bioceramics have been used for over 30 years in clinical applications (Desai, 2007). However, it is well-known that human bone is a hybrid composition of inorganic (~70 % apatitic calcium phosphate with a Ca/P ratio 1.66) and organic (~30 % collagen) materials (Ahmed and Ahsan, 2008). The apatitic component termed as Calcium hydroxyapatite [HA, $Ca_{10}(PO_4)_6(OH)_2$)] gets enormous attraction as an implant material for bone substitution (Kamitakahara, Takahashi and Ioku, 2012). Indeed the excellent bioactivity, biocompatibility and osteoconductivity makes the hydroxyapatite (HA) as the principal candidate to be used in the fields of orthopaedics, bone tissue engineering, as well as for dental applications. However, in addition to this HA, (where Ca/P molar ratio is 1.67) two other forms of Calcium phosphate e.g. α-tricalcium phosphate (α-TCP) and β-tricalcium phosphate (β-TCP) are also used as biomaterials. However, wider applications of synthetic HA are somewhat restricted due to its poor thermal stability, undesirable fast dissolution rates *in-vivo* and poor mechanical properties, like low-impact resistance (Webster, Massa-Schlueter, Smith and Slamovich, 2004). On the other hand, higher dissolution rate of β-TCP promotes the formation of continuous interface between Calcium Phosphate ceramics and bone. Hence, this biomaterial also received attention of researchers (Ito, and Ichinose, 2005).

Nowadays, researchers are making efforts to develop doped apatites through the substitution of chemical species found in natural bones. Flexible structure of HA admits several substitutions, which can incorporate cations with different oxidation state, but anions with the same oxidation state as that of $-OH^-$ group. Such incorporations play a significant role in synthesizing HA with enhanced mechanical and physiological stabilities that could be used for restoration of hard tissue, such as bone and teeth (Tang, et al., 2009; Tas, Bhaduri and Jalota, 2007). Recently, due to the diverse role of Zinc (Zn) in biological functions, it has been considered as one of the preferable candidates to develop HA in doped form. The slow release of Zn incorporated into an implant material can accelerate the recovery of a patient by promoting bone formation around the implant (Ming'Ou, et al., 2008). On the other hand, fluoride substituted apatite has attracted much attention due to its extensive performance relating to the stability of apatite and also for its preventive role in dental carries (Kannan and Ferreira, 2006). Although a number of techniques (e.g. wet chemical precipitation method, sol-gel method, hydrothermal synthesis procedure, thermal deposition and solid state reaction method) have already been developed (Balázsi, et al., 2007; Feng, Mu-sen, Yu-peng and Yong-xin, 2005) to synthesize the bioceramic materials in both pure and doped form, but the wet chemical precipitation route scores high as the most popular approach.

Considering the above facts, we have focused on developing Calcium phosphate bioceramics in pure and doped form (Zn and fluoride doped) from egg shell

* Bangladesh Council of Scientific and Industrial Research (BCSIR), Dhaka, Bangladesh. † Email: shanta_samina@yahoo.com
** Department of Applied Chemistry and Chemical Engineering, University of Dhaka, Bangladesh.

through a simple-solid state approach. Such an attempt would obviously be beneficial not only to make the process economically feasible, but utilization of egg shell would also create an effective material-recycling technology for waste-management.

2. MATERIALS AND METHODS

2.1 Synthesis of Pure and Doped Calcium Phosphate Bioceramics

Prior to the synthesis of bioceramic materials, raw egg shells were cleaned, washed and dried at 100°C in an oven. The oven-dried egg shells were then powdered and finally characterized as mentioned previously (Kabir, Ahmed, Ahsan and Mustafa, 2011). Analar grade chemicals (ZnO, $(NH_4)_2HPO_4$ and NaF) obtained from either E. Merck or BDH were used.

Pure and doped bioceramics (apatites) were synthesized through a simple solid-state approach described as follows. In order to synthesize pure apatite, requisite amount of egg shell powder and $(NH_4)_2HPO_4$ were mixed thoroughly maintaining Ca/P ratio at 1.66. The mixture was then ball milled for about 8 hrs. While in case of Zn and fluoride doped apatite, ZnO and NaF were added, respectively, to the egg shell powder before ball milling (the ratio of doping precursor and egg shell powder was 1.10). After the completion of the ball milling operation each of the mixture was calcined at 900°C for 30 minutes. The calcination temperature was raised slowly (3°C / min). The apatites thus formed by this solid-state reaction method were then characterized by FTIR, XRD, SEM and EDS techniques.

2.2 Characterization of Pure and Doped Calcium Phosphate Bioceramics

The presence of the functional groups in the developed apatite samples were investigated through the FTIR analysis. FTIR peaks were recorded by using FTIR- Prestige 21 (SHIMADZU). Samples-to-KBr ratio of 1:100 was used to obtain experimental spectra and the samples were scanned in the mid infrared-wave number range of 4000 cm^{-1} to 400 cm^{-1} with an average of 30 scans. The resolution of the spectrometer was 4 cm^{-1}.

The phase analyses of the raw materials and the synthesized apatites were accomplished using X-ray diffractometer (PANalytical X'Pert PRO XRD PW 3040). The intensity data were collected in 0.02° steps at the scanning range of $2\theta = 5° – 90°$ using CuKα (λ = 1.54178°A) radiation. The phases present in the developed Calcium phosphate based bioceramics were compared and confirmed using standard JCPDS files for hydroxyapatite and β-TCP.

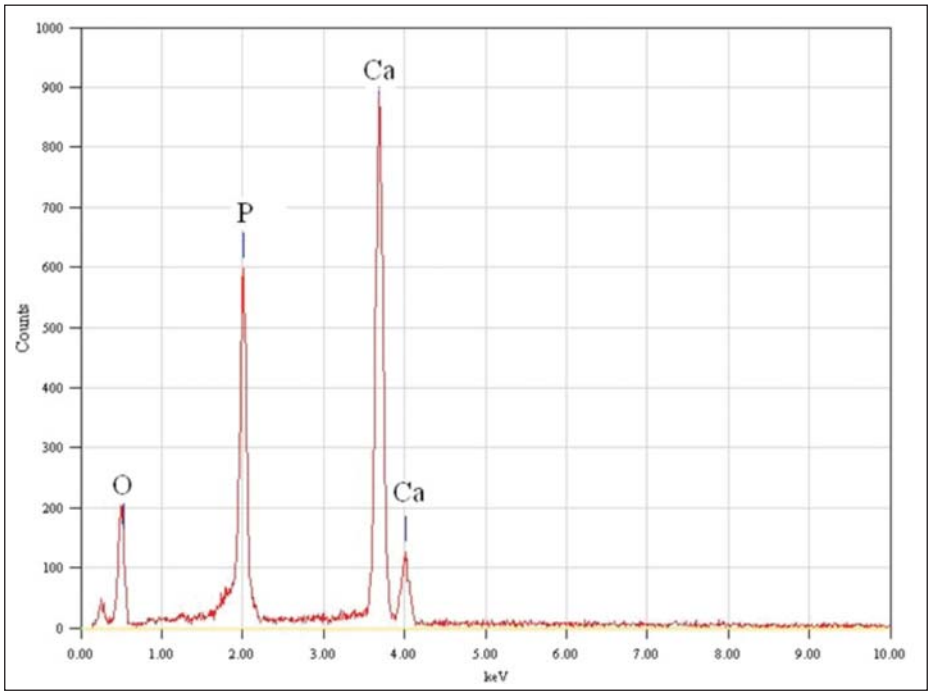


Figure-1(a): EDX Spectrum of Pure Calcium Phosphate Bioceramic

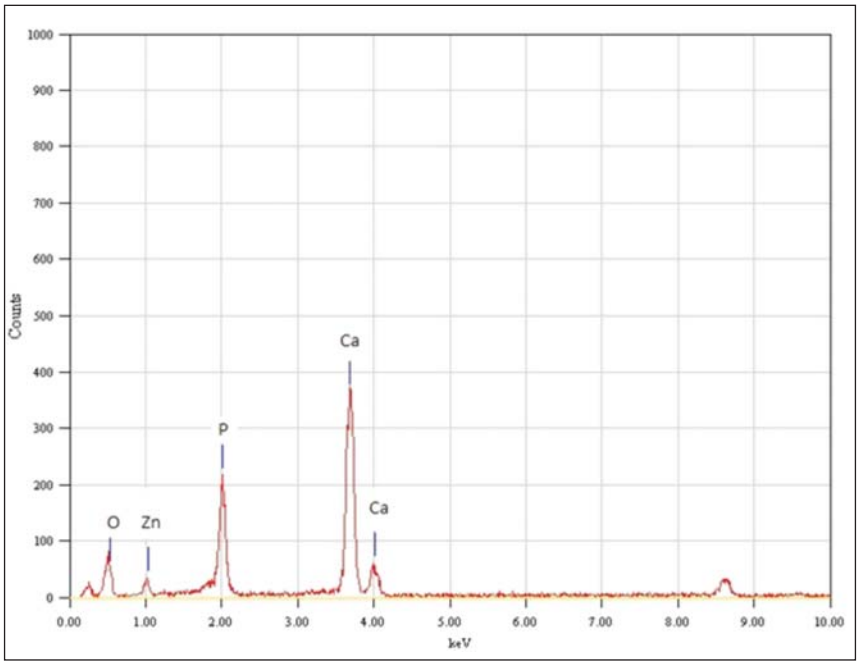


Figure-1(b): EDX Spectrum of Zn Doped Calcium Phosphate Bioceramic

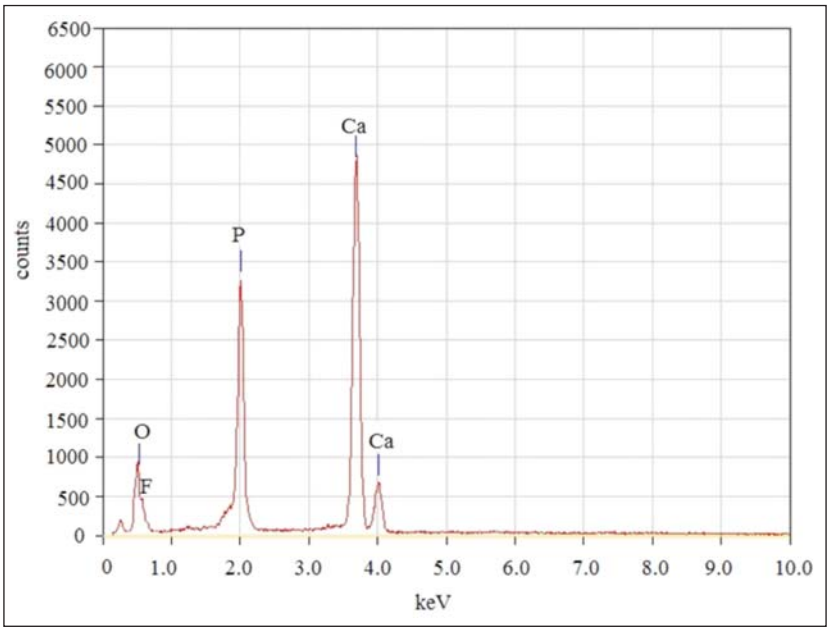


Figure-1(c): EDX Spectrum of F Doped Calcium Phosphate Bioceramic

The surface morphology and microstructural features of the synthesized bioceramic materials were observed by JEOL-JSM 6490LA scanning electron microscope (SEM) equipped with Energy Dispersive X-ray (EDX). The EDX spectra ensured the presence of the expected elements in the synthesized bioceramics.

3. RESULTS AND DISCUSSION

3.1 EDX Analysis

The recorded EDX spectra of the synthesized Calcium Phosphate bioceramic materials are depicted in Figures-1(a – c), which clearly visualize the presence

Table-1: FTIR Band Positions and their Corresponding Assignments

Observed band positions (cm^{-1}) in the Ca-phosphate bioceramics			Corresponding assignments
Pure form	**Zn doped**	**Fluoride doped**	
495.71	445.56	468.70	ν_2 PO_4^{3-} bend
551.64	551.64	570.93	ν_4 PO_4^{3-} bend
607.58	601.79	603.72	ν_4 PO_4^{3-} bend
727.16	--	744.52	CO_3^{2-} group
974.05	--	--	ν_1 PO_4^{3-} stretch
1037.70	1037.70	1047.35	ν_3 PO_4^{3-} stretch
3442.94	3442.94	3441.01	OH^- stretch
--	--	3533.59	OH…F bond

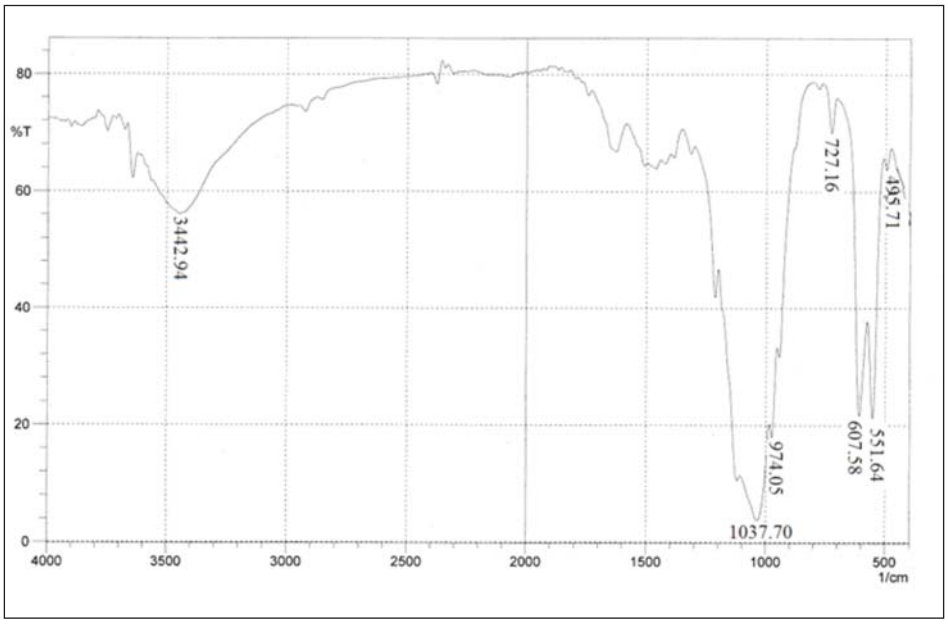


Figure-2(a): FTIR Spectrum of Pure Calcium Phosphate Bioceramic

of the elements Ca, P and O in all the three synthesized samples. However, in addition to these elements, the presence of Zn and F are also evident in the Zn-doped and fluoride doped apatites, respectively (Figures-1(b) and 1(c)).

3.2 FTIR Analysis

The resulted FTIR spectra of the synthesized Calcium phosphate bioceramic materials are shown in Figures 2 (a – c), while the observed band positions and their respective assignments are tabulated in Table-1. It is evident from Table-1 that the corresponding band positions for PO_4^{3-}, CO_3^{2-}, OH^- groups and OH…F bond are well-defined and in excellent agreement with the characteristic FTIR data for crystalline apatite phase as observed in many previous studies (Rameshbabu, Kumar and Rao 2006; Eslami, Solati-Hashjin and

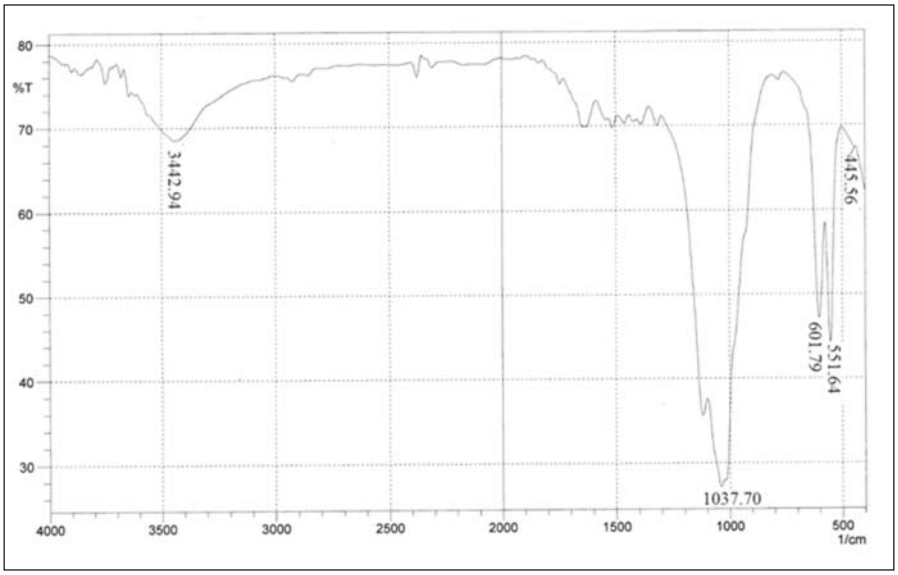


Figure-2(b): FTIR Spectrum of Zinc Doped Calcium Phosphate Bioceramic

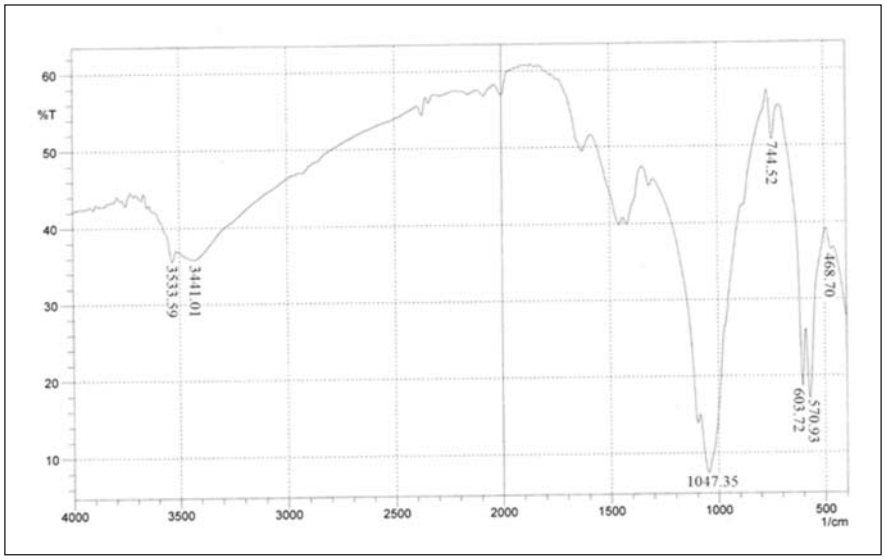


Figure-2(c): FTIR Spectrum of F Doped Calcium Phosphate Bioceramic

Tahriri, 2008; Montazeri, et al., 2010). However, the distinct features of all the synthesized bioceramics are summarized as follows:

i) The noticeable large separation between the two bands at 551.70 cm^{-1} – 570.13 cm^{-1} and 601.79 cm^{-1} – 607.58 cm^{-1} further suggested that the synthesized bioceramic materials are well crystallized and comprised apatitic phase (Ahmed and Ahsan, 2008).

