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ENVIRONMENTAL CHALLENGES FOR THE DEVELOPING COUNTRIES

Commission on Science and Technology for Sustainable Development in the South

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Commission on Science and Technology for
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EDITORIAL

With growing realization of the gravity with which the deterioration of environment is affecting life in all its forms, endeavours around the world to anticipate and address the hazardous impacts of environmental degradation are also gaining pace. All the nations, whether developed or developing, need to work together in order to abate the atrocious implications of this overarching global phenomenon. The recent efforts to stir awareness in this regard were the marking of 2009 as the 'Year of Environment' and holding of the Climate Conference in Copenhagen on December 6-18, 2009. Showing solidarity with the global initiatives, COMSATS has given this issue of Science Vision volume 15(1), the theme of 'Environmental Challenges for the Developing Countries'.

It has been one of COMSATS' highest priorities to contribute to the international development focusing especially on the developing countries, which have generally lagged behind on various fronts. Accordingly, COMSATS has been bringing out *Science Vision* as its scientific journal since 1995, to cover articles related to advances in science and technology in the North and the South, having relevance to sustainable development. These scientific articles have been a mix of research and review papers during the first ten years, but there has been a gradual shift of emphasis towards review articles since the year 2001. From 2002 onwards till 2008, besides research papers, proceedings of national and international events organized by COMSATS on various themes were included. These events focused on: S&T for sustainable development, water resources, mathematical modeling, capacity building; lists of contents of the books published under the *COMSATS' Series of Publications on Science and Technology*, during that time, were also covered in the journal.

The character and the frequency of the journal were revised in the light of the recommendations of COMSATS Coordinating Council made during its 12th meeting held in Nigeria, in April 2009. Efforts were made during the subsequent months to give this journal a thematic character that would enable it to individually address, through science and technology, some of the dominant issues faced by the developing world. The volumes 15(1) and 15(2) for the first and the second halves of 2009, respectively, are being brought out with this aim in view. The themes of these two issues originate from two of COMSATS' most important thrust areas, environment and renewable energy technologies.

COMSATS' Centres of Excellence, scientific institutions, research organizations and academies of science from across the world were requested to contribute review papers for inclusion in this issue. Although most of the papers in this issue have been contributed by authors from within Pakistan, the facts and findings given here can be related to other developing countries, on the basis of similitude of geographical and/or socio-economic conditions. Moreover, in the process of obtaining papers for this issue, it has transpired that some good papers were received on topics bordering on the general theme. Accordingly, the strict thematic concept has been made somewhat flexible to accommodate articles slightly deviating from the theme. We believe that, in this manner, the content of the journal would be enriched, broadly encompassing various issues of a thematic area without altering it much.

The eight papers included in this issue have been placed in two sections of environment-related issues, namely, 'Impact of Environmental Degradation and Climate Change' and 'Water Resource Management'. We hope that the scholars and policy-makers of the developing world would benefit from the contents of this issue. Volume 15(2) would be titled 'Renewable, Clean and Economical Energy Resources for Development'. We take this opportunity to request policy-makers, scientists, researchers and scholars, especially those from the Centres of Excellence of COMSATS, to send appropriate contributions for this journal so that a wider range of developmental issues related to various parts of the developing world could be addressed.

(Dr. M.M. Qurashi)
Chief Editor - Science Vision

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ENVIRONMENTAL CHALLENGES AND OPPORTUNITIES FOR THE DEVELOPING COUNTRIES

*Hasibullah**

ABSTRACT

Environmental degradation and issues of climate change have attracted world's attention during the past several decades. Both rich and poor nations are prone to the adverse socio-economic consequences of environmental deterioration and Global Warming. But the poor and developing countries suffer much more than the developed ones. Due to economic compulsions and technological constraints, a large number of developing countries is unable to take firm policy-decisions for quick actions to address the climate and environment-related problems. Most of the challenges in this regard are specific to the developing countries. This article identifies some of these challenges, which pertain to conceptual uncertainties, energy scarcities, disappointment with the multilateral initiatives, weak international cooperation and lack of global direction for the future action. However, some opportunities have also been envisaged despite these challenges. As a major opportunity, the case of nuclear power has been highlighted, which has the potential to address the climate-related problems with appreciable advantage over other carbon emitting energy sources. The role of renewable energy technologies in mitigating carbon dioxide emissions is also important, although these technologies still require further technical advancement and commercial acceptability.

International mechanisms to manage nuclear power on global level have good prospects in the future. Policy perceptions for a consensual, legally binding and sustainable post Kyoto Protocol agreement have also been treated with reference to the requirements of the developing countries. The conclusions re-emphasize the need of collective global action against the climate change, on urgent basis, and more proactivity on the part of developing countries to draw benefits from the post-Copenhagen negotiations. Developed countries need to enhance cooperation with the developing countries in capacity-building through transfer of technology and financial assistance.

1. INTRODUCTION

During the past several decades, two main issues of socio-economic importance have attracted extensive international attention. These are sustainable development and the environmental degradation. The emergence of both these issues at the world scene was primarily due to the social, economic, political and security imperatives, which had surged, partly as a consequence of the two world wars and rapid decolonialization. Both the issues are deeply interconnected and universal in nature. They cannot be addressed separately or by compartmentalized policy approaches, as was perceived in the early years of the debate. Environment constitutes an essential component of any policy or strategy dealing with sustainable socio-economic development.

A lot has been said and written about the environment and its relationship with the well-being of human society. Mankind is well-aware of the fact that an unhealthy environment is a major obstacle to achieving social and economic progress, happiness and peace in the world. It is also sadly acknowledged that Earth's environment, as a whole, is being degraded at an alarming rate without much convincing prospects of its early addressal or retrieval. The world is mainly engaged in endless rhetoric rather than decisive actions to mitigate the widespread devastation of the planet that may occur due to the casual attitude of its inhabitants.

Among so many negative consequences of the continued environmental deterioration the most harmful for the entire planet is thought to be the climate-change, which is attributable to Global Warming. Scientists have shown that Earth's atmosphere and oceans are becoming increasingly warm due to increased concentrations of emitted carbon dioxide, methane, oxides of nitrogen and chlorofluorocarbons, commonly known as greenhouse gases (GHGs). These GHGs are thrown into the atmosphere as a result of human activity, like burning of fossil fuels, certain agricultural practices and widespread use of cryogenic appliances.

Awareness campaigns all over the world have made Global Warming and climate-change very commonly used terms. People believe that most of the natural calamities and erratic weather patterns are due to climate change, pollution and other adverse effects of the environmental degradation. This is indeed a positive development as far as general awareness is concerned, as both rich and poor countries are becoming increasingly conscious of the negative influence of the climate change on their lives. They are more motivated to act and to contribute to the remedial schemes prescribed by the governments, NGOs and other concerned stake-holders.

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2. THREATS AND PROMISES

The harmful effects of climate change affect every one on this planet, but the people of poor and developing countries bear the brunt. The rich nations, using their abundant intellectual, economic, political and technical resources, can deal with climate related problems much more efficiently and easily than the resource-starved poor nations. The irony is that the rich nations have been, and still are, the biggest contributors towards world's pollution and carbon dioxide emissions, but they demand sacrifices from the poor and developing countries to mitigate the effects of Global Warming. However, due to global nature of climate change, both rich and the developing countries are now equally obliged to listen to each other for sharing the climatic burden. In this context, the time has come when Nature itself will force both the developed and the developing countries to come to the negotiating table and agree on sensible decisions that are necessary for future course of action.

However, the developing countries must realize that they will suffer much more than the developed countries due to the adverse consequences of unabated climate change, if they do not re-align their national policies with the forthcoming opportunities of international cooperation aimed at ameliorating the global climate. With this cooperation, many existing challenges for the developing countries may very likely change into opportunities, providing them benefits, such as access to higher scientific and technical knowledge, better industrial capacities, transfer of sophisticated technologies, stronger commercial interactions, chances of more patents, enhancement in communication capacity, better vocational training facilities, all leading to stronger economies and higher standards of living. The most profitable occasion to create such an international cooperation will be the post Copenhagen negotiations, leading to the extension of Kyoto Protocol which is to expire in 2012.

3. PRESENT POSITION OF THE DEVELOPING COUNTRIES

The developing countries are aware that the adverse effects of climate-change and unchecked environmental pollution may continue to play a negative role in their socio-economic development, unless appropriate remedial measures are taken as early as possible. They are also aware that climate change will require review of their relevant policies and strategies. They are equally cognizant of the fact that rich and poor countries have to fight the battle against the climate-change collectively over a long period of time, which will require massive financial assistance and transfer of technology from the advanced nations. The costs of fighting the climate-change for the developing countries are very high. A serious and prolonged effort by these countries will not be possible from their own inadequate resources. They may agree to take some small steps under international pressure, but such attempts may soon become unsustainable. The existing atmosphere of uncertainty in the availability of timely international cooperation to effectively undertake necessary corrective measures for tackling the problems of climate-change may retard the pace of decision making in the developing countries.

4. SOME PERTINENT CHALLENGES

Given the aforestated background, a large number of developing countries are facing some pertinent challenges in the fight against atrocities of climate-change. These may be briefly described as follows:

4.1 Conceptual Challenges

These challenges are linked with doubts about the reality of the climate-change itself, credibility of the supporting scientific evidence, authenticity of the climate policies, and the unresolved confusion on adopting either sustainable or conventional socio-economic patterns of development. These conceptual challenges force the poor and developing countries to raise two questions. First, should they really invest in the climate-change and, second, should they adopt the environment-sensitive sustainable socio-economic development plans, given the fact that they are living under severe economic stresses and uncertainties.

It seems appropriate to further elaborate the aforementioned conceptual challenges for clarity and better understanding.

4.1.1 The Contrary Views on Climate Change: A short critical review (Sacchetti, 2008) has forwarded arguments against the commonly held view that the atmosphere is alarmingly getting warmer and that whatever Global Warming is taking place is actually not the Anthropogenic Global Warming (AGW), i.e., warming caused by human activity. It says:

- The Earth is not significantly hot. "The average global temperature has not increased during the

years since 1998, despite an increase in atmospheric carbon dioxide of 15 ppm (4%) over the same period".

- Historical precedence shows that the past highs and lows in Earth's temperatures have occurred without industrial human activities. Why cannot the present climate trends also reflect a similar natural trend? This thinking is backed by a Harvard-Smithsonian study of 2003. In this study, some 200 climate studies were examined and the conclusion was that the 20th century was neither the warmest century, nor the century with the most extreme weather of the past 1000 years.

- There is one common ground among all sides of the Global Warming debate, that Earth's climate has always seen changes. Through examination of historical accounts and scientific evidence, it is clear that Earth's climate has never stayed constant. The argument goes further saying that for small changes in climate with tenths of a degree, there is no need for an external cause and that Earth is never exactly in equilibrium.

- Some scientists correlate Earth's warming with radiation influx from the Sun. Solar radiation fluctuations over a period of time have the ability to create some effect on Earth's climate. In addition to the Sun's variable activity, radiations from the depths of the space also enter Earths' atmosphere and create electrically charged ions, which spur cloud formation. It is argued that these cosmic particles from far reaches of space may play a role in climate-change. A corollary to this hypothesis would be that a hyperactive Sun may divert the interstellar radiation, diminishing the cloud formation, which could in turn spur Global Warming.

- There are some other hypotheses about Global Warming which involve factors like ocean trends, water vapours, celestial phenomena, etc. Some skeptics refer to uncertainties associated with the computer models, which can cause doubts about the real authenticity of findings and predictions on Global Warming.

4.1.2 Doubtful Scientific Claims: Intergovernmental Panel on Climate Change (IPCC) has been a long time international authority to conduct scientific research and to give advice on climate-related policies. In its 4th Assessment Report, the IPCC has given a statement that the Himalayan glaciers could completely disappear by 2035. This claim has been strongly contested by scientific community on climate-change and other concerned quarters (Nature, 2010, and Hulme, M., 2010). However, now IPCC has admitted that in drafting the relevant paragraph, clear and well-established evidences were not applied properly. Nevertheless, IPCC stood by the conclusion about glacier-loss in this century in major mountain ranges, including the Himalayas. This kind of scientific reporting can create doubts in the minds of policy-makers about the authenticity of scientific findings on which they have to base their national-level decisions - in this case involving a particular view on climate-change. A conceptual challenge of this nature can create a far reaching effect on the readiness of a developing country to move forward and make investment of its meager financial resources.

4.1.3 Policy Dilemmas: Another conceptual challenge facing many poor and developing countries is linked to the unsettled debate on the choice of sustainable socio-economic development over the conventional development. The sustainable development demands additional efforts for ensuring an equally prosperous future for the coming generations as that of the present generation. This also involves sacrifices by the present generation to spare enough economic resources for the use of the future ones. As environment constitutes one of the essential components of sustainable socio-economic development, special but tough economic arrangements have to be made so that the coming generations inherit a unadulterated environment from the previous generations.

The poor and developing countries are usually unable to meet the requirements of sustainable socio-economic development easily, as they are more concerned with addressing the immediate needs of their people. Two articles on the contentious debate on sustainable development and uncertainty of its conclusions with particular reference to the developing countries may provide further elaboration of this issue (Hasibullah, 2006 and 2007). However, in the context of development itself, a new approach is emerging, which emphasizes the preference of equity and social justice over the concept of excessive economic growth. This approach is gaining consensus (Khan, A. 2010). The full-fledged emergence of this approach may also present a new challenge for the developing countries to devise right policies to tackle climate-change in conjunction with economic development. Such policy-difficulties can be appreciated when one considers, for example, the inferences of two studies

published recently. The first study (Jones and Olken, 2010) says that in poor countries, a 1 degree Celsius rise in a climate related temperature in a given year reduces its economic growth by about 1.1 percentage points and its exports can drop by 5.7%. The second study, on the other hand, finds that "the poor want biomass, not biodiversity" (Lewis and Antony, 2010). These two climate-related yet oppositely oriented ground-realities represent typical policy dilemmas faced by several poor and developing countries.

4.2 Energy Challenges

Energy is the lifeline of all mankind. Socio-economic development of all nations, rich or poor, depends upon energy supply and security. Fossil-fuel is the main source of energy around the globe. Combustion of fossil-fuel produces carbon dioxide, which is considered to be the major cause of Global Warming and consequent multifarious environmental problems. People in rich countries use about 25 times more energy than those in the developing countries. Consequently, they pollute Earth's atmosphere with carbon dioxide and other GHGs in overwhelmingly higher proportions than do the developing nations. However, the negative socio-economic impacts due to climate-change, caused primarily by the rich societies, are much more devastating for the poor countries than the developed countries. The world's consumption of energy produced by fossil-fuels, more by the industrially advanced societies than the others, will expectedly grow continuously. However, the industrially advanced countries are expecting that the developing countries will drastically reduce their GHG emissions.

Unfortunately, the alternative energy sources, like hydro, solar and wind, etc., that do not pollute atmosphere significantly are neither enough to meet the present and the near-future energy demands of the world, nor will they be economically attractive to the general public, at large. Replacement of technology, based on fossil-fuel with clean-energy technology will involve huge investments and a long time. Consequently, the developing countries may have to live with climate-change and other environmental problems for many decades to come. This view is supported by the figures given in the Table-1 that offers a glimpse of the trends of world energy scenario till 2030 (Estimated Figures) in relation to population increase (slight decrease expected during 30s) and carbon dioxide emissions. This table shows approximately 51% increase in the world carbon dioxide emissions in 20 years' time if the current policies and practices continue. It is not clear how developing countries will be able to adjust themselves, in terms of climate-change threats and their economic progress.

The following points, given in the World Bank's Report, "Johannesburg and Beyond: An Agenda for Action", need consideration in the context of economic growth and related environmental risks:

- In order to meet MDG of halving, by 2015, approximately 29% of world's population living on less than one US dollar a day, the low-income countries will have to grow at per capita rate of 3.6%.
- In 2050, around 65% of people will be living in urban areas, if the present trend continues.
- At current rate of biodiversity-loss, the world in 2050 will be much less biodiverse and huge funding would be required to preserve biodiversity.

Table - 1: World Energy Scenario upto 2030

Year	2010	2020	2030
Population (Million)	6855	7558	8164
Final Energy Consumption *(Mtoe)	8682	10425	12132
Electricity Generation (TWh)	19339	26122	34716
Percentage of Renewables in Gross Inland Consumption	11	9	8
Electricity Consumption per capita (KWh)	2.4	3.0	3.7
Carbon Dioxide Emissions (MT of CO_2)	29376	36738	44498

* Mtoe: Mega tonnes of oil equivalent
Source: World Energy Technology and Climate Policy Outlook 2030 (EU Publication)

- At estimated growth rate in per capita GDP of 2% in rich countries and 3.3% in low-income countries, the world income will rise to over 80 trillion US dollars by 2030, as 65% of the countries would be in high-income category. By 2050, world's income will be around 140 trillion, with 40% low and middle income countries. This growth-pattern would pose risks to the natural environment and these risks are greater in the developing countries. It is also envisaged that by 2050 another 150 million megawatts of electricity capacity would be required, which will most likely entail an environmental threat within the current technological paradigm.

Another pertinent study (UN-WEC, 1995) on "Global Energy Scenarios to 2050 and Beyond" by World Energy Council takes into account the long-term issues of environment and climate-change. This report in collaboration with the International Institute of Applied System Analysis (IIASA) gives a coverage of scenarios upto 2050 and also upto 2100. However, on account of more reliability of short-term scenarios, it is appropriate to refer to those which terminate by 2050. Table-2 gives a comprehensive picture of 2050 scenario comprising population growth and the energy scenarios along with other related information.

The figures appearing in Table-2 are only estimates based on "middle-of-the-line" assumptions and are independent of those given by another source in Table-1. Growth in population will result in growth in demand and consumption of energy, which will be much higher in the developing countries than the developed ones as seen in Table-2. The carbon dioxide emitting energy-sources, i.e., coal, oil and gas, will outweigh the renewable energy sources (64% vs. 22%) thus resulting in colossal addition of 10 giga tons of carbon in the atmosphere by 2050. This is why there is an immediate need of increasing the share of nuclear energy in the overall mix of global energy demand. Nuclear energy is well-developed and has much more potential of coming on the grid on global level, than the renewables which are still waiting to be developed for sustainable commercial utilization. There is another reason for the nuclear energy to quickly come to the world energy scenario. This is a fact that the economies of developing countries, particularly in Asia, are growing rapidly and there is no alternative to using fossil-fuel as a major mix for the total energy requirement. Increased economic activity will lead to more GHG emissions and subsequent climate-change. Emissions are expected to grow by a factor of 4 in China and India by 2030 (Amann and Wagner, 2008-2009). This will have a huge impact on

Table - 2: 2050 Scenarios (Estimates based on moderate assumptions)

World Population (2050)	10 Billion
World Economic Growth (1990-2050)	2.2% p.a.
Primary Energy Demand (2050)	20 (Gtoe)
Primary Energy Mix (2050)	**Share**
• Coal	21%
• Oil	20%
• Gas	23%
• Nuclear	14%
• Renewable	22%
Energy Consumption Increases (1990-2050)	**Estimates (in 60 years)**
• OEDC Countries	33%
• Economies in Transition	41%
• Developing Countries	281%
• Global	118%
Carbon Emissions (2050)	10 (Gtc)
Environmental Taxes	Nil

Gtoe: Giga tons (10^9) of oil equivelant
Gtc: Giga tons of carbon
Source: World Energy Council Report: Global Energy Scenarios to 2050 and Beyond

environment and climate-change and will thus remain a huge challenge for the developing countries for a long time to come.

4.3 Challenges Arising from Multilateral Initiatives

Environmental degradation and climate-change are global issues and therefore an integrated cooperation between the advanced and developing nations is essential for their satisfactory addressal. Two major initiatives, in this connection, have been taken by the world community. The first is the poverty alleviation initiative, called the Millennium Declaration and the second is popularly known as the Kyoto Protocol. The former prescribes 8 goals to eradicate poverty, hunger, disease, illiteracy, etc., from the developing world. Environmental sustainability is one of its important goals. Targets and relevant assessment of each goal are given annually. The overall final review is expected in 2015. The developing countries had attached great hopes to this initiative ten years ago when it was launched but so far the results have not been upto their expectations (United Nations, 2009). Regarding the goal on environment, the targets states, "Integrate the principles of sustainable development into country policies and programmes and reverse the loss of environmental resources". The assessment given in the above referred report states, "A continued rise in greenhouse gas emissions is another reminder of the urgency of climate-change problem". This grim warning arises due to the reported figures of carbon dioxide emissions which show increases between 1990 (base year) to 2006 in both the developing and developed world. The problem with the MDGs initiative is that most of the responsibility of achieving the prescribed targets is left to the governments. This is not a realistic approach for the developing countries. The international cooperative mechanisms for the implementation of the MDG policies and strategies are vague and weak. Lack of commitment on the part of developed countries to provide funding and technical assistance are considered to be the major cause of disappointment. Developing countries may not be able to meet the environmental targets of the MDGs by the deadline of 2015. Addressal of environmental issues by the developing countries alone under the existing circumstances will remain a big challenge for several decades to come.

The second international initiative related specifically to climate-change - the Kyoto Protocol - may have even more disappointments for the developing countries. This overambitious, highly committed Protocol, consisting of 28 Articles, was born in Kyoto-Japan in 1992 under the UN Framework Convention on Climate Change and was aimed at stabilizing and reducing the global carbon dioxide emission to a reasonable limit with closer international cooperation. Funding and technical assistance was to be provided by the industrially advanced nations to the developing countries to enhance their capacities to confront the climate related problems. The developed nations were required to assume greater role to reduce the adverse effects of climate change as they had been bigger contributors of carbon dioxide emissions for the past two centuries. However, the developed countries did not show enough willingness to take solid political, social and technical measures, mainly due to the fear of economic problems. These measures were necessary to make the Protocol a success. This response from the developed countries was the main reason for the slow progress of the Protocol. It took 5 years for the Protocols' development and another 10 years to ratify it. Even other countries, which are parties to the Protocol, have not done enough to achieve the desired results.

Several international meetings have since been held in order to find a common agreement on the size of cuts on carbon dioxide emissions, responsibilities of developed and developing member countries, funding mechanisms and nature of technology-transfer. In order to find a legally binding successor of Kyoto Protocol, which is ending in 2012, the world leaders met in Copenhagen (Denmark) in December 2009. Against all hopes, this well-attended conference could not reach a clear agreement on the nature of the intended legal instruments. It is said that the failure was mainly due to sharp disagreements among the developing countries on various elements of the text. However, a deal was struck among some major players and it was hurriedly announced to the other participants, causing a great deal of resentment and frustration among them.

The only positive aspects of the conference were that a commitment to limit Global Warming to 2 degree Celsius (without setting global emission targets for 2020 or 2050) was made and the developed countries pledged US$ 30 billion for the developing countries for the period 2010-2012, as well as long-term financing of a further US$ 100 billion a year by 2020 to be mobilized from a variety of sources (IISD, 2009). These pledges have not materialized so far, to the disappointment of the developing countries (AFP, 2010). Meanwhile, the International Institute for Environment and Development has mentioned several hurdles in delivering these finances (IIED,

2010), which could jeopardise the outcome of the conference. The main hurdle, quoted by this policy analysis, would be the unpredictability of the time when these funds will be made available to the developing countries. With the expectation that a large number of developing countries would be in favour of an international, legally binding and consensus agreement which could provide them a good opportunity to play their due role in the international efforts to combat the climate- change, it would be unfortunate if the attitude of the advanced countries as shown in the Copenhagen Conference prevails in the future negotiations on climate issues. Denial of equal participation of the developing countries in policy and decision-making processes would presumably pose another crucial challenge for the developing countries.

4.4 Role of the United Nations Organization

The United Nations Organization (UNO) can play an important role in creating an international consensus to meet various challenges that have been lingering on for a long time concerning the climate-change. As a matter of fact it was the United Nations under whose patronage the international negotiations on climate-change started in 1991 (UN Framework Convention on Climate Change) and have continued with the involvement of the world community, scientific fora, and NGOs, etc. It was also the UN General Assembly which in 2000 adopted the Millennium Development Goals that are intrinsically related to environment and its links to the world's socio-economic development. The UN has held major conferences on environment in 1972, 1992 and 2002. Moreover, the UN has hosted all negotiating processes on global climate affairs, such as ozone depletion, air pollution, biodiversity, desertification, drought and regulation of toxic chemicals. Therefore, it is logical that the UN may continue to help the international climate negotiations, especially those now due after the Copenhagen Summit Conference held in December 2009. The UN can use its diplomatic expertise to push the climate-negotiations to a successful conclusion, to the satisfaction of all the concerned parties.

It is widely believed that the UN would be the most logical and productive forum for strengthening international cooperation for the transfer of technology and provision of funding to implement the agreed decisions linked with all environmental and climate-change affairs. However, the present procedures of the UN are considered to be time-consuming. For the climate-change issues, the UN may consider reforming the relevant procedures, so as to accelerate decision-making in its various departments. The Kyoto Protocol is going to end in 2012 and there is still a lot to be done by the international community to prepare itself for an agreeable, viable and productive post-Kyoto Agreement that would be legally binding for all its signatories. There would be need of a dedicated organizational entity within the UN system that could permanently manage the climate-change affairs and other environmental issues, which come under the UN purview.

Again there will be specific collaborative issues with respect to the developing countries when the UN moves forward on climate-policies and strategies. For example, the replacement of current technology being used in the developing countries with new environment-friendly technologies will be one of the major challenges. This will require close understanding and spirit of cooperation among the industrially advanced and economically poor countries. The UN will need special mechanisms to create a sustainable collaborative relationship between the rich and the poor countries in order to achieve the climate-change targets. In this context, the industrially advanced nations will have to show strong commitments towards collaboration, allowing the developing countries to have access to the knowledge, technology and expertise available to them. The UN will also play its due role in ensuring the flow of timely and certain financial assistance from the advanced countries to the developing ones. Only two years are left before the world community decides on a viable successor to the Kyoto Protocol. The UN has to take a leadership role to make that happen. The developing and developed countries are still optimistic about the continuing efforts of the UN to save them from the threats of Global Warming and the environmental degradation.

4.5 Opportunities within the Challenges

The world's energy demands will continue to increase in the future, due to economic growth and rapid population expansion. Carbon dioxide emissions from burning the fossil-fuel, under business as usual scenario, will also increase and will further aggravate the climate conditions. It is very likely that a point of "no return" may come well within this century. Supplementing the future energy demands with non - carbon dioxide emitting sources thus becomes inevitable.

Unfortunately, the alternate clean energy sources are not yet available in sufficiently enough quantities to

fulfill the needs of the world. Only hydro and nuclear electricity generating possibilities are there to partly meet the needs of industry, transport, construction, district-heating, etc. The hydro-potential in most of the developing countries is almost saturated due mainly to severe water shortages, which are attributed significantly to climate-change. Solar, wind, geothermal energy as well as energy from oceanic waves have not become economically viable so far. The only practical option left is the nuclear electricity.

Nuclear Energy: The world has a long and satisfactory working experience with nuclear power plants; the misconceptions about safety and waste-management are largely sorted out by now. The initial costs of nuclear power plants are still higher than those of the conventional power plants but the cost of production of electricity is quite economical. It is anticipated that considerable cost reductions in nuclear power plants will take place when more plants are ordered on global scale. Due to world's energy-security concerns, arising out of fossil-fuel price-hike, oil spills, green-energy movements and political policies, the overall public opinion is gradually reverting back to the nuclear energy as an option to meet energy needs. According to the International Atomic Energy Agency (IAEA) publication (IAEA Document, 2009), there were 438 nuclear power plants worldwide at the end of 2008 with generating capacity of 371562 MW (e). At the same time there were 44 new reactors under construction with a capacity of around 40000 MW (e). The share of nuclear power in global electricity generation was 14%. Total operating experience through 2008 was about 13475 years. Europe's four industrially advanced countries are now using nuclear electricity upto 50% of the total energy mix, viz. Belgium 54%, France 76%, Lithuania 73% and Slovakia 56%.

The revival of nuclear power in the world can be weighted from the following facts reported in the above-mentioned IAEA report:

- Construction work on 10 new nuclear power reactors had started in 2008.
- Many countries are raising their targets for the share of nuclear power in meeting their energy needs in the near future. These include India, China and the Russian Federation.
- The UK, according to a White Paper published in January 2008, has stressed that it was in the public interest for nuclear energy to continue to form part of the UK's low carbon energy mix, in order to help meet targets of reduction in carbondioxide emissions and to ensure the security of energy supplies.
- Italy, Romania, Bulgaria, Finland, Switzerland and Slovakia are taking necessary measures to restart or expand their nuclear power programmes.
- In Canada, licenses have been issued to build new reactors or to extend the operation of their already existing nuclear power plants.
- In the USA, ten power uprates have been approved, totaling 2178 MW(th). Three license renewals totaling 51 by 2008 have been made. Applications for 26 new nuclear power plants have been launched.
- World interest in starting new nuclear power programmes has been high. IAEA has been requested by 55 Member States to assist them to introduce nuclear power in their energy mixes.
- The number of approved IAEA technical cooperation projects on analyzing energy-options increased from 29 to 41 for the project-cycle in 2009. The number of projects on uranium exploration and mining increased from 4 to 9, and the number of projects on introducing nuclear power increased from 13 to 44. Ten IAEA expert-missions to help Member States to introduce nuclear power were conducted during 2007 and 2008 in Belarus, Egypt, Jordan, Nigeria, Philippines, Sudan and Thailand.

In addition to the above-mentioned revival activities for the use of nuclear power in a wide global geographical range, two significant developments have taken place in the oil-rich Middle East. Saudi Arabia and the Gulf Cooperation Council have shown interest in nuclear power, for which they have already taken initial steps (Swahel 2006 and 2010). According to this report by Science and Development Network, Saudi Arabia is planning to create a city for nuclear and renewable energy to meet Saudi Arabia's growing energy needs and reduce its dependence on fossil-fuels. Also the six-member Gulf Cooperation Council has agreed to develop nuclear energy technology jointly for peaceful purposes. It may be significant to reckon that members of the Gulf Cooperation Council received three IAEA's advisory missions on nuclear power development during the period 2007 and 2008.

The interest of the above oil-rich nations in nuclear power shows two trends. First, the long-term dependence on oil cannot be ensured and the second that the Middle Eastern region is increasingly becoming sensitive to climate-change. This major policy-shift in the oil-producing and exporting countries of the Middle East is a positive sign for the future of Earth's climate.

The worlds' confidence in utilizing nuclear power as an answer to the future clean energy demands is also evident from the projected growth figures published by the IAEA (Nuclear Technology Review, 2009). IAEA has revised both the low and high projections upwards. In the updated low projections, global nuclear power capacity reaches 473 GW(e) in 2030 compared to a capacity of 372 GW(e) at the end of 2008. In the updated high projection, it reaches 748 GW(e). Three other world energy agencies, i.e., the OECD's International Energy Agency, OECD's Nuclear Energy Agency and US Energy Information Administration have also revised their future nuclear electricity projections for 2030 and 2050 showing significant increases in the installed capacity (ibid). Table-3 shows percentage increases (high and low) of world's projected nuclear capacities in 2030 by four international agencies in comparison with IAEA's figures of 2009. The increase in the trend is obvious. The lower values are generally consistent at around 45% increase. Leaving aside the higher values, the lower values show significant increase in the next 20 years.

The 2009 Review also quotes International Energy Agency's two climate policy scenarios. The "550 policy scenario", which corresponds to long-term stabilization of the atmospheric greenhouse gas concentration at 550 parts per million of carbon dioxide, equates to an increase in global temperature of approximately 3°C. The second scenario, "450 policy scenario" equates to a rise of around 2°C. In the 550 policy scenario, installed nuclear capacity in 2030 is 533 GW(e); in the 450 policy scenario it is 680 GW(e). This shows that lower global temperatures can be achieved with higher share of nuclear power in the overall energy mix.

It appears that nuclear power will be the only practicable clean energy source for future replacement of fossil and other carbon dioxide emitting fuels on a bigger scale. Other clean sources like hydro, solar, wind, etc., may also serve as valuable sources for the future energy mix but on a much smaller scale. As and when the world community decides in line with this premise, an excellent opportunity will be available for the developing countries to participate in the efforts of the technically advanced countries in the future development and expansion of nuclear power on a commercial scale. The nuclear power technologies can develop much more quickly as there already exists sufficient knowledge, industrial infrastructure, management and marketing experience in the world. Funding mechanism's can be evolved on global level to facilitate nuclear power's commercialization and deployment under international policy frameworks.

Renewable Energy Technologies: Notwithstanding the high potential of the nuclear energy to provide assured and clean source of power in the coming decades, the importance of renewable energy technologies cannot be ignored. Generally speaking, this category of energy sources includes solar energy, wind power, hydropower, biomass, biofuel and geothermal energy. Out of these, biomass and biofuel, which are gaining increasing attention these days, are

Table - 3: Comparison of Nuclear Energy Projections (% age Increase in Low and High Values for 2030 as Compared to IAEA's values of 2009)

Name of the Agency	Low	High
IAEA	46	131
EIA	46	50
IEA	42	112
WNA	-23	131

IAEA: International Atomic Energy Agency
EIA: Energy Information Administration (USA)
IEA: International Energy Agency (OECD)
WNA: World Nuclear Association
Source: IAEA Nuclear Technology Review 2009

carbon-emitting and, hence, cannot be considered as clean sources of energy. The remaining sources are clean but limited in their commercial use. Nonetheless, around 18% of global energy-consumption has been reported to have come from renewables in 2006 (Wikipedia, 15th July 2010). Table- 4, derived from the same source, illustrates the increase from 2004 to 2008 in some mainstream renewables.

If the commercial interest continues globally on renewables, it is likely that cost reductions and easy operability of the appliances would help the public acceptability of the renewable energy sources. However, the general trends in commercial break-throughs during the last two decades have been somewhat erratic. The commercial R&D on the renewables showed ups and downs with the fluctuating prices of oil. Shortfalls in research-funds due to recent international economic crisis have also impeded the progress of commercial development and marketing. Table-2 shows share of renewables as 22% of the total primary energy mix in 2050 whereas nuclear energy has been kept at the same level (14%) as present. This does not seem to be a likely scenario as the assumptions on which the estimates of nuclear energy in Table-2 were made in 1995 have considerably changed after 2000 because the use of nuclear energy is being revitalized on large scale due to changed governmental policies of the industrialized world. Renewable energy technologies, due to their limited scope in industrial and public consumption, will largely remain as compensatory technologies in the overall global energy production sources for some time.

4.6 Policy Perspectives

Environment and climate concerns are changing the world's thinking on the relationship between the developed and the developing countries for shaping a healthy, prosperous and peaceful future. Climate-change sees no borders. The atmosphere and environment is common for both rich and the poor countries. All nations of the world will have to make concerted efforts to face the challenges of climate-change and environmental degradation. The climate-change can become a binding force among the rich and poor nations to adopt common policies and strategies and fight a united battle against all the odds. Climate-change has a strong potential to create a spirit of wider international cooperation and networking.

Presently, the international community does not seem to be reacting seriously to the fast deteriorating condition of the environment. Both the developed and the developing countries have to take decisions for action, without further delays. Developing countries will have to overcome decision-making challenges, with the encouragement, cooperation and help of the developed countries. Green house gases are being released into the atmosphere continuously and in constantly increasing quantities but enough is not being done to address this activity. Nevertheless, some concerned sections of the society have been giving due consideration to the policies and strategies that can bring a change. A selected compilation of such policy-considerations, made partly from the IAEA Bulletin of March 2008, is given below:

- To confront climate-change, there should be no distinction between the developed and the

Table - 4: Renewable Energy Technologies Increases (2004-2008)

Renewable Energy Source	Increase
Solar photovoltaic capacity	6 fold to 16 gigawatts
Wind Power capacity	25% to 121 gigawatts
Solar heating capacity	2 fold to 145 gigawatts
Biodiesel Production	6 fold to 12 billion liters per year
Ethanol production	2 fold to 67 billion liters per year
Total power capacity from new renewables	**75% to 280 gigawatts**

developing countries.

- An appropriate post-Kyoto agreement, under the aegis of the UN is required soon. This should offer an opportunity and due flexibility to the countries to implement GHGs emission-reduction strategies that are in harmony with their national circumstances. This international agreement should also include consensus on four pathways for addressing mitigation (activities to halt or to reduce the rate of climate-change), adaptation (to change life-style to lower the shocks of climate-change), technology hurdles and financial constraints. As far as mitigation and adaptation initiatives are concerned, it will be useful if a mix of policies for both these initiatives is evolved.

- There should be an agreement on global targets to start with. For example, all countries should commit to collectively reduce global emissions by at least 50% by the year 2050. Different developing countries may agree to reduce their energy intensity targets appropriately and in line with their responsibilities and capacities.

- It may be recognized that all emission sources and sinks are relevant to climate-change solutions and should be included in the proposed agreement.

- Harmonized universal carbon-taxation system could reduce emissions and generate financial resources that could be used for developing clean energy sources.

- Placing a price on carbon may be considered for ensuring dissemination of right technologies on right scale. Additionally, there would be a need of a policy mix that relates to regulations in buildings, construction design and resource allocation for public transport options.

- The poor societies in developing countries do not possess enough capabilities for adaptation. Strong mitigating measures are needed to minimize the cost of adaptation, without which adaptation may be impossible in some countries.
- Adaptation should be a part of poverty-reduction strategies. Special funds need to be allocated for adaptation plans in the developing countries.

- A climate fund would be needed to address the risks of climate-change. For developing countries this fund should be at least US $ 50 billion per year in order to undertake activities supporting a comprehensive climate-change agreement, which should be free from administrative or technical hurdles.

- It is essential to build trust between the rich and poor countries at all levels of development and create an equitable basis and new modalities for genuine international cooperation to tackle the intertwined challenges of energy and climate-change.

- Reduction of global GHG emissions by 50% at acceptable costs by clean technologies requires a technological revolution similar to that in the space and telecommunication sectors. But it is essential that appropriate clean energy technologies are made available, as widely as possible, to the developing countries. It is also important that as much research as possible should be carried out exclusively in the developing countries. Without technology transfer and provision of adequate funding, the gigantic task of reducing GHG emissions cannot be accomplished.

- Nuclear power would play a pivotal role for providing an assured and clean energy supply in the future energy-scenarios linked with reducing GHG emissions. A global mechanism under IAEA supervision, needs to be developed that could look after all the matters connected with nuclear-power production, distribution, finances, safeguards, regulation, safety and security, waste disposal and decommissioning of facilities. IAEA's proposal on multinational management of nuclear fuel-cycle (Rauf and Vovchok, 2008) may be revamped to facilitate adequate increase in the world nuclear electricity generation, as an integrated support mechanism for meeting the challenge of climate-change and environmental degradation. Maximum number of clean energy starved countries of the world need to include nuclear power in their national development policies, alongwith renewable clean energy technologies as an appropriate energy mix.

5. CONCLUSIONS

- Continued deterioration of Earth's environment and unchecked greenhouse gas emissions into the atmosphere will present more serious socio-economic challenges to the poor and developing countries than to the developed nations.

- The negative impacts of unabated environmental deterioration on the rich and industrialized nations would be due to two factors. First, the universal disasters will increase and affect their economies. Second, the flow of economic resources from the poor and developing countries to the rich nations will be constrained due to their increased vulnerability towards the climate-change.

- Environmental threats and challenges are universal. Both developed and developing countries will have to assume equal and collective responsibilities to address the threats and challenges, in this regard. The world may not succeed in halting or reducing the devastating effects of climate-change and environmental degradation, unless there is firm commitment on part of the developed and developing countries for a sustainable cooperation over a long period of time. Capacity building in the developing countries to a sufficiently high level is necessary, with the help of the developed countries.

- Nuclear power generation on global level will have to be increased sufficiently in order to provide the world with a clean and assured energy source on the industrial scale. The scope of developing other clean-energy sources like hydro, solar, wind, is quite limited for the time being. These sources can however, serve as a supplement to the nuclear energy, if developed to an acceptable level.

- Politicizing the environmental and climate-change issues, while deciding a universal regime that may serve as a successor to Kyoto Protocol, will not be in the interest of the international community. Plain objectives to confront climate-related issues with international scientific, technical and financial cooperation, would be a hallmark of a realistic international agreement. Lessons learnt from the Copenhagen Conference in December 2009 can serve as guidelines for future climate negotiations.

- The world does not have long to prepare itself to launch a well-planned, integrated, strategized and determined campaign to combat the climate-change and environmental deterioration. Many years may be needed to stabilize the greenhouse gas emissions, check deforestation and stop chemical pollution of land, air and oceans. By that time, Earth's environment may well reach a point of no return. This cautionary scenario demands more alertness from the developing countries. Early preparedness for the future challenges and opportunities, at national and global levels, would serve their socio-economic interests, as well as of the future generations.

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CLIMATE-CHANGE ASPERSIONS ON FOOD SECURITY OF PAKISTAN

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ABSTRACT

The economy of Pakistan is agrarian. The production system is predominantly irrigated that uses 90% of the available river-water and provides over 80% of agricultural produce. The productive resources of land and water, which are the base for food production, are limited, rather dwindling due, inter alia, to the changing climate. The climate change is exerting pressure on these resources, both directly (e.g. through increased glacier-melt, increased evapotranspiration, increased land-degradation, etc) and indirectly (e.g. via enhancing soil processes, such as, denitrification leading to emission of greenhouse gases, and unavailability of plant-nutrients, increasing crop-water requirements, etc). Not only this, but the frequency and intensity of extreme climate events of floods, drought, cyclones, etc., is on the increase with serious consequences for the standing crops apart from immeasurable damage to life and property.

These changes are expected to have significant impacts on food security of the country. Global assessment (projections) of the impact of climate change on agriculture suggests-losses in crop yields, reduction of growing-season length, increased water-requirements of crops and decreased irrigation water-supplies as a result of warmer temperatures. This paper presents results of some studies carried out at GCISC with the help of DSSAT-based crop-simulation models (CERES-Wheat and CERES-Rice) on impacts of climate change on the productivity of two major food crops, wheat and rice, of Pakistan. The paper also discusses food-security prospects of Pakistan towards the end of this century in the light of the above-mentioned analyses.

Keywords: *Climate Change, Food Security, Crop Simulation Modelling, Pakistan*

1. INTRODUCTION

To feed its inhabitants adequately and efficiently is the first and the foremost duty of a government. The national planners are always in need of data for assessment of the food-security situation, i.e. the food stocks required for their people in the short and long-term, in the background of prevailing state of the productive resources of land and water.

Food security can be defined in hundred and one ways in the light of objective for which it is to be used. The definition by FAO is the most comprehensive and appropriate one. It states "food-security exists when all people, at all times have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food-preferences for an active and healthy life" (FAO, 2004). This definition embodies three dimensions; adequacy of food (effective supply), ample access to food (ability of individual to acquire sufficient food) and reliability of supply and access (equity of food distribution). This paper concentrates on the food-production aspect of food security.

2. CLIMATE CHANGE AND AGRICULTURE

Weather and climate are the key factors in the agricultural productivity. Being open to vagaries of nature, the agriculture sector is highly vulnerable to climate-change phenomena. Weather is defined as the 'state of the atmosphere at a given time and place, with respect to variables, such as temperature, moisture, wind velocity and barometric pressure (Dictionary.com 2009 http://dictionary.Reference.com/browse/weather). It is a short-term state, for a day or a week. Climate is the 'average weather' or statistical description of mean weather-conditions over a period of time, ranging from months to thousands or millions of years, typically 2 to 3 decades. The classical period is 30 years, as defined by the World Meteorological Organization (WMO).

"Climate change" refers to a statistically significant variation in the mean state of climate or its variability persisting for extended years (typically decades or longer). Climate change may be due to natural internal processes or external forcing, or due to persistent anthropogenic changes in the composition of atmosphere or in land-use. United Nations Framework Convention on Climate Change (UNFCCC) defines climate change as "A change of climate which is attributed, directly or indirectly, to human activity that alters the composition of global atmosphere and which is in addition to natural climate variability observed over comparable time periods". (http://www.wmo.int/pages/prog/wcp/ccl/faqs.html)

The climate-related parameters that influence agricultural productivity include: carbon dioxide (CO_2), temperature, solar radiation, precipitation, and others (wind speed and direction, soil moisture, water vapours, etc). A basic understanding of functions and mode of action of these parameters helps us to manipulate plants and management-practices to meet human needs of food, fiber, and shelter. The

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parameters also help understand impacts of climate change on productivity and devise adaptation/mitigation strategies to counter the negative impacts.

3. CHANGING CLIMATIC TRENDS

The Inter-Governmental Panel on Climate Change (IPCC), the apex international body on climate-change research, makes periodic assessments on the status of climate change. Based on its latest Assessment Report (AR4), published in November 2007, the future concentration of CO_2 was calculated. The concentration in the atmosphere has increased from the pre-industrial revolution value of 280 ppm in 1780 to 383 ppm in 2007, and is projected to increase to 550 ppm by 2050 (Iqbal and Arshad, 2008). The global average temperature has increased by 0.6°C during the last century and is likely to increase by 1.8° to 4°C, by the end of this century. The changes in rainfall are not uniform; in sub-humid and humid areas there will be increase in monsoon rainfall, whereas in the coastal and hyper-arid areas there will be decrease in winter and summer rainfalls (IPCC, 2007).

4. FOOD PRODUCTION IN PAKISTAN

Although agriculture's contribution to national GDP has decreased, from 53% in 1949-50 to 21.8 % in 2008-09, and that of industry has increased to 17%, agriculture is still the predominant sector of national economy. It provides food and fiber to the growing population of the country, hence is an important contributor to food-security and it presently employs 44.7 % of Pakistan's labour force (GoP, 2009).

The agricultural production system is predominantly irrigated. Out of the total cultivated area in Pakistan of 22.05 million hectares (mha), 19.12 mha or 84% is irrigated and the remaining totally rainfed. The irrigated agriculture uses more than 90% of the available fresh-water resources and provides over 80% of the produce (Bhatti and Akhtar, 2002).

A good part of Pakistan is classified as arid to semi-arid, where rainfall is not sufficient to grow agricultural crops (Waraich, 2005). The extent of dry areas in Pakistan is given in Table-1. About 11% of the area has annual rainfall of 250-500 mm, about one half has rainfall ranging from 150-250 mm and about one-third has less than 150 mm annual rainfall. The country on the whole is classified as Arid country.

5. PERFORMANCE OF AGRICULTURE SECTOR: 1990-2009

Pakistan's agriculture has seen many upheavals during the past 50 years. Some years have been of slow growth, while the others have registered good growth. During this period, the population has increased over four-fold, while wheat production has more or less kept pace. Wheat production grew from 14,585 m tons in 1990-91 to 21 m tons in 2007-08. Rice production rose from 0.86 m tons in 1950-51 to 5.56 m tones in 2007-08 (GoP, 2009). The dip in production during early 1990s and late 1990s has been attributed to dry spells related to climate change. Such spells can signal an increase in food-insecurity in the country. This is now becoming more and more significant.

6. IMPACTS OF CLIMATE CHANGE ON AGRICULTURAL PRODUCTIVITY

It has been increasingly realized that climate change is the single important factor that is likely to exert pressing effect on productive resources and, ultimately, on agricultural productivity in a number of ways. These impacts include:

i. Shortening Length of Growing Period: Climate change increases the span of growing period, the

Table - 1: Extent of Dry Areas, Based on Aridity Index, in Pakistan

Area	Rainfall Regime	Million hectares	% of Total
Total Area	<150->1,000 mm	79.61	100
Semi-arid	250-500 mm (Aridity Index 16-31)	8.76	11
Arid	150-250 mm (AI 8-16)	38.21	48
Hyper-arid	< 150 mm (AI < 8)	26.27	33

Note: Aridity Index =Σ1.65(Precipitation/Temperature+12.2)x0.9

optimum period during which a crop can be raised, due to high temperature. It is represented as sowing window. The actual growing season length or cycle of growth of a crop, i.e. time taken from sowing to maturity, on the other hand, gets shortened as a result of rise in average temperature, which forces crops to mature earlier; hence full crop production cannot be realized. The growing season length is represented by 'Growing Degree Days'. These both (growing period and growing season length) are commonly used synonymously, but erroneously.

ii. Losses in Crop Yield: The shortening of growing season length, or the crop life-cycle, leads to concomitant loss in yield, as the crop is unable to realize its full production-potential. Also, the rise in temperature affects crop-yield directly. Crop simulation-modeling studies, based on future climate scenarios, carried out in Pakistan and in other countries, point to considerable losses in crop yields. Fischer et al. (2002) reported that substantial losses are likely in the rainfed areas of wheat production in South and Southeast Asia. In South Asia, the drop in yields in non-irrigated wheat and rice will be significant for a temperature increase greater than 2.5°C, incurring a loss in farm level net-revenue between 0 and 25% (Kumar and Parekh, 1998). The net cereal production in South Asian countries is projected to decline at least 4 to 10% by the end of this century, under the most conservative climate-change scenarios (Alam et al., 2007). However, regional differences in the response of wheat, maize and rice yields to projected climate change are likely to be significant (Parry et al., 1999, Rozenweig et al., 2001).