ii) The band positions appeared at 3533.59 cm^{-1} in the fluoride doped apatite represented the stretching mode of OH…F bond. The presence of this band demonstrated that some of the OH^- groups of HA were substituted by F ion as expected.

iii) Another significant observation was the absence of the band at ~632 cm^{-1} in the FTIR spectra of all

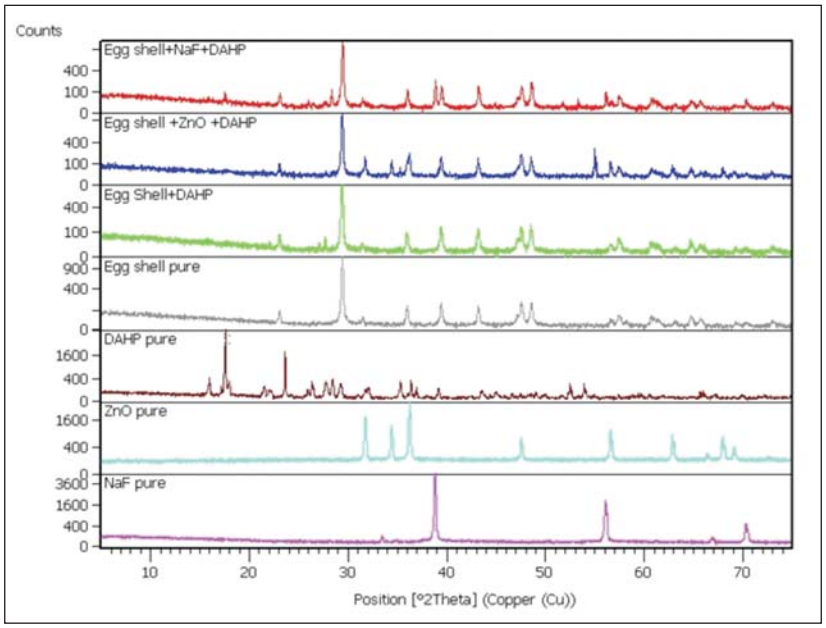


Figure-3: XRD Spectra of the Raw Materials used to Synthesize Pure HA, Zn Doped HA, and Fluoride Doped HA

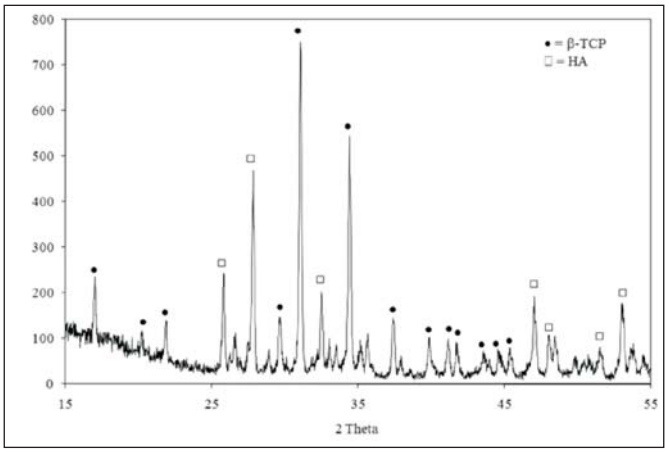
synthesized samples. The band position at ~632 cm^{-1} signified the presence of structural OH^- (OH liberation mode) in HA (Ahmed and Ahsan, 2008). However, in the case of fluoride doped apatite, lack of this band further ensured the OH^- group of the HA has been substituted by the desired fluoride ion (Montazeri, et al., 2010). On the other hand, in the case of pure and Zn doped apatite, absence of this structural OH^- band at ~632 cm^{-1} indicated the transformation of HA into β-TCP, which is also verified by XRD data.

3.3 XRD Analysis

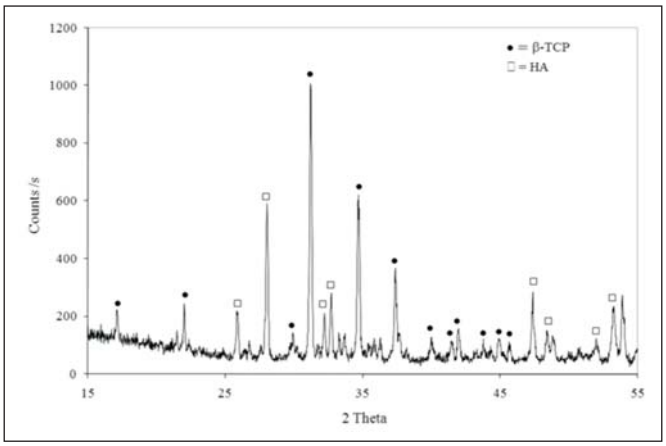
The XRD spectra of the raw materials (in pure and mixed forms) used for the synthesis of HA and doped apatites are shown in Figure-3. Prior to the XRD, the raw materials were only ball milled but not calcined. Clearly, the XRD spectra of the raw materials (egg shell, ZnO, NaF and di-ammonium hydrogen phosphate, DAHP), show the characteristic peaks for calcite (ICDD Ref. code 01-072-4582), ZnO (ICDD Ref. code 01-070-2551), NaF (ICDD Ref. code 00-001-1181) and DAHP (ICDD Ref. code 00-008-0033), respectively. However, the XRD spectra (Figure-3) of the uncalcined raw materials in mixed form (i. egg shells and DAHP; ii. egg shell, ZnO and DAHP; iii. egg shell, NaF and DAHP) show only the characteristic peaks for the respective raw materials but not for any HA or β-TCP formation. This observation ensured that without sintering no desired product formation occurred.

The XRD spectra of the synthesized bioceramic materials are depicted in Figures-4(a-c). The recorded spectra of pure and Zn doped HA Figures 4(a) and (b) resulted several sharp and intense peaks characteristic of HA and β-TCP. This observation suggests a truly crystalline nature of the synthesized apatites. On the other hand, the XRD of the fluoride doped HA revealed only the peaks of HA. The major d-spacing values as tabulated in Tables 2-3 are compared with the JCPDS standard data for HA (Ref. code:89-6439) and β-TCP (Ref. code:09-0169) (Kannan and Ferreira, 2006; Kannan, Ventura and Ferreira, 2007).

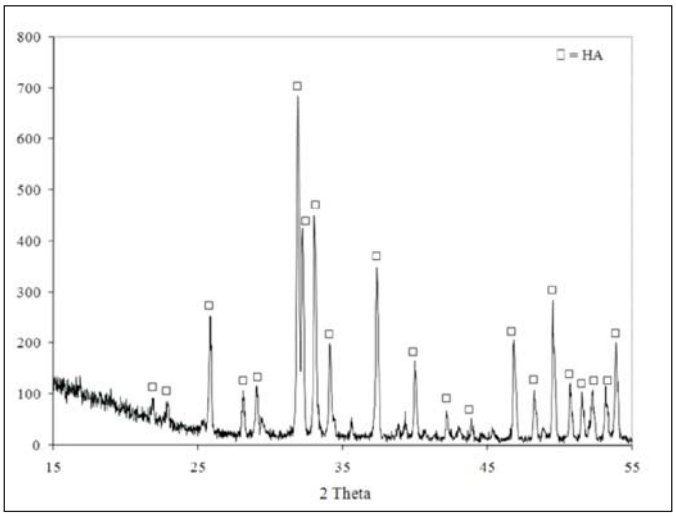
It is obviously confirmed from Tables 2-3 that the fluoride doped apatite is formed in purely single phase containing HA of hexagonal structure (Ahmed and Ahsan, 2008). Particularly, the strong diffraction peaks corresponding for HA at 2θ position 31.87° (2 1 1 plane) together with other two peaks at 32.20° (1 1 2 plane) and 33.03° (3 0 0 plane) of almost equal intensities confirmed the formation of well-crystalline pure HA (Ahmed and Ahsan, 2008). However, the most noteworthy detection was the shift of 2θ positions for (3 0 0), (4 1 0) planes to higher diffraction angles, while (0 0 2), (0 0 4) planes appeared at lower diffraction angles as compared with the JCPDS values



(a)



(b)



(c)

Figure-4: XRD Spectrum of (a) Pure Calcium Phosphate Bioceramic; (b) Zinc Doped Calcium Phosphate Bioceramic; (c) Doped Calcium Phosphate Bioceramic

Table-2: Comparative d-spacing Values of Synthesized Calcium Phosphate Bioceramics and JCPDS Standards for HA

JCPDS standards for HA		Experimental values of the synthesized Calcium phosphate bioceramics						h k l
		Pure form		Zn doped		Fluoride doped		
d-value	Intensity %	*d*-value	Intensity	*d*-value	Intensity %	*d*-value	Intensity %	
4.077	6.40	4.060	17.14	--	--	4.060	11.84	2 0 0
3.440	35.50	3.450	31.80	3.440	17.76	3.446	36.81	0 0 2
2.813	100.00	2.812	6.60	2.812	5.45	2.810	100.00	2 1 1
2.774	47.60	2.779	6.52	2.777	15.47	2.778	61.12	1 1 2
2.718	64.20	2.710	9.19	--	--	2.710	67.12	3 0 0
2.629	21.90	--	--	--	--	2.629	23.90	2 0 2
2.261	22.20	2.260	12.64	2.253	7.95	2.255	20.49	1 3 0
1.943	27.60	1.932	19.76	1.948	1.82	1.940	28.18	2 2 2
1.840	30.30	--	--	--	--	1.840	41.00	2 1 3
1.720	13.70	1.721	15.77	1.720	18.59	1.722	15.77	0 0 4

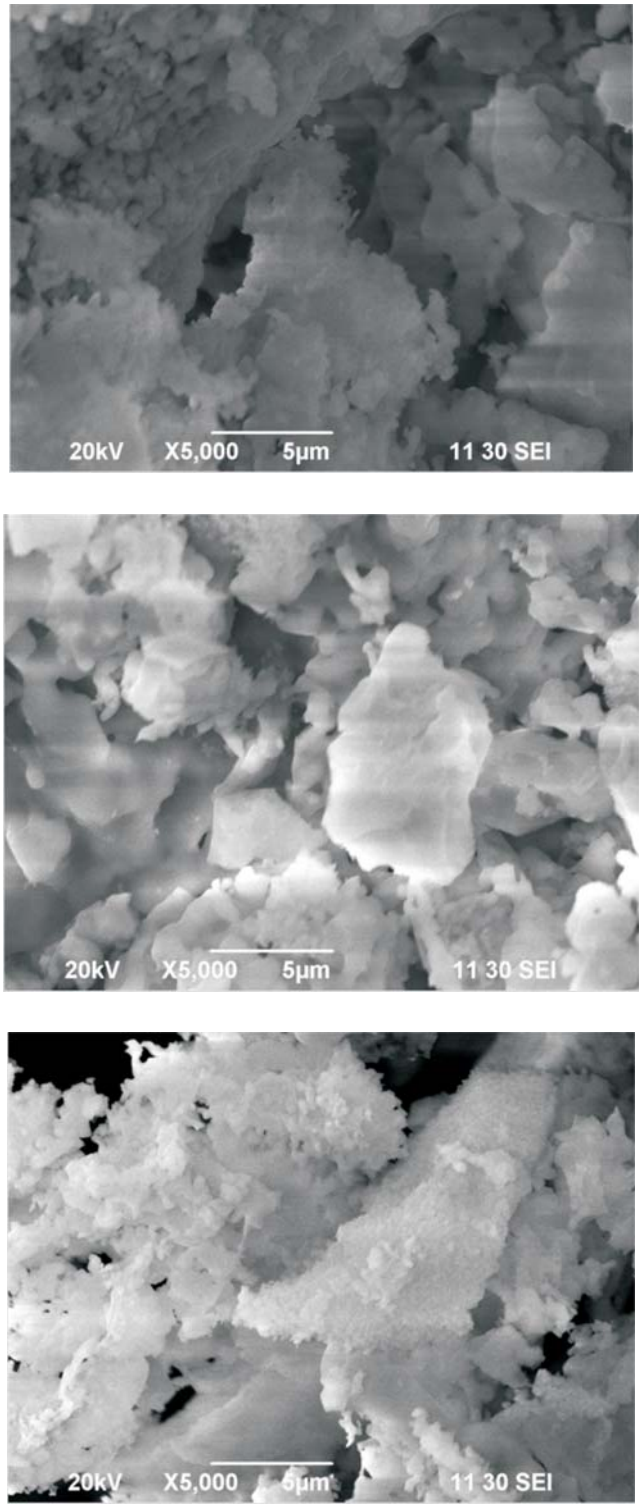
Table-3: Comparative d-spacing Values of Synthesized Calcium Phosphate Bioceramics and JCPDS Standards for β-TCP

JCPDS standards for β-TCP		Experimental values of the synthesized Ca-phosphate bioceramics				h k l
		Pure form		Zn doped		
d-value	Intensity %	*d*-value	Intensity %	*d*-value	Intensity %	
3.00	12.20	3.01	17.85	2.99	10.39	3 0 0
2.87	100.00	2.87	100.00	2.86	100.00	0 2 10
2.75	22.20	2.75	26.21	2.74	24.55	1 2 8
2.61	64.80	2.61	60.97	2.59	58.48	2 2 0
2.07	5.50	2.07	7.03	2.07	7.54	0 0 18

Table-4: Calculated Crystallographic Parameters for the Synthesized Calcium Phosphate Bioceramics

Ca-phosphate bioceramics	Identified phases	Calculated crystallographic parameters	JCPDS data
Pure form	β-TCP (dominant phase)	*a* = 10.44 Å, *c* = 37.37 Å *V* = 3527.29 Å	(for β-TCP) *a* = 10.43 Å *c* = 37.38 Å *V* = 3520.91 Å (for HA) *a* = 9.41 Å *c* = 6.88 Å *V* = 1577.25 Å (for F-HA) *a* = 9.37 °A *c* = 6.88 °A *V* = 1563.2 Å
	HA	*a* = 9.42 Å, *c* = 6.88 Å *V* = 1580.6 Å	
Zn doped	β-TCP (dominant phase)	*a* = 10.39 Å, *c* = 37.26 Å *V* = 3483.3 Å	
	HA	*a* = 9.39 Å, *c* = 6.86 Å *V* = 1565.98 Å	
Fluoride doped	Fluoroapatite (F-HA) (single phase)	*a* = 9.37 Å, *c* = 6.89 Å *V* = 1566.1 Å	

for pure HA. This observation is quite consistent with the previous results (Barinov, et al., 2004). These shifts indicated the substitution of OH^- with F ions in the apatite structure (Montazeri, et al., 2010) and are characteristic of fluoride doped hydroxyapatite formation. Such observation obviously validated the FTIR spectral data, as illustrated previously.