The work done in this regard at GCISC will be described and the major results presented in the subsequent sections.

iii. Changes in River-Flows: Pakistani rivers derive upto 80% or more of their water from Hindu-Kush Himalayas (HKH) glaciers (WAPDA-IDRC-WLU, 1990; http://www.idrc.ca/en/ev-5441-201-1-DO_TOPIC.html). Rising atmospheric temperatures are increasing the glacier melt. According to IPCC (2007), glacier melt in the Himalayas is projected to increase flooding within the next 2-3 decades. This will be followed by decreased river-flows, as the glaciers recede. Rapid melting of glaciers will have serious consequences for river- flows. The expected changes in river-flows will have the following implications for Pakistan:

- More water will be available in the first few decades, but the flows would decrease thereafter, due to reduced glacier volume (Malik, 2007).
- There will be total dependency on precipitation/rainfall
- There will be changes in the intra-annual pattern of river-flows
- Increased frequency and intensity of floods and droughts, due to reduction of natural reservoirs (ibid).
- There will be a need for increased water-storage in view of increased frequency of floods and droughts, and changes in intra-annual river-flow patterns.
- Energy-security will be threatened, as water storage in dams will be affected by changes in seasonal and total flows.

iv. Increased Evapotranspiration: A rise in average temperature causes more water to evaporate from the soil surface, as well as to transpire from the plant leaves, together called as "evapotranspiration losses". Higher evapotranspiration means that more water will be needed by the plant to perform its physiological functions and maintain optimum growth, hence increased requirements of irrigation or rain water.

v. Land Degradation: The deterioration of productive resources of land, which provide foundation for food production, is one of the major causes of low productivity. The land degradation may be due to various causes, namely:

a. Waterlogging: The continuous seepage of water from canals, percolation after heavy or extended rainfall events or water stagnation for long periods leads to rise in water table. The state of soil when it is saturated with water is called "waterlogging". Waterlogging may be transient or permanent. According to an estimate, about 2 mha of land is affected by waterlogging, of which about 0.8 mha is in Punjab and 1.1 mha in Sindh (GoP, 2007). Waterlogging per se is inhospitable to optimum crop-growth. It causes suffocation of plant-roots due to lack of aeration, unavailability of plant-nutrients due to development of anoxic condition and incidence of root-diseases due to dampness. The anoxic conditions in the rhizosphere lead to denitrification - a process wherein nitrogenous fertilizer in soil is lost to atmosphere in gaseous form, as N_2O. The N_2O is a GHG having warming potential of 2,100 times that of CO_2.

b. Salinity: Waterlogging eventually leads to

salinity problems, particularly in the irrigated areas. The gradual rise of water, containing dissolved salts, upwards to the soil-surface, in response to evaporation, brings the dissolved salts to the surface. The high temperature obtaining at the surface causes water to evaporate, leaving the salts deposited on the surface, giving rise to salinity. This process is dictated by climatic parameters, such as, temperature, wind-velocity, solar-radiation and water-vapour content in the atmosphere, etc. Accumulation of salts at the soil-surface is characteristic of arid and semi-arid environments, especially where pumped groundwater irrigation is practiced. Salinization occurs both naturally (primary salinity) and as a result of human activity (Secondary salinity).

The salt-affected area in Pakistan is 6.67 mha (Khan, 1998), of which 80% lies in Punjab. About 6.14 mha of land is affected by salinity and sodicity, with Punjab having the highest share (3.9 mha), followed by Sindh (0.6 mha) and Baluchistan (0.2 mha) (GoP, 2007). Salt has always been part of Pakistan's environment. Accumulation of excessive salts at the surface is injurious to plant growth. The salts inhibit germination, lead to poor crop stand, to physiological drought and, in severe cases, to death of growing crops. Makhdum and Ashfaq (2008) showed that salinity and waterlogging were negatively associated with wheat production. Waterlogging and salinity have also adverse social (e.g. migration and diseases) and economic (increase in poverty) effects on communities in Pakistan, causing poor living-standards, crumbling mud and brick houses, health problems for humans and animals, and bad condition of roads.

c. Water and Wind Erosion: Soil erosion is universally recognized as a serious threat to land resources. The land resources are also being degraded in Pakistan due to erosion by water and wind. The climate of the country in arid and semi-arid areas has extreme variation in temperature. The watersheds in Upper Indus and its tributaries suffer from unfavourable soil and moisture regimes (http://www.nssd.net/country/pakistan/pamtr8b.htm), thereby exacerbating erosion. It has been estimated that 11.2 mha of land, mostly in northern mountainous region, are affected by water-erosion. About 3-5 mha are affected by wind-erosion in arid regions of Punjab (Cholistan), Sindh (Tharparker) and Baluchistan (Chaghai Desert and sandy areas along the coast). Some of the areas have 0.5 to 4m high moving sand-dunes, posing danger to cultivation and local infrastructure (GoP, 2009).

Wind erosion is the direct consequence of climatic parameter of wind-velocity and temperature. Water erosion is caused by high-intensity rainfall and deforestation, with the consequent water-runoff from the bare or slopy land. Geographic Information System (GIS) and Remote Sensing (RS) are efficient tools for assessment and management of soil-erosion for large catchments. Nabi et al. (2008) have estimated soil-erosion from Soan river catchment, using RS and GIS techniques.

vi. Extreme Climate Events: The incidence of extreme climate events, such as flash floods, heavy precipitation events, droughts, cyclones, hail storms, dust storms, has been on the increase in the recent past, with telling effects on life and property. The extreme events are hard to predict. According to IPCC (2007), their frequency and intensity is likely to increase in future. Such events can affect food-security in the following ways:

- By destroying the food-crops standing in the field that are otherwise bumper and healthy;
- By damaging stored grains in the godowns – due to roof leakage, fungus development, attack of diseases because of dampness; and
- By spoiling the quality of food grains.

7. GLIMPSES OF WORK DONE AT GCISC ON IMPACTS OF CLIMATE CHANGE ON PRODUCTIVITY OF CROPS

Global Change Impact Studies Centre (GCISC) is a public-sector organization dedicated to research on climate change. Simulation studies, using crop-growth simulation model CERES, were carried out on impact of climate change on life-cycle of crops. Growing-Season Length (GSL), and yield of wheat and Basmati rice (Iqbal et al. 2009a and 2009b). For wheat, the impact was studied in four agro-climatic zones of Pakistan (Figure-1). The zones are: northern mountainous region, northern sub-mountainous region, southern semi-arid plains and southern arid plains.

Wheat: The impact of temperature increases from baseline to 5°C, with increments of 1°C on GSL of

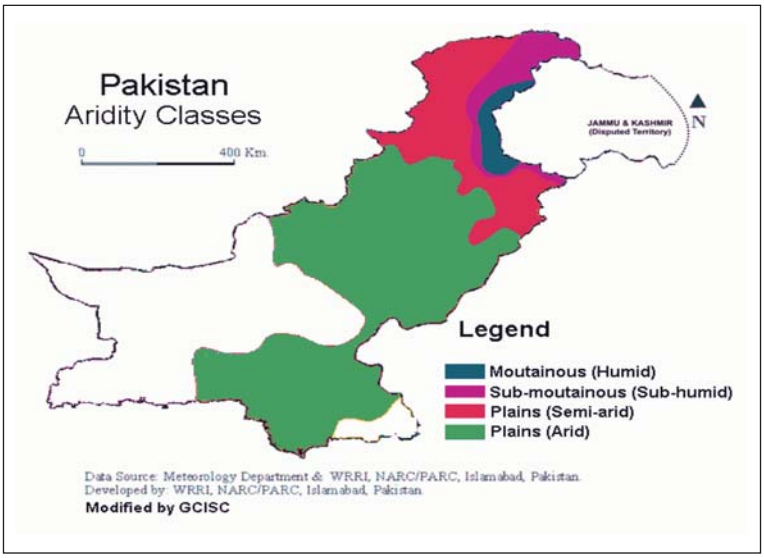

Figure - 1: Agro-climatic Zones used by GCISC for Climate Change Impact Studies on Agriculture in Pakistan

wheat is presented in Table-2. It can be seen that GSL decreases in all the agro-climatic zones, even with 1°C increase in temperature, but the magnitude of decrease is different. The largest decrease occurs in the northern mountainous region, where GSL decreases by 14 days (from 246 to 232 days) for 1°C increase in temperature and 52 days (from 246 to 194 days) for 5°C increase in temperature. The corresponding decreases predicted in other zones were relatively less.

The impact of increasing temperature (keeping other climatic factors constant) on yield is shown in Figure-2. The hypotheitical scenarios of increase in temperature above the baseline are used. As per IPCC (2007), the temperature is likely to increase by 1.8 to 4°C by the end of this century.

The yield increases in the northern mountainous region with each degree rise in temperature until 4°C whereafter the yield levelled off. The yield in the other three zones (northern sub-mountainous, southern semi-arid plains and southern arid plains) consistently decreased with each degree rise in temperature.

The projected impact of climate change on wheat-yield, under IPCC scenario A2 [developed for Pakistan by GCISC from the outputs of six Global Circulation Models (which embodies changes in climatic parameters of CO_2 concentration, temperature and precipitation in the four agro-climatic zones under study), towards end of this century] is presented in Figure-3. The IPCC A2-scenario family describes a very heterogeneous world. The underlying theme is self-reliance and preservation of local identities. Economic development is primarily regionally oriented and the per-capita economic growth and technological change is more fragmented and slower than for other

Table - 2: Impact of Rise in Temperature on Growing Season Length of Wheat in Northern and Southern Parts of Pakistan

Temperature ˚C (increase over baseline)	Growing Season Length (Days)			
	Northern Pakistan		Southern Pakistan	
	Mountainous (Humid)	Sub-Mountainous (sub-humid)	Plains (Semi-arid)	Plains (Arid)
Baseline	246	161	146	137
1	232	155	140	132
2	221	149	135	127
3	211	144	130	123
4	202	138	125	118
5	194	133	121	113

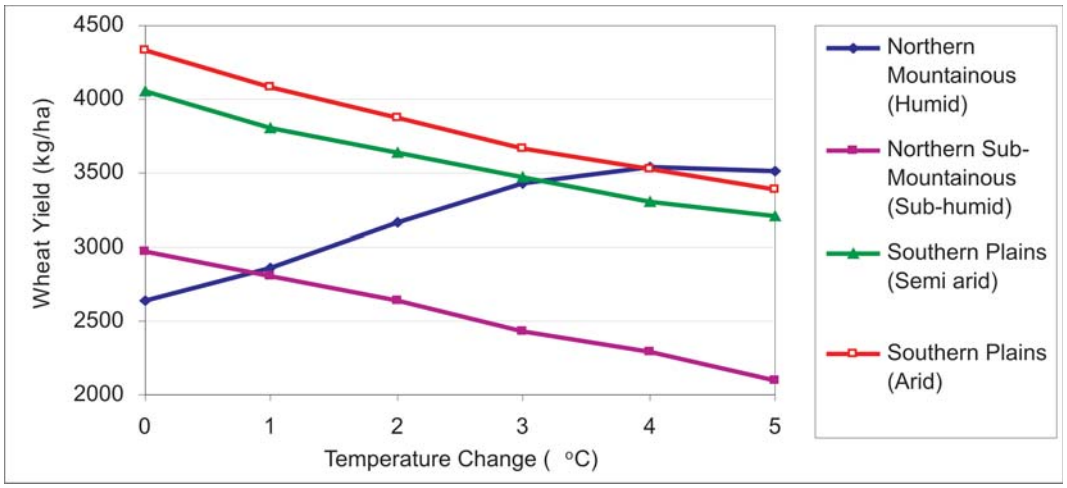

Figure - 2: Effect of increase in temperature (keeping other climatic factors constant) on wheat-yield in different agro-climatic zones of Pakistan

storylines. The B2-scenario family describes a world in which the emphasis is on local solutions to economic, social and environmental sustainability. It is a world with continuously increasing global population, at a rate lower than A2, intermediate levels of economic development, and less rapid and more diverse technological change.

It will be seen that the yield will increase in northern mountainous region, whereas it is likely to decrease in the remaining three zones by 2080s. The wheat-production situation in these areas towards the end of this century (Table-3) shows that, by 2085, there will be about 6% reduction in wheat production in Pakistan even though there will be an increase in production in the northern mountainous region by 50% under A2 and 40% under B2-scenario. But, given a meager (2%) share of this area in national production, it will not make any significant impact on wheat-production in Pakistan. The increase will, however, be beneficial locally from view-point of food self-sufficiency and livelihood of the dependant communities.

Rice: In case of rice, only the fine-grain aromatic Basmati rice was studied. The Basmati rice is grown chiefly in the central Punjab in semi-arid plains of the country. The impact of climate change on Basmati rice was studied, under IPCC A2 and B2-scenarios, using crop-growth simulation model CERES-Rice. The results (Figure-4) show that rice will suffer reduction in yield, and the reduction will be greater than that in wheat. There will be an expected shortfall of 18%

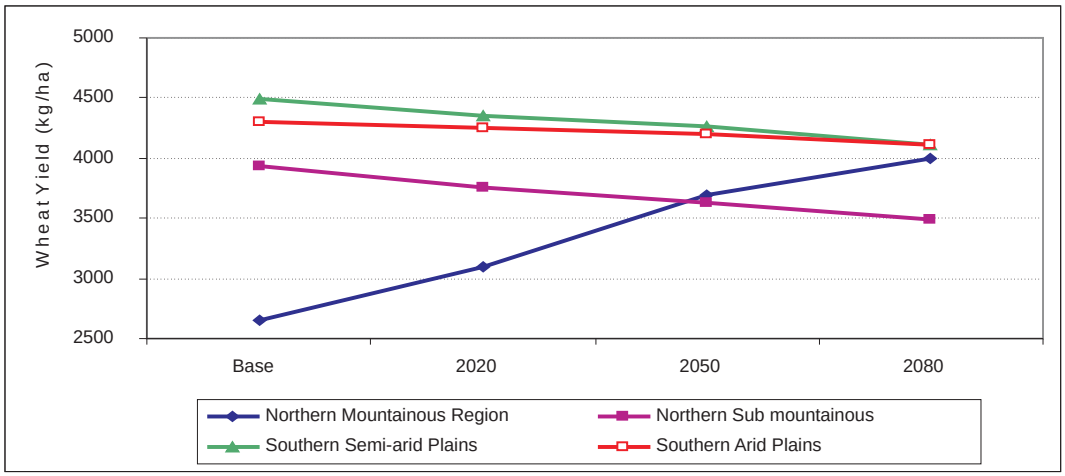

Figure - 3: Wheat yield in Different Agro-climatic Zones of Pakistan, at Different Time-slabs Towards end of this Century, under IPCC A2-Scenario

Table - 3: Climate-Change Impact on Wheat Production in Pakistan by 2085, under the IPCC A2 and B2 Scenarios

Region	% Share in National Production	Baseline Yield (kg ha^{-1})	% Change in yield in 2085	
			A2 Scenario	B2 Scenario
Northern Mountainous	2	2658	+50	+40
Northern Sub-mountainous	9	3933	-11	-11
Southern Semi arid Plains	42	4306	-8	-8
Southern Arid Plains	47	4490	-5	-6
Pakistan	100	4326	-5.7	-6.4

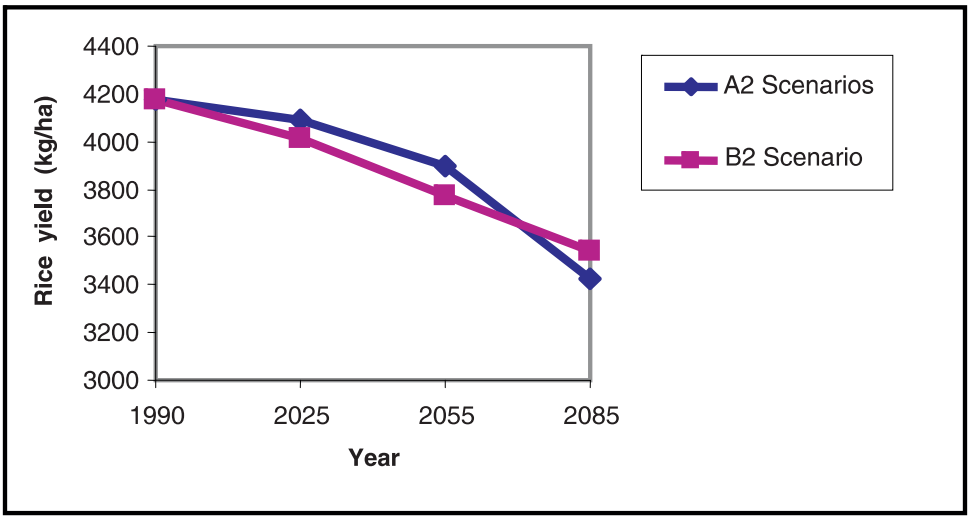

Figure - 4: Basmati Rice Production in Central Punjab in Semi-Arid Plains, by 2085 under IPCC A2 and B2 Scenarios

under A2 and 15% under B2-scenario in rice production by 2080s, if the climate change is allowed to go unchecked.

8. SOME ADAPTATION POSSIBILITIES

The studies reported above and those reported in literature elsewhere point to the need of adaptation to counter the negative impacts of climate change (Iqbal et al., 2009c). Some adaptation possibilities are indicated below:

- Alteration in sowing dates to escape the intense heat at the time of sowing, or at other sensitive

growth-stages.
- Use of new crop-varieties, which have been designed to be high-temperature tolerant and are of short duration.
- Advance seasonal weather forecast in order to take appropriate adaptive measures.
- Changes in irrigation methods for making the most efficient use of the available water- resources.
- Changes in planting techniques – for sowing rice by dry method, as in wheat, instead of conventional transplanting technique.
- Use of resource-conservation technologies, such as bed and furrow sowing, laser land-leveling, furrow irrigation, to save on water and cost of cultivation.

Some of these adaptation possibilities are presently being studied at GCISC.

9. CONCLUSIONS

The agriculture production system of Pakistan is predominantly irrigated, which derives 60-80% of its water from snow/ice melt. It is under threat from climate change which has both positive and negative impacts; the negative impacts outweigh the positive impacts. The major impacts include:

- The large variability of river flows caused by glacier-melt will make irrigated areas highly vulnerable.
- Variability in frequency and intensity of rainfall will adversely affect productivity of rainfed areas.
- Drop in crop-yield due to rising temperatures is likely to cause shortfall: in wheat production by about 6-8%, and in rice by about 15-20%, towards the end of this century.
- The land resources are likely to be degraded further, due to (a) water-logging and salinization, and (b) water and wind erosion.
- Added to the above will be the loss in production caused by increased frequency and intensity of floods and droughts.
- Most of the above-mentioned challenges can be met by developing appropriate adaptive measures well in time to counter the negative impacts.
- This will require coordinating long-term efforts.

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ENVIRONMENTAL DEGRADATION IN THE MOUNTAINOUS REGIONS OF PAKISTAN

*Abdul Qayyum Kazi**

ABSTRACT

Environmental degradation in the mountainous regions of Pakistan is accelerating due to increase in population, exploitative agriculture and mining, melting of glaciers, deforestation and devegetation, and intervention of people with nature. This situation is resulting in soil erosion, floods, limited supply of fresh water and fuelwood for domestic use, decline in agricultural productivity, loss of biodiversity and migration of people to the plains.

Although dozens of institutions have been established and international conventions/protocols signed to protect the environment, but little effort is made to mitigate the miseries of the mountain people and to check the environmental degradation in the mountain regions of the country.

This article presents the possibility of increasing forest-cover; improving efficiency of cooking stoves, micro-hydel plants for generating electricity for domestic purpose and cottage industries; developing appropriate technologies for income diversification; and maintaining biodiversity for beneficial use. Pertinent priority-areas are identified for improving quality of life of the mountain people and preserving indigenous knowledge and mountain ecosystem. Active cooperation should be sought with the ICIMOD for sustainable development of mountain regions.

1. INTRODUCTION

Environmental degradation is fundamentally linked to poverty and hunger in the majority of developing countries, including Pakistan. This was stated by the Pakistan delegation at the United Nations Conference on the Human Environment, held in Stockholm from 5 to 16 June 1972. This was the first major step on global level in the field of environment that provided awareness in protecting the environment and creating institutions to control environmental degradation, either in the plains or in the mountains. As a sequel to this, the United Nations established the UN Environment Programme at Nairobi. Pakistan prepared the country report on Environment, created an Environment and Urban Affairs Division in 1974 and promulgated the Pakistan Environmental Protection Ordinance in 1983.

The Earth Summit was held in Rio de Janeiro (Brazil), in 1992 (3-14 June), which was attended by more than 100 heads of states and 30,000 delegates, and brought the environmental issues to the forefront. Agenda-21 contained chapter 13, Managing Fragile Ecosystems: Sustainable Mountain Development. The major Earth Summit achievements included:

i. Agenda-21, comprehensive blueprint to the global actions to affect the transition to sustainable development;
ii. The Rio Declaration on Environment and Development;
iii. A set of principles to support the management of forests worldwide.

There United Nations Framework Convention on Climate Change (UNFCCC) was adopted. This Convention was signed by 154 states, including Pakistan. UNFCCC aimed at stabilization of greenhouse-gas concentration in the atmosphere. Another legally binding Convention on Biologically Diverse Species was also signed.

Another World Summit to Sustainable Development was organized in Johannesburg in 2002. Declaration on Sustainable Development agreed to make a determined effort to respond positively to the need to produce a practical and visible plan to bring about poverty eradication and human development.

The third meeting of the UNFCCC was at Kyoto (Japan) in 2005, which adopted the Kyoto Protocol and the parties agreed to reduce their combined greenhouse-gas emission by 5.22 per cent below the 1990 level during the period 2008-12, but this major reduction is not being achieved by most countries. The protocol also introduced clean-development mechanism, in order to achieve sustainable-development goals in developing countries. So far these promises and targets have not been achieved by the developed countries, nor by the developing countries. Pakistan has also acceded to this protocol.

The voluminous report prepared by the UNFCCC was considered at the Climate Change Summit in Copenhagen from 7-18 December 2009. The global warming is unequivocal and the delay in reducing the greenhouse-gas emissions significantly increases the risk of severe climate-change impacts. It confirms that climate change is now threatening the world with rise in temperature, long summers, severe winters and snow, rise in seawater level, and depletion of the ecosystem. The pandits of Climate Change

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prophesied that thousands of glaciers will disappear by the year 2035, causing floods, soil erosion, unsettlement of population and other miseries. The summit ended with a non-binding agreement to reduce greenhouse-gas emissions and temperature, and noted that the institutional framework could not be established to assist developing nations to address climate change. The fund, amounting to $30 billion, was announced for this purpose, which could go upto $200 billion by the year 2020. These promises were never implemented, as in the past. The organizers hoped that the climate-change meeting in Mexico this year may give positive results, subject to commitment from the United States.

2. PHYSICAL POSITION OF MOUNTANOUS AREAS

The whole of Pakistan lies in the warm temperature-zone between 24°N and 37°N latitude. Out of six major regions of Pakistan, three are the Northern Mountains, the Western Bordering Mountains and the Balochistan Mountains. The northern mountains cover the area of Kashmir and northern parts of Pakistan. These mountains have an average height of 20,000 feet and are permanently covered under snow. Some of the highest peaks in the world are to be found in the northern Himalayan region (K2 - 28,250 feet high). The low hills, about 3,000 feet high, known as Sivaliks, lie adjacent to the plains. The western mountains consist of several parallel ranges and are much lower than the Himalayas. Most of the ranges lie outside the paths of monsoon and so (the rainfall being low) these are almost bare of vegetation. South of the Kabul river lies the famous Khyber Pass, which connects Peshawar with Kabul. Also south of Kabul river is Safed Koh range, with an average height of 12,000 feet and peaks frequently covered with snow. The Balochistan mountains consist of north west, the large part of which is desert; the north east range is higher than the south and contains valuable deposits of coal, iron, chromites and other materials. Some of the valleys are baskets of fruit trees of apples, plums, peaches, pears, apricot, grapes and figs.

Less than 20 per cent of the 88 million hectare land of the country has the potential for intensive agriculture. Its area classified as forest covers 4.57 million hectares or 5.2 per cent of the land area, of which less than 3 million hectares are actually under some form of tree-cover. And the government is committed to increasing the forest-cover to 5.7% by 2011 and to 6.0% by the year 2015, whereas area under forest should be 20-25 per cent of the total land area. The coniferous forests in the mountainous areas consist of Deodar, Spruce, Fir and Dir and the Baluchistan hill-forests flourish with Pines and Juniper.

The distribution of forests is as follows: total state forest – 61.5%, total private forests – 34% and mixed forests – 4.5%. Depletion of forest resources due to mismanagement and declining agricultural productivity are threatening the socio-economic fabric of the mountain people.

The mounting threats to the mountain ecosystems of Pakistan are numerous: poverty, population-growth, exploitative agriculture and mining, deforestation, intensive rains and severe drought, climate change, unfair treatment to mountain people and loss of biodiversity and traditional knowledge. We examine a few of these in detail.

Pressure of Population: Pakistan's population was only 32.9 million at the time of its creation (1947), and it is projected to reach 173 million in the current year, while for the year 2025, the projected figure is 221 million. It may just be possible to accommodate this quantum of people by adopting sustainable-development programmes. Nearly 67.5 per cent of the country's population is living in rural areas and mountainous regions, where extreme poverty and hunger prevails.

The mountainous areas of Pakistan have the highest population per cultivated hectare, the highest ratio of human-to-land, and the greatest pressure to use extreme marginal soils and slopes most intensively. Increasing population has adverse pressure on land, natural resources, migration of people to plains, security and environmental balances.

3. WATER AVAILABILITY AND MELTING OF GLACIERS

Pakistan is divided into nine major ecological zones, which are very divergent in nature ranging from depth of Arabian Sea to the towering mountains of the western Himalayas, Hindu Kush and Karakoram. These ranges stretch across Afghanistan, Bangladesh, Bhutan, Myanmar, China, India, Nepal and Pakistan. The glaciers are the main source of fresh water for the millions of people of the region. Fresh water is now a scarce source in Pakistan, where 92 per cent of the land is covered by arid or semi-arid regions. The water resources originating from Indus river and its tributaries vary seasonally and their distribution is uneven. Water availability in Pakistan continues to change, both in total amount and per-

Table-1: Per-Capita Water Availability from 1951 to 2001, and Projections for 2013 and 2025

Year	Population (million)	Availability (m^3)
1951	34	5300
1961	46	3950
1971	65	2700
1981	84	2100
1991	115	1600
2001	141	1200
2013	181	850
2025	221	659

capita availability. In 1951, when the population was 34 million, the per-capita availability was 5,300 cubic meter. This has now decreased to 1,105 cubic meter, and is projected to further reduce to 659 cubic meter per-capita per year in 2025 (Table-1). The water requirement for agricultural sector is not as good as for drinking water.

It is reported that some 1.1 billion people in developing countries have inadequate access to water and 3.6 billion people lack basic sanitation. Close to half of these countries suffer at any given time from the health problems caused by water and sanitation deficits (for example, malaria, diarrhea). These deficiencies are also prevalent in the mountainous regions, where the entire source of water is glaciers, flowing streams and water falls.

3.1 Melting of Glaciers

There is no seriousness about the accelerated melting of glaciers in the region, although measurements taken reveal a general shrinkage of mountain-glaciers on global scale, due to increasing global temperature, The International Panel on Climate Change (IPCC) in the Fourth Assessment Report (2007) pointed out overwhelming evidence of the global relevance of climate change, and its consequences are now a well accepted truth. Just consider the impact of climate change on glaciers and snow-cover in the mountainous areas, resulting in flooding of rivers, soil erosion and loss of biodiversity due to more frequent weather events. The Panel's report projected that an increase of 1.0 to 6.0 degree Celsius in the annual temperature of the region is likely to result in decline in the current covering of glaciers by 43 to 61 per cent by 2100. The declared probability of thousands of glaciers in the Himalayas "disappearing by the year 2035 and perhaps sooner is very high, if the earth keeps warming at the current rate". Although, now IPCC admitted that in drafting the paragraph in question, the clear and well established evidence were not applied properly. Nevertheless, the IPCC stood by the conclusion about loss of glaciers in this century in major mountain ranges, including the Himalayas.

There is no doubt that the glaciers are melting and it is a threat to the ecosystems as well as to agriculture, forestry, water conservation and safety of the people living in the region. Considering this situation, the International Center for Integrated Mountain Development (ICIMOD) has documented 3,253 glaciers in Nepal alone, spread over 5,324 square kilometers. In other countries of the region, this task has not been undertaken; these countries have not yet established a warning system to study and watch the effect of climate change on the glaciers. China, India and Pakistan have used glaciers only for defense purposes.

Institutions with trained manpower and equipment are needed for research on the impact of climate change on glaciers, assessment of the change in the pattern and amount of river-flows from glacier melting, as well as in the climate-pattern and consequential effect on local communities, agriculture, ecosystem and communication. So, using the experience gained by the ICIMOD is of value to Pakistan.

4. DEFORESTATION AND FUEL-WOOD REQUIREMENTS

Forest-cover in Pakistan is less than 25 per cent of the world-average. The trees and shrubs are presently the major resource for providing energy and, naturally the local people resort to cutting of trees and using dried branches and leaves. Notwithstanding the growing scarcity of energy-sources, it is estimated that 90 per cent of all rural households still meet their fuel requirements (for heating and cooking) from fuel-wood and other biomass sources. The wide range of various forms of biomass in Pakistan, as source of energy, is given in the Table-2.

In the mountain regions, the major source of energy is fuel-wood (derived from trees), shrubs and animal dung. There is increasing demand for energy and, thus, more pressure on forest resources due to

Table - 2: Percentage of Various Forms of Biomass in Pakistan as Source of Energy

Biomass	Percentage
Fuel-wood	54
Bagasse	16
Shrubs	6
Cotton Stubs	6
Animal Dung	16
Others	2
Total	**100**

increasing population, as well as inefficient cooking stoves.

It is essential that affordable substitute-fuels for household use should be made available and that extensive community reforestation programme is undertaken. Local people need to be involved to protect and nurture the forests. There is a need to develop wood-fuel plantation, as a part of reforestation effort, through community-based management approach. Training is needed on planting and tending the young trees in order to planting fast-growing species.

The government agencies and NGOs working in the field should look into the Domestic Energy-Saving Project sponsored by the German Agency for Technical Cooperation (GTZ) during the 1980s. This project aimed to develop an energy-efficient cooking stove for individual domestic use and an efficient Tandoor (oven) for bakers to supply bread to a whole community. Traditional cooking stoves have an efficiency-rating of 10 to 15 per cent, depending on the quality of design. The cooking stove designed by GTZ had an efficiency of 30 to 35 per cent and assisted in reduction of wood consumption. Some 100,000 stoves and tandoors had been provided, primarily for Afghan refugees. The Pakistan Council for Renewable Energy Technologies (PCRET) has more than 30 years of experience in developing appropriate technologies for efficient cooking stoves, preservation of food, and micro-hydel plants. These technologies can be adopted, with ease, to avoid deforestation.

4.1 Micro-Hydel and Mini-Hydel Units

Instead of cutting down trees, resulting in deforestation and water and soil erosions, it is possible to generate energy locally for lighting the house as well as developing cottage industry in the Northern mountainous regions of Pakistan. Micro hydro-power plant (less than 1 MW) technology is well developed and is effectively being used in many countries of the world. A small decentralized hydel plant, based on natural water-falls, is a very desirable option for generating electricity. Perennial waterfall is channelized and allowed to fall on the turbine from the forebay, through a penstock. In Pakistan, several water-fall sites have been identified. In collaboration with the local population, PCRET has installed over 235 units, with a total potential of generating 2.8 MW electricity. Experience gained by PCRET has been utilized by other organizations as well. In Pakistan, so far 290 micro-hydel plants, with a total generation capacity of 4MW, have been installed for electrifying about 300 villages comprising 25,000 homes. It is estimated that as much as 30,000 MW electricity can be generated through installation of such micro and mini-hydel (1-10 MW) plants. Local people are willing to cooperate to light their houses and start cottage industry, like floor mill and saw mill, etc.

Small hydro-power technology is today a mature and proven technology. It is rather strange to find that neither the government, nor the dozens of NGOs working in the mountainous regions are keen to adopt this technology to light the homes of the poor segment of the society living in very severe environmental conditions. Just to quote an example, in Austria there are 1690 small hydro-power plants with a total of 600 MW capacity.

4.2 Capturing CO_2

Another recent development is that engineers in Britain are developing forests of artificial trees to remove the CO_2 from the atmosphere. The synthetic tree, costing £15,000, could capture ten times of CO_2 from the air everyday, making it thousand times more efficient in absorbing carbon dioxide than a real tree, thus reducing chances of warming of the atmosphere due to green house effect.

Further researches are in progress on technology to beat the threat of global warming and disappearing of glaciers and forests and loss of biodiversity. One can only hope that it does not take as much time as that of reducing the cost of photovoltaic power-generation technology.

5. LOSS OF BIODIVERSITY

Biodiversity constitutes a capital asset, with great potential for yielding sustainable benefits. It provides food, clothing, natural drugs for medicinal use, as also supplements for improving quality of agricultural crops. There are an estimated 30 million species of animals and plants worldwide. Out of several thousands of plant-species investigated, only about 300 species have been commercially exploited, whereas only 30 crops account for 95 per cent of the world's food-consumption, mainly rice, wheat, maize, potatoes and casava. The natural ecosystems, including mountains, contain most of the earth's biodiversity. The indiscriminate use of natural resources has continuously led to environmental degradation, causing soil and water erosions, decline in agricultural productivity, rapid loss of habitat and genetic diversity. This further accelerates poverty, hunger, poor health, unemployment, migration to the plains and loss of biodiversity.

The governments should take necessary measures to establish and strengthen the national inventory of flora and fauna and ensure conservation of biological diversity in the mountainous region. It is also important to take appropriate actions to respect, record, protect and promote the wider application of the existing knowledge, innovation of practices of indigenous and local communities embodying traditional knowledge for the conservation of biological diversity and sustainable use of biological resources.

Pakistan is a signatory to the Convention on Biological Diversity. This Convention came into force in 1993 and has three objectives: conservation of biological diversity; sustainable use of biological diversity; and fair and equitable sharing of benefits arising from utilization of genetic resources and associated traditional knowledge. Not much has been done to achieve/implement these objectives, whereas six multi-national corporations, namely Aventis, Dow, Du Pont, Mitsui, Monsanto, and Syngenta, are gaining more access to the wild species flourishing in the mountainous regions. The basic Pakistan Institutional Framework for Protection of Mountain Regions is given as follows:

6. INSTITUTIONAL FRAMEWORK FOR PROTECTING ENVIRONMENT IN MOUNTAINOUS REGION OF PAKISTAN

Since 1972, the government of Pakistan has initiated several strategic plans, established appropriate institutions, approved national policies and action plans, signed international agreements/protocols and launched dozens of programmes and projects to conserve environment leading to sustainable development, but very few related to integrated mountain development. Some of the actions taken are presented in Table-3.

The mountain people understand well the threats of expanding population, deforestation, excessive grazing, loss of biodiversity, flash floods, poverty and hunger. But their knowledge and resources are too limited for them to follow the integrated approach to solve the problems. The government agencies, too, have limited experience of working in the mountain environment and hence they should seek assistance from the concerned regional institutions, e.g. ICIMOD, which is described below:

Table - 3: Initiatives of the Government of Pakistan for Development of Mountainous Regions

Institutions	– National Council for Conservation of Wildlife
National Policies and Action Plans	– National Forestry Policy and Action Plan
Signatory to Conventions/Protocols	– On biodiversity, migratory species, wetlands of international importance, Kyoto protocol on climate change, desertification – Protection of substances that deplete ozone layer – Management of hazardous wastes – International trade in endangered species of wild flora and fauna
Programmes and Projects	– Forestry sector research and development project – Mountain-area conservatory project – Mainstreaming biodiversity on Juniper forest

7. INTERNATIONAL CENTRE FOR INTEGRATED MOUNTAIN DEVELOPMENT

The only regional centre for integrated mountain development is located in Nepal. The International Centre for Integrated Mountain Development (ICIMOD) was established on 5th December 1983, with its headquarters in Kathmandu, and legitimized through an Act of the Parliament in the same year. The centre brings together the countries of Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal and Pakistan, to foster collective knowledge-sharing and coordinated action for sustainable mountain development and reducing environmental degradation. It is governed by a Board of Governors, consisting of one representative from each of the eight regional countries (initially five countries, later joined by Afghanistan, Bangladesh and Myanmar), and six independent members who are nominated by the ICIMOD Support Group, based on their professional expertise and experience.

Its mission is to enable and facilitate the equitable and sustainable well-being of the people of Hindu-Kush Himalayas by supporting sustainable mountain development, through regional cooperation. It is to develop and provide integrated and innovative solutions in cooperation with national, regional and international institutions, which foster action and change for overcoming mountain people's economic, social and physical vulnerability. Some of the programmes/projects deal with geographic-information system; remote sensing; soil and water-conservation technologies; management of aromatic and medicinal plants; conservation of biodiversity and sustainable use of biological resources; global warming; ecological state of rivers; energy-saving devices; flash-flood risk management; rural income diversification and developing mountain technologies for poverty alleviation. However, the central role as a regional centre of knowledge sharing, information exchange and capacity-building is yet to be established.

Pakistan contributes $100,000 annually towards functioning of the ICIMOD, and the Secretary, Ministry of Food, Agriculture and Livestock, attends the Board of Governors' meeting regularly. Yet few projects are undertaken in the mountains of Pakistan. Furthermore, over 90 per cent of technical staff of ICIMOD belongs to Nepal, India and China (in that order). The rest of the countries have one or two experts employed in the Centre. This needs attention.

Pakistan has competent experts in all the subject areas of investigation, related to sustainable development in the mountainous region. What is needed is more realization that mere policy-making does not solve problems or provide relief to the poor and vulnerable groups living in the mountain region. Action is needed and the role of local people in mobilizing their knowledge and skills for collective action should be appreciated. Coordinated effort is required for improving quality of life of the mountain people.

8. FUTURE LINE OF ACTION

a. Sustainable Mountain Development Cell

Considering the above-mentioned situation, it is essential to establish a Sustainable Mountain Development Cell in the Ministry of Food, Agriculture, Forestry and Livestock to: initiate action in the formulation of National Policy; review and study the administrative, financial, technical and other implications and the policy proposal; and to prepare action-plan to implement it. Needless to say, all stakeholders should be involved in this exercise and the institutional cooperation is vital in this multi-disciplinary area dealing with agriculture, biodiversity, climate change, land degradation, watershed management, socio-economic conditions of the mountain people and other relevant subjects.

Government at the appropriate level, with the support of regional and international organizations, should ensure that policy and policy-instruments support the sustainable development of the natural resources and rehabilitation of the environmental degradation in the mountainous regions of Pakistan. The policy is also required to comply with various objectives of the UN Conventions, like Convention on Biodiversity, Kyoto Protocol on Climate Change and Convention on Combating Desertification, and to acquire financial and technical support from the international agencies for the improvement of the fragile mountain ecosystems.

b. Reforestation and Continuous Training

Furthermore an important natural source is the forest and rangelands and their optimal utilization. Under the Millennium Development Goals related to forestry sector, Pakistan is committed to increase forest-cover from the existing 5 per cent to 5.7 per cent by the year 2011 and 6 per cent by the year 2015. This implies an additional 1.05 million hectares of land-area under forest. Presently, Pakistan is a forest-deficient country, facing timber and fire-wood shortage of about 29

million cubic meters. Beside attempting to introduce new fast-growing plant species, tree-planting campaigns are organized twice a year and millions of saplings are planted. But not much care is taken of these saplings and, thus, survival loss is maximum.

The mountain people need training and technical guidance for planting and tending the young saplings of the newly introduced and the traditional plant species. This aspect needs institutionalization. The reforestation shall provide additional fire-wood for domestic use and timber to earn additional income, in addition to mitigating the negative impact of environmental degradation in the mountains. Also, encouragement in terms of adaptation of new technologies, financial support and training is required to develop and maintain medical botanic resources. Cropping and harvesting should be done carefully to ensure quality products and that populations are sustained in perpetuity. Some countries are earning millions of dollars annually by exporting medicinal plant-products (for example China, India and South Korea). Pakistan has the potential to benefit from cultivating the medicinal plants and processing thereof. Employment avenues and enhancing quality and life have to be explored, to avoid migration of people to the plains. Some other priority-areas for sustainable development is the mountainous regions are summarized below.

9. PRIORITY AREAS FOR SUSTAINABLE DEVELOPMENT IN THE MOUNTAINOUS REGIONS

These are listed below:

i. Survey of types of soils, forms of forests, commercial plant-species and methods of plantation, availability, distribution and use of water, plant and animal resources of mountain ecosystems be carried out, on priority basis.
ii. Active cooperation be established with ICIMOD, to identify location of glaciers and their status of melting, to watch the effect of climate change and the related issues.
iii. Develop national policies that would provide incentives to the local communities to undertake conservation measures and to adopt environment-friendly technologies (for example cultivation and processing of medicinal and aromatic plants).
iv. Every effort be made to conserve and preserve indigenous plant-species to avoid loss of biodiversity and to utilize local knowledge in the process.
v. Integrated watershed programmes be launched, through effective participation of the local people to prevent further ecological imbalance.
vi. Micro-hydel technology is a mature and proven technology and can be adopted with ease in the mountainous regions. The experience gained by PCRET over the last 35 years be availed to provide light & power to the remote areas in the mountains.
vii. Reforestation needs immediate attention. Provide training to the local community on planting and tending the young plants of fast-growing trees.
viii. Promote alternate livelihood opportunities, particularly through development of employment schemes that increase the productive base.

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INVESTIGATING THE EFFECTS OF OZONE LAYER DEPLETION: A SERIOUS THREAT TO THE SURVIVAL OF SOME MARINE ORGANISMS

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ABSTRACT

It has been established beyond all doubts that ozone shield efficiency is changing because of natural as well as artificial causes, which also affects the increased radiations, inflicting damage to DNA of living organisims. In this situation, we can well conceive the danger of annihilation of various animal and plant species because of Ozone Layer Depletion (OLD). In this context, the direct and indirect affects of OLD and UV radiations on marine organisims, especially the fish and the food-chain that supports their yield, phyto-plankton, zooplankton and fish-larvae, are particularly studied with reference to Pakistani coasts.

1. INTRODUCTION

A 4% decrease in ozone-content causes a 10 % increase in radiation in the range between 280 and 320 nm. Damage suffered by DNA from UV radiation is cumulative, and the integrated dose over many years produces skin cancer in human and causes mutations in the animals and plants. DNA molecules undergo most intense absorption of UV radiation in the range of 265 nm to 300 nm. Proteins have absorption-maxima around 275 to 285 nm and these bands also extend to 300 nm. Plants are sensitive to UV radiation below 310 nm [1-8][9][10][11].

It has been observed from our studies on marine organisms that there is a remarkable increase in the flux of UV radiation reaching the Arabian sea through the ozone filter.

It is effective in particular in Pakistan Atmospheric Region (PAR) that is situated in the west and north-west of South Asia. It lies from 23.45° to 36.75° in the northern latitudes, and from 61° to 75.5° eastern longitudes. This region is critical because of the existence of a large positive correlation between the potential vorticity deviations and the ozone-mixing-ratios in its stratosphere. It makes the transport of ozone (along with the seasonal variations) possible to Pakistan's atmospheric region.

The coastal region of Pakistan is spread from 24° to 26° north and 62° to 68° east. It includes Karachi coast (Sindh) and Makran coasts (Balochistan) as shown in Figure 1. These coastal regions and the adjoining seas are full of resources that have a potential to contribute to our economy substantially.

Marine fisheries are a considerable part of these resources. If there is any threat to their survival, it should be given due consideration and the reasons and causes deserve to be deeply studied. OLD and leads to the consequent increase of UV radiations and its effects on our marine fisheries, thus, appear as the focus of our study. Here we will stress on the study of direct and indirect effects of OLD and UV radiations on marine organisms. Fish are of our particular interest and the food chain that supports their yield. Phyto-plankton, zoo-plankton and fish-larvae contribute considerably to this food-chain so have worth to be studied in the above-mentioned UV scenario. Studies of the effects of OLD on vertical migration of fish appear in [12][13][14], we will study the effects of OLD via UV flux increase on fish yield. This appears to be the first attempt of its kind for Pakistan coasts as to the best of our knowledge; no formal or informal study of the effects of OLD on marine organisms for Pakistan's coastal line is available yet.

2. UV RADIATION AND MARINE ORGANISMS

Now we will use the quantification of the UV flux for Pakistani air space to study the effects of UV radiation on marine organisms. We will start with studying the effects of UV on plankton. Plankton is the terminology applied to all those animals and plants that survive on water (ocean or fresh) with less power of locomotion. Mostly, the motion is that by the drift of water currents. However, some forms such as arrow worm, many crustacea and fish-larvae can swim with slow speed. Much of their movement is in the vertical plane from place to place and very limited in the horizontal plane. There are two main categories of planktons:

i. Phyto-plankton that are all plant-like organisms, plant-like in the sense that they are auto-trophic and contribute to the food available in the surface-waters by building up their protoplasm and food reserves directly from carbon dioxide and salts in the sea.

ii. Zoo-plankton that consists of animals such as protozoans (microscopic one-celled animals living chiefly in water, sometimes parasitic). Practically every major group of animals has its representation in the zoo-plankton either as adults or as larvae.

The division into phyto-plankton and zoo-plankton is taxonomic, so the border-line nature of the organisms

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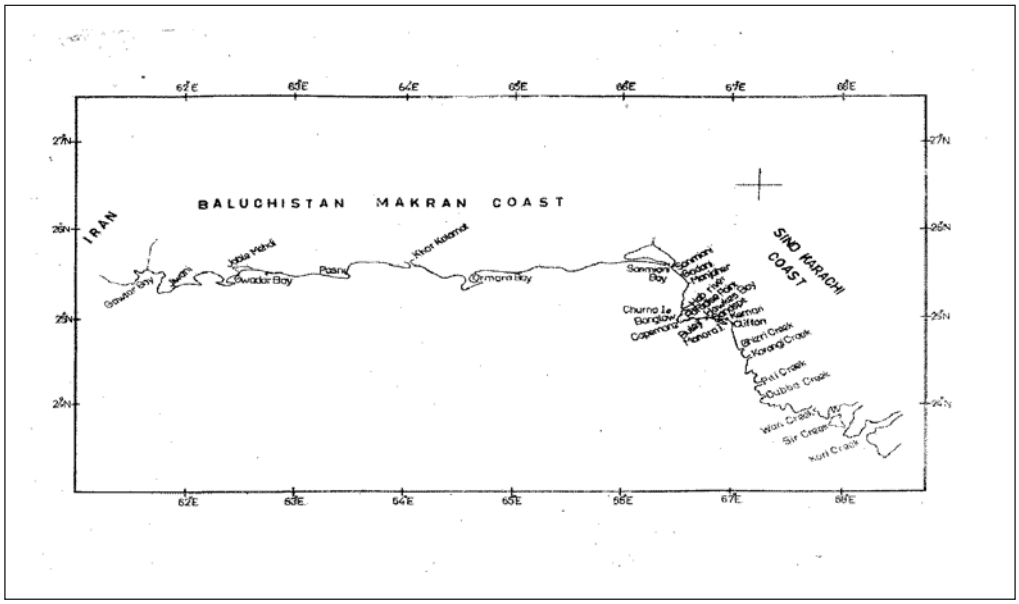

Source: M. Ayub Khan Yousaf Zai, 2004

Figure - 1: Coastal Regions of Pakistan

can be neglected to deal with the zoo-plankton and phyto-plankton groups. Effects and toxicology of UV on aquatic ecosystems are studied by Haggan & Ozaki [15] and Cleveland & McGill [16].

In this section, we will estimate the effects of UV radiation via ozone layer depletion on phyto-plankton, zoo-plankton and fish, using the time series of a bivariate population. The fish-yield data of Sindh and Baluchistan coasts are correlated with the intensity of UV radiation reaching the Arabian sea. The prediction using our constructed models will be helpful for various public, private and governmental organizations.

3. PHYTO-PLANKTON

The synthesis of organic carbon in the marine surface-waters is governed by the phyto-plankton activity. The rate of change of phyto-plankton concentration in the euphotic zone is a balance between growth and losses from cell respiration, carbon excretion, sedimentation and grazing. Also, advection and diffusion can locally increase or decrease the phyto-plankton. Algal growth depends on the carbon input by phytoplankton and is influenced by environmental conditions, as well as ecological factors [9]. Carbon uptake is affected by quality and quantity of light, nutrient availability and temperature. Therefore, phyto-plankton are limited to surface-waters as they are dependent on the visible light (400-700nm) for photosynthesis. The requirement for solar radiation makes them susceptible to UVR (280-400nm) exposure [18], particularly UV-B (280-320) is more damaging per photon. UV-B accounts for approximately 0.01% of the photons absorbed by phyto-plankton and is damaging to different molecular targets. Its effect is usually measured by screening UV-B from the sunlight [19]. Some other studies related to the effects of UVR on marine organisms, such as phytoplankton are discussed by Delcourt, P.A. & Delcourt H.R [20] and Gates [21]. Pigment bleaching which is a common response of the UVR has presently been studied. The effects of UV-B on the growth of specific species of marine phyto-plankton of tropical and temperate regions are studied by Henderson-Sellers [22].

As discussed by the Delcourt [20], the seasonal distribution of chlorophyll-a shows a decreasing trend as it moves from high values above 0.4 μg per litre in January to very low values of about 0.05 μg per litre in May (at about 30 meters ocean depth), as discussed in detail by Yousuf Zai [13].

We have found a correlation between the chlorophyll-a (for a depth of 30 meters and shallower) data and our data for UV-B flux due to OLD, as shown in Figures 4.1 and 4.2 of Yousuf Zai's 'A Quantitative Study of effects of Ozone Layer Depletion on Marine Organisms with reference to coastal regions of Pakistan' [13]. This shows a decreasing trend for both the cases. The

respective trend equations are:

$$Y_t = 0.351 - 0.0502\,t + \varepsilon$$

and

$$Y_t = 1.95 - 0.33\,t + \varepsilon$$

which can be used for future predictions. Using these equations, the rate of decrease of Chlorophyll-a with UV-B comes out to be 0.01 μg Chl /litre/watt /square meter.

4. ZOO-PLANKTON

The damaging effects of solar UV radiation on aquatic organisms, such as sunburn (erythema) in fish, have been reported in 'Frontiers in Probability and Statistics' [17]. Seasonal variations and abundances of two species of zoo-plankton, copepoda and chaetognatha of the Arabian Sea (along the Karachi coastal regions) are discussed by Basu and Srivastava [17,23]. These findings are based on monthly analyses of plankton samples collected from three different stations from January 1983 to December 1985. We have found a correlation between the above-mentioned data of Basu and Srivastava and our computed UV–B data. The relative abundances in percentage of the two species of zooplanktons are plotted as a function of UV-B radiation reaching the Arabian Sea as shown by Yousuf Zai in the figures 4.3 & 4.4 of his study 'A Quantitative Study of effects of Ozone Layer Depletion on Marine Organisms with reference to coastal regions of Pakistan' [13]. We have observed that the relative abundance decreases with increasing intensity of UV-B radiation.

The model equations for the Copepoda and Chaetognatha are:

$$Y_t = 132.806 - 0.811\,t + \varepsilon$$

and

$$Y_t = 5.77 - 0.04\,t + \varepsilon$$

In order to strengthen our claim on the damaging effects of UV-B radiation on the marine organisms, we have also assessed the effects of UV-B radiation on the population of Windowpane Oyester Plaucuna Placenta in the Arabian Sea [24]. The 12-point data ranges from February 1990 to January 1991 that we have plotted against corresponding the data of UV-B flux intensity by Yousuf Zai [13].