(a)

(b)

(c)

Figure-5: XRD Spectrum of (a) Pure Calcium Phosphate Bioceramic; (b) Zn Doped Calcium Phosphate Bioceramic; (c) F Doped Calcium Phosphate Bioceramic

On the other hand, in the case of pure and Zn doped apatites although the presence of HA phase was visible (Table-2), but β-TCP of rhombohedral structure was indexed as the dominating phase (Table-3). Particularly the corresponding diffraction peaks for (3 0 0), (0 2 10) and (2 2 0) planes reflected the presence of β-TCP along with the HA. The volume fraction (X_β) of β-TCP was estimated using the following equation (Saranya, Kowshik and Ramanan, 2011).

$$X_\beta = \frac{PW_\beta}{[1+(P-1)W_\beta]} \quad \text{.....(1)}$$

$$\text{where } W_\beta = \frac{I_\beta}{I_\beta + I_{HA}} \quad \text{.....(2)}$$

I_β and I_{HA} are the XRD intensity values of β-TCP at [0 2 10] and HA at [2 1 1] reflections, respectively. The coefficient P is the integrated intensity ratio of HA at [2 1 1] to β-TCP at [0 2 10] reflection. The value of P was determined as 2.275 using the XRD of the mixtures of standard HA and β-TCP (Saranya, Kowshik and Ramanan, 2011). Percent (%) volume fraction (X_β) of β-TCP in synthesized pure and Zn doped HA was found to be 97 and 98, respectively. Thus, calcination of HA at 900°C facilitated the formation of β-TCP according to the following equation:

$$Ca_{10}(PO_4)_6(OH)_2 \rightarrow 3\,Ca_3(PO_4)_2 + CaO + H_2O \quad \text{.....(3)}$$

3.4 Crystallographic Parameters

The crystallographic parameters of the synthesized pure and doped (Zn and F doped) bioceramics (both hydroxyapatite and β-TCP) were calculated using the Equation-4, which is usually used for both hexagonal and rhombohedral crystal systems, because rhombohedral crystal system belongs to the special type of trigonal class and the difference between the trigonal and hexagonal system is the symmetry. A hexagonal unit cell has C_6 symmetry, whereas a trigonal unit cell has C_3 symmetry.

$$\frac{1}{d^2} = \frac{4}{3}\left(\frac{h^2+hk+k^2}{a^2}\right) + \frac{l^2}{c^2} \quad \text{.....(4)}$$

The volume (V) of the hexagonal unit cell for HA and the rhombohedral unit cell for β-TCP were calculated using Equations 5 and 6, respectively.

$$V = 2.589a^2c \quad \text{.....(5)}$$

and $$V = 0.866a^2c \quad \text{.....(6)}$$

Given in Table-4 are the calculated crystallographic parameters for all the samples as compared with the standard JCPDS files (Kannan, Ventura, Ferreira, 2007; Barinov, et al., 2004). The experimental values of pure and F doped form of Calcium phosphate bioceramics are in good agreement with the standard JCPDS data. The contraction of a-axis of the fluoride doped apatite (Table-4) is because of the smaller size of F ion (ionic radius = 1.36) compared to -OH ion (ionic radius = 1.68). On the other hand, the values of a and c-axes of Zn doped bioceramic are slightly smaller than the JCPDS values. Such contraction in a and c-axes reflects the effect of smaller ionic radius of Zn^{+2} (0.74) than the Ca^{+2} (0.99) (Miyaji, Kono and Suyama, 2005).

3.5 SEM Observation

The recorded SEM images (5000 magnification) of the three types of synthesized apatites are shown in Figures 5(a-c). All of these SEM micrographs visualized an aggregate consisting of interconnected particles. However, the grain sizes of the synthesized apatites were in the following order: Zn doped apatite > pure apatite > F.e doped apatite.

4. CONCLUSIONS

Considering the importance of bioceramic materials in the fields of orthopaedics and dentistry, Calcium phosphate based bioceramics in pure and doped form (Zn and fluoride doped) have been successfully synthesized from egg shell by solid state method for the first time. Under the present experimental protocol, pure and Zn doped bioceramics were formed in mixed phases where β-TCP was the dominant phase along with small amount of the HA phase. On the other hand, fluoride doped apatite was synthesized in single phase, which was solely fluoroapatite (F-HA). Experimental results were validated using the JCPDS standard values, and a very promising matching between the experimental data and the JCPDS values was observed.

Since choices of raw materials and the methodology are very important in developing a cost-effective protocol, egg shell was chosen as the raw material of

Ca source, while simple solid-state reaction was followed to synthesize the Calcium phosphate based bioceramic materials. Thus, such selection would obviously be very helpful not only to make the process economically feasible, but also to create an effective material-recycling technology for waste-management.

5. ACKNOWLEDGEMENTS

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MONITORING DEFORESTATION AND URBANIZATION GROWTH IN RAWAL WATERSHED AREA USING REMOTE SENSING AND GIS TECHNIQUES

Muhammad Amir Saeed[†], *Arshad Ashraf***, *Bashir Ahmed*** *and Muhammad Shahid****

ABSTRACT

The Rawal watershed in Pothwar region of Pakistan has undergone significant changes in its environmental conditions and landuse activities due to numerous socio-economic and natural factors. These ultimately influence the livelihood of the inhabitants of the area. The connected environmental changes are resulting in accelerated land degradation, deforestation, and landslides. In the present study, spatio-temporal behaviour of landuse/landcover in the Rawal watershed area was investigated using Remote Sensing (RS) and Geographical Information System (GIS) techniques. Satellite image data of LANDSAT ETM+ of 1992, 2000 and 2010 periods were processed and analyzed for detecting landuse change and identifying risk prone locations in the watershed area.

The study results revealed significant changes in the coverage of conifer forest (34 % decrease), scrub forest (29 % decrease) and settlement (231 % increase) during the decade 1992-2010. The rate of decline in conifer class is about 19 ha/annum while that of scrub class is 223 ha/annum. In both the cases, the rates of decrease were higher during the period 1992-2000 than the period 2000-2010. The Agriculture land has shown an increase of about 1.8 % while built-up land had increased almost four folds, i.e. from 2.6 % in 1992 to 8.7 % in 2010. The growth in urbanization may result in further loss of forest cover in the watershed area.

The findings of the study could help in developing effective strategies for future resource management and conservation, as well as for controlling land degradation in the watershed area.

Keywords: *Deforestation, Urbanization, Rawal Watershed Area, Remote Sensing, Geographical Information System (GIS).*

1. INTRODUCTION

The forest and agricultural lands are a vital resource of Pakistan, which is being degraded with time. The loss of a forest cover from a steep slope often leads to accelerated surface erosion, and dramatically increases the chances of landslides as well as surface runoff. The consequences of deforestation include raised riverbeds due to increased channel siltation, which ultimately leads to more flooding in low-lying areas; destruction of aquatic habitat and deterioration the quality of water. Increase in population leads to urbanization and conversion of agricultural land into built-up land, as well as forest land into agricultural/built-up land, etc. The Rawal watershed is facing risks of rapid urbanization and deforestation, due to which landuse of watershed is changing. This situation is ultimately affecting climate and watershed health, i.e. Rawal lake storage-capacity has been reduced by 34 % due to sedimentation (IUCN, 2005).

Comprehensive information on the spatial and temporal distribution of land use/landcover is essential for planning, utilization and better management of land resources, especially for developing countries. Monitoring of landuse/landcover is useful to plan development activities, such as major schemes for community requirements and sustainable watershed management. This information is also helpful in monitoring the dynamics of landuse resulting from the growing needs of the population growth. There is no systematic study carried out to document the landuse variability in the Rawal watershed yet.

Rawal dam, which is the main source of water supply for Rawalpindi city of Pakistan, generates almost 33,995 hectares feet of water in an average rainfall/year and 83 million liters/day to fulfill drinking and other household needs (IUCN, 2005). It also provides a limited water supply for irrigation to downstream areas. Many recreational initiatives have been developed in the watershed, e.g. Lake View point, Chatter and Valley parks, etc., and agricultural and residential activities in progress in the watershed area. The spatial and temporal landuse of watershed is changing rapidly due to different human and natural activities that are also degrading the watershed health (Aftab, 2010). The watershed land is being degraded due to conversion into settlements, ultimately resulting in forest-cutting. Population is increasing due to migrations from rural/other cities due to better provision of services/facilities and employment opportunities in the study area. Mushrooming of residential and commercial buildings in the area is occurring (IUCN, 2005). Also, well-off and elite families of these areas are migrating to the capital of Pakistan, Islamabad, which occupies 47 % area of Rawal watershed. Due to high cost of land, many poor people of the area are selling their inherited lands to start businesses for improved livelihoods. Many

* PARC Institute of Advanced Studies in Agriculture, NARC, Islamabad, Pakistan. [†] Email: amirsaeeduaf@yahoo.com ** Water Resources Research Institute (WRRI), NARC, Islamabad, Pakistan. *** Pakistan Atomic Energy Commission (PAEC), Islamabad, Pakistan

housing schemes and real estate agencies are promoting agricultural farmhouses in the watershed. Illegal wood cutting continues in the watershed area to meet the construction needs of houses for the local population due to high value of forest wood. These activities are resulting in accelerated deforestation in the watershed area. So far, there is no systematic study carried out to document the landuse variability in the watershed area. To assess the spatial and temporal urban and forest landuse/landcover, the role of Remote Sensing (RS) and Geographic Information System (GIS) is very important.

2. REMOTE SENSING APPLICATION IN LANDUSE MONITORING

Satellite imagery is a useful source for landcover information, and urban landcover has been identified and mapped using remotely sensed data with a fine spatial resolution (Yang, 2002; Tapiodor and Casanova, 2003). In recent years, there has been an increasing awareness of the effects of geographical variables in eco systems. In particular, fundamental variables, such as scale and spatial patterns, have become increasingly important in a vast array of ecological research (Drakare Lennon and Hillebrand, 2006; Agrawal, et al., 2007). RS now regularly provides agricultural scientists and ecologists with information on the earth and its environment at scales from the local to global. GIS provides, among other things, a means to store analyze and visualize spatial data including those derived from remote sensing together with associated advancements in computational facilities and specialist tools, such as methods for spatial analysis (Austin, 2007; Osborne, Foody and Seoane, 2007).

Considering the spectral resolution of the RS data, the technique has high potential for monitoring landcover/landuse behaviour, natural resource environment and risk of land degradation at watershed area in Pakistan. RS and GIS can contribute to monitoring landuse/landcover in a wide variety of ways. RS has frequently been used to derive landcover information. Changes in landuse and landcover are major variables affecting ecological systems. Landcover types, for example, differ greatly in their biogeochemical cycling, and thus knowledge of their distribution is important in many environmental modeling studies. Landcover change has major impacts on issues ranging from climate change to biodiversity conservation. Given that the remotely sensed response is essentially a function of landcover type, there has been considerable interest in using remotely sensed data as a source of information on landcover.

To assess the spatial and temporal urban and forest landuse/landcover, the role of RS and GIS is very important. Zafar, Baig and Irfan (2011) studied landuse changes using satellite RS data for management zoning of the Margalla Hills National Park based on different environmental factors. Rabab (2011) used time-series RS data for discrimination of Rabi crops and associated landcovers. Wheat yield was estimated based on the interpretation and analysis of the image. Ashraf, Naz and Mustafa (2011) studied satellite image data of drought (2001) and post drought (2006) periods in order to assess changes in landuse and vegetation cover through hybrid (visual and digital) interpretation technique.

Diallo and Zhengyu (2010) used RS technology to assess Bamako's landcover change in China within a 20 year period. Issa (2009) utilized change detection techniques to assess land development achievements on Al Sammalyah Island, off the coast of Abu Dhabi, capital city of United Arab Emirates. Kamran and Jamil (2008) used RS and GIS techniques for the detection of urban growth in Islamabad and its impacts on climate. Malik and Husain (2006) used SPOT XS (multi-spectral) satellite image data for mapping different landuses/landcovers in the suburbs of Rawalpindi to assess the impact of urbanization on the scrub forest dominated by Acacia modesta. Roohi, Ashraf and Ahmed (2004) conducted a study to evaluate the capability of LANDSAT-TM data for identification of various landuse and vegetation covers, like forest, crop, shrubs and grasses near Fatehjang area. Singh and Khanduri (2011) studied landuse/landcover of Pathankot and Dhar Kalan tehsil using RS data of 1991, 2002, and 2006 periods in order to detect changes that had taken place particularly in the built-up and forest areas and evaluate socio-economic implications of the predicted changes.

In the present study, an attempt has been made to investigate the status of landuse/landcover and changing behaviour particularly of the built-up, agricultural and forest land in the Rawal watershed area during the last two decades. The risk-prone areas were identified and causative factors of land degradation were studied. The findings of this study would provide basis to organize better management strategies for the watershed area.

3. MATERIALS AND METHODS

3.1 Study Area

Rawal watershed lies within longitudes 73º 03´ - 73º 24´ E and latitudes 33° 41´ - 33° 54´ N in the Pothwar region of Pakistan (Figure-1). It has an undulating topography with terraced land for agriculture, high slopes and dissected patches under natural vegetation. It covers an area of about 272 sq. km out of which 47 % lies in the Islamabad Capital Territory, 43 % in Punjab and the rest 10 % in the Khyber Pakhtunkhwa (KPK) province. It is well connected through Murree Road and Express Highway with Islamabad and Rawalpindi. Physiographically, the watershed area comprises of 34 % hilly area (<700 m), 62 % Middle mountains (700-2000 m) and 4% high mountains (>2000 m). The elevation ranges from 480 m to 2,168 meters above sea level (m.a.s.l).

Korang River is the main channel flowing in the watershed. The soil in steep southern and western slopes was extremely thin and sterile (Rasheed, et al., 1988). The soils formed over shale are clayey and have a weak coarse and medium sub-angular blocky structure. Soils developed on the sand stone are moderate to weak medium sub-angular blocky in structure and sandy loam to sandy clay loam in texture (Shafiq, et al., 1997).

The area lies in sub-humid transitional to humid sub-tropical continent with highest rainfall during monsoon season. The hottest months are May, June, and July in the study area. Average high temperature exceeds 38 ºC. The winter months are from October to March. During winters temperature in area remains mild, with occasional snowfall over the Margalla Hills. There are two distinct rainy seasons, one in summer (Kharif) with a peak in July-August and the other in winter (Rabi) with a peak in February-March. Mean annual rainfall is about 1,202 mm. Mean annual maximum temperature is 23.75 ºC, while mean annual minimum is 2.06 ºC. The average temperature ranges from 15 ºC in January to 37 ºC in June. The highest temperature was recorded at 46.6 ºC in 2005 and the lowest was recorded at -3.9 ºC in the year 1967.

3.2 Vegetation and Landuse

The flora is mainly natural with xeric characteristics, broad-leaved deciduous, evergreen trees and diverse shrubs on the southern slopes. The dominating plant species are *Olea ferruginea* (Wild Olive), *Carissa spinarum* (Granda) and *Dodonaea viscose* (Sanatha). Transition zone scrub occurs in the higher and cooler altitudes. Vegetation is open with scattered patches of pine trees. Sub-tropical pine zone stretches over higher elevations. The dominant plant species present are *Pinus Roxburghi, Quercus Incana and Myrsina Africana*. Due to extensive cattle grazing and wood

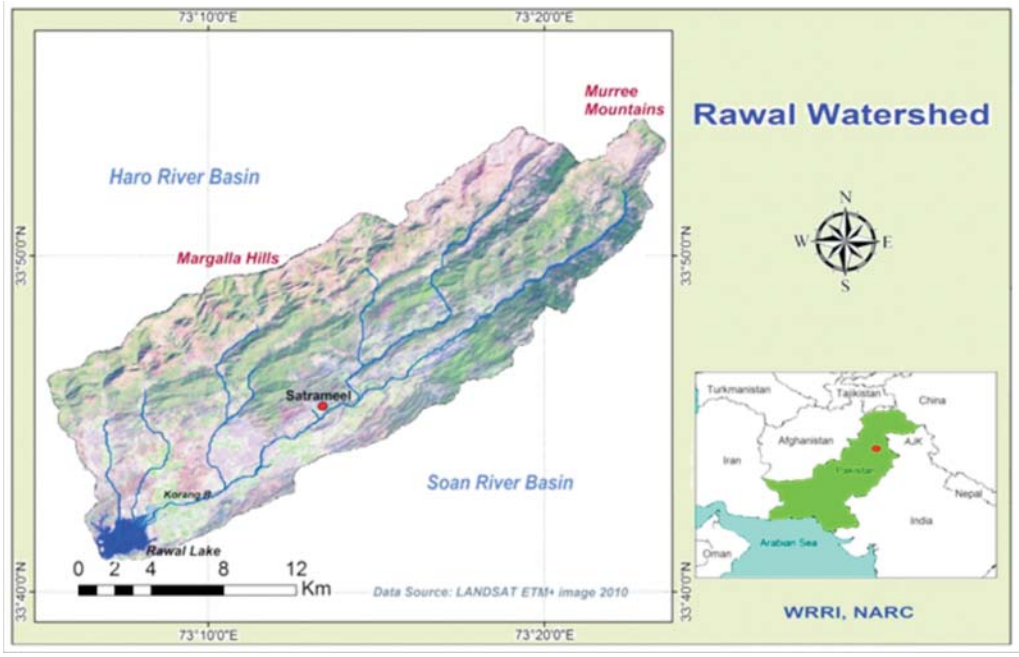

Figure-1: Location Map of the Study Area

cutting by the communities, many plants have been deformed to bushes (Shafiq, et al., 1997).

3.3 Data Used

The RS images of LANDSAT-ETM+ (Enhanced Thematic Mapper Plus) having path-row, 150-37 of 1992, 2000 and 2010 periods were used in the present study. These images were corrected geometrically and radiometrically using toposheets of the area and ground control points (GCPs) collected through Global Positioning System (GPS) survey (Figure-3). The coordinate system of Universal Transverse Mercator (UTM) (Zone 43: 72º -78º Northern Hemisphere) was used.

3.4 Data Preparation

The base map of the study area was prepared by generating and integrating thematic data of elevation, physiographic map, infrastructure using Arc GIS 9.3 software. The boundary of the watershed area and sub basins was delineated using Aster 30 m DEM of the area in HEC-GeoHMS extension in Arc View 3.2 GIS software. Elevation range map was prepared from DEM data to analyze vertical behaviour of landuse/landcover in the watershed area. The major elevation classes include >1600 m, 1200-1600 m, 800-1200 m and <800 m range (Figure-2). The image data was geo-referenced using Universal Transverse Mercator (UTM) coordinate system (Zone 43 North). For the present study, seven major landuse classes were selected based on their distinct reflectance characteristics and ecological importance in the watershed area. These classes include: conifers forest, scrub forest, agriculture, rangeland, soil/rocks, settlement and water. Following criteria was adopted for defining different landuse/landcover classes.