It is obvious that the population decreases with the enhancement of UV flux at sea-level. Fitted time series model equation is given by the following equations:

$$Y_t = 1190.047 - 12.225\,t + \varepsilon$$

5. EFFECT OF OZONE LAYER DEPLETION ON FISH YIELD AT COASTAL REGIONS OF PAKISTAN

There exists a large number of causes affecting fish-yield that are also the point of concern of an equally large number of studies. What is the proportion of OLD in this saga of cause and effect? We are not at present in a position to answer this question with certainty. We are not claiming that this is the only cause or a major cause of decreasing fish-yield. Our only concern is to spot out that it is one of the serious causes that need attention and to be the focus of future studies. There are various modes of OLD affecting fish-yield. Due to OLD the probability of UV incidence increases that increases the production of hydrogen peroxide (H_2O_2). This in turn raises the danger of diminishing the available hatching sites. OLD is considered to be one of the causes of Global Warming and the rise in the temperature of the ocean creating hot waves that can cause erosion of the harbour. In addition to the increase in expenditure made on necessary repairs and restructuring of the harbours, fish yield will be affected as well [17].

As mentioned above, the infiltration of UV radiation results in the production of H_2O_2. It intoxicates the surrounding seawater abandoning the growth of zoo-plankton and phyto-plankton. In turn the predator-prey ecological processes are disturbed. Consequently the whole food chain is affected. Two time-plots are constructed for Balochistan and Sindh coasts and their trend analyses are given below:

i. Trend Analysis for Coastal Line along Balochistan

Data N = 420.00, Fitted Trend Equation

Yt = 169.320 + 22.3376*t, accuracy measures, MAPE: 15.7922, MAD: 469.051,
MSD: 20378

ii. Trend Analysis for Sindh coast

Data N = 420
Fitted Trend Equation

Yt = 2297.80 + 55.3585*t, accuracy measures,

MAPE:10.3563,
MAD:1188.61,

MSD: 2581372. These figures are reflected in Figures 4.6(a) and 4.6(b) of Yousuf Zai's paper 'A Quantitative Study of effects of Ozone Layer Depletion on Marine Organisms with reference to coastal regions of Pakistan' [13].

6. SAMPLING DISTRIBUTION OF THE MEANS FOR FISH-YIELD DATA

a. Baluchistan Coast

For the sampling distribution of the mean for the Bauchistan fish-yield data, we have randomly selected one sample consisting of 102 points with mean: 1975.22 and variance: 909.69 and testing the null hypothesis H_o: μ = 1975.220 against the alternative hypothesis H_1: μ < 1975.220. We found that the null hypothesis should be rejected. This concludes that the standardized mean fish-yield for Balochistan coast is less than 1975.220 metric tons.

This also reflects the high non-stationarity of the respective data. Note that the coefficient of variation for this data comes out to be 0.5687. This shows that the data are sufficiently consistent.

b. Sindh Coast

For the sampling distribution of the mean for the Sindh fish-yield data, we have randomly selected one data consisting of 102 points with 13950.77 and 6909.698 and testing the null hypothesis H_o: μ = 13950.77 against the alternative hypothesis H_1: μ < 13950.77. In this case also we found that the null hypothesis should be rejected. This concludes that the standardized mean fish-yield for Sindh coast is less than 13950.77 metric tons.

As observed earlier, this is also a reflection of the high non-stationarity of the respective data. Note that the coefficient of variation for the data is 0.4952. This shows that the data are sufficiently consistent.

7. EFFECTS OF OLD AND UV FLUX ON FISH-YIELD

Now we come to find the correlations between fish yield data of Balochistan and Sindh, and ozone layer depth, ozone layer depletion and UV flux reaching the Arabian Sea.

8. CORRELATIONS OF BALOCHISTAN FISH-YIELD DATA

In the correlation between fish-yield data of Balochistan coast with ozone layer depth, ozone layer depletion and UV flux reaching the Arabian Sea respectively, the corresponding correlation coefficients 'r' come out to be 0.72, -0.37, and 0.51, respectively. The positive correlation of fish-yield indicates that to uphold the current status of fish-yield, steadiness in the ozone layer depth could prove to be favourable. However, the negative correlations in the other two cases are the indicators of the unfortunate stance of scarce fish-yield.

9. CORRELATIONS OF SINDH FISH-YIELD DATA

The correlations of fish-yield data of Sindh coast with ozone-layer depth, ozone layer depletion (OLD) and UV flux reaching the Arabian sea, respectively, show that the situation in Sindh is not different from that of Balochistan and the OLD can be held responsible for worsening the fish-yield scenario.

It can be easily computed that the coefficient of correlation is found to be calculated for both the cases mentioned above using the mathematical relationship. The value of 'r' for the figures above-mentioned are 0.32, - 0.63, and -0. 37.

The negative correlation shows that as the UV-B increases, the yield of fish decreases. Similarly, the value of 'r' for both the cases represents the negative correlation and it can be observed that the fish-yield decreases with increasing UV flux that reaches the Arabian Sea. The positive correlation shows that, as the depth of ozone increases, the yield of fish increases. It also depicts the dependence of ozone-layer depth on the fish-yield for Balochistan-Makran coast. It can be concluded that as the depth magnitude increases the depletion of ozone decreases, which in turn, shows that the yield of fish increases. It can be observed that as the depletion of ozone layer reduces then it prevents the UV-B entering Pakistan's atmosphere and thus to have little effects on the marine eco-system.

Similarly, the dependence of ozone-layer depletion on the fish-yield for Karachi-Sindh coast would show that as the depletion of ozone layer increases, the yield of fish decreases, because of increase in UV flux at sea-level. It can be observed that as the depletion of ozone layer reduces, it prevents the UV-B from entering Pakistan's atmosphere and thus decreases their

effects on the marine eco-system.

It has been seen that the scatter diagrams mentioned above can also be utilised to acquire probability forecasts of the events, such as the effects of ozone-layer depletion on the biosphere. It is sufficient to indicate that this procedure can accommodate several predictors and provides the meteorologists or the forecasters with a considerable degree of flexibility in analysing relationships between these variables.

Trend equations are given as:

$Y_t = 16,397.04 - 31.075\, t + \varepsilon$ (Sindh coast)

$Y_t = 55,71.197 - 08.889\, t + \varepsilon$ (Balochistan coast)

Thus, we have a 1:1 correspondence with fish-yield and the ozone layer depletion, and the UV flux penetrating through the ozone filter. Now we can argue that the fish or other inhabitants of sea cannot be saved without urgent action.

The UV component of solar radiation is found to be a significant and pervasive selective force in aquatic ecosystems. The new challenge for future UVR research is to incorporate present knowledge of UV flux reaching sea level into a broader ecological context.

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EFFECTS OF GLOBAL WARMING ON THE FREQUENCY OF EARTHQUAKES IN THE NORTHERN AREAS OF PAKISTAN

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ABSTRACT

As reflected in this paper, an attempt has been made to establish a correlation between temperature increase and increase in frequency of earthquakes in the Northern Areas of Pakistan. The data utilized contains decadal averages (1961-2000) and a six-year average (2001-2006) of temperature. Temperature observations are taken from the Gilgit, Skardu, Chitral and Islamabad-based observatories. The seismic block lies between latitude and longitude 29°-37.2° and 65°-77°, respectively. The seismic data being used for this study is for the years 1961-2005.

The study has shown that there exists a correlation between temperature increase and frequency of earthquakes. As the study area contains numerous glaciers, the increase of temperature causes these glaciers to melt thus releasing pressure on earth below and, as a result, the earth possibly rebounds causing earthquakes. This increases in frequency of earthquakes, in correlation with the temperature, lies in the magnitude ranging from 3.0 to 3.9. Similarly, depth study indicates that increase in the frequency of shallow-level (0-80km) earthquakes can be correlated with temperature. The month-wise study has shown that this continuous increase in earthquake frequency occurs in the months of October, November, December and February.

Keywords: *Global Warming, Glacier Melting, Isostatic Rebound, Gradual Increase in Seismic Activity.*

1. INTRODUCTION

The increasing temperature is very hazardous to life on Earth. There are various theories to explain it but the fact that cannot be denied is that the temperature of Earth is rising. Global Warming is not only changing our world's climate but, it is also causing direct and indirect changes on the surface as well as within the surface of Earth. This effect is no less threatening for Pakistan that has glaciers spreading over vast area in the North, which is also our study- area for this paper (Figure-1). As this region contains many active faults (Figure-2) (Kazmi and Jan, 1997) like Reshun Fault (RF), Upper Hunza Fault (UHF), Main Karakoram Thrust (MKT), Hamran Fault (HF), Main Mantle Thrust (MMT), Raikot-Sassi Fault, Kund Fault (KF), Harban Fault, Sassi-Dassu Fault, Shinkiari Fault, Indus (Darband) Fault, Nawshera Fault, Kund (Manki) Fault, Peshawar Basin Fault and Main Boundary Thrust (MBT) (ibid).

Due to these faults, this zone is seismologically very active and earthquakes occur more frequently here than anywhere else in Pakistan. This zone is also sensitive to changes that are caused by Global Warming, like receding of glaciers. As glaciers weigh billions of tons, their melting can cause the crust of Northern Areas to relax and rebound. As wasting ice-sheets and ice-caps unload the solid earth, stresses released both deform the Earth's surface (Pagli and Sigmundsson, 2008) and decompress the Earth's mantle (Sigvaldason, Annertz and Nilsson, 1992). If erosion or melting ice reduces load, the crust slowly rises by isostatic rebound (Wicander and Monroe, 2006).

In the last twenty years, there has been significant increase in the number of earthquakes that have been located each year. This increase in the number of earthquakes is partially due to the fact that there has been a tremendous increase in the number of seismograph stations in the world and many improvements in global communications have taken place (Alternat1ve, 2008).

In high mountain environments, geotechnical hazards are being increasingly considered in relation to the possible interaction with changing glacial and permafrost conditions (Harris, 2005) and (Huggel, 2008).

In response to increasing temperature over past 100 years, glaciers have gradually underwent thinning, loss of mass and retreat (Singh, Arora, and Goel, 2005). Although other factors like precipitation and cloud cover also affect the retreat of glaciers, air temperature is considered the most important one (ibid).

Global annual mean surface temperature of the globe has increased by 0.6 ± 0.2 °C between 1860 and 2000 (IPCC, 2001). Extent of snow-cover has been decreased by about 10% on average in the northern hemisphere since late 1960s (ibid). It has been said that Himalayan glaciers will melt away within 40 years leading to drastic reduction in river flow and widespread water-shortage (Pearce, 1999; and WWF, 2005).

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Figure - 1: (Taken from Google Earth) The location of seismic block. The area bounded within blue line is our study area. The place marks in above map shows the locations from where the observatories for temperature are taken.

Note: The blue line boundary is an estimated boundary it does not show the exact location of study area

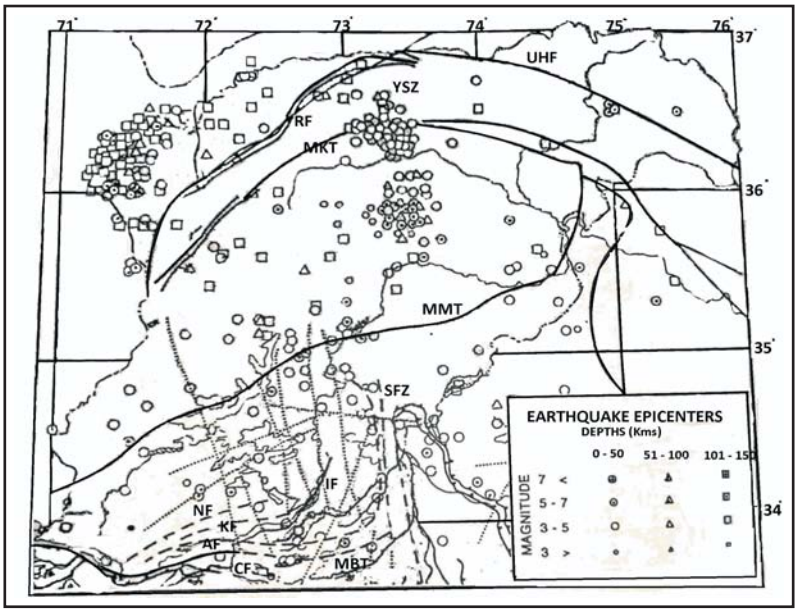

Figure - 2: Seismotectonic map of study area

Note: the location of Yasin (YSN) and Hamran (HSZ) Seismic zones. Faults UHF=Upper Hunza Fault, RF=Reshun Fault, MKT=Main Karakoram Thrust, MMT=Main Mantle Thrust, NF=Noushera Fault, KF=Kund Fault, AF=Attock Fault, IF=Indus Fault, MBT=Main Boundary Thrust

Accelerated glacier retreat has occurred in Nepal and Bhutan over the last two decades of 20th century (Kadota, et. al., 2000; Ageta, et. al., 2001; and Fujita, et. al., 2001). Since 1840, most of the Himalayan glaciers have retreated more than 1200m (Ahmed and Rais, 1998). Individually, Pindari has retreated 3500m in 139 years, Gangotri has retreated 35m in 34 years, Snatopath, 50m in 30 years, Milam 35m in 55 years, Bara Singri, 55m in 90 years. Parbati glacier in Beas valley, Sona Pani glacier in Chenab valley have been retreating (ibid). In this zone most of the glaciers are covered with debris eventhough they are receding (ibid).

Projections from Earth-climate Model suggest that global surface air temperature will increase substantially in future due to radiative effects of enhanced atmospheric concentrations of gases (Delworth, Mahlman and Knutson, 1999).

2. AIM OF THE PRESENT STUDY

The aim of our study is to find the correlation between temperature-increase and frequency of earthquakes in the Northern Areas of Pakistan. This study will hopefully help to predict frequency of earthquakes in future for taking various preventive measures.

3. MATERIAL AND METHODS

The data utilized contains decadal average of temperature (1961-2000) and six-year average of temperature (2001-2006). For recording temperatures, the observatories established at Gilgit, Skardu, Chitral and Islamabad. The temperature data of Chitral observatory starts from 1971. The seismic block lies between latitude 29^{o}-37.2^{o} and longitude 65^{o}-77^{o}. The period of seismic data utilized for this study is 1961-2005. The temperature and seismic data for the study has been provided by Pakistan Meteorological Department (PMD).

Selection of Study-Area: For study, the Northern Areas of Pakistan have been selected, as this region contains a number of glaciers. The duration of study is 1961-2005, during which:

i PMD (Pakistan Meteorological Department) was only source for monitoring earthquakes;
ii No new seismic stations were developed by PMD;
iii No new sensitive instruments were installed.

Temperature study: A network of four observatories has been used (Figure-1). The average increase in temperature has been shown in Table-1. As ten hottest years ever measured in the history of Earth i.e., 1991, 1995, 1997, 1998, 1999, 2001, 2002, 2003, 2004 & 2005 (Al Gore, 2006) lie within the time-span 1991-2006, which means that the said span will show a sudden rise in average temperature compared to that of 1961-1990. Considering this fact, calculations have been made to show the average increase of temperature in the two following spans:

Span 1: It contains average increase of temperature during 1961-1990. Span 2: It contains average increase of temperature during 1991-2006 (Table-2).

Seismic study: The study has been made with seismic data for the period 1961-2005. The latitude & longitude of the seismic block are 29^{o}-37.2^{o} and 65^{o}-77^{o}, respectively. The seismic block contains Hindukush mountains, some parts of Afghanistan, Upper Punjab, Upper Balochistan, Tribal Areas, Northern Areas of Pakistan and Kashmir Region (Figure-1). For the purpose of study, the Northern Areas of Pakistan has been selected while other areas have been neglected as they either don't have glaciers or have different sources for monitoring earthquakes.

During the period of study, the frequency of earthquakes and average number of earthquakes per year has been shown in Table-3. To observe in which range this increase in earthquake-frequency lies, study has been made with respect to magnitude, depth and month-wise occurrence (Tables-6, 7 & 8, respectively). Like temperature, the seismic data has been studied in two time spans: Span 1: from 1961 to 1990 and Span 2: from 1991 to 2005 (Table-4).

4. RESULTS

Table-1 and Figure-19 show the increase in average temperature, while Table-2 shows span-wise increase in the average temperature of the study-area in the prescribed duration of study. Table-3 and Figure-20 show increase in earthquake-frequency in the study-area. Table-4 shows span-wise earthquake-frequency and average number of earthquakes per year. Table-5 shows span-wise earthquake frequency and average number of earthquakes per year by excluding the earthquakes of year 2005. Table-6 and Figure-3 and 4 show magnitude-wise; Table 7 and Figure-5 and 6 show depth-wise; and Table-8 and Figure-7 to 18 show month-wise frequencies of earthquakes that occurred during the period of study.

TEMPERATURE STUDY TABLES

Table - 1: Gradual Increase in Average Temperature of the Study-Area by Using Four Observatories

Stations / Duration	Islamabad	Chitral	Skardu	Gilgit	Average Temp. of the Study Area
1961-70	21.153		11.318	15.683	16.052
1971-80	21.383	15.9	11.482	15.783	16.137
1981-90	21.444	15.828	11.638	15.594	16.126
1991-00	21.562	15.858	11.885	15.685	16.248
2001-06	22.329	16.424	12.337	16.034	16.781

Table - 2: Average Increase in Temperature during Spans 1961-1990 and 1991-2006

Span Name	Duration	Increase in Temp. in ^{0}C
Span 1	**1961-90**	0.08
Span 2	**1991-06**	0.53

Note: During the span 1 there is small increase in average temperature, but Span 2 shows considerable increase in average temperature.

EARTHQUAKE STUDY TABLES

Table - 3: Earthquake Frequency and Average Earthquake in a Year during 1961-2005

Duration	No. of Earthquakes	Average Number of Earthquakes Per Year
1961-70	45	4.5
1971-80	121	12.1
1981-90	236	23.6
1991-00	395	39.5
2001-05	992	198.4
1961-05	**1,789**	**39.8**

Note: As we move down in this table, that is from 1961-70 to 2001-05, we find gradual increase from 1961-70 to 1981-90 and a sudden jump from 1991-00 to 2001-05, in earthquake frequency and average earthquake per year.

Table - 4: Earthquake Frequency and Average Earthquake a Year during 1961-1990 and 1991-2005

Span Name	Duration	No. of Earthquakes	Average Number of Earthquakes Per Year
Span 1	**1961-90**	402	13.4
Span 2	**1991-05**	1387	92.5

Note: This table shows that there is a sudden increase in earth earthquake frequency and average earthquake a year in span 1991-05 compared to span 1961-90.

Table - 5: Earthquake Frequency and Average Earthquake a Year in spans 1961-1990 and 1991-2004

Span Name	Duration	No. of Earthquakes	Average Number of Earthquakes Per Year
Span 1	**1961-90**	402	13.4
Span 2a	**1991-04**	761	54.3

Note: Here we have excluded year 2005 due to earthquake of 8 October 2005. But again the span 2a's average and frequency of earthquake is greater than span 1 average and frequency of earthquakes.

Table - 6: Magnitude-wise Frequency of Earthquakes

Magnitude / Duration	2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	Total
1961-70	0	2	35	8	0	45
1971-80	0	14	85	21	1	121
1981-90	0	65	156	11	1	233
1991-00	2	231	131	9	0	373
2001-05	2	492	411	45	1	951
1961-05	**4**	**804**	**818**	**94**	**3**	**1,723**

Note: As we move down in this table, that is from 1961-70 to 2001-05, we find that earthquakes of magnitude 3-3.9 are showing increase in their frequency in correlation with temperature. Earthquakes of magnitude 4-4.9 showing net increase and earthquakes of magnitudes 5-5.9 and 6-6.9 do not show any gradual increase in their frequency.

Table - 7: Depth-wise Frequency of Earthquakes

Depth / Duration	Shallow (0-80KM)	Intermediate (81-300KM)	Deep (Above 300KM)	Total
1961-70	22	21	1	44
1971-80	82	37	2	121
1981-90	115	121	0	236
1991-00	165	225	4	394
2001-05	828	164	0	992
1961-05	**1212**	**568**	**7**	**1,787**

Note: This table shows that the frequency of shallow level earthquakes has increased in correlation with temperature during the period of study. The earthquakes of intermediate level are also showing a net increase in their frequency.

Table - 8: Month-wise Frequency of Earthquakes

Months / Duration	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1961-70	8	4	3	4	5	1	6	2	7	1	3	1	45
1971-80	7	6	13	11	9	2	8	8	35	9	3	10	121
1981-90	22	16	27	19	18	13	20	25	33	15	10	18	236
1991-00	30	30	39	39	50	32	43	33	18	23	24	34	395
2001-05	22	38	33	30	24	21	24	13	21	513	177	76	992
1961-05	**89**	**94**	**115**	**103**	**106**	**69**	**101**	**81**	**114**	**561**	**217**	**139**	**1789**

Note: There is increase in earthquake frequency in months of October, November, December and February in correlation with temperature, as we move from top to bottom that is from 1961-70 to 2001-05 in this table.

Magnitude-wise Earthquake Frequency

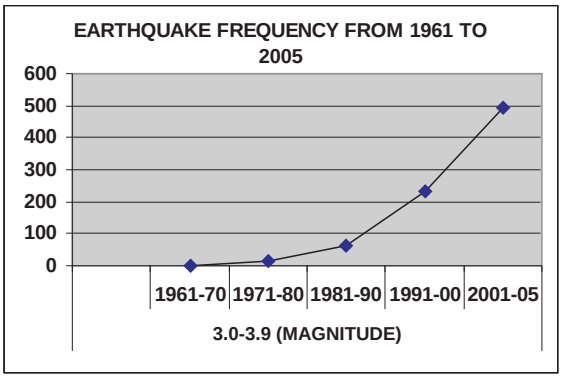

Figure-3: Earthquakes of magnitude 3.0-3.9 showing increase in their frequency in correlation with average temperature (Fig-19)

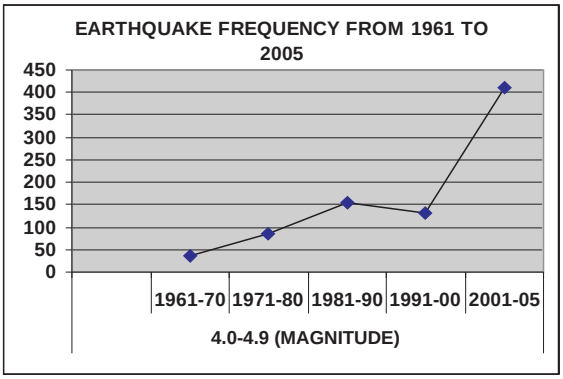

Figure-4: Earthquakes of magnitude 4.0-4.9 showing a net increase in the frequency

Depth-wise Earthquake Frequency

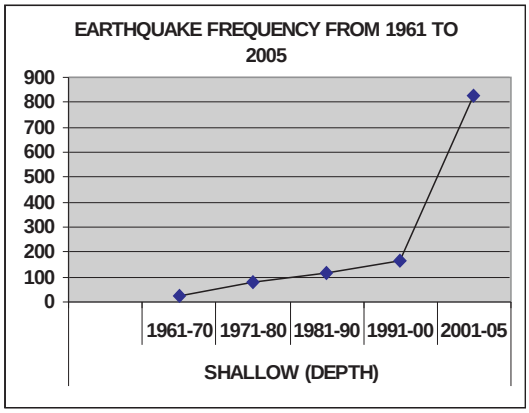

Figure-5: Shallow earthquakes (0-80km) showing gradual increase in there frequency correlation with average temperature (Fig-19)

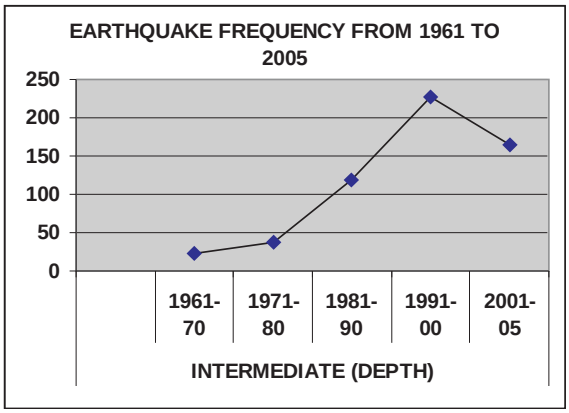

Figure-6: Intermediate earthquakes (81-300km) showing net increase in their frequency

Month-wise Earthquake Frequency

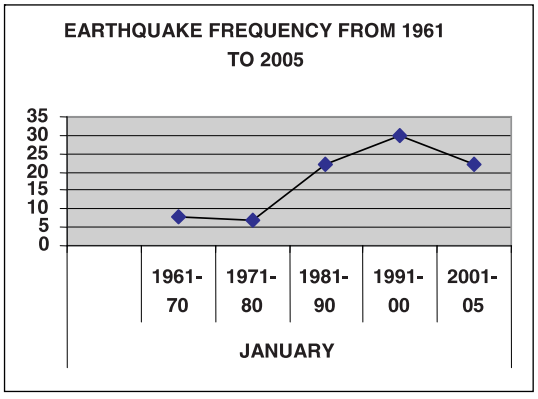

Figure-7: This figure shows a net increase in month-wise frequency of earthquakes

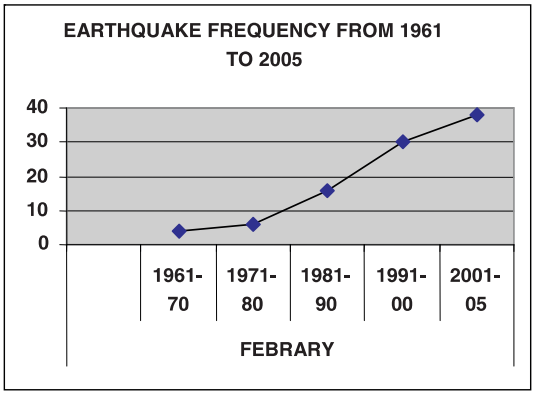

Figure-8: This figure shows increase in month-wise frequency of earthquakes in correlation with temperature (Fig-19)

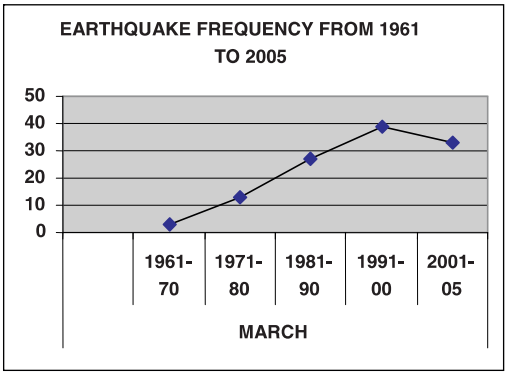

Figure-9: This figure shows a net increase in month-wise frequency of earthquakes

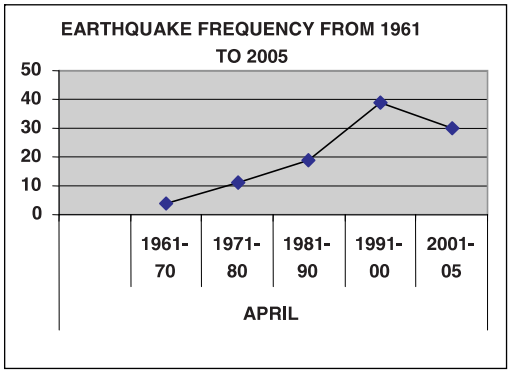

Figure-10: This figure shows net increase in month-wise frequency of earthquakes

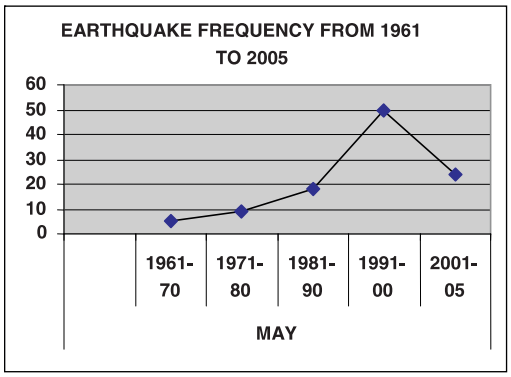

Figure-11: This figure shows net increase in month-wise frequency of earthquakes

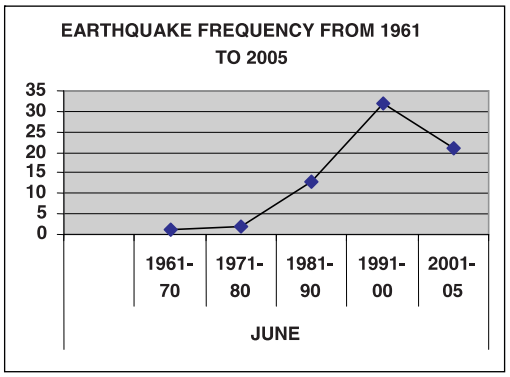

Figure-12: This figure shows a net increase in month-wise frequency of earthquakes

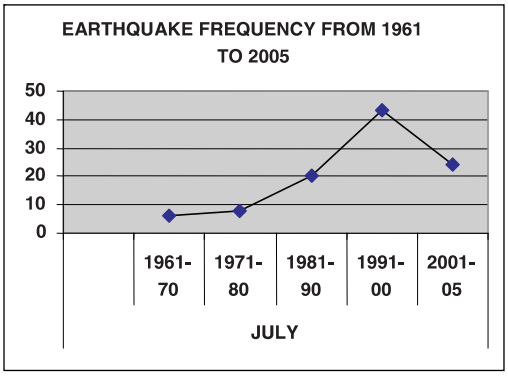

Figure-13: This figure shows a net increase in month wise frequency of earthquakes

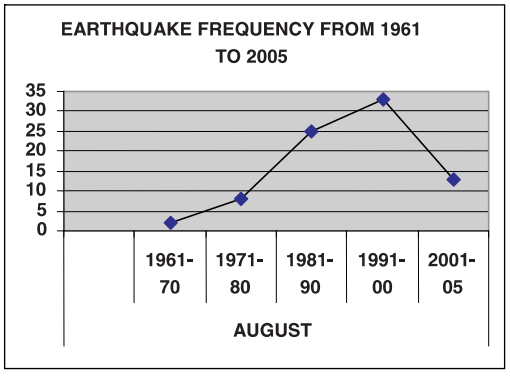

Figure-14: This figure shows net increase in month-wise frequency of earthquakes

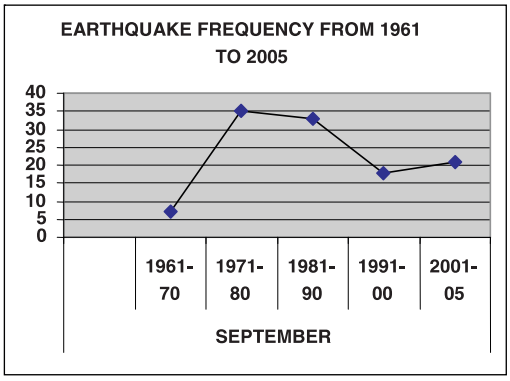

Figure-15: This figure shows a net increase in month wise frequency of earthquakes

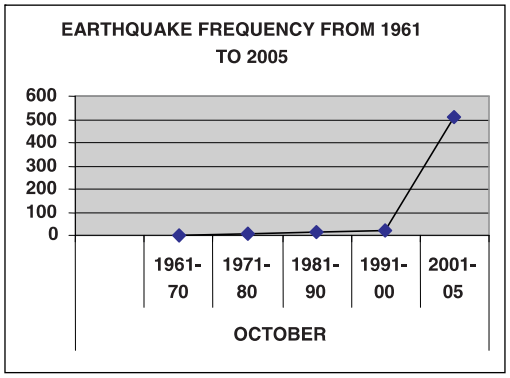

Figure-16: This figure shows increase in month wise frequency of earthquakes in correlation with temperature (Fig-19)

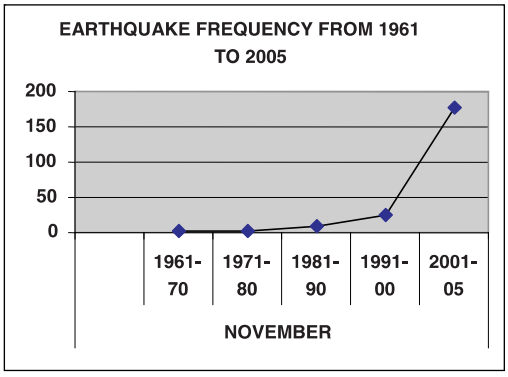

Figure-17: This figure shows increase in month wise frequency of earthquakes in correlation with average temperature (Fig-19)

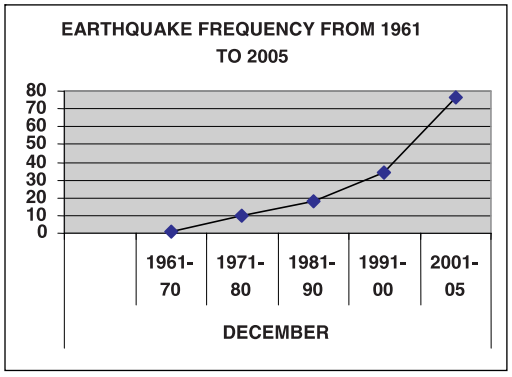

Figure-18: This figure shows increase in month wise frequency of earthquakes in correlation with average temperature (Fig-19)

Increase in Earthquake Frequency with the Increase in Temperature during Period 1961-2005

Average Temperature	
1961-70	16.051
1971-80	16.137
1981-90	16.126
1991-00	16.248
2001-06	16.781

Earthquake Frequency	
1961-70	45
1971-80	121
1981-90	236
1991-00	395
2001-05	992

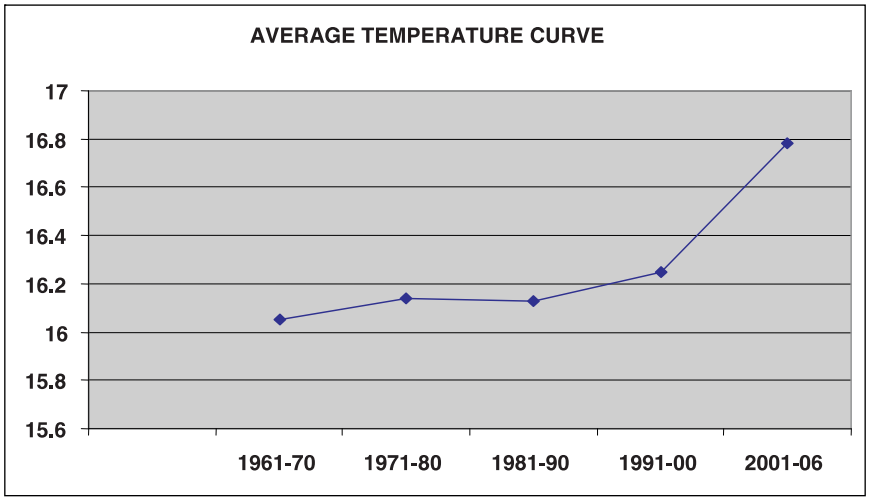

Figure-19: This figure shows average surface temperature of study area in duration 1961-06

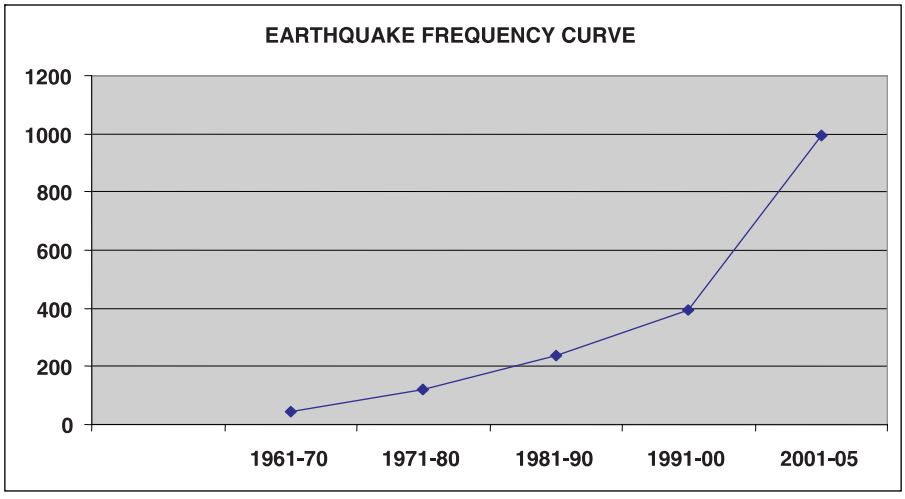

Figure-20: This figure shows earthquake frequency in study area in duration 1961-05

5. DISCUSSION

During the last twenty years, there has definitely been an increase in the number of earthquakes that have been located each year. This is because of the tremendous increase in the number of seismograph stations in the world and many related improvements in global communications (Alternat1ve, 2008)

As, in our study-area, during the period of study, the source, stations and instruments for monitoring earthquakes have remained the same. It means, if there is any increase in earthquake-frequency during the period of study, it can be explained by isostatic rebound of earth resulting from glacial retreat. The main cause for this glacial retreat is Global Warming. So, temperature can also be a cause for enhanced seismic activity.

Global annual mean surface temperature has increased by 0.6 ± 0.2 °C between 1860 and 2000 (IPCC, 2001). Since 1840, most of the Himalayan glaciers have retreated more than 1200m (Ahmed and Rais, 1998). It means that the increase in temperature is causing Himalayan glaciers to retreat. In our study-area, the average temperature has gradually increased (Table-1). As this area contains numerous glaciers, so increase in temperature is causing these glaciers to retreat like other Himalayan glaciers. So, they are releasing stress on the crust below. If erosion or melting ice reduces load, the crust slowly rises upward by isostatic rebound (Wicander and Monroe, 2006). As wasting ice-sheets and ice-caps unload the solid Earth, stresses released both deform Earth's surface (Pagli and Sigmundsson, 2008) and decompress Earth's mantle (Sigvaldason, Annertz, and Nilsson, 1992). As the study area contains many active faults (Kazmi and Jan, 1997) the isosatic rebound of Earth resulting from glacial retreat due to increased average temperature can create movement along these faults to trigger earthquakes. If there are any dormant faults, they can become active. It means that with the gradual increase in average temperature in glacial zone, the earthquake frequency should also increase.

In study area during the period of 45 years, there have been 1789 earthquakes (Table-3). It is clear that with passage of time the frequency of earthquakes has increased (Figure-20). There is a clear correlation between average temperature increase and increase in earthquake frequency with respect to time (Figures-19 and 20). For more confirmation, when span-wise study has been made, (Table-2 and 4) we see that during the span 1961-90, there is a small increase in average temperature that is about 0.08 °C and the earthquake occur at average of about 13 earthquakes a year. But, when span 1991-2005 is studied, it is noted that there is a considerable increase in temperature that is 0.53 °C and the earthquakes occur at an average of about 93 earthquakes a year. The year 2005 alone has 626 earthquakes. They are the result of tremendous aftershocks produced by October 8, 2005 earthquake with its centre in Muzafarabad. So, there is a possibility that a sudden jump in earthquake frequency might be caused by October 8, 2005 earthquake. So the frequency of earthquakes and average earthquake a year has also been studied by excluding the earthquakes of the year 2005. Calculation of results, excluding the earthquakes of the year 2005, are: from 2001-2004 there are 366 earthquakes with the average of 92 earthquakes a year. Again, this result is greater than any previous yearly average of earthquakes as shown in Table-3. If the yearly average of earthquakes in span 1991-2004 is calculated we find average of 54 earthquakes a year, which is again far greater than span 1 average that has average of 13 earthquakes a year (Table-5). All these observations indicate an increasing tendency of earthquakes. As temperature of study-area is also increasing, so there seems to be a clear correlation between temperature increase and earthquake frequency.

To observe in which range the increase in earthquake frequency lies, the study has been made to observe the increase in earthquake frequency with respect to magnitude, depth and month-wise occurring.

For studying the magnitude of earthquakes, Mb scale (Body Wave Magnitude) has been used. Total Mb readings are 1728 (Table-6). It is found that the earthquakes of magnitude 3.0 to 3.9 have gradually increased during 1961-90 and considerably increased during 1991-05 (Figure-3), while the readings of earthquakes of magnitude 4.0 to 4.9 also show net increase in the occurrence (Figure-4).

The earthquake-study has also been made with respect to depth and total depth readings are 1787 (Table-7).The three divisions of depth are shallow (0-80km), intermediate (81-300km) and deep (above 300 km). The depth study indicates that frequency of shallow earthquakes has increased (Figure-5) in correlation with the average temperature (Figure-19), during the period of study. The intermediate earthquakes also show a net increase in their frequencies (Figure-6).

Month-wise study (Table-8) shows an increased frequency of earthquakes in October, November, December and February (Figures-16,17,18 and 8, respectively) in correlation with average temperature increase (Figure-19). The months January, March and April, May, June, July, August and September also show net increase in earthquake-frequency (Figures-7, 9, 10, 11, 12, 13 and 14, respectively).

6. CONCLUSIONS

This study shows that with the increase in temperature, the earthquake-frequency also increases. As in the study-area the analytical tools, such as source, stations and seismographs, have remained same during the period of study, it means that the main factor for increase in earthquake frequency can be temperature. Global warming is causing glaciers to melt thus releasing pressure on Earth below causing the Earth below to rebound that results in earthquakes. This increase in earthquake frequency, in correlation with temperature, lies in magnitudes ranging from 3.0 to 3.9. Depth study shows that the occurrence of shallow-level earthquakes has been increased during the period of study. The months of October, November, December and February also show increase in earthquake frequency in correlation with temperature.

The correlation between temperature increase and earthquake frequency is presently explained by glacier melting. Figure-19 gives clue that temperature of study area will increase rapidly in future. If the line of temperature (Figure-19) continues to rise, like from 2001-2006, than coming years can show extensive glacier melting, that may result in enormous flooding and earthquakes, which can be record breaking. The chances of various geological hazards (like land-sliding) relating to flooding and earthquakes should also increase.

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TOWARDS SUSTAINABLE RURAL SANITATION: THE ROLE OF THE UNIVERSITY IN PARTICIPATORY TECHNOLOGY DEVELOPMENT IN PAKISTAN

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ABSTRACT

While the provision of and access to clean water by the poor has been an important international focus in recent years, issues of sanitation are as yet not nearly as thoroughly analyzed. Evidence of the inadequacy of conventional approaches to sanitation is nevertheless rapidly emerging, as we discover that they are in themselves neither effective in improving health, nor sustainable and rarely accessible to rural populations in the South. The importance of developing socially, institutionally, economically and environmentally sustainable solutions for rural sanitation is therefore quickly becoming apparent. There are a number of challenges, however, in moving out of a conventional sanitation paradigm towards more innovative approaches. Technology development in sanitation has proven to be power-laden, with little room for maneuver within an engineering-based regime. There are, however, exceptions. Sustainable sanitation is an emerging field of research in the North that has shown promising results in addressing environmental issues, and may prove relevant in the South. This will require that the process of technology development be both re-conceptualized and contextualized, to ensure that technologies are not only effective and sustainable but equitable and empowering as well and in fact lead to a better quality of life for rural women, men and children.

This paper explores processes of innovation and technology-development in sustainable sanitation, through an analysis of a joint Pakistani-Norwegian research programme. We explore the proposition that institutions and actors with similar approaches, ontologies, epistemologies, and methodologies tend to band together in powered knowledge regimes, reinforcing each other, and preventing the development of alternative constellations, both within their institutions and with external actors. We also contend that, by identifying the underlying approaches of various institutions or actors, and the constitution of power relations, one can better understand how alternative framings might be constructed and new alliances formed, leading to the emergence of new regimes of knowledge-sharing and development, and thus new pathways toward sustainable development. Case data was obtained through observation of and participation in research and education proposal development, programme-planning meetings and stake-holder workshops in Norway, Nepal and Pakistan, during the period from January 2007 to June 2009. Based on this case, we argue that the University can play an important role in managing a new regime of technology-development and promoting social change, particularly where there is a strong policy-focus on participation and equity issues.

1. INTRODUCTION

Provision of and access to clean water by the poor has been an important international focus in recent years, most clearly defined in the Millennium Development Goals (MDGs). This has mobilized vast resources globally in the form of international forums, etc. Issues of sanitation, however, although mentioned as well in the MDGs, have only recently begun to be considered in any comprehensive manner, and are as yet not nearly as thoroughly analyzed as water supply and access. How sanitation systems develop, are managed, and influence health and the environment, is therefore poorly understood. Particularly rural sanitation issues have been neglected, with sanitation being considered either as a purely hygiene-practice issue or the construction of latrines. Concerns over the inadequacy of these conventional approaches to sanitation, however, are rapidly emerging, as we discover that they are neither effective in improving health, nor sustainable. The importance of developing socially, institutionally, economically and environmentally sustainable solutions in rural sanitation is quickly becoming apparent.

There are a number of challenges, however, in moving out of a conventional sanitation paradigm towards more innovative approaches. Technology development in sanitation has proven to be power-laden, with little room for maneuver within an engineering-based regime. There are, however, exceptions. Sustainable sanitation is an emerging field of research in the North that has shown some promising results in addressing environmental issues, and may prove relevant in the South. This will require, however, that the process of technology- development be re-conceptualized and refocused to ensure that technologies are not only effective and sustainable, but equitable and empowering as well, and in fact lead to a better quality of life for rural women, men and children. It will thus require a departure from existing hegemonic sanitation-framings, and the development of a new technology-regime, in order to re-frame the issues and shift the pathway of development toward a more sustainable sanitation. In particular, it requires a new look at the role that universities can play in linking

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research and development, not only in theory but in practice as well.

This paper explores processes of technology-development in sustainable sanitation through an analysis of a joint Pakistani-Norwegian research programme. We explore the proposition that institutions and actors with similar approaches tend to band together in powered knowledge-regimes, reinforcing each other, and preventing the development of alternative constellations both within their institutions and with external actors. We also contend that by identifying the underlying approaches of various institutions, or parts of institutions, or actors within institutions, and the constitution of power relations, one can better understand how alternative framings might be constructed and new alliances formed, leading to the emergence of new regimes of knowledge-sharing and development, and thus new pathways towards sustainable development.

Case data was obtained through observation of and participation in research and development proposal development, programme planning meetings and stakeholder workshops in Norway, Nepal and Pakistan, during the period from January 2007 to June 2009. As participants in the process, this posed particular challenges to the authors in reflecting over our own roles and interests in the program. On the other hand, it gives a unique insider-view of the way the programme was negotiated by the various actors involved.

We begin with a presentation of the case; how the programme in sustainable sanitation has evolved in Norway, Pakistan and Nepal. We then offer an introduction to competing paradigms in technology-development in sanitation, and how this has lead to the need for a different kind of analysis of technology-processes, which would explore a range of issues, interests and power relations that are not normally apparent in conventional understandings of innovation and technology development. We then introduce the idea of technology-regimes and their transformation, focusing on four main areas, which we find important in understanding the ways actors relate to each other in technology regimes:

- Professional environments, incentives and networks;
- Approaches to analysis, and complexity self-reflexivity;
- Understandings of technology, innovation, knowledge and participation;
- Views of development, equality and equity.

In doing this, we combine emerging perspectives in innovation and technology with development perspectives on power-relations, participation, action research, and equity so as to explore alternative ways of framing sanitation-issues in a new technology-development regime. By anchoring the discussion in a specific process of technology-development, in this case Norway and Pakistan, we gain insight into what re-framing of sanitation issues, and re-defining the roles of the actors involved could actually mean in practice. Based on this discussion, we argue that the university can play an important role in managing systems of technology-development and promoting social change, particularly where there is a strong policy focus on participation and equity issues.

2. THE CASE

The Norwegian University of Life Sciences (UMB), and COMSATS Institute of Information Technology (CIIT), Abbottabad, Pakistan, have been collaborating in the field of Environment and Development Studies since 2005. In September 2008, CIIT launched an MS programme in Sustainable Water, Sanitation, Health and Development, in collaboration with UMB and Tribhuvan University, Kathmandu, Nepal. Funded in part, by the Norwegian government[1], this is an interdisciplinary programme combining technical, ecological, institutional and socio-cultural perspectives. In addition to curriculum, students are required to complete a participatory, field-based research.

The impetus for the MSc programme came from researchers and PhD students at partner institutions in Pakistan and Nepal, who had studied sustainable sanitation at UMB in Norway. Recognizing the potential of this type of technology in their countries, they entered into discussions with UMB on how it might be promoted in their countries. The timely availability of Norwegian funding for the establishment of MS programmes provided a specific entry point for such collaboration.

The MS programme principles were laid down early; the programme was to be interdisciplinary and

1 Funding was provided under the NOMA Programme (Norad's Programme for Master's Studies).

innovative, and the research participatory and rural-based. Development of the programme involved choosing courses from highly different disciplines, and many of the courses were themselves interdisciplinary in nature, while some of the courses already existed at one or more of the institutions, and yet others were completely new. This process required intense negotiation by academics from all the institutions over not only the content of the courses, but also to decide which courses would be obligatory and which would be elective, and what the entry requirements would be for students coming from very different academic backgrounds.

In Pakistan, plans developed simultaneously for a comprehensive research programme, in which the MS students' research could be embedded so as to contribute to longer-term, strategic research in this area. A workshop was therefore held in March 2009 in Abbottabad, where NGOs and government officials involved in the areas of sanitation and health were invited to share their ideas on what kind of research would be useful to them as implementers and policy-makers. The participants clearly stressed the inadequacy of the existing approaches to rural sanitation and the need to find more sustainable solutions, particularly for the poorest community members. There was a keen interest on part of the NGOs in not only conducting participatory research, together with students and researchers, but also sending their staff, village activists and government counterparts to CIIT for short- and medium-term courses, where they could learn about more sustainable approaches to rural sanitation and health, as well as share their own experiences of the field.

Follow-up meetings with NGOs and policy-makers in Islamabad confirmed a high interest in developing a comprehensive education, research and training programme at CIIT, into which implementers could be integrated. A number of funding sources were identified, which would serve to strengthen the quality of the programme and provide additional scholarships[2]. The stage was now set for this new configuration of actors to share their knowledge and develop new insights to and technologies for sustainable sanitation and health. Even with existing funding, the programme would be able to operate on a very limited scale, such that education and research would be conducted. Also, the NGOs were willing to pay CIIT from their own budgets to send their staff and partners to the courses they requested, making the training economically sustainable. Preliminary results from student research, conducted together with villagers and NGOs, will be available within the first year in the form of result workshops. Longer-term results, of course, take more time, depending on the nature of the research conducted.