The dense forest appearing in dark green color and having more than 60 % coverage of large woody trees, i.e. usually over 7 m height at high altitude of mountainous terrain, were classified as conifer forest. There was a mixing of shadow and scrub pixels in this class. The low to medium dense woody forest consisting of trees/plants of around 3 m height appears in plain green to bluish green color in the image. The forest cover is classified as scrub forest. This class also contains some misclassified pixels of shadow, agriculture and rangeland classes. Scrub and rangeland classes were mixing with agriculture. Soil, rocks, and settlement classes were mixing in rangeland. Agriculture (or cropland) class appears in light green color pixels with arranged pattern of

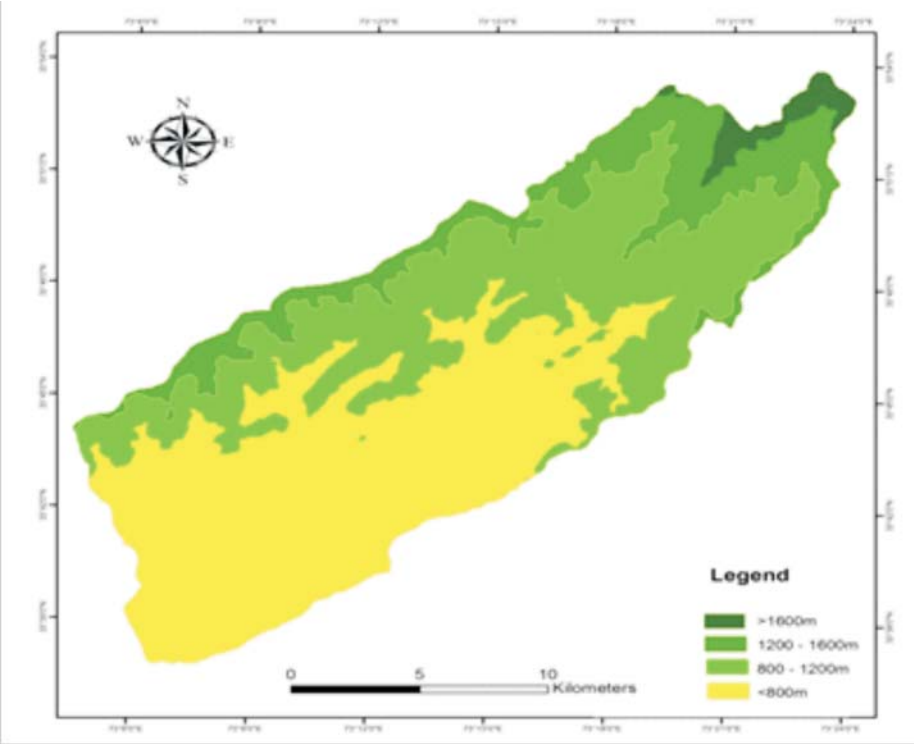

Figure-2: Elevation Ranges in Rawal Watershed Area

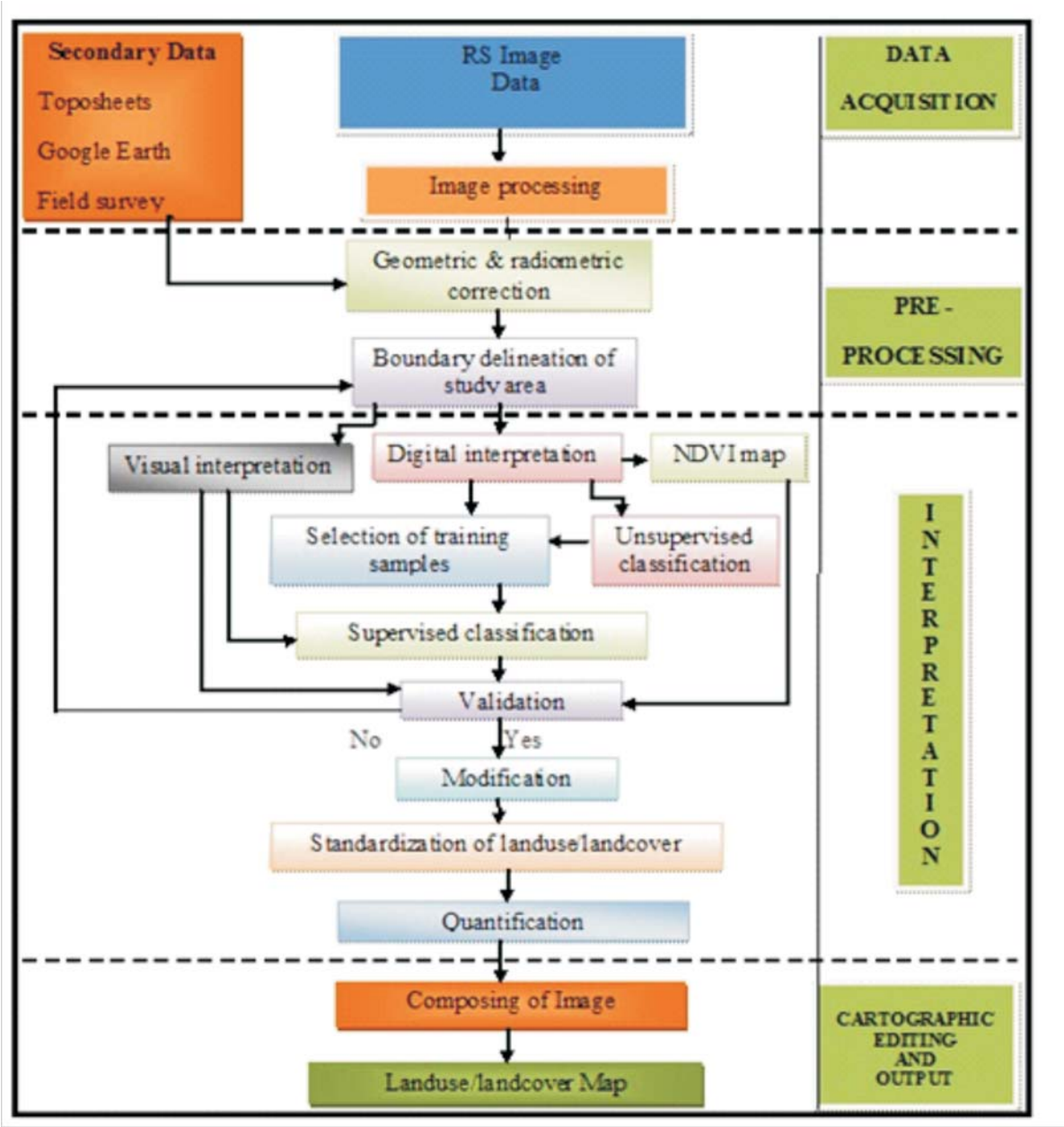

Figure-3: Methodology Adopted for Landuse/Landcover Assessment

vegetation in distinct field boundaries. The rangeland class consisting of various types of grasses and shrubs appears in yellow green, pale and blue green colors in the false color composite image due to mixing of wet and dry biomass, background reflectance of soil/rocks under thin and sparse vegetation cover. At some locations, rangeland class pixels mixed with settlement and soil/rocks classes.

Light pink and white color pixels were classified as settlements. The built-up landuse/landcover includes, not only urban infrastructure within towns and cities, but also individual dwellings, roads linking settlements, and other structures built by humans. At some locations, built-up class mixes with the soil/rocks class due to similarity in reflectance. Soil and rocks were appearing in reddish brown to pink colors that show a close resemblance, so these were merged into a single class of soil/rocks due to their similarity in reflectance and minor areal coverage. Although it may

consist of less than 10 % vegetation cover, but areas cleared off from vegetation for development, through natural process, i.e. landslides, erosion in the valleys and slopes, and some fallow land as well as exposed bare rocks include in it. The dark blue and black color pixels of water class were mixing with shadow and conifer forest. The shadow areas in the hilly terrain were eliminated considering their association with the surrounding landcover.

3.5 Image Analysis

The satellite images data were analyzed to observe spatial variability of landuse through visual and digital interpretation techniques. The visual interpretation was performed for qualitative analysis while digital interpretation for quantitative analysis of the image data. Satellite images have been studied thoroughly to ascertain the probable landuse classes and their respective range of reflectance values (DN values). The normalized difference vegetation index (NDVI) technique was used to separate the spectral reflectance of the vegetation from background reflectance of soil and water. Roohi, Ashraf and Ahmed (2004) compared the results of NDVI and supervised classification method and found them relating to each other. Bashir (2009) identified protected vegetation cover using NDVI technique for soil erosion analysis in Rawal watershed area. NDVI values give the density of green vegetation cover in the area. To determine the NDVI, band 3 and band 4 of LANDSAT ETM+ are used as:

NDVI = (TM4 - TM3) / (TM4 + TM3).....(a)

Initially, unsupervised classification was applied on multi-temporal RS images. It aggregates them into a number of classes based on natural grouping or cluster present in image values. The classes that resulted from unsupervised classification are spectral classes. Supervised classification has been performed for various images. The supervised classification results were supported with NDVI data and map output. To enhance the classification accuracy, knowledge-based expert system was used for post-classification refinement of initially classified outputs. Initially, the algorithm was developed through supervised training process, after collection of parametric and nonparametric signatures (training samples). Signatures are further evaluated using error matrix, which contain the number and percentage of pixels that are classified as expected. Signatures are refined, deleted, renamed and merged after evaluation to ensure the uni-modelity of their histograms, statistical parameters and error matrix. Overall accuracy of the signatures evaluated of three images through error matrix was more than 95 per cent. After evaluating the accuracy of signatures, final classification of the images was performed. Later, filtering technique was applied to remove noisy/misclassified pixels of the classes from the recoded image data. The doubtful areas of classes were modified after ground truthing, i.e. performing field validation survey and using Google Earth imageries. The landuse/landcover change has been detected between 1992 and 2010 periods using the respective images. Image processing and data manipulation in GIS were carried out using Erdas Imagine 9.2 and Arc GIS 9.3 softwares.

4. RESULTS AND DISCUSSION

Image analysis was performed through visual and digital interpretation of the RS data. Through visual interpretation of RS data, different land features like infrastructure, boundaries of built-up land, cropping fields, tree/plantation cover and drainage pattern of the study area were investigated. In False color composite of 5, 4, 2 (RGB) of LANDSAT image data, the landcover is visible in true color, i.e. vegetation in green, soil in pale to reddish brown, and water in shades of blue. The built-up area can be identified in white, brown, and purple colors due to variation in density of constructed area, mixing of new and old settlements, presence of variable land features, i.e. lawns, parking sides, water ponds, mettled and non-mettled roads, etc.

The landuse/landcover condition of the watershed was estimated for different time periods, i.e. 1992, 2000 and 2010 (Figure-4). In the year 1992, scrub forest was found dominant over 55 % of the total watershed area. Conifer forest indicated coverage of about 4 % in the upper half of the watershed area (Table-1 and Figure-5). The rangeland class was found in scattered form over 30 % in the study area. Settlement class stretched over 2 % area mainly in patches and scattered form. The agriculture class was found over 6 % area generally in the vicinity of settlement class. Agriculture is practiced in small to medium farms in plains and in patches over hill terraces in the watershed area.

In year 2000, scrub forest was dominant, covering over 45 % of the study area (Figure-5). The conifer forest was found over 3 % area mainly in the upper half of the watershed area. Rangeland was found in scattered form over 36 % of the study area. Settlement

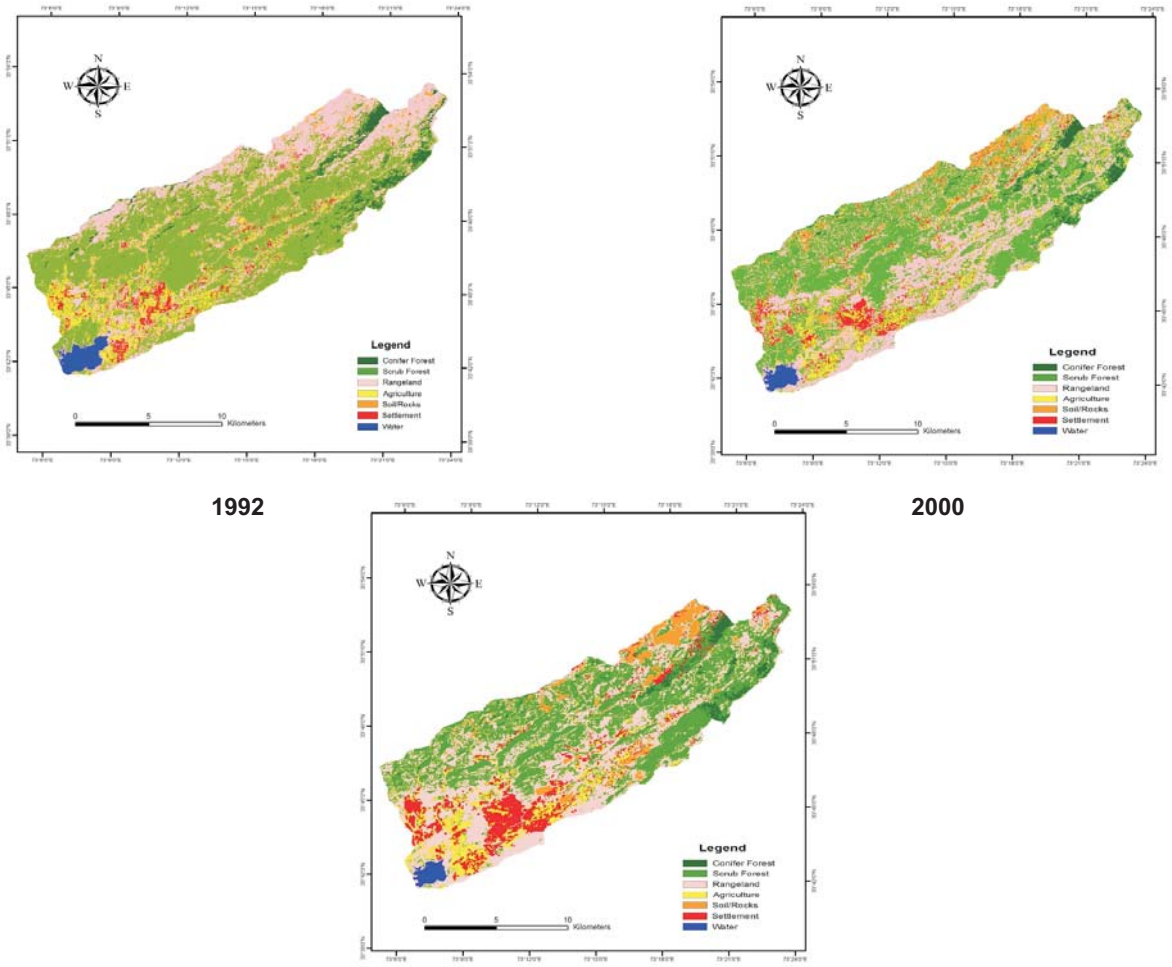

Figure-4: Temporal Variation in Landuse/Landcover of Rawal Watershed Area

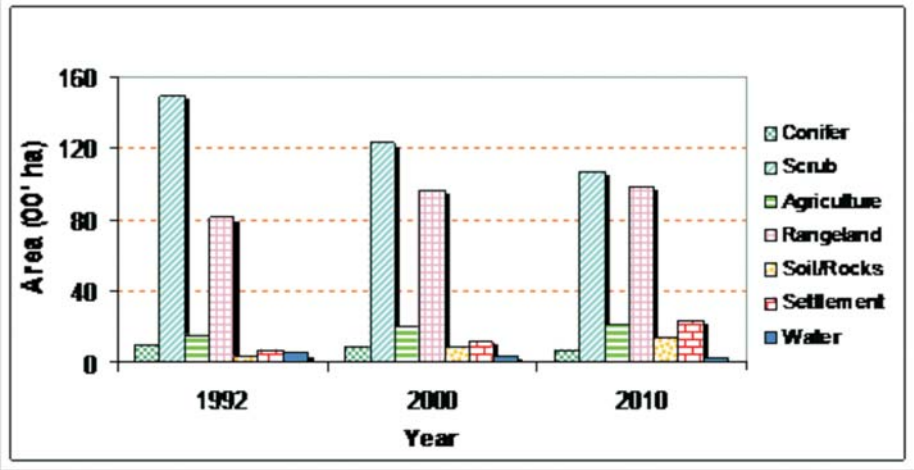

Figure-5: Temporal Variation in Landuse during 1992-2010

Table-1: Landuse Variations Detail during 1992-2010 Period

Landuse	1992		2000		2010		1992-2010	
	Area (ha)	%	Area (ha)	%	Area (ha)	%	Change (ha)	Change %
Conifer	1038	3.8	860	3.2	680	2.5	-358	-34
Scrub	14878	54.7	12317	45.3	10634	39.1	-4244	-29
Agriculture	1545	5.7	1970	7.2	2041	7.5	496	32
Rangeland	8159	30.0	9653	35.5	9863	36.3	1704	21
Soil/Rocks	336	1.2	939	3.5	1317	4.8	981	292
Settlement	717	2.6	1144	4.2	2374	8.7	1657	231
Water	528	1.9	318	1.2	290	1.1	-238	-45
Total	27200	100	27200	100	27200	100		

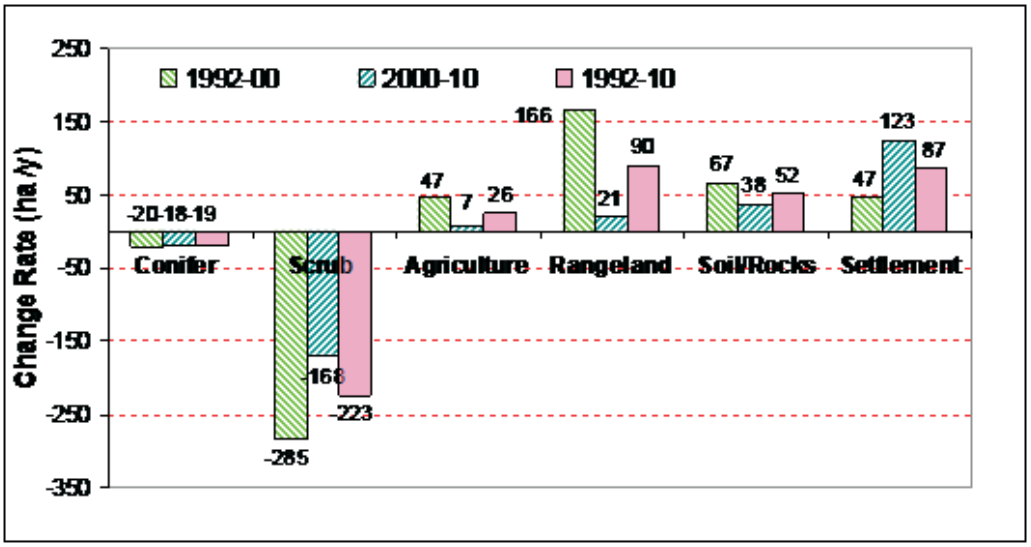

Figure-6: Annual Rate of Change in Landuse Coverage during Different Periods.

class stretched over 4 %, while agriculture class over 7 % area generally association with each other. About 4 % soil/rocks were found mainly in the upper left corner of the study area and water bodies occupied 1 % area.