Thus, one year on from receiving funding to start an MS programme, an entirely new knowledge-sharing system had been established that links villagers, NGOs, government staff and policy-makers, and researchers and students from the South and the North, to conduct action-research in rural sanitation, health and development. Although this initiative is still quite young, it nevertheless represents an interesting case where it happened rather quickly and has received such broad-based support from both the universities and institutions involved in rural sanitation in Pakistan. It would therefore be interesting to examine closely the conditions under which this programme was established, which contributed to its apparent acceptance. By analyzing the process this far, we might also gain insight into whether this initiative might be sustainable institutionally, and contribute to positive social change in the communities, as well as farther-reaching changes within the universities in both Norway and Pakistan.

3. INNOVATION IN SANITATION: PARADIGMS IN TECHNOLOGY DEVELOPMENT

Sustainable sanitation[3], is gaining ground in the North as an alternative to the shortcomings of conventional systems of sanitation, particularly in rural environments, but also more recently in urban settings. Langergraber and Muellegger (2005) see it as a 'way to solve global sanitation problems' through minimizing hygienic risks and protecting the environment. The sustainable sanitation 'movement' itself is global, with researchers, activists and policy-makers participating in a number of global forums[4] to promote the approach in both policy and practice. According to Langergraber and Mueller (ibid), the sustainable sanitation paradigm 'is based on ecosystem approaches and the closure of material-flow cycles' where 'human excreta and water from households are recognized as a resource (not as waste), which should be made available for re-use'.

2 The NOMA programme provided only 5 scholarships, the remaining 20 were financed by CIIT in order to support the programme in its early stages.
3 Sometimes referred to as ecological sanitation, or EcoSan, depending on what one includes in the definition.
4 World Water Week.

(p.435). It is a holistic, systematic approach, with a focus on ecologically and economically sound sanitation.

One of the key ideas in this approach is that technologies are considered as means to an end, and are only ecological in relation to the observed environment. Technologies could therefore range from latrines to natural filtration systems and biogas plants, depending on the natural, social and economic context. This is a significant break from an approach that focuses on the technologies themselves as inherently environmentally sound or not. Thus, those following a sustainable sanitation approach in this broader sense, are highly dependent on a detailed understanding of both the natural and social environment in order to design ecologically, economically and socially acceptable sanitation systems. It also implies that a new assessment of these aspects is necessary for each environment and a unique solution is developed, necessarily with the participation of all the stake-holders. This has, in fact, enormous implications for how sanitation systems are both conceived and promoted, since it breaks radically with the conventional focus on sanitation-hardware and on making small changes to existing systems to make them more environmentally friendly.

In addition, sanitation systems in developing countries have their own set of challenges, which can be quite different from those in the North. Langergraber and Muellegger (2005) note that while the main challenge in sanitation in the North is to limit negative environmental impacts, in the South the focus should be one of reducing health risks. This in turn implies an understanding of the link between hygiene and sanitation, which requires detailed knowledge of local hygiene practices and perceptions of health. In addition, there are significant challenges in the South in addressing the needs of the poor particularly in rural areas, who are often without access to basic public goods and services. There is thus a dimension of equity in the development sanitation systems in the South, which is less acute in the North, where public services are far more likely to reach the majority of the population.

Conventional theories of processes of innovation and environmental technology development offer limited insight into how new sanitation-systems, radically different from conventional systems can, in practice, be developed. The bulk of literature on environmental technology development has focused almost exclusively on innovation in terms of discrete technologies, in the context of private firms, and realizing the importance of price as 'an efficient means of inducing technological and organizational innovation' (Berkhout 2002:1). Such analyses, however, have been unable to capture the significance of the complex social, political and economic systems in which technology development is actually embedded. Firms, for example, have to relate to wider markets, consumer demand, regulatory systems, infrastructural limitations when considering technological changes, but as, Smith et. al., note that they 'have little room for unilateral maneuver in relation to these factors' (2005:1491). The possibility of the rapid spread of technological innovation initiated through firms, therefore, is inherently limited. Also, there may be little incentive for private firms to take the lead in developing technologies accessible to the poor, without significant support from the public sector, which in many countries is not viable due to weak public institutions.

Alternatively, more recent literature has suggested a complete reframing of technology analysis away from firms, to focus on the shifts and transformations of larger technology-regimes (Kemp et al., 1998; Berkhout 2002; Smith et. al., 2005). Such analyses broaden the scope to consider the interaction of social, economic, political and institutional aspects of technology-development in either reinforcing or changing technology-regimes. *In this approach, issues of agency and power in the transformation of socio-technical regimes become central. Regimes are not comprised of static institutions linked together in relations of equality, but of institutional and individual actors who differ in the degree to which they can influence the direction of innovation within a regime.* Smith et. al. argue, therefore, that in order to consciously change regimes (purposive transformation), one must consider the ways in which the many actors who are members of the regimes negotiate with each other and exercise their influence over the pathways of innovation. This will require careful analysis of who the different actors are; what their interests are; what resources and competence they have at their disposal and which contexts they can influence change and in which ways. Through such an analysis, the complementarities of the actors, as well as possible competing agendas can be identified, and their power relations can be better understood.

Deconstructing and re-constructing technology regimes in this analysis will involve the examination of four sets of issues:

- Professional environments, incentives and networks;
- Approaches to analysis, self-reflexivity, and complexity;
- Views on technology, innovation, knowledge and participation;
- Views of development, equality and equity.

The choice of these four represents a synthesis from several distinct but relevant areas, including science studies, development studies, and ecological/environmental sanitation studies. In practice, these areas overlap and interconnect, reinforcing or disconnecting to form a web of relationships between actors in a technology regime. Thus, while we have organized the sections below according to these sets of issues, they are nevertheless not treated as completely separate; but are woven into the discussion whenever relevant. Since this analysis is concerned not only with a description of a regime but also the processes of change we need, as well as a way to conceptualize what we mean by regime change or change in the pathways of socio-technical development. Berkhout (2002:3) outlines three ways of conceiving change:

- Multiple, cumulative, often incremental changes that occur within regimes (no major shift in regime, but improved efficiency);
- Smooth re-orientation of prevailing trajectories (re-orientation in direction over time, but no change in the technologies and supporting institutions);
- Replacement of an incumbent system with a superior one.

It is the last example which describes a shift form one regime to another. According to Berkhout, 'Truly revolutionary innovations are likely to start small, and they will come to define through co-evolutionary processes a new regime for themselves' (Ibid). It is perhaps this type of regime shift that is occurring, within the sanitation regime in our case, to varying degrees and with varying success in the different contexts.

4. PROFESSIONAL ENVIRONMENTS, INCENTIVES AND NETWORKS

Sanitation technology has conventionally been placed firmly within the field of engineering and professionals are being trained in engineering and water and sanitation positions being filled by engineers. This network has proven to be powerful, both nationally and internationally, and in terms of sanitation it has turned rather conservative. Alternative approaches to sanitation have struggled where they have tried to operate within this established professional sphere. Also, due to the hardware aspects of conventional sanitation, there is a network of contractors and suppliers which would prefer a continued focus on existing options. *It is clear in any case that these environments are ill-quipped to consider the complex and interdisciplinary issues which form the new paradigm in sustainable sanitation.*

In order to develop new approaches to sanitation, a shift out of mainstream engineering into new spaces has occurred, for example environmental engineering, environmental sciences, or multi-disciplinary centers of research and innovation. In Norway, environmentally conscious sanitation has developed in at least two separate research environments, each with its own regime of institutions and resources. In one environment[5], the focus has remained within the engineering world, albeit environmental engineering. These efforts are highly commercialized, funded largely through research grants from private industries, but with an element of public funding from the research council. In this regime, the approach has remained one where sanitation innovation is concerned with producing increasingly more sophisticated hardware to address environmental concerns, mainly in the context of Norway.

The second environment[6] in Norway has shifted its focus increasingly farther away from an engineering paradigm, and moving its center away from environmental engineering to both environmental sciences and development studies. *This does not mean that environmental engineering is not an important field in which to work, it is merely that it no longer lies in the center of the wheel. One of the spokes of an interdisciplinary approach to addressing sustainable sanitation is considering a myriad of aspects, such as development, health, environment, culture, socio- economic, politics and institutions.*

In many countries of the South, however, the development of water and sanitation systems remains firmly within the sphere of engineering, with environmental engineering securing a small space within that discipline. This is the case, for example, of Nepal, where the sustainable sanitation collaboration

5 Here we refer to the environmental sanitation work connected to NTNU and its partners.
6 Here we refer to the work at UMB and Bioforsk, in the Aas environ.

is placed in a sub-section of the main engineering department at Tribhuvan University, where a few environmental engineers are located. In Pakistan, a different institutional approach has been taken. The programme is currently based in Environmental Sciences, is run by the Head of the Development Studies Department, in collaboration with the Department of Management Sciences and the Engineering Department. This is a radically different way of organizing research and education in sustainable sanitation. One important advantage of this arrangement is the fact that there is no established engineering field at the university working in sanitation that would resist a shift away from conventional approaches to sanitation, rather the engineering department at this campus focuses on electrical engineering. It could thus be considered as a process of 'niche formation', where there is a break with the existing institutional relationships. *In order for this to succeed, however, the university leadership must be highly committed to the idea of interdisciplinarity and to create incentives for departments to collaborate among established departments.*

As mentioned earlier, sanitation networks extend beyond university, as in government and NGOs. In particular, sectoral approaches to water and sanitation, health and hygiene, and environment are manifested in government departments and NGOs through the hiring of staff according to their professional background. For example, engineers in Pakistan receive their training from Civil Engineering Departments) and health staff from medical colleges. Integration between these fields has proven difficult; for instance it is quite common in NGOs in Pakistan that the health and hygiene programmes are staffed by health professionals, the water and sanitation are staffed by engineers, and the two programmes are run separately. Starting a sustainable sanitation programme is also a challenge for these professionals. What we do find at the national level, however, is an interest in the Ministry of Environment in exploring more environmentally friendly ways of approaching sanitation, although the impact of this at lower levels of government is limited.

Thus, in the case we are describing, we can see three sets of regimes, where institutions form networks, either on a disciplinary or sectoral basis (see Figure-1). First, the conventional engineering network (in yellow), second the sectoral networks in the field (yellow and purple) that reinforce their sectoral approaches through professional training and hiring, and, third, the emergence of a new network in sustainable sanitation, which encompassed three university departments at UMB in Norway and three departments at CIIT in Pakistan (with connecting lines). This new network, however, is not in itself sufficient to change the way sanitation technology is developed. It must link with the actors involved in both the policy-making and implementation of sanitation at the village level, who as we see are still stuck in a sectoral approach. This will involve not only the forming of new networks, but gaining an understanding of the sometimes fundamental differences in approach between these factors, which made the break with conventional engineering necessary in the first place.

5. APPROACHES TO ANALYSIS AND APPRAISAL, COMPLEXITY AND UNCERTAINLY, AND REFLEXIVITY

How different environments view the tasks of appraisal and analysis is central in enabling academics from different disciplines, policy-makers, government staff, local NGOs and villagers to interact constructively. According to Stirling et al., (2007), there are fundamental differences in the ways in which certain actors or groups of actors frame issues that will affect the way they view the tasks of analysis and appraisal. Rather than being based on differences in disciplinary background, or quantitative vs. quantitative dichotomies, he suggests that there are cross-cutting issues which transcend these dichotomies. One of these is the extent to which analyses and appraisals 'open up' or 'close down' the scope of enquiry, analysis and policy-making (Stirling, 2005; Stirling, et al, 2007). According to Stirling, these involve quite different normative, substantive and instrumental understandings of the purpose of an appraisal or analysis, and will impact the way it is carried out as well. If, for example, the purpose of a technology process is either to provide policy-makers with clear, instrumental justification for policy-making, or to provide the single 'best option' to users, the role of the appraisal and analysis process 'lies in cutting through the messy, intractable and conflict-prone diversity of interests and perspectives to develop a clear, authoritative, prescriptive recommendation to inform decisions' (2005:228). Key characteristics of such an approach are that it is unitary and prescriptive, with a limited number of 'best options'.

If, however, the purpose of a technological process is to open up choices, as well as to ensure an understanding of the consequences of alternative framings on the results, the appraisal and analysis

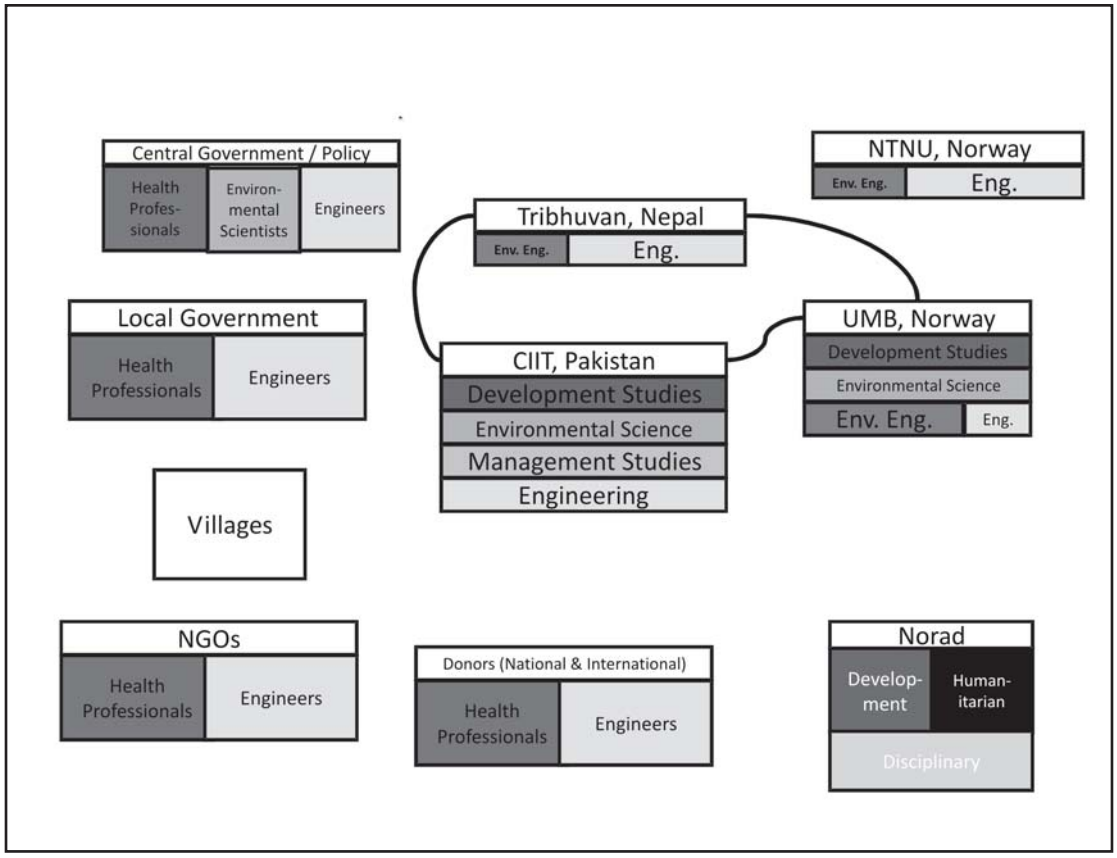

Figure - 1: Institutions and Actors in Sanitation in Pakistan, Norway and Nepal

process would focus to: ask alternative questions; addressing neglected issues, including marginalized perspectives, triangulate contending knowledge; test sensitivities to different methods; consider ignored uncertainties; examine different possibilities; and highlight new options (Ibid: 229). *In such an approach, the 'outputs' to policy-making would be 'plural and conditional' (Stirling, 2003), 'illuminating the potential for accommodating more diverse portfolios of social choice' (Stirling, 2005: 229).*

In our case, we can see how the academic actors in the new sustainable sanitation regime are promoting a clear 'opening-up' approach, which involves a broad appraisal and analysis based on the inherent complexity of designing socially, economically, institutionally, and ecologically sustainable sanitation systems. Since the success of such systems will be completely dependent on the development of contextually appropriate solutions, simplified, single-solution approaches would simply not be possible. This could be one explanation of how environmental engineers and scientists could ally relatively easily with social scientists in the institutions involved in the collaboration. Environmental sciences recognize the inherent complexity and context-specific diversity of ecological processes, which, in some respects, is mirrored in the world of social science, where people and their social relations are complex and diverse as well. An 'opening-up' approach in itself, however, is not sufficient to comprise a strong, alternative technology regime, and needs to be combined with other aspects, that are presented here in the next two sections.

While the universities involved in the programme have a clear 'opening-up' approach to sustainable development, they will likely encounter challenges when engaging with other environments who may instead lie firmly within a closing down, prescriptive mode. This might include policy-makers faced with the need for clear, often sectoral direction, as well as donors and government staff who are conceptually located in a service-delivery/hardware mode of operation, with pressure to 'scale-up' interventions. Hence, it will be critical that the outcomes of an opening-up approach are made explicit in the process,

in terms of both the development of innovative, appropriate and robust systems, but also the ways in which the inclusion of local women and men in a participatory technology development process is ensured for capacity-building in terms of the development of local competence in appraisal, analysis and deliberation over alternatives.

6. UNDERSTANDINGS OF TECHNOLOGY, INNOVATION, KNOWLEDGE AND PARTICIPATION

Another group of related issues revolves around how actors understand processes and concepts embedded in technology development. Starting with the idea of innovation, we argued above that innovation with a technological paradigm is considered as the domain of private-sector firms. Evidence from other sectors, however, shows us that innovation, in fact, occurs elsewhere as well. One well-known example of this is the research and innovation by small farmers in the South adapting and developing agricultural technologies, either on their own or in collaboration with agricultural researchers and extension agents[7]. Literature is filled with examples of how farmers have been innovative, in light of their own diverse needs, interests, and dynamic situations and most recently adaptation to climate change[8].

In the field of sanitation, however, models of innovation development are still in their infancy. While there is evidence of innovation by villagers in collaboration with NGOs (Nyborg, et. al., 2009). This innovation is little known in conventional sanitation environments, and completely separate from the existing sanitation-technology regime led by government engineers and policy-makers. The question thus arises on how to include local innovation-processes in a broader technology-development regime. A closer look at the way technology itself is understood by different actors, and how this is linked to the contemporary views of knowledge and participation, will provide clues as to how a new regime may be constituted.

One of the fundamental shifts in the understanding of technology over the last 30 years has been the acknowledgement that technology is not merely the production of discrete 'things' but is in fact a 'process' embedded in socio-cultural, economic and institutional norms and practices through which discrete 'things' may or may not be developed. However, despite the emergence of the field of science and technology studies in the 1970s and a plethora of anthropological work examining local knowledge-systems and their meeting with modernization processes, the view of technology-development as an embedded process has not managed to infiltrate the mainstream technology-development regime in sanitation. In Norway, for example, civil engineering educational programmes can exist side-by-side with society, technology and culture studies (e.g. at NTNU), but with not one course in the civil-engineering programme on social aspects of technology. At UMB, the social study of science and technology is conspicuously missing.

The lack of reflection over how science and technology relates to society puts conventional sanitation regimes at a disadvantage in understanding how local knowledge can, in fact, become an integral part of technology development, particularly in the South. In the current sanitation-regime, knowledge owned and practiced by scientists and government engineers is privileged over other types of knowledge (experience-based and socially and culturally embedded). In Pakistan, sanitation solutions are based on technologies developed by 'credible knowers,' (i.e. government engineers) and then transferred to local populations. If there are problems in the acceptance or use of such technologies, this is considered mainly the fault of the villagers, whose cultural practices hinder their learning of the 'correct' way to behave and use the new technology. While there have certainly been attempts to consider local preferences in technology development, the impact remains limited. As long as the mode of participation remains inherently consultative, and the view of technology as created by the 'knowers',(i.e. the university) and disseminated to 'users' (i.e. villagers) sanitation technology will remain firmly within a 'technology transfer' paradigm, with local knowledge valued only as an input in a process controlled by others.

There are, however, alternate views of knowledge and participation which have grown out of a mix of anthropological, feminist, development and participatory research-literature. Particularly influential has been Haraway's (1999) view of knowledge, where she rejects the myth of the objectivity of knowledge through her claim that all knowledge is situated and partial, embedded in social

7 For example Reij, Chris and Ann Waters-Bayer (2001)
8 See for example Lars Otto Næss (2005), Eriksen et al (2007).

position, place and time. *The idea of knowledge being both situated and partial implies that no one type of knowledge is able to supply a complete picture of a situation or condition, and must be complemented by other types of knowledge to offer a better picture of the world. Thus privileging one type of knowledge, like scientific knowledge, and excluding knowledge produced in other ways, would, in fact, prevent better accounts of the world (Fortmann 2008).* With such a view of the embeddedness of knowledge creation, the interaction of several types of knowledge throughout a process of technology-development becomes a prerequisite to creating sustainable solutions. Each 'knower' takes to the table his or her unique perspective and experience, whether it be generalized or localized. Participation is thus perhaps no longer the most useful term to describe this relationship. *Fortmann's (2008) concept of 'interdependent science' may offer a better way forward in understanding how conventional science and citizen science might interact.* For this to be possible, issues of unequal power in terms of resources, framing and with credible knowledge at different points in the process have to be addressed. In Pakistan, the way in which researchers and sanitation implementers approach and interact with villagers in the initial assessment phase, when the problems are being defined, will be particularly telling. 'Who will be included in initial assessments?', 'What type of data will be collected and discussed', and, 'How it will be analyzed and acted upon?' are all questions which will likely require serious negotiation between a diverse set of actors to determine whose knowledge is most when relevant, as well as whose voice will be heard at what point during the process of technology development.

Power relations between scientists and citizens are not the only power relations to be considered. Technology development in both Norway and Pakistan is mitigated by a variety of actors both in the process of development and its use, and becoming thoroughly embedded in social, political and economic institutions along the way of development. In the following section, we will consider, in particular, the role of development aid in sanitation-technology development in Pakistan.

7. VIEWS ON DEVELOPMENT, EQUITY AND EQUALITY

A fourth dimension, which we find important, is the way in which different actors may or may not consider development, equity and equality in their understandings of technology-development processes for sustainable sanitation. In Norway, since sanitation systems already have near-complete coverage, equity issues are perhaps most relevant in terms of who should bear the burden (private vs. public) for a switch to more environmentally sound sanitation. In Pakistan, however, poor sanitation and the lack of sustainable solutions have a direct effect on rural development, and there are serious issues of unequal access to the limited sanitation technologies which might persist. Therefore, the ways in which actors relate to these issues will influence how they think about appropriate and sustainable solutions.

The development of conventional sanitation solutions on the basis of technical or engineering specifications and efficiency, combined with a focus on the provision of hardware and government contracts with private suppliers, has a propensity to define development in terms of infrastructural modernization, rather than those of health benefits, access or equity. Thus, capital intensive infrastructural investment takes precedence over low-cost solutions made with local materials, which although accessible to the poor, may be perceived as steps away from rather than towards development (Nawab and Nyborg 2009). In Pakistan, this view is quite common amongst both government technical officials and village elites, who view development as emulating the infrastructural achievements of the cities and the West (ibid).

If, however, development is viewed as improving the health and well-being of all[9], then equal access to sustainable sanitation becomes an important criterion. In Pakistan, this also entails the involvement of development organizations into the institutional landscape, each with their own set of interests, aims and interpretations of rural development, and, in turn, sanitation technology. International and national NGOs, supported by donor funding, influence both government policy-making and local implementation of sanitation programmes. Rather than reflecting one view of development, however, they represent a range of views, influenced by many of the professional and disciplinary splits that can be seen both within universities and between government ministries and departments.

Also, there can be a difference in the underlying approach to development of the NGO, in terms of whether it focuses on service delivery, or social and

9 As in, for example, the MDGs

political rights, and capacity building. The strength of these organizations is that they work directly with the communities, where they see the problems faced by local women, men and children first-hand. They are themselves, however, constrained in addressing these problems in several ways. They promote participatory development in principle, but nevertheless continue to deliver services and training based on a dissemination paradigm. This is particularly true in terms of sanitation technology. While they may have become better at interacting with communities on a more equal basis in some areas, they continue to come to the communities with finished technical solutions. Their staff carries on the scientific traditions from whence they came, for example, for water and sanitation programmes they recruit engineers, and for health and hygiene projects they recruit health staff. Both of these are trained in the design and delivery of technical solutions[10]. This can in fact result in different views of the nature of both knowledge and participation within the same organization.

In terms of equity and equality, the emphasis of development organizations on these issues opens for an alliance in a move towards improved access by the poor to sustainable sanitation solutions. In fact, in Pakistan, there has been quite a lot of NGO activity to support improving sanitation systems, and the introduction of CLTS has increased the focus on motivating local communities to address their sanitation problems such that they are low-cost and accessible to the poor. Despite a good degree of innovation, however, they have expressed the need to the development of more sustainable solutions, as their locally developed solutions are not able to fully address the environmental and institutional needs of these rapidly growing rural communities, particularly in schools and other public spaces.

Collaborating with the university in the development of more sustainable technologies is thus of great interest to these organizations. The nature of this collaboration could take two distinct pathways, depending on the way views of knowledge and technology coincide with views of equity, equality and the nature of development. In one scenario, where equity is defined as equal access to improved technology and the organization has a focus on service delivery, improved sanitation could merely involve the transfer of finished technology having a certain amount of local involvement in construction and testing. However, in another scenario where the development organization is more concerned with equality of voice and equity in participation, technology development could be seen as a process through which members of the community engage with scientists to develop a new, appropriate technology on a more equal basis. *It is, of course, the second scenario towards which the sustainable sanitation programme in Pakistan is trying to move.*

8. RE-DEFINING ROLES WITHIN A NEW SUSTAINABLE TECHNOLOGY REGIME

The previous sections explored sets of issues which have been shown to be important when considering how the different actors working in sanitation technology relate to one another in the practice of technology development. It has been both a reflection of what has happened so far in the process, as well as a refection over what may be found important to consider in the programme as it develops further. Returning to the idea of the creation of a new technology regime, or at least to what Kemp, et. al., (1998) term niche formation, we can then pose the question, 'How does one successfully form a niche, and what does one have to be aware of in order to ensure that the process is not co-opted? Both Smith et al., (2005) and Kemp et al. (1998) cite several conditions which are necessary to ensure that transitions to new technology regimes are successful. Kemp et al, for example, warn against the inclusion of actors with vested interests in competing technologies, since they may, in fact, slow down or even stop the niche from developing (p.191). In our case, it is not possible to completely close out competing actors, as we will meet many actors, particularly practitioners, who still lie firmly within conventional engineering, health, or service delivery traditions. We can, however, being aware of the particular issues discussed above, develop strategies on how to promote a better understanding of sustainable sanitation amongst conventional actors.

Smith's discussion of the 'purposive transitions' of regimes goes further by identifying three arenas where attention to power and agency particularly matters: the ways in which membership networks are formed, how resources are distributed amongst these members, and the degree to which visions and expectations are shared. All three aspects are

10 As described by NGO workshop participants themselves

important, and have been touched upon in various ways in our analysis above. We would, however, like to examine more closely the implications of the third arena, shared visions and expectations, on the development of a new technology regime. As Smith et al., State, 'different core members will have different ideas and shared narratives bearing on regime-development and technology appraisal'. This is also clear in our case, as we have seen above how different actors had different understandings of and approaches to ideas of knowledge, participation, technology, development and equality. In forming a new regime, the ability to drive forth, amongst a diverse set of actors, a common vision and understanding of sustainable sanitation and all of its complexity is a key-factor for the ability to develop and sustain a new technology regime. This task is not of 'control', but of having 'legitimate authority to push change through, or, the resources available to build consent, to raise informed dissent, or even to block change' (2005:1508). Who should take the lead in such an endeavour? We have already discussed the limitations of private industry in leading environmentally friendly technology development for the poor. Public policy-makers as facilitators has also been suggested, 'to ensure that the processes of co-evolution of technology supply and demand lead to desirable outcomes' (Kemp et al., 1998:191). While this could be a possibility in the future, the government sector in Pakistan currently remains too sectorally focused and embedded in competing political interests so much so that it may not be able to live up to such a challenge in the short-term (Nawab and Nyborg, 2009).

9. CONCLUSION

In our case, it is the university sector that has taken upon the role of both guiding and managing a new technology regime in sustainable sanitation. As we discussed earlier, however, it is a group of particular actors, with particular interests and backgrounds, at the universities involved that have taken this initiative. Also, while the university sector can certainly suffer from lack of funds and capacity, both in the North and the South, they have nevertheless several important attributes that could support their ability to manage a new regime in sustainable sanitation since:

- As a public institution, it is not excused as private firms might be, from accountability to public policy i.e. poverty goals, etc.(Leach, Scoones and Wynne 2005)
- Its business is not only research, but education and training as well (unlike NGOs, private business and government). Therefore, lessons learned from research feed directly back into education and training and visa versa.
- It can 'open-up' the field, and offer comprehensive analyses of both research processes and outcomes, and address broader issues of complexity and interdisciplinarity, but still make sense of the 'messy' data.
- It can respond to the need for competence building in the art of reflective thinking and practice, as well as meta-thinking.
- Since universities are permanent institutions, they will continue to have a mandate for education and research in the long run.

While in this case the university may be an appropriate manager for developing a new technology regime in sustainable sanitation, there may be other institutions more adept in other fields of technology or development. Nevertheless, there may be an untapped potential in using universities as hubs of knowledge networks, innovation and social change, both in the North and South. This has been recognized by UNESCO, who has recently published 'Higher Education: New Challenges and Emerging Roles for Human and Social Development, the third volume of a series specifically devoted to examining the social commitment of universities (GUNI 2008). There are also a number of innovative grass-roots initiatives, such as Earth University in Costa Rica, and Brighton University, UK, who foster close interaction with local communities as an integral part of their education and research programmes. In our case of sustainable sanitation in Pakistan, we see the emergence of a new technology regime as an opportunity to forge new alliances between the public and the private, citizens and government, which, if followed closely, could contribute to new and better pathways towards sustainable development in rural Pakistan.

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THE WATER WARS

*Khwaja Yaldram**

ABSTRACT

Land, water and air are the three basic components of the Biosphere and most environmental issues stem from the use or mis-use of these three. Water is particularly important because it is needed for life to exist. Many uses of water include agricultural, industrial, household, recreational and environmental. It is important to remember that only 2.5% of water on Earth is fresh water, and over two-thirds of this is frozen in glaciers and polar ice-caps.

Water-demand already exceeds the supply in many parts of the world, and many more areas are expected to experience this imbalance in the near future. Climate-change will have significant impact on water-resources around the world, because of the close connection between climate and the hydrologic cycle. Due to the expanding human-population, competition for water is growing and many of the world's major aquifers are becoming depleted.

Demand for clean water, caused by surging population-growth, environment abuse and poor water-management is today becoming a source of friction amongst nations in many parts of the world. Add to this the changing pattern of glacier melting, due to global warming, and we have a sure recipe for disaster. More and more conflicts and rising tensions in the world over control of the existing fresh-water reserves are brewing up among nations than have been witnessed in the past. More than 50 countries in five continents might soon be caught up in serious water-disputes, unless they move quickly to establish agreements on how to share reservoirs, rivers, and underground water aquifers. The management of water-resources is therefore a strategic issue in several parts of the world, in which borders and the sharing of resources have to be dealt with together. In this article we discuss some major flash-points that have the potential of erupting into full-scale wars among nations.

1. INTRODUCTION

It is not easy to pin-point which of the triad of land, water and air that constitute the Biosphere is the most important. But one thing is certain that man has always been dependent on water, not only for his life, but also for his food. Habitation grew up around springs and rivers, and dwindled as these became insufficient.

There are four main points that come to mind when one talks about global water-issues. These are:

Water Sanitation: In poor and developing countries, the main issue is the provision of clean drinking water to the masses. In far-flung and remote areas, villages and slums that have come to be associated with big cities, the inhabitants are deprived of the basic city-services like sewage-treatment and delivery of water through pipes. It is estimated that about 2.6 billion people lack these basic facilities, leading to about 5 million deaths per year.

Access to Clean Drinking Water: Even if there is enough drinking water in a certain area, the access to it may be difficult because of the nature of the terrain, lack of infrastructure and poverty.

Management of Resources: Managing the already available scarce water-resources and distributing it equitably among various groups, and vying for access to it may be a difficult task that has to be tackled politically at the national-level.

Scarcity of Water: The changing climate scenario is already leading to erratic weather patterns, resulting in drying up of traditional water sources. This has not only affected agriculture, it has put extra strain on the inhabitants for acquiring clean drinking water for their survival.

Climate-change, together with surging population-growth, compounded with poor water- management, is in fact becoming a source of friction amongst nations in many parts of the world. "Just as war over fire sparked conflict among early prehistoric tribes, wars over water may result from current tensions over resources in the next few years", says a report by the consultancy Pricewaterhouse Coopers (2009). A figure released by the United Nations (Development Report, 2003 and 2006) suggests that there are around 300 potential conflicts over water that are brewing up around the world and can even lead to major wars between Nations. As the demand for water increases, Nations are fighting over transboundary fresh-water reserves. More than 50 countries in five continents might soon be caught up in water disputes unless they move quickly to establish agreements on how to share reservoirs, rivers, and underground water acquifers.

- In Southern Asia, the biggest problem is the India-Pakistan dispute over the Indus waters, while in Central Asia "there are high risks of conflict"

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between Uzbekistan, Kazakhstan, Kyrgyzstan and Tajikistan over the Amu Daria and Syr Daria rivers and the already depleted Aral Sea (Ludqvist J. and Gleick P.H., 2000).

- In Africa, the Chobe, a tributary of the Zambesi, has become a cause of tension between Botswana, Mozambique, Zambia and Zimbabwe, while there have been border incidents between Mauritania and Senegal over control of the Senegal River.

- The Near and Middle East are the zones where there is the greatest threat. Two-thirds of the water consumed in Israel comes from the occupied territories, while nearly half of the Israeli water-installations are located in areas that were not part of its pre-1967 configuration. Friction between Lebanon and Israel rose sharply after the Jewish state accused its Northern neighbour of seeking to divert water from a river that feeds the Sea of Galilee, Israel's prime source of fresh water.

- Other big flare-points in the region are Turkey's plan to build dams to store the waters of the Tigris and Euphrates rivers, a scheme that is strongly opposed by Syria and Iraq; the Iraq-Iran row over the Shatt al-Arab waterway; and disputes over the use of water from the Nile, embroiling Egypt, Sudan and Ethiopia.

The forces behind such disputes are clear, according to the World Health Organisation (WHO), which pin-points fast-growing population in poorer countries and water-resources that are often squandered or polluted. "Around one-sixth of the 6.1 billion people in the world lack access to improved sources of water, while 40 per cent are without access to improved sanitation services," it says. Each year, 3.4 million people, mostly children, die from water-related diseases.

2. INADEQUACY OF INTERNATIONAL LAW

There is no well-defined international law on the sharing of water-courses, rivers or cross-border aquifers. Water cannot be owned, but the methods by which an individual, a group, a legal entity or a nation can store, transfer and regulate the flow of water, makes this person “in control”. Governments, organisations and individuals reach bilateral agreements, using a mixture of customary use, local and traditional laws, and the established right of use over a period of time not specified. Such a mixture is often contradictory and in itself a cause of conflict. Ancient history contains many examples of civilizations that gave special attention to the storage and provision of clean water for its citizens, e.g. Rome and Baghdad.

Not many agreements have been reached between Nations on how the water should be shared. The agreements that have been reached are most often seen as unjust, as the upstream countries with the hands on the tap can dictate their terms and believe that they should control the flow of the rivers, taking what they like, if they can get away with it. This is true of countries like Turkey and India. Downstream countries, if they are more advanced and militarily stronger, have always challenged this assumption, like Egypt and Israel. It is a recipe for confrontation. The non-clarity of international law is a matter of great concern. In case neighbouring countries seek intervention of international bodies, like the UN international law commission or the International Court of Justice, there are very few precedents for these bodies to go by and not many countries have gone to these bodies as yet. The position may change in the future, as quarrels amongst nations come to a boiling point.

Only the World Bank (Barrett S., 1994) has set a precedent of loaning money, conditional upon the agreement of parties involved on coming to an understanding, on sharing the benefits of the dam between riparian nations. Independent studies are commissioned to alter designs and modify plans, in order to minimise the harm that the project might inflict on neighbouring people. This only works when nations approach the World Bank for a loan to finance a water scheme - like in North of Syria and South of Turkey in the 1950's and Pakistan and India in the 1960’s. But, as history has shown, nations that did not go to the World Bank to finance their water-schemes had no ombudsman or a neutral observer to arbitrate between them and their neighbours. There was - and there still is - no provision in international law to stop them imposing their will on weaker or smaller neighbours, uprooting ethnic minorities by force or by ending their way of life and even having far-reaching and lasting devastating effect on the environment, all because they carried out their ambitious water-scheme, away from world-supervision without any proper studies, while mankind helplessly looked on.

We now take a brief look at some of the major potential flash-points regarding the use of water-resources.

3. THE SINO-INDIAN WATER DIVIDE

The rapid industrial development of two of the most rapidly growing economies of the world, China and India, has given rise to a middle class in both the countries. The demands of this middle class, together with the spread of irrigated farming and water-intensive industries, has led to a severe struggle for more water (Juha I.U. et al., 2002, Meredith G. et al., 2002, Gleick P.H., 1993). Even though India has more arable land than China – 160.5 million hectares, compared to 137.1 million hectares – Tibet is the source of most major Indian rivers. The Tibetan plateau's vast glaciers, huge underground springs and high altitude make Tibet the world's largest fresh-water repository after the polar ice-caps. Indeed, all of Asia's major rivers, except the Ganges, originate in the Tibetan plateau. Even the Ganges' two main tributaries flow in from Tibet.

China is pursuing major inter-basin and inter-river water-transfer projects on the Tibetan plateau, which threatens to diminish international-river flows into India and other co-riparian states (Li Ling, 2005). China has been damming most international rivers flowing out of Tibet, whose fragile ecosystem is already threatened by global warming. The only rivers on which no hydro-engineering works have been undertaken so far are the Indus, whose basin falls mostly in India and Pakistan, and the Salween, which flows into Burma and Thailand. Local authorities in Yunnan province, however, are considering damming the Salween in the quake-prone upstream region.

India's government has been pressing China for transparency, greater hydrological data-sharing, and a commitment not to redirect the natural flow of any river or diminish cross-border water flows. But even a joint expert-level mechanism – set up in 2007 – merely for "interaction and cooperation" on hydrological data – has proven of little value (Chellaney B., 2009; Stobdan P., 2009).

The most ambitious-idea China is now contemplating is the northward re-routing of the Brahmaputra river, known as Yarlung Tsangpo to Tibetans, but which China has renamed Yaluzangbu. It is the world's highest river, and also one of the fastest-flowing. Diversion of the Brahmaputra's water to the parched Yellow river is an idea that China does not discuss in public, because the project implies environmental devastation of India's north-eastern plains and eastern Bangladesh, and would thus be akin to a declaration of a "water war" on India and Bangladesh.

Nevertheless, an officially blessed book published in 2005 (Li Ling) openly championed the northward re-routing of the Brahmaputra. The issue now is not whether China will re-route the Brahmaputra, but when. Once authorities complete their feasibility studies and the diversion scheme begins, the project will be presented as a fait accompli . China already has identified the bend where the Brahmaputra forms the world's longest and deepest canyon – just before entering India – as the diversion point.

China's hydro-engineering projects and plans are a reminder that Tibet is at the heart of the India-China divide. Tibet ceased to be a political buffer when China annexed it nearly six decades ago. But Tibet can still become a political bridge between China and India. *For that to happen, water has to become a source of cooperation, not conflict.*

4. TURKEY AND ITS NEIGHBOURS

Turkey, Syria and Iraq are in confrontation regarding the waters of Tigris and Euphrates. This historic and geostrategic conflict sheds new light on the interest which the Occident has today in this cradle of the ancient Ottoman Empire. Turkey controls the supply of water to its two neighbours.

In 1990, Turkey stopped the flow of the Euphrates, ostensibly to fill up the large lake in front of the newly constructed Ataturk dam (Gleick P.H., 1993). In fact, this decision had hidden political connotations. The aim was to show Syria what could happen if the then President Hafez-al-Asad continued his support for Kurdish rebels in South-East Anatolia. The only problem was that this also brought severe water-shortage in Iraq. Two sworn enemies forgot their old antagonism to form a common front against Turkey. Faced with this unforeseen development, Turkey allowed the river to flow again after three weeks of stoppage.

Trouble between Turkey and Syria over water can not be ruled out. So far, Turkey has completed only about half of the projected 22 dams and reservoirs on the Euphrates to reclaim 1.7 Mhectare of land. When the project is completed, the quantity and quality of water-flow to Syria will be reduced by an estimated 40 per cent of its 1980 flow (which was 7,000 bn gallons of water). Turkey says the water will eventually return back to the river after watering its fields, but the water will be much saltier by then, the Syrians say. After the projects on the Euphrates are complete, the Turks intend to harness the Tigris. That will have a direct

effect on Iraq. This could again force Syria and Iraq into an alliance against Turkey - though they almost went to war in 1975, when Syria built the Thawrah dam. President Suleyman Demirel summed up the intransigent attitude of the Turks: `Neither Syria nor Iraq can lay claim to Turkey's rivers, any more than Ankara could claim their oil . . . We have a right to do anything we like. The water resources are Turkey's, the oil resources are theirs. We don't say we share the oil resources, and they cannot say they share our water resources.'

5. THE NILE BASIN

Egypt is as ready as any other country to use force to protect its vital water resources. It is worried about dams that might be built in the Ethiopian highlands, which will affect the flow of the Nile, and about grandiose plans for a canal that could tap the sources of that great river in central Africa (Gleick P.H., 1990 and 1991).

The Blue Nile with its source in Ethiopia contributes about 85 per cent of the annual flow that reaches Egypt. In November 1989, the Ethiopian ambassador was summoned to the Foreign Office in Cairo to provide an explanation on the presence of Israeli hydrologists and surveyors studying the areas on the Blue Nile, with the possibility of building a number of dams to store 51 billion cubic meter. He was left in no doubt about Egypt's stern response. On the same day Egyptian members of Parliament lined up one speaker after the other saying they would back the government in taking military action in Ethiopia.

Egypt is equally worried about Sudan. Cairo blames extremists across the border for the wave of terrorist attacks that have halved its tourist trade. Egypt may seek an excuse to intervene in Sudan: ‘any `unauthorised' interference with the flow of the Nile would be an ideal pretext'.

A more immediate danger to the Nile basin and the environmental welfare of the valley is posed, in the eyes of the Egyptians, by Colonel Muammar Gaddafi's `Great Man-Made River' in neighbouring Libya. A huge pipeline carries water from 120 wells, tapping the Kufrah aquifer in the sparsely populated south of the country, to the arid, densely inhabited coast in the North.

In addition to the huge cost of the project (the final cost could exceed $32 billion, the cost of a dozen desalination plants - while the water, which could be mined just once, is unlikely to last more than 15 years). According to some hydrologists, the rapid depletion of this aquifer could lead to seepage from the Nile. Meanwhile, some geologists fear a change in the sub layers or rocks under the desert as a result of speedy pumping of the water. There are reasons to suspect that in the event of geologists presenting the proof that mining water by the Libyans is having a direct effect on the Nile bed, the Egyptian army may, directly or indirectly, intervene to put an end to the project.

6. THE MIDDLE EAST

In the Middle East, water plays a strategic role that is often overlooked. Occupation of Trans-Jordan by Israel can only be understood by recognizing the fact that this provides Israel an aquifer that allows the survival of its colonies and supplies a quarter of the water of the country. The same is true of the Golan plateau, a rich source of water for the region. The survival of the state of Israel depends on the control of these waters (Bullock J. et al., 1993; Hussain A. A. 2002; Munther J. H., 2002; Darwish A., 1994).

The short, muddy Jordan flows through the most hotly disputed territory of all, and is bordered by countries that have history of using force to gain their ends. The annual flow in the whole area controlled by Israel, since 1967, is just under 500 cubic metre per person. The 1991 figures indicate that Israelis use 375 cubic meter apiece and Palestinians 180 cubic meter apiece (assuming 5 million Israeli citizens and settlers and 2 million Palestinians and Golan heights residents). Looking at birth rates, the population could double some time between 2010 & 2020. The flow of the river Jordan cannot be improved either. Even less than 15 months after some unusual heavy rain in 1991 that caused flood, water shortages were endemic in Amman despite ongoing water-rationing.

A study, in 1990, by Dan Zaslavsky, Israel's national water commissioner, found that 10 consecutive years of above-average rainfall are needed to replenish the heavily overtaxed underground resources. In the five years since, it only happened in 1991, and partly early 1993.

In the Jordan basin, it is a zero-sum game. If Israel obtains more, Jordan will receive less, and vice versa. One of the bitter sources of conflict, which Arabs never fail to mention, is that while the Jordanian average-use is 80 litres per day, Israelis use 300 litres of the same river and the same aquifers! If you go to the West Bank, an area of 5,890 square kilometres occupied by

Israel, the differences are great and both sides' belief, in their right to water, makes their ideological differences over land, and religious interpretation, etc., seem moderate.

The presence of some 100 Israeli settlements (populated by over 100,000 Jews) on land occupied in the West Bank in 1967, is a thorny issue. Water is very much at the heart of the conflict. The 100,000 settlers are given (100 million cubic meter) almost as much water as the one million Palestinians who live in the region (given 137 million cubic meter). This is a source of bitterness and a real obstacle for peace. All Israeli settlements have water, lawns and swimming pools, while dozens of Palestinian villages are with inadequate water-supplies and suffer from water-shortage.

Figures published by Palestine Hydrology Group (PHG) indicate that Israelis take 80 per cent of the annual flow of 615 million cubic metre of mountain aquifers that should be Palestinian water. This means that one quarter of water used by Israelis annually is seen by Arabs as `stolen water', which they want back. The PHG also accuses the Israeli occupation authority of forbidding Palestinian civilians from drilling new wells or deepening existing wells since 1967, while Israeli wells are six times deeper causing Palestinian wells to be totally dry for more than 5 months a year. As a result, the PHG argue that irrigated Palestinian farmland declined from 27 per cent of all agricultural land in 1967 to a meagre 4 per cent in 1990.

The Israeli counter-argument is based on their military superiority and a status quo that won't help peace, as well as the lack of provision on water use in international law. Before the six day war, Israel controlled less than 10 kilometres or 6.25 miles only of the Yarmuk River, now it has a de-facto control that stops Syria and Jordan from diverting the headwaters if they chose to. A report prepared by the Israeli Military warned the then Prime Minister, Yitzhak Rabin, against pulling out of the Golan Heights. Two reasons were given; first water security and second the army intelligence-gathering operation.

Even if some generous compensations are to be paid to the settlers to hand back settlements to the Palestinians, no electable Israeli government is likely to let go of control of water-supplies, unless alternative source is found by some miracle. In 1989 - just less than two years before the Arabs and Israelis met in Madrid - an official publication issued by Israel's Ministry of Agriculture, which was then headed by the hardliner Rafael Eitan, concluded that full control of the mountain aquifers are our vital necessity : "It is hard to conceive of any political solution consistent with Israel's survival that does not involve complete and continued Israeli control of the water-system." General Eitan later argued that, overriding any religious and even security grounds for keeping the West Bank is Israel's need to stay because it must have the water.

7. THE INDUS BASIN

The waters of the Indus basin begin in the Himalayan mountains of Indian-held Kashmir. They flow from the hills through the arid states of Punjab and Sindh, converging in Pakistan and emptying into the Arabian Sea located South of Karachi. Where once there was only a narrow strip of irrigated land along these rivers, developments over the last century have created a large network of canals and storage facilities that provide water for more than 26 million acres - the largest irrigated area of any one river-system in the world.

The partition of the Indian sub-continent created a conflict over the plentiful waters of the Indus basin (Gulhati N., 1973; Michel A., 1967; Undala Z.A., 2002). The newly formed states were at odds over how to share and manage what was essentially a cohesive and unitary network of irrigation. Furthermore, the geography of partition was such that the source rivers of the Indus basin were in India. Pakistan felt its livelihood threatened by the prospect of Indian control over the tributaries that fed water into the Pakistani portion of the basin. While India certainly had its own ambitions for the profitable development of the basin, Pakistan felt acutely threatened by a conflict over the main source of water for its cultivable land.

On April 1, 1948, India had stemmed the flow of tributaries to Pakistan and discontinued water to the Dipalpur Canal and main branches of Upper Bari Doab Canal. Pakistan wanted an equitable allocation of the flow of Indus River and its tributaries between India and Pakistan. Negotiations had started from 1951, and the treaty was signed in 1960 that gave Pakistan the right to receive unrestricted flow of the western rivers, and it was obligatory on the part of India to allow the flow of water unimpeded, with minor exceptions. It was provided in the treaty that in case of a dispute, the World Bank would appoint a 'neutral expert', whose decision would be final.

The matters did not end there. Unilaterally, India embarked upon projects on the rivers that had been

allocated to Pakistan. These included the Kishanganga, Baglihar and Wullar Projects.

The proposed Kishanganga Hydroelectric Project is located in Indian-occupied Kashmir on River Neelum. Under the project, the water is to be diverted through a 21-kilometre tunnel to produce 330 MW of power. The water, after production of power, will join the Wullar Lake. Pakistan raised objections to the diversion of flow and the design of the project.

The Baglihar Hydro-electric Plant was constructed by India on River Chenab. India provided information about the plant in May 1992, under the relevant provision of the Indus Waters Treaty. Pakistan raised objections to the design of the plant. Since the Indus Commission could not resolve the differences, Pakistan referred the dispute to the World Bank, which appointed a neutral expert in May 2005. The expert called the two parties to Paris in June 2005 and formulated modalities in the form of a protocol. The expert gave his final determination on February 12, 2007. The decision of the neutral expert upheld Pakistan's contention that the design by India is not in conformity with the Treaty.

In February 1985, Pakistan learnt that India was planning the Tulbul Navigation Project at Wullar Lake on River Jhelum. In March 1985, Pakistan conveyed its concerns to India and sought details. The Indian position is that it is a navigational structure, rather than a storage facility. It also believes that Pakistan's downstream uses are not prejudiced by the project. Pakistan's point of view is that the structure is essentially a barrage, which will convert the natural Wullar Lake into a man-made storage.

Recently, the officials of General Headquarters (GHQ), National Engineering Services of Pakistan (NESPAK), Water and Power Development Authority (WAPDA), Irrigation Department of Punjab and Pakistan Commission of Indus Water met to discuss the adverse impacts on Pakistan's water and defence interests of the ongoing construction of the three dams in Ladakh region on River Indus (Jamil M., 2009). India is constructing large dams on River Indus, which include Nimoo Bazgo, with a height of 57-metre; Dumkhar of 42 metres height; and Chutak Dam of 59 metres height, to basically