In year 2010, scrub forest was a dominant class covering about 39 % of the study area. Conifer forest stretched over 2 % area while rangeland over 36 % area of the watershed. The NDVI has improved the segregation of vegetative and non-vegetative, i.e. bare ground. The NDVI values that range greater than 0.4 were categorized as high dense green-cover mainly containing thick scrub and conifer forest, while values that range between 0.24 to 0.4 were categorized as medium density green-cover, consisting of grown-up crops and shrubs in the watershed. Sparse vegetation like grasses, stunted shrubs and bushes, etc. was found under low-density green cover class (NDVI range 0.17-0.24) in the area. These results are in conformance with findings of Naseem (2008), which shows NDVI values ranging from 0.2 to 0.41 for the forest area in Murree and Margalla Hills.

Settlement occupied almost 9 % area while agriculture about 8 % of the study area, mainly in patches and strips over terraces of the hills. The built-up and agriculture land are mainly concentrated in the lower half of the study area. The soil/rocks were found in nearly 5 % area mainly in the upper half of the study area (Table-1).

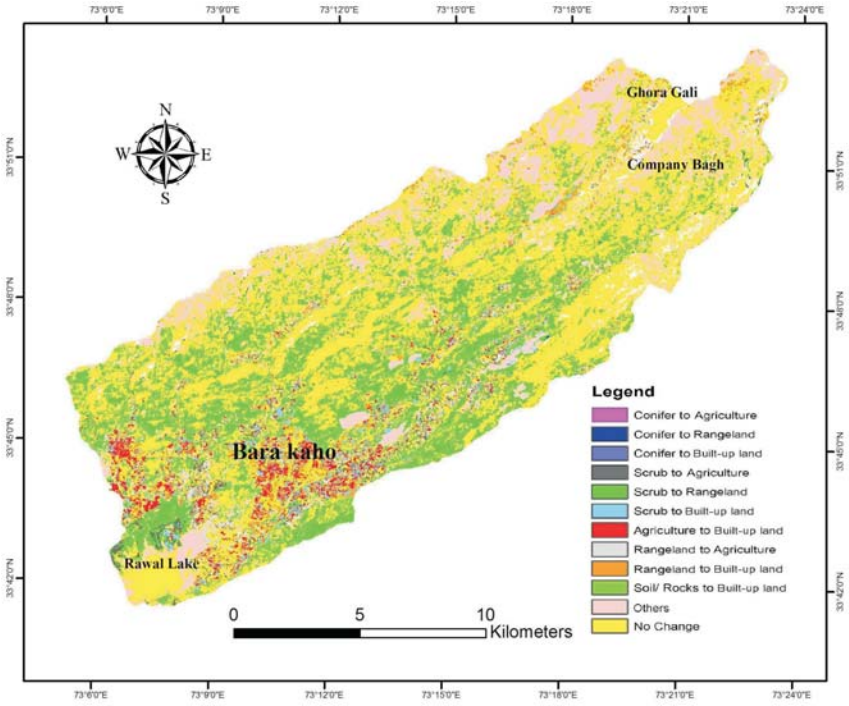

Figure-7: Spatio-temporal Change in Landuse during 1992- 2010

Major landcover change was observed in scrub forest class that indicated a reduction of about 4,244 ha in coverage during 1992-2010 period. The rate of decrease in scrub cover was higher during 1992-2000, i.e. about 1.9 % per year, than it was during 2001-2010, i.e. about 1.1 % per year. The scrub wood is mostly used as fuel at local level due to non-availability of other energy sources in the area. Due to extensive wood cutting, scrub forest has changed into rangeland and a major part of it had been converted into agriculture and built-up land. These results are verified by the study of Arfan (2008), which highlighted maximum decrease in scrub forest during 30-year period, i.e. 1977-2006 in Rawalpindi watershed area.

Similarly, conifer forest had shown higher rate of decrease, i.e.1.9 % per year during 1992-2000 than about 1.7 % per year in the preceeding decade. The results are in conformance with the findings of FAO (2005) that reported deforestation in the country at a rate of 1.5 % annually between 1990 and 2000. There are many factors involved in degradation of the forest cover like illegal cuttings due to its high value in the market, intensive use of forest wood for household needs (cooking, heating, timber, etc.), as well as forest disease and ineffective forest management, etc. The forest cover had been cut down for construction of Express Way from Satrameel to Lower Topa, Murree, after 2000 (IUCN, 2005). According to Ali and Benjaminsen (2004), it is commercial and illegal harvesting that has left the forest in such a depleted state that it can no longer withstand the pressure from local use.

The agriculture land has shown an average increase at a rate of about 26 ha per year during 1992-2010, which was about 47 ha per year during 1992-2000 and 7 ha per year during 2001-2010 period (Figure-6). The settlement area had shown higher rates of increase, i.e. about 123 ha per year during 2001-2010 than during 1992-2000 with average increase at rate of 87 ha per year during 1992-2010 period. The growth in urbanization was indicative from almost four-fold increase in built-up land, i.e. from 2.6% in 1992 to 8.7 % in 2010 (Table-1). The change in water class is due to seasonal variation in lakes surface area.

The landuse/landcover change had been detected in about 53 % of the study area while remaining 47 % area was found unchanged during 1992-2010 period (Table 2). Overall scrub class has shown highest conversion to agriculture class, i.e. about 3 % of the total watershed area followed by rangeland indicating conversion of about 2.3 % land into agriculture class. The conversion of conifer class to agriculture was very low. The conversion of landuse into settlement class

Table-2: Summary of Conversions of Landuse Classes from 1992 to 2010

Sr. No	Landuse Change from	Area (ha)	Area (%)
1	Conifer to agriculture	1	0.003
2	Conifer to range	35	0.13
3	Conifer to settlement	12	0.04
4	Scrub to agriculture	802	2.95
5	Scrub to range	5,447	20.03
6	Scrub to settlement	662	2.43
7	Agriculture to settlement	558	2.05
8	Rangeland to agriculture	616	2.27
9	Rangeland to settlement	709	2.61
10	Soil/Rocks to settlement	33	0.12
11	Other	5,560	20.42
12	No change	12,767	46.94
Total		**27,200**	**100.0**

was high from rangeland class, i.e. about 2.6 % of the area, followed by scrub forest, which indicated transformation of 2.4 % area into settlement class. Also about 2 % land under agriculture was converted into settlement class during 1992-2010 period. The spatial change of different landuse/landcover classes in the study area is shown in Figure-7.

The changes in landuse/landcover were variable on different elevation ranges. The conifer forest has shown a decrease from 134 ha to 102 ha at greater than 1600 m elevation range, while from 343 ha to 238 ha within 1200-1600 m elevation range during 1992-2010. The scrub class indicated decrease of about 11 per cent within 800-1200 m range, while 65 % in less than 800 m elevation range. Contrary to this, agriculture class had shown increase of about 65 % within 800-1200 m range while 29 % in less than 800 m elevation range during 1992-2010.

The agriculture class had shown an increase of about 496 ha in coverage, i.e. at annual rate of about 1.7% during the last two decades. The rate of its increase was higher during 1992-2000, i.e. about 3 % per year, than during 2000-2010 period, i.e. 0.5 % per year. This indicates that there was intense agriculture activity in the former decade that was replaced by rapid growth in urban development in the later decade. Due to increasing population food needs are also increasing and thereby increase in the agricultural development in the watershed area. The settlement class had shown an increase of almost four times, i.e. from 717 ha to 2,374 ha between 1992-2010 period. The rate of increase in this class area was very high during the last decade (2000-2010), i.e. over 17 % per year, which was about 7% per year in the 1992-2000 period. This situation indicates rapid development of built-up land due to various factors like increasing population, migrations from rural to urban areas, and developments of different housing societies, better job opportunities, provision of better medical and education facilities, etc. in the study area. One more reason is that built-up area is mostly increasing in the capital city, Islamabad. Similarly ,infrastructure developments like Lake View Point and some new roads (Express Way) in the area have greatly contributed in the growth of built-up land. These factors are also supported by the report of IUCN (2005); Kamran and Jamil (2008); Arfan (2008); and Tanvir, Shahbaz and Sulehri (2006), which concluded that urban development is increasing at very high rate in Islamabad and Rawalpindi areas. According to Tanvir, Shahbaz and Sulehri (2006), intensive use of forest wood for household needs (cooking, heating, timber, etc.) and ineffective forest management strategies by the forest department were some of the key reasons of deforestation in the study area.

5. CONCLUSIONS

During the last two decades, built-up land has shown an increase from 717 ha to 2,374 ha indicating rapid urbanization in the Rawal watershed area. This rapid growth in urbanization needs to be monitored on

regular basis in future using RS technique. Overall, 53 % area of the watershed has undergone landuse/landcover change during 1992-2010 period. The conifer class and had shown a decrease of 34 % and 29 % in coverage, respectively, scrub class during 1992-2010 period. The decline in forest cover is likely due to changing socio-economic and environmental conditions in the watershed area. Haphazard, and uncontrolled urbanization and illegal wood cuttings should be controlled by involving local communities and other stakeholders. Similarly, environmental laws should be reinforced fully to control deforestation and loss of biodiversity in the watershed area. The risk-prone areas can be managed through afforestation and adopting suitable soil-water conservation techniques. Mass awareness and media campaigns should be launched periodically to encourage people to protect natural resource heritage of the nation. The RS and GIS techniques can be effectively used for regular monitoring of landuse/landcover changes and natural environment of the watershed area. These techniques could be integrated with advance modeling tools to study impacts of landuse change on the hydro-environment of the watershed area.

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Olivier De Schutter and Gaëtan Vanloqueren***

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In Brief

The combined effects of climate change, energy scarcity, and water paucity require that we radically rethink our agricultural systems. Countries can and must reorient their agricultural systems toward modes of production that are not only highly productive, but also highly sustainable. Following the 2008 global food price crisis, many developing countries have adopted new food security policies and have made significant investments in their agricultural systems. Global hunger is also back on top of the international agenda. However, the question is not only how much is done, but also how it is done—and what kinds of food systems are now being rebuilt.

Agroecology, the application of ecological science to the study, design, and management of sustainable agriculture, offers a model of agricultural development to meet this challenge. Recent research demonstrates that it holds great promise for the roughly 500 million food-insecure households around the world. By scaling up its practice, we can sustainably improve the livelihoods of the most vulnerable, and thus contribute to feeding a hungry planet.

Some crises appear and disappear in global media while remaining acute in the lives of real people. Global food insecurity is this type of crisis. In January 2011 the Food and Agriculture Organization of the United Nations (FAO) warned that global food prices in December 2010 exceeded the 2008 peak during the so-called food price crisis that sparked food riots across Africa, Asia, and Latin America.[1] The UN also warned that the price increase would not stop overnight and that we were entering danger territory.[2] Although prices stabilized in the spring, global food prices in May 2011 remained higher than they were in June 2008. We will see more price spikes in the future, due to a growing discrepancy between supply and demand, the impacts of climate disruption on agricultural production, and the merger of the energy and food markets. The food crisis is here to stay.

Governments have pledged to reinvest massively in agriculture. After three decades of neglect, this is welcome news. However, as countries announce impressive figures on the scope of their reinvestment, we tend to forget that the most pressing issues today regarding agricultural reinvestment involve not only *how much,* but *how.*

The choice between agricultural development models has immediate and long-term consequences. Since 2008 some major reinvestment efforts have been

UN Photo/Eric Kanalstein

A farmer gathers wheat in Bamiyan, Afghanistan

* UN Special Rapporteur on the Right to Food; Professor at the University of Louvain, Belgium. Email: olivier.deschutter@uclouvain.be
** Research Associate at the Earth and Life Institute of the University of Louvain, Belgium. Email: gaetan.vanloqueren@uclouvain.be

Key Concepts

- There are roughly 925 million hungry people on the planet. Many of them are smallholder farmers or farm laborers.
- With many governments poised for a large-scale reinvestment in agriculture, the question is not only how much, but how.
- Agroecology the effort to mimic ecological processes in agriculture could provide a framework for this reinvestment. Already, agroecological practices are being used around the world, increasing productivity and improving efficiency in the use of water, soil, and sunlight.
- But before agroecological practices can be scaled up globally, we must assess the market and political obstacles that stand in their way. Here, we present six principles that could help us overcome these obstacles.
- Our farmers-in-chief heads of states can make the new paradigm on agriculture, food, and hunger a reality.

channeled into a slightly modified version of the Green Revolution without fully considering our other great contemporary challenge of climate change. In contrast, scant attention has been paid to the most cutting-edge ecological farming methods methods that improve food production and farmers incomes, while also protecting the soil, water, and climate.

Yet, with an estimated 925 million hungry people on the planet,[3] we must think outside the box. Major shifts in food security policies are being discussed in most countries. Yet the best options are simply not being promoted sufficiently.

The first Green Revolution as developed in Mexico and then in South Asia in the 1960s succeeded in improving yields in the breadbasket regions where it was implemented.[4] But it sometimes came at a high social and environmental cost, including the depletion of soils, pollution of groundwater, and increased inequalities among farmers.[5] And the productivity gains were not always sustainable in the long term.

Our strategy today must recognize the connection between climate change and food security. It must leverage the potential of the new sustainable agriculture paradigm with policies designed to scale up and mainstream the systems that have proven records of success. It must not only preserve land and other agricultural resources for future generations; it must actively restore lands and resources that have been degraded. It must monitor progress using multiple indicators, ones that go beyond the amount of money invested and the amount of crops harvested. It must also create the enabling macroeconomic environment needed to link sustainable agricultural systems to markets.

Because hunger can be attributed to a wide range of causes, a comprehensive strategy to combat food insecurity would have to address issues such as an international trade regime that penalizes developing countries through subsidies that stifle local markets, the infliction of an unsustainable burden of foreign debt, and the impact of speculation on commodities markets. We do not focus on these themes, which are well known. Our interest is in the paradigm of agricultural development under which most policymakers work, and whether it meets the challenge of today and tomorrow. We believe it does not, and we seek to outline an alternative path.

Climate Change and Energy Scarcity: Key Elements of the New Food Security Context

Climate change is already having dramatic consequences for agriculture and international food security. Rain patterns are shifting, leaving farmers unable to harvest mature crops. More prevalent droughts and floods place unprecedented stress on agricultural systems. Water sources are more variable and are rapidly exhausted. Peasants are already struggling with these disruptions in Central America and East Africa. And, by 2080, 600 million additional people could be at risk of hunger as a direct result of climate change.[6] In Sub-Saharan Africa, arid and semiarid areas are projected to increase by 60 million to 90 million hectares, while, in Southern Africa, it is estimated that yields from rain-fed agriculture could be reduced by up to 50 percent between 2000 and 2020.[7] Losses in agricultural production in a number of developing countries could be partially compensated by gains in other regions. But the overall result would be a decrease of at least 3 percent in productive capacity by the 2080s, and up to 16 percent if the anticipated carbon fertilization effects (incorporation of carbon dioxide in the process of photosynthesis) fail to materialize.[8] Without closer international cooperation, the FAO and the Organisation for Economic Co-operation and Development (OECD) warn that the direct impacts of climate disruptions on food production patterns will also lead to more extreme volatility events on international food commodities markets the economists way of describing the 2008 global food price crisis.

Additionally, our current systems of agriculture are utterly dependent on fossil fuels. FatihBirol, the chief economist at the International Energy Agency, warned in August 2009 that oil is running out far more quickly than previously predicted, and that global production is likely to peak in about ten years. A study of the 800 biggest oil fields reveals that the rate of decline in the output of the world s oil fields is 6.7 percent a year.[9] The impacts of energy scarcity have been obscured by the economic crisis over the past two years. However, the price of the crude oil barrel has constantly increased in 2009 and 2010 thanks to economic growth in China and other emerging countries. Its level in May 2011 exceeds the level preceding the 2008 food price crisis.[10] Although the geopolitical situation in the Arab world and speculations about its consequences are currently driving oil prices up, economic recovery in developed nations and growth in the rest of the world will keep prices high.

Modern agriculture is highly sensitive to oil prices. Our food relies on oil or gas at many stages: nitrogen fertilizers are made of natural gas, pesticides are made out of oil, agricultural machinery runs on oil, irrigation and modern food processing are highly energy-dependent, and food is transported over thousands of miles by road or air. While the exact impacts of peak oil on the availability and cost of both oil and natural gas are unknown, it will undoubtedly affect food security. Energy scarcity is thus a key element of any policy for reinvestment in agriculture. But it is one that many current efforts lack.

Our current methods of food production are thus deeply unsustainable. Water scarcity and land degradation two of the anticipated results of climate change in many regions will add to the challenge of feeding the world. Already, 37 percent of China s total territory suffers from land degradation. And, while China has 21 percent of the world s population, it has only 6.5 percent of the freshwater available globally.[11]

This can be changed. Some agricultural systems can mitigate greenhouse gas emissions and increase resilience to climate extremes. According to a United Nations Environment Programme (UNEP) report, the agricultural sector could be largely carbon neutral by 2030 and could produce enough food for a population estimated to increase to 9 billion by 2050 if systems proven to reduce emissions from agriculture were widely adopted today.

Roots of the Future: The New Agricultural Paradigm

A few decades ago, agronomists were faced with a sharp increase in pest outbreaks in modern monocultures, while ecologists were starting to model the complex interactions between insects and plants. At the same time, scientists were observing the effectiveness of traditional farming systems. The two scientific disciplines of agronomy and ecology converged, shaping the field of agroecology. Agroecology is the application of ecological science to the study, design, and management of sustainable agriculture.[12,13] It seeks to mimic natural ecological

Christian Dupraz

An agroforestry system (interplanting poplar trees and wheat) in southern France. The system produces more grain and wood by hectare than if the two crops were cultivated separately

processes, and it emphasizes the importance of improving the entire agricultural system, not just the plant.

The pioneers of agroecology proposed that agroecological systems be based on five ecological principles: (1) recycling biomass and balancing nutrient flow and availability; (2) securing favorable soil conditions for plant growth through enhanced organic matter; (3) minimizing losses of solar radiation, water, and nutrients by way of microclimate management, water harvesting, and soil cover; (4) enhancing biological and genetic diversification on cropland; and (5) enhancing beneficial biological interactions and minimizing the use of pesticides.[14] Now, agroecologists are looking to integrate food systems, as well as agricultural systems, into the scope of agroecology.[15]

A growing number of scientists work and publish on this field,[16,17] and, recently, the International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD), a four-year study involving 400 experts from all regions as well as international organizations such as the World Bank, the FAO, and UNEP, called for a fundamental paradigm shift in agricultural development and strongly advocated the increase of agroecological science and practice.[18] Agroecology is also at the core of the latest reports published by the FAO and UNEP.[19,20] Meanwhile, the farmers united through La Via Campesina, the largest transnational peasant movement, have rapidly integrated agroecological principles in recent years.[21]

Today, agroecology has concrete applications on all continents. Its results speak for themselves. The widest study ever conducted on these approaches, led by Jules Pretty of the University of Essex, identified 286 recent interventions of resource-conserving technologies in 57 developing countries covering a total area of 37 million hectares in 2006.[22] The average crop yield increase was 79 percent, and a full quarter of projects reported relative yields greater than 2.0 (i.e., 100 percent increase). Malawi, which ramped up its fertilizer subsidy program in 2002 following the dramatic drought-induced food crisis the year before, is now also implementing agroforestry systems using nitrogen-fixing trees.[23] (Agroforestry involves planting trees with crops to more efficiently use land, nutrients, and water.) By mid-2009, over 120,000 Malawian farmers had received training and tree materials from the program, and support from Ireland has enabled extension of the program to 40 percent of Malawi s districts, benefiting 1.3 million of its poorest people. Research shows that the program has increased yields from one ton per hectare to two to three tons per hectare, even if farmers cannot afford commercial nitrogen fertilizers.[23] With an application of a quarter-dose of mineral fertilizer, maize yields may surpass four tons per hectare. The Malawi example shows that while investment in organic fertilizing techniques should be a priority, it should not exclude the use of other fertilizers. An optimal solution could be a subsidy to sustainability approach: an exit strategy from fertilizer subsidy schemes that would link fertilizer subsidies directly to agroforestry investments on the farm in order to provide for long-term sustainability in nutrient supply, and to build soil health for sustained yields and improved efficiency in fertilizer use.[23] In Tanzania, 350,000 hectares of land have been rehabilitated in the Western provinces of Shinyanga and Tabora using agroforestry.[24] In Zambia, agroforestry practices outperform fertilizers in rural areas where road infrastructure is poor and transport costs for fertilizer are high (which is the case in much of the African continent). The benefit to cost ratio for agroforestry practices ranges between 2.77 to 3.13 in contrast to 2.65 with subsidized fertilizer applications, 1.77 in fields with nonsubsidized fertilizer, and 2.01 in nonfertilized fields.[25] Dennis Garrity, the director of the World Agroforestry Centre in Nairobi, estimates that a global implementation of agroforestry methods could result in 50 billion tons of carbon dioxide being removed from the atmosphere about a third of the world s total carbon reduction target.[26] Such agricultural developments are examples of what many experts and scientists are calling the evergreen revolution. Among them is M.S. Swaminathan, the architect of the first Green Revolution in India, who now advocates organic farming.

In West Africa, stone barriers built alongside fields help retain water during the rainy season, improving soil moisture, replenishing water tables, and reducing soil erosion. Significant gains result: the water retention capacity of the soil is increased five to ten-fold, the biomass production ten to twenty-fold, and livestock can feed on the grass that grows along the stone barriers after the rains. Such water harvesting techniques are highly efficient in fighting desertification. They match the efficiency of mechanized irrigation, and are vital for food-insecure communities who live in dry environments. Indeed, it is impossible to build a truly *Green* Revolution without what Alan Savory calls a *Brown* Revolution: one that enhances soil organic matter, leading to sustainable productivity gains.[27]

In Kenya, researchers and farmers developed the push-pull strategy to control parasitic weeds and insects that damage crops. The strategy consists of pushing away pests from corn by interplanting corn crops with insect-repellent crops like Desmodium, while pulling them toward small plots of Napier grass, a plant that excretes a sticky gum that attracts the pest and traps it. The system controls pests without using costly and harmful insecticides. It also has other benefits, as Desmodium can be used as fodder for livestock. The push-pull strategy doubles maize yields and milk production while improving soils. The system has already spread to more than 10,000 households in East Africa through town meetings, national radio broadcasts, and farmer field schools.

Agroecological practices enhance on-farm fertility production. Malawian farmers call it a fertilizer factory in the fields. These practices reduce farmers reliance on external inputs and state subsidies. This, in turn, makes vulnerable smallholders less dependent on local retailers and moneylenders.

Similar examples exist around the world. In Japan, farmers found that ducks and fish were as effective as pesticide for controlling insects in rice paddies, while providing additional protein for their families. The ducks eat weeds and insects, thus reducing the need for labor-intensive weeding, otherwise done by hand by women, and duck droppings provide plant nutrients. The system has been adopted in China, India, and the Philippines. In Bangladesh, the International Rice Research Institute reports 20 percent higher crop yields, with net incomes increasing by 80 percent.[28] In 1998, after Hurricane Mitch, agroecological plots on sustainable farms from southern Nicaragua to eastern Guatemala had on average 40 percent more topsoil, 69 percent less gully erosion, higher field moisture, and fewer economic losses than control plots on conventional farms.[29] This greater resistance to climatic disruptions will be vital in the coming decades.

This is only the tip of the iceberg. Cutting edge innovation in agroecology is taking place in research centers in Santa Cruz, Nairobi, and Beijing. Scientists are discovering Iroko trees that build a carbonate-layer in the soil from CO_2 captured in the atmosphere, offering new opportunities for long-term carbon sinks.[30] They are designing future perennial cereal systems for sustainable grain production.[31] And they are developing mycorrhizal products that could be applied in small doses to mimic in modern farming the mycorrhizal systems that exist between fungus and trees, a source of extraordinary productivity.[32]

It would be unwise, however, to wait for a silver-bullet solution to emerge from years of research and development. The most urgently needed effort for increasing food security is the scaling up of existing systems. Understanding what keeps agroecology

2006 IDEI, Courtesy of Photoshare

Women work on a small farm in Orissa, India

underdeveloped is a necessary first step.

The Obstacles to the Necessary Change

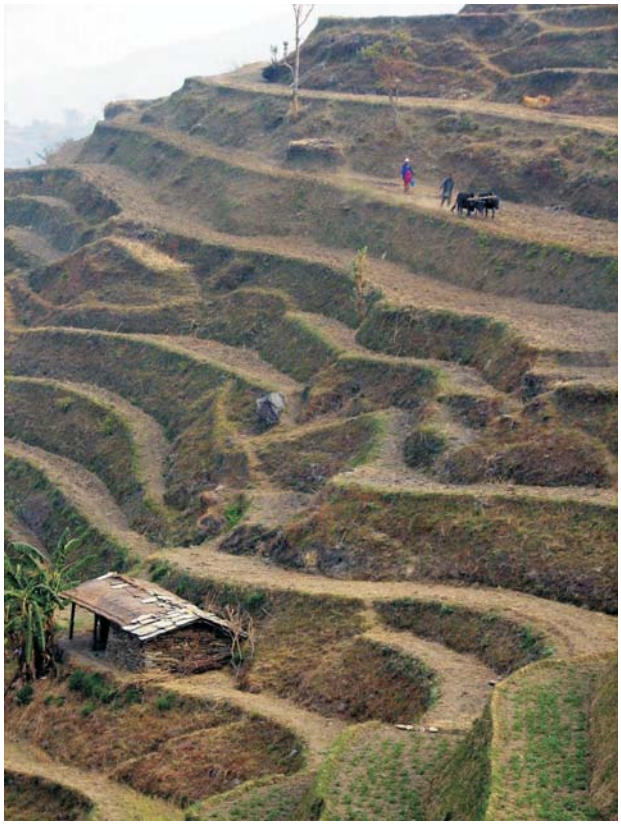
We identify at least seven, largely self-reinforcing obstacles to the expansion of agroecological practices.

First, small-scale farmers, the primary practitioners of agroecology and the main beneficiaries of its expanded use, are marginalized in policy decisions. Small-scale farms use land and water more efficiently, and economists have long demonstrated the inverse relation between farm size and land productivity.[33-40]

However, a number of factors in the real world favor large farms: Large-scale operations are more competitive in the agribusiness sector because of facilitated access to credit (including from state-owned development banks). Large farms have a greater ability to integrate globalized food chains and to comply with the standards of the retail industry, including quality and sanitary standards but also social and environmental certification schemes. They also benefit from recent technological innovations that are designed to meet their needs, such as genetically modified crops, information technology, and zero-tillage machinery.[40,41] In addition, decentralized small farmers experience agency problems and transaction costs that cannot be underestimated.[35]

At the same time, the belief that larger farms are more productive continues to be disseminated by influential authors.[42] This is a mistake. Large, mechanized, monocropping operations are more competitive than small farms for the reasons explained above, but competitiveness and productivity are different things. Big farms outperform small farms according to only one measure of economic efficiency: productivity per unit of labor. Indeed, one agricultural worker on a modern, mechanized farm in the most fertile regions of the world can manage as much as 100 hectares of land, with a total output of 1,000 tons of cereal a year. A small-scale farmer with only a hoe can manage just one hectare, with a productivity per hectare as low as one ton a year in many African regions.[43,44] But the global expansion of highly mechanized farming is something the planet simply cannot afford. The agroecological approaches highlighted above not only are more resource efficient that is, they produce more from less they also, with appropriate kinds of support, have a higher productivity per hectare, a different measure of productivity. The fact that some agroecological approaches require more labor can actually be positive, if the harvest provides sufficient incomes, since it can slow rural flight to cities and encourage rural development by attracting off-farm labor in rural areas. This is not a minor advantage as many countries face double-digit rates in urban unemployment.

Second, agroecology has rarely been supported by mainstream trade and agricultural policies. While agroecology supports diversified production systems, short food chains, and a balance of power among all actors, the structural adjustment programs of the 1980s and 1990s and the schedules of commitments under the Agreement on Agriculture of the World Trade Organization (WTO) led to a rapid (albeit still partial) liberalization of agricultural trade. This liberalization, in turn, encouraged the building of an export-led sector based on monocultures and the globalization of food chains, making transnational agribusiness companies



2009 Jesse R Lewis, Courtesy of Photoshare

Villagers sow crops like wheat, barley, and mustard on the mountain slopes of the Himalayas in Nepal using traditional farming techniques, such as terracing and labor intensive agriculture

increasingly influential.[45] Similarly, while the development of agroecology would have required a strong state to empower small-scale farmers, disseminate best practices, and invest in agriculture, the Washington consensus was imposed on most developing countries through the International Monetary Fund (IMF) and the World Bank. This orientation toward economic deregulation and privatization resulted in a 25-year downsizing of public services and disinvestment in agricultural systems.[46-50]

The dominance of neoliberal thinking during the last three decades has had lasting impacts on agricultural policies. Although some questioned this dominant model after the 2007 2008 food price crisis, it continues to influence current debates and many elites in developing countries continue to believe that they must mimic the modernization-liberalization path pursued by developed countries.

The combination of the first two obstacles explains why small farmers are unable to compete with large-scale enterprises. Although the World Bank has put more emphasis on their importance in its 2008 World Development Report,[51] small-scale agriculture is still seen as nonviable in many mainstream policy discourses.

Third, the development of agroecology is impeded by the absence of security of land tenure for a large fraction of small-scale farmers. Improved security of tenure plays a vital role in agroecology: it encourages the planting of trees, the more responsible use of soils, and other practices with long-term payoffs (planting fruit trees, for example, also contributes to improved nutrition and health). However, some recent developments are increasing the threats to security of tenure: large-scale land acquisitions and leases (widely known as land grabs) are putting an enormous pressure on land access for vulnerable land users. Yet the policy debate on their regulation continues to be largely influenced by the belief that any private investment, whatever form it takes, will contribute to food security.[52]

Fourth, the common belief that a Green Revolution complemented by a gene revolution could solve global hunger puts scientific and technological progress at the core of efforts to alleviate hunger, diverting attention from a broader exploration of agricultural development. Agroecological research struggles with inconsistent research investments as well as a lock-in situation (an accumulation of obstacles) in agricultural research systems, which both hinder its development.[53]

Fifth, agroecology has been mischaracterized as a return to the past and as incompatible with the mechanization of agriculture. Agroecology is not about a return to a model of agriculture that relies solely on human power for tilling and harvesting. Agroecological approaches are perfectly compatible with a gradual

Gaëtan Vanloqueren

An agroforestry system in Morocco that combines a staple food crop (cereals) with a cash crop (the oil from argan trees is used in expensive cosmetics). The argan trees provide an extra source of income, especially for women, who have established cooperatives in Morocco to process and sell the oil

and adequate mechanization of farming. However, for the farmers who have only hoes for tools and who live in areas where oil is scarce, the first step toward development may well be use of animal traction rather than tractors. A forced path toward mechanization one that focuses on rapid mechanization of farming or use of technology that is not affordable for small-scale farmers could aggravate rural depopulation. One tractor replacing the daily work of twenty landless laborers is only progress if nineteen jobs are created in the secondary and tertiary sectors.[43]Yet most developing countries currently cannot offer urban job opportunities to those who leave the farming sector. Instead, the production of simple mechanical equipment adapted to smallholders and fit for agricultural techniques that conserve soil and water will actually result in more jobs in the manufacturing sector in developing countries.[54]

Sixth, the absence of full inclusion of externalities in agrifood price systems has enabled the development of industrial farming despite important social and environmental costs, and has hindered a comprehensive valuation of the benefits of agroecology.[55] The success of large plantations is, in part, attributable to the fact that the price of food does not reflect the real costs to society resulting from their operations, particularly from the impacts of their modes of production on the soil and climate and on public health.[56]

And, finally, organizations with vested interests in the status quo have ignored or resisted the benefits of agroecology.

Scaling Up Sustainable Agriculture: Policies for Change

Despite these obstacles, the scaling up of existing agroecological practices is achievable if we can develop a policy framework to move from successful pilot projects to nationwide policies.[57] Six key principles could help us do this.

First, we need better targeting. Focusing our efforts on the needs of smallholders may seem obvious, yet only a few existing programs effectively target this group. Today, 50 percent of the hungry live in small-scale farming households, living off less than two hectares of land, and 20 percent are landless.[58] This is unacceptable. Nor is it adequate to fixate on productivity improvements in breadbasket regions while ignoring the people who live in more inhospitable environments such as semiarid lands or hills. Trickle-down economics failed the test in Africa and South Asia the two regions with the highest incidence of hunger. In the 1960s, investing in the Punjab (as the Green Revolution did) did little to improve the situation of farmers in the eroded hills of Karnataka.

Second, the redistribution of public goods must be prioritized in food security policies. Agroecological practices require public goods such as extension services; storage facilities; rural infrastructure (roads, electricity, and information and communication technologies) for access to regional and local markets; credit and insurance against weather-related risks; agricultural research and development; education; and support to farmers organizations and cooperatives. The investment can be significantly more sustainable than the provision of private goods, such as fertilizers or pesticides that farmers can only afford so long as they are subsidized. World Bank economists have rightly noted that underinvestment in agriculture is [ ] compounded by extensive misinvestment [59] with a bias toward the provision of private goods, sometimes motivated by political considerations.[60] A 1985 2001 study of 15 Latin American countries in which government subsidies for private goods were distinguished from expenditures on public goods indicated that, within a fixed national agriculture budget, a reallocation of 10 percent of spending to supplying public goods increases agricultural per capita income by 5 percent, while a 10 percent increase in public spending on agriculture, keeping the spending composition constant, increases per capita agricultural income by only 2 percent.[61] In other words, even without changing overall expenditures, governments can improve the economic performance of their agricultural sectors by devoting a greater share of those expenditures to social services and public goods instead of non-social subsidies. [62] Thus, while the provision or subsidization of private goods may be necessary to a point, the opportunity costs should be carefully considered. Extension services that can teach farmers often women about agroecological practices are particularly vital. In today s knowledge-based economies, increasing skills and disseminating information are as important as building roads or distributing improved seeds. Agroecological practices are knowledge-intensive and require the development of both ecological literacy and decision-making skills in farm communities.

Market failures affect the provision of these services. There is just too little incentive for the private sector to invest in these domains, and transaction costs are too high for local communities to create these goods

themselves. States must step in. Seeds and fertilizers at subsidized prices are not a substitute for these public goods, although they may be competing for the provision of private assets in public budgets. Increasing the share of public goods in the government s budget would have a significant positive impact on rural per capita income.

Third, if we want the best food security policies, we need a richer understanding of innovation that includes indigenous, local, and traditional knowledge. Simply put, not all innovations come from experts in white coats in laboratories. In large areas of Asia, farmers now join farmer field schools, a group-based learning process that enables farmer-to-farmer instruction. In India, farmers pool their seeds in community seed banks, which are administered through institutional arrangements to ensure the availability of planting material and the preservation and improvement of agrobiodiversity. And in Ghana, scientists launched radio broadcasts in local languages to popularize the best techniques to grow rice without additional inputs, rather than breeding new rice varieties. These techniques were identified through consultations with peasant groups, and they resulted in an average yield increase of 56 percent.[63]

Farmer field schools and community seed banks are not new technologies: they are social or institutional innovations. Such innovations are important to future food security because they can channel farmers experiences into knowledge-sharing processes with a considerable multiplier effect and at minimal cost.

Fourth, programs and policies must involve meaningful participation of smallholders. While some of the largest efforts to reinvest in agriculture shy away from a genuine engagement with representative farmer organizations, participation, if done properly, has several advantages for food security. First, it enables us to benefit from the experience and insights of the farmers. Second, participation can ensure that policies and programs are truly responsive to the needs of vulnerable groups. Third, participation empowers the poor, a vital step toward poverty alleviation because the lack of power exacerbates poverty: marginal communities often receive less support and are less able to advocate for their rights than the groups that are better connected to government. And finally, collaborations between farmers, scientists, and other stakeholders will facilitate innovation and create new knowledge.[64]

Existing projects demonstrate that participation works. Farmer field schools have been shown to significantly reduce pesticide use: large-scale studies from Indonesia, Vietnam, and Bangladesh recorded 35 to 92 percent reduction in insecticide use for rice.[65] At the same time, the schools have contributed to a 4 to 14 percent improvement in cotton yields in China, India, and Pakistan.[65] In Syria, Nepal, Nicaragua, and many other countries, participatory plant breeding schemes have been introduced in which researchers work directly with farmers, often combining traditional seeds with modern varieties.[66] This practice empowers poor rural women who are key actors in seed management.[67] In Latin America, the Campesino a Campesino movement has demonstrated that, when given the chance to generate and share agroecological knowledge among themselves, smallholders are very capable of improving their methods.[68] In Cuba, a country that met its own peak oil when cheap oil imports from the USSR stopped, the adoption of agroecological practices was supported by the National Association of Small Farmers: between 2001 and 2009, the number of promotores (technical advisers and coordinators) increased from 114 to 11,935 and a total of 121,000 workshops on agroecologicalpractices were organized.[69] Participation, a key principle in the activities of the grassroots organizations and NGOs that currently promote agroecology,[68,70] should be an element in all food security policies, from policy design to management of extension services. Experts, technical advisers, and farmers should be encouraged to collaborate in identifying innovative solutions.[71]

Fifth, states could use public procurement to speed a transition toward sustainable agriculture. In several European countries, schools have already started sourcing food from local producers with sustainability criteria. In June 2009 Brazil decided that 30 percent of the food served in its national school-feeding program should come from family farms.[72]

Sixth, performance criteria used to monitor agricultural projects must go beyond classical agronomical measures, such as yield, and economic measures, such as productivity per unit of labor. In a world of finite resources and in a time of widespread rural unemployment, productivity per unit of land or water is a vital indicator of success. Overall, measuring efficiency in the new agricultural paradigm of agroecology requires a comprehensive set of indicators that assesses the impacts of agricultural projects or new technologies on incomes, resource efficiency, hunger and malnutrition, empowerment of beneficiaries, ecosystem health, public health, and nutritional adequacy. The assessment of progress

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Women in Myanmar work in a rice field using organic farming methods

should be appropriately disaggregated by population, so that improvements in the status of vulnerable populations can be monitored.

Promoting agroecological approaches does not mean that breeding new plant varieties is unimportant. Indeed, it is vital. Already, new varieties with shorter growing cycles enable farmers to continue farming in regions where the crop season has already shrunk and where classical varieties did not have time to mature before the arrival of the dry season. Breeding can also improve the level of drought resistance in plant varieties, an asset for countries where lack of water is a limiting factor. Reinvesting in agricultural research must involve continued efforts in breeding, though caution is needed due to the drawbacks of current seed policies and of intellectual property regimes on seeds.[73] Just as breeding should not be discontinued, but rather done with the participation of the farmers most in need, fertilizers should not be forbidden. Agroecology provides the larger framework for their use, and it emphasizes that fertilization can be pursued through natural means, such as nitrogen-fixing trees.

Linking Sustainable Farming to Markets: The Political Economy of Food Chains

The above principles are not sufficient in themselves. Efforts by agronomists will be pointless if the right institutions, macroeconomic regulations, and accountability mechanisms are not established and implemented. In other words, farmers need enabling economic and institutional environments, allowing the 500 million households that depend on small-scale farming today not only to put food on the table, but also to market their surpluses. Public action is needed, not in order to feed the world, as stated in the food security policies of the past century, but rather in order to help the world feed itself.

Many, including respected food security pundits, think smallholder farmers are incapable of producing sufficient food for rapidly growing urban markets. This is simply false. The reality is that small food producers face a number of obstacles when trying to market their surpluses. We met with smallholders in Benin who insisted that improving market conditions is a greater priority than and a condition for improving crop productivity.[74] An enabling market environment does not mean greater trade liberalization and a favorable environment for investment, as proponents of the new conventional wisdom, a slightly adapted version of the Washington consensus, contend.[75] Rather, it means supporting the diversification of trade and distribution channels in order to create the conditions for genuine choice by small farmers between rural and urban markets and, in some cases, the high-value markets of industrialized countries.[76] It also means preventing gains from being wrested from smallholders by better-resourced farmers.
Today, the limited number of buyers, the paucity of

information on prices, and the absence of storage facilities all contrive to deprive farmers of any choice but to sell during the harvest period, when prices are at their lowest. A rapid and significant expansion of storage facilities capable of preventing postharvest losses in rural areas is needed. Mechanisms such as warehouse receipt systems are spreading across Asia and Africa. Such systems enable farmers to sell crops to warehouses at harvest time, but obtain the additional revenue generated when the food is sold at higher prices during the dry season.[77]

States should also aim to improve equity in the food system, especially in global supply chains where inequity is most pronounced. In too many cases, global food chains primarily reward large producers who have access to inputs (land, water, and credit), technologies, and political influence, and who can meet the volume and standards required by global buyers and retailers. Where small food producers are willing to be integrated into global food chains, states should actively support them through technical assistance and cheap credit, if needed. The promotion of modern farmer cooperatives is one way to improve the market position of producers, especially women. Ultimately, what matters, from a social point of view, is that the incomes of the poorest increase, whether they choose to serve local, regional, or global markets. As Nobel laureate AmartyaSen has remarked, hunger is not necessarily a problem of food availability; it is primarily a problem of people lacking the purchasing power to procure the food they need.[78]

Because the power relationships that exist in food chains are so central to global hunger over two-thirds of those who are hungry today produce food centralized control over key agricultural functions must be dismantled.[79] In the Brazilian soybean market, 200,000 farmers attempt to sell to five main commodity traders. Three large transnational commodity buyers ADM, Cargill, and Barry Callebaut dominate the Ivorian cocoa industry. Four firms carry out 45 percent of all coffee roasting, and four international coffee traders control 40 percent of an industry on which 25 million producers depend. The result of this power distribution is that a significant portion of the reinvestment in agriculture will be captured by global players, instead of vulnerable food producers.

Stopping the Damage: The Role of Land

Farmers around the world face increasing pressures from large-scale development projects (including dams), extractive industries, logging, land conversion to agrofuels, and the creation of special economic zones. The result is that the poorest farmers are priced out of land markets and that evictions are rising everywhere, cutting farmers off from their livelihoods.[80-82]

States should strengthen customary land tenure systems, while at the same time weeding out their discriminatory components against women, and should reinforce tenancy laws in order to significantly improve the protection of land users. There is also ample empirical evidence of the positive impacts of land redistribution on the livelihoods of smallholders as well as on broader rural development.[37] Agrarian reform with a strong redistributive component has been an important element in economic growth in South Korea and China. The belief that land redistribution is communism has led many to reject it out of hand. But, if it is part of comprehensive rural development policies that support the beneficiaries of land redistribution, complemented by an implementation of the six principles we put forward in this paper, it can contribute to increased food security and nutrition, prevent environmental losses, and put people to work in rural areas, thus reducing the effects of ecological, financial, and economic crises. The current wave of large-scale land acquisitions and leases unfortunately moves us in the opposite direction: in many cases it amounts to nothing less than a counter-agrarian reform that poses threats to food security.[52]

Farmers-in-Chief

Our farmers-in-chief heads of states can make the new paradigm on agriculture, food, and hunger a reality.[83] The strategies highlighted in this essay can shape productive, sustainable, healthy food systems for the twenty-first century. Concrete recommendations to states and donors have been identified to scale up these promising agroecological farming systems and to shape an economic and institutional environment that will allow them to thrive. If significant progress is not achieved in the next three years, huge opportunities will be missed for feeding the world s poorest people, mitigating climate change, and avoiding worsening water scarcity. In that case, coming generations will judge us harshly.

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OVERVIEW OF BIOMASS CONVERSION TECHNOLOGIES

Sohail Noor†, Atif Latif*, Nazir Jan* and Muhammad Ishaq**

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ABSTRACT

A large part of the biomass is used for non-commercial purposes and mostly for cooking and heating, but the use is not sustainable, because it destroys soil-nutrients, causes indoor and outdoor pollution, adds to greenhouse gases, and results in health problems. Commercial use of biomass includes household fuelwood in industrialized countries and bio-char (charcoal) and firewood in urban and industrial areas in developing countries. The most efficient way of biomass utilization is through gasification, in which the gas produced by biomass gasification can either be used to generate power in an ordinary steam-cycle or be converted into motor fuel. In the latter case, there are two alternatives, namely, the synthesis of methanol and methanol-based motor fuels, or Fischer-Tropsch hydrocarbon synthesis.

This paper deals with the technological overview of the state-of-the-art key biomass-conversion technologies that can play an important role in the future. The conversion routes for production of Heat, power and transportation fuel have been summarized in this paper, viz. combustion, gasification, pyrolysis, digestion, fermentation and extraction.

Keywords: *Biomass, Combustion, Gasification, Pyrolysis, Digestion, Fermentation.*

1. INTRODUCTION

Global energy-demand is expected to increase from the current 400 ExaJ per year to as much as 700-1,000 EJ per year by the middle of this century. Recent life-cycle analysis suggest that pursuing both strategies of renewable energy sources and renewable feedstocks (i.e. biomass) will be needed to meet these competing demands [1]. Sustainable and renewable natural resources like biomass that contains carbon and hydrogen elements can be potential raw materials for energy conservation [2]. Biomass is one of the most promising renewable energy sources, especially in regions where it is in abundance [3].

Biomass research has been carried out in many countries around the world and various biochemical and thermochemical technologies have been developed for the utilization of biomass for energy production. Such thermo-chemical technologies, especially in the form of combustion and gasification, are considered to be promising solutions for producing energy from biomass; their most advanced forms are fluidized bed combustion and gasification. Materials resulting as by-products of agricultural or agro-industrial activities, e.g. straw, pits, hulls, pods, cobs, etc., are thought to be the most important, especially in under-developed areas of the world where the use of these biofuels for energy-production could cover a substantial gap in the energy bill of the local communities [4,5,6,7].

2. COMBUSTION

Combustion of fuelwood, charcoal, and non-woody biofuels is a daily practice for half the world's population. Most of this domestic biomass-burning takes place in the developing world, where, mainly due to economic reasons, vital energy-needs for cooking, heating, and lighting have to be met by biofuels. In many rural regions on the African continent, more than 90 % of the energy requirements are met by biofuels [8,9,10,11].

In developing countries, such as Turkey, these materials are typically burnt in simple stoves with incomplete combustion. Continuous indoor burning of biomass and exposure to large amounts of biomass smoke, starting in childhood, with inefficient conditions for removing smoke and air pollutants, may cause pulmonary diseases such as repetitive upper and lower respiratory infections, and chronic obstructive pulmonary disease [12, 13, 14].

In Pakistan, the combustion-device for indoor cooking reported is ordinary *choolah* (An indigenous single-chamber stove with no aeration vents). A *tanoor* is used for out-door cooking, mainly bread-making. The annual hours of use of the combustion device is 50 % higher in the mountainous areas, compared to plain lands; due to lower atmospheric pressure, the food takes extra time for cooking. The people living in the mountains use their breathing air to ignite the fire, while the residents in the plains are using highly

* Pakistan Council of Scientific & Industrial Research (PCSIR) Laboratories Complex, Peshawar-25120, Pakistan.
† E-mail: sohailpcsir@yahoo.com

inflammable material, such as kerosene and dry grass. The cooking utensils used are ordinary loose-lid type, increasing the time of cooking [15].

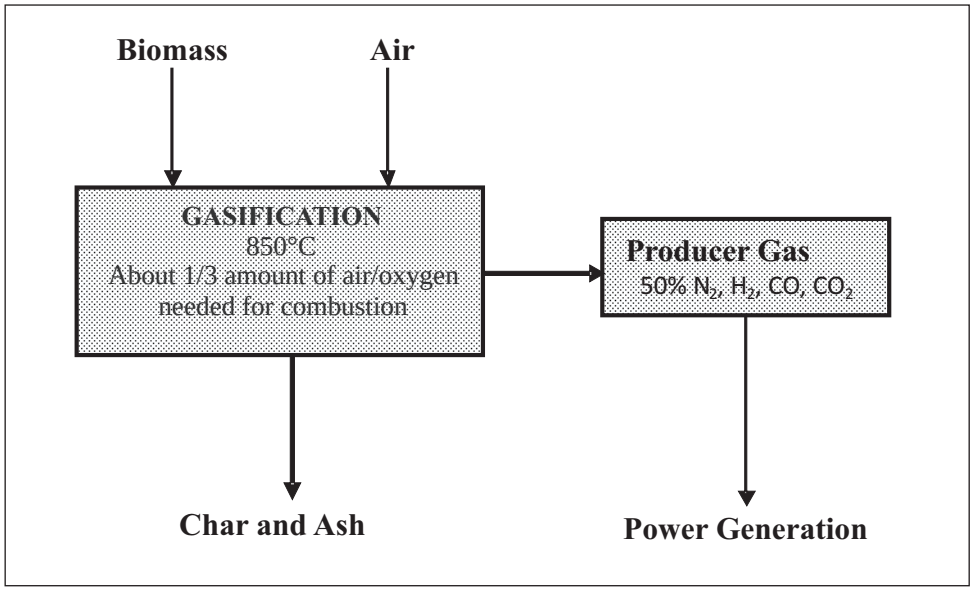
Traditional use of wood generally has a low efficiency (sometimes as low as 10 %) and is generally accompanied with considerable emissions, e.g. of smoke and soot. Technology development has led to the application of strongly improved heating systems, which are, for example, automated, have catalytic gas cleaning and make use of standardized fuel (such as pellets). The efficiency benefit compared to open fireplaces is considerable; open fireplaces may even have a negative efficiency over the year (due to heat loss through the chimney), while advanced domestic heaters can attain efficiencies of 70 to 90 % with strongly reduced emissions. The application of such systems is widespread in Scandinavia, Austria and Germany. In Sweden, in particular, a significant market has developed for biomass pellets, which are fired in automated firing systems [16].

Larger-scale combustion of biomass for the production of electricity (plus heat and process steam) is applied commercially worldwide. Many plant configurations have been developed and deployed over time. Basic combustion-concepts include pile burning, various types of grate firing (stationary, moving, vibrating), suspension firing and fluidized-bed concepts. An example for the application of biomass combustion for power generation is seen in the paper and pulp (P&P) industry for combustion of black liquor and waste incineration. Conventional boilers for combined production of power and process steam, and recovery of pulping chemicals is common technology for the P&P sector. Waste incinerators were widely deployed, starting in the nineteen eighties, in countries like Germany and the Netherlands, combined with very stringent emission standards. Biomass burning became the key waste-to-energy technology deployed in Europe, but it is relatively expensive. In recent years, advanced combustion concepts have penetrated the market. The application of fluided-bed technology and advanced gas-cleaning allows for efficient operation and production of electricity (and heat) from biomass [17].

3. GASIFICATION

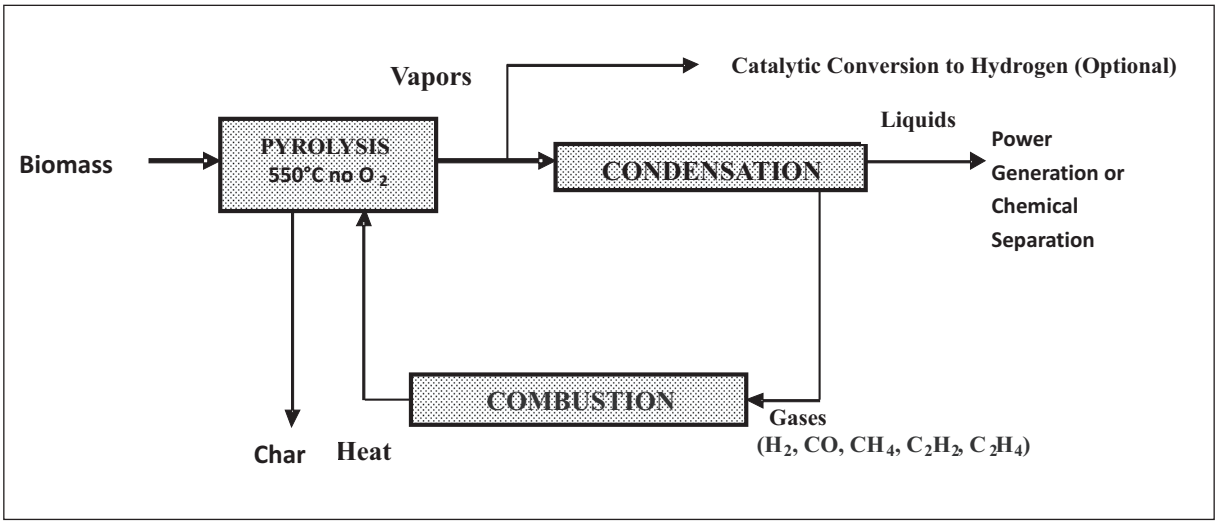
Gasification, as a means to convert a diversity of solid fuels to combustible gas or syngas, received considerable attention in the nineteen eighties worldwide, especially in Europe. Gasification converts biomass into fuel gas, which can be further converted or cleaned prior to combustion (e.g. in a gas turbine; when integrated with a combined cycle) [18].

The most efficient way of utilizing biomass as a renewable energy source is through gasification. A



Source: *US Department of Energy, "Energy Efficiency and Renewable Energy" EERE (2005)*

Figure-1: Biomass Gasification



Source: *U.S Department of Energy, "Energy Efficiency and Renewable Energy" EERE (2005)*

Figure-2: Biomass Liquefaction via Pyrolysis

particularly attractive feature of this method is that the gas produced by gasification of biomass can either be used to generate power in an ordinary steam cycle or be converted into motor fuel (Figure-1) [19].

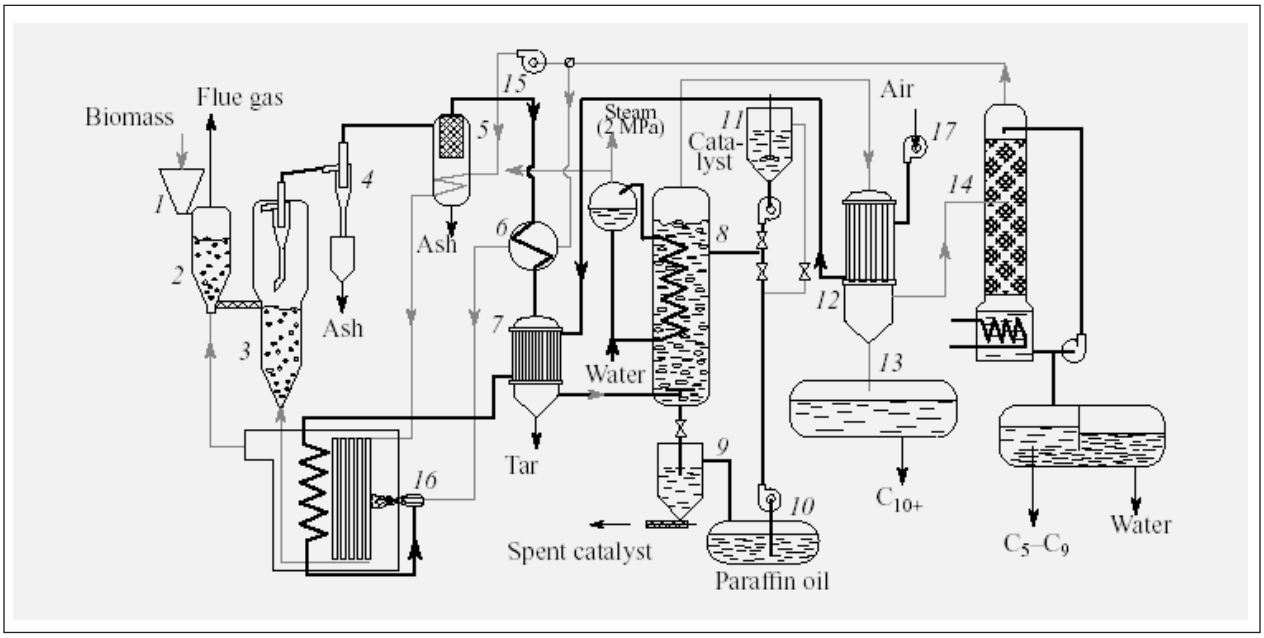
In the latter case, there are two alternatives, namely: (a) the synthesis of methanol and methanol-based motor fuels, and (b) Fischer-Tropsch hydrocarbon synthesis (Figure-2). These processes have long been implemented in the industry, and the prospects of their application in the production of motor fuels are governed by world oil-prices. However, considering the huge amounts of wood waste at wood-working facilities, as in some parts of Russia, motor fuel production at small-scale plants in the immediate vicinity of raw material sources may be profitable [20].

The experiments with gasification of wood in argon/steam plasma proved the capacity of plasma for complete gasification of wood (with production of syngas having high content of hydrogen and carbon monoxide). Despite very low mass flow-rates of plasma generated in water stabilized arc, the mixing of treated material with plasma and intensive energy transfer is ensured in the reactor. The flow within the reactor is almost completely controlled by gasification of the material, as the flow-rate of gas coming from gasification is up to hundred times higher than the flow-rate of plasma. Therefore, the gasification rate is high, especially for high feeding rates of material. Syngas, with calorific value double the power spent for the process, is produced. The measured dependencies indicate that further increase of the material feeding-rate would result in even higher ratio. The efficiency of the process could be increased substantially by utilizing the power lost to the cooling-water in the torch and in the reactor [21].

Heat production using gasifiers is commercially established. Finland in particular was successful in the 1980s in deploying smaller scale gasifiers for heat production (Bioneer). Nevertheless, gasification for production of heat finds a strong competitor in combustion. A key concept pursued for a long period of time was the use of agricultural residues close to the source, thus minimizing transport distances. A wide array of concepts for gasifiers, gas cleaning and system-integration for such concepts was proposed and tested in a wide variety of conditions. Technology was also exported to many developing countries, with support from international bodies such as the World Bank [18].

4. PYROLYSIS AND LIQUEFACTION

Pyrolysis converts biomass to liquid (bio-oil), gaseous and solid (char) fractions at temperatures around 500°C in absence of oxygen. With flash-pyrolysis techniques (fast pyrolysis) the liquid fraction can be maximized (up to 70 % of the thermal biomass input). Bio-oil contains about 40 weight percent of oxygen and is corrosive and acidic. Crude bio-oil can, in principle (after some modifications and only for better quality oils), be used for running engines and turbines [22].



Source: *Analyzing Biomass Conversion into Liquid Hydrocarbons (Theoretical Foundations of Chemical Engineering) [35].*

Figure-3: Schematic Diagram of a Plant for Biomass Conversion into Liquid Hydrocarbons

Most renewable sources used in the pyrolysis of biomass have been higher plants, including woody materials, rather than marine microalgae, although the latter are the main primary producers in oceans and they constitute the largest biomass in nature (Figure-3) [23].

Liquefaction and HTU (Hydro thermal upgradation) is a process that converts biomass to bio-crude at a high pressure, in water and moderate temperature. This is another way of producing 'raw intermediate liquids' from biomass [24].

5. DIGESTION

5.1 Biogas

Digesters maintain suitable conditions for bacteria to digest the biologically active component of the manure, resulting in the production and capture of biogas, which is 60-80 % methane and, thus, highly combustible [25].

Thermal conversion of wood to produce charcoal and volatiles is very old technology, the use of which has considerably reduced over the years due to the utilization of liquid fuels and coal. However, the recent concerns over global warming and requirements to reduce greenhouse gas emissions [26] have placed biomass fuels, such as wood, straw, bagasse, peat and municipal solid waste, at the forefront in reduction of the pollution as biomass is considered to be CO_2 neutral. These fuels have the advantage of being renewable and their conversion to energy provides a sustainable waste-management practice as they primarily consist of wastes [27]. Current research trends in biomass utilization are based on designing co-firing technologies, in which biomass is combusted in mixtures with other fuels, mainly coal. Biomass-conversion technologies can also consist of pyrolysis and gasification of the renewable-energy sources in order to produce higher calorific-value fuels, i.e. oil-liquids, hydrocarbon rich gases [28] and/or hydrogen [29].

In these technologies, biomass undergoes thermal treatment and decomposition, where volatiles and tars are evolved, followed by consequent heats of reactions [30].

Therefore, to be able to understand and design the conversion processes during biomass decomposition, thermal investigation of the devolatilisation is essentially an initial stage.

5.2 Landfill Gas Utilization

A specific source of biogas is landfills. The production

of methane-rich landfill-gas from landfill sites makes a significant contribution to atmospheric methane emissions. In many situations, the collection of landfill gas and production of electricity by converting this gas in gas-engines is profitable and the application of such systems has become widespread. The benefits are obvious: useful energy-carriers are produced from gas that would otherwise contribute to a build-up of methane GHG in the atmosphere, which has stronger GHG impact than the CO_2 emitted from the power plant [31].

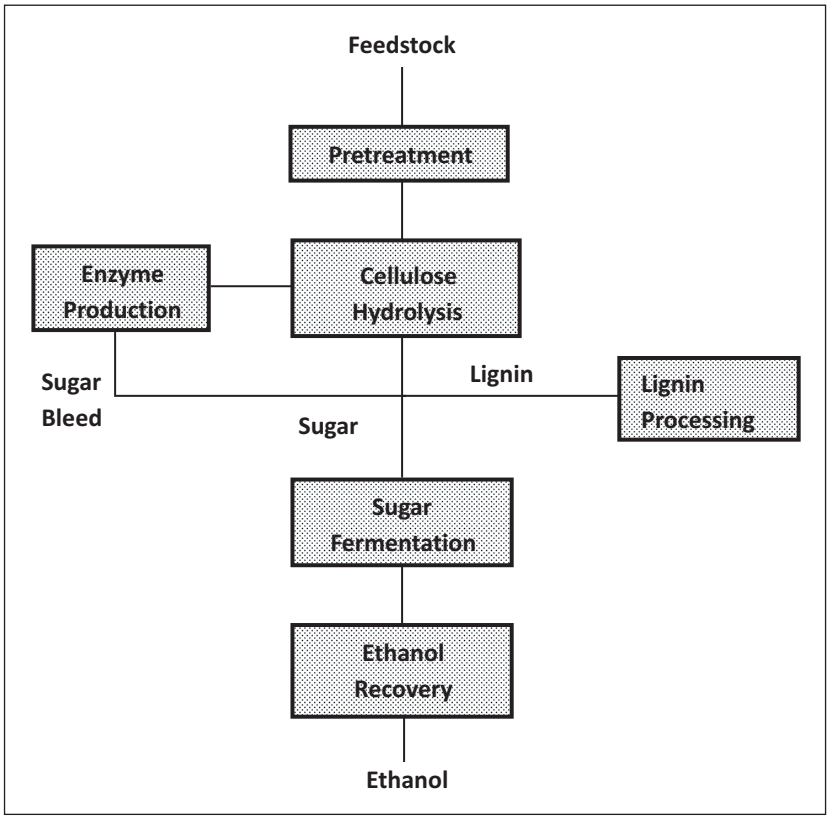
6. PRODUCTION OF TRANSPORTATION FUEL

6.1 Gasification

Methanol, hydrogen and Fischer-Tropsch diesel can be produced from biomass through gasification. All routes need very clean syngas before the secondary energy-carrier is produced using relatively conventional gas-processing methods. Besides MeOH, hydrogen and FT (Fischer-Tropsch) liquids, DME (DiMethyl Ether) and SNG (Synthetic Natural Gas) can also be produced from syngas. We will however focus on the first three fuels mentioned. Several routes involving conventional, commercial, or advanced technologies under development are possible. A train of processes to convert biomass to the required gas specifications precedes the methanol or FT reactor, or hydrogen separation. The gasifier produces syngas, a mixture of CO and H_2, and a few other compounds. The syngas then undergoes a series of chemical reactions. The equipment down-stream of the gasifier for conversion to H_2, methanol or FT diesel is the same as that used to make these products from natural gas, except for the gas cleaning train. A gas turbine or boiler, and a steam turbine optionally employ the unconverted gas fractions for electricity co-production [32].

6.2 Fermentation and Hydrolysis

A cellulosic feedstock material, such as straw, corn stover, or grass, is subjected to pre-treatment, i.e., cooked in the presence of acid to break down its fibrous structure. After pre-treatment, the material has



Source: *Tolan logen's process for producing ethanol from cellulosic biomass [33]*

Figure-4: Production of Ethanol from Cellulosic Materials

a muddy texture. Cellulase enzymes are added to the pre-treated material to hydrolyze the cellulose to the simple sugar glucose; this is known as cellulose hydrolysis. The cellulase enzymes are made at the plant site by using a wood-rotting fungus in large fermentation vessels. This is known as cellulase enzyme production. After enzymatic hydrolysis, the sugars are separated from the unhydrolyzed solids, which include lignin and residual cellulose. These solids are burnt to provide energy for the entire process (Lignin processing). The sugars are fermented (sugar fermentation) to ethanol, using simple brewer's yeast (to ferment the glucose) and more recently developed microbes for the sugars more difficult to ferment, including xylose and arabinose. In ethanol recovery, the ethanol is recovered by conventional distillation (Figure-4) [33].

Starch-based or sucrose-based processes are already widely used to make ethanol. The leading starch-based material is corn, which is widely used to make ethanol in the U.S. Starch is converted to glucose by grinding (in a dry milling process) or by steeping in dilute sulfurous acid (in a wet milling process), then using starch-degrading enzymes known as amylases. The glucose is then fermented to ethanol. Sucrose-based feedstocks include sugar cane (Brazil) and sugar beets (Europe). These feedstocks are ground and washed with water to extract the sucrose, which is then fermented to ethanol by yeast. Other feedstocks used to make small amounts of fuel ethanol in some regions include potatoes and Jerusalem artichokes. The conversion of cellulosic biomass to ethanol is more difficult than starch or sucrose. However, cellulose is available in much greater quantity and offers the potential for much greater ethanol production than the others. In addition, ethanol from starch and sucrose faces competition for the feedstock from the food and cattle-feed industries, which exerts pressure on the price of the ethanol. Most cellulosic biomass is free of competition from other uses. Cellulosic biomass can be grown in a wider variety of climates and soils than starch and sucrose and, therefore, represents a new agricultural opportunity in many areas. Finally, ethanol from cellulose is expected to be neutral, relative to the production of greenhouse gases. Corn, sugarcane, and sugar beets require large amount of energy-intensive fertilizers and do not have the energy-generation from the lignin- byproduct that is present in cellulosic biomass. Corn, sugarcane, and sugar beets all contain a small amount of cellulose and hemicellulose. Cellulose conversion technology represents an opportunity to improve the yields and decrease the wastes from these processes. Many cellulosic materials, including straw and grass, contain up to 10% starch. This is converted to glucose during pre-treatment and carried through to glucose fermentation, where it is converted to ethanol. Ethanol is produced from cellulosic materials in various ways. The main features of the different ethanol processes are outlined in Figure-4 [32].

6.3 Extraction

Oilseeds, like rapeseed, can be extracted and converted to esters and are well suited to replace diesel oil as "bio-diesel". Rapeseed production and subsequent esterification and distribution are established processes in Europe [34].

7. CONCLUSIONS

Biomass is a fuel that people are familiar with, due to traditional use of biomass fuel. It currently provides the majority of energy to the domestic sector in developing countries. However, continued use of traditional biomass will provide for basic needs, but it will not solve the problem of providing the modern energy-services required for economic growth and improved living standards.

Modern commercial energy-production from biomass for industry, power-generation or transport fuel has a significant contribution and this contribution is growing faster, but its use should be carefully modernized to fit into a sustainable development path.

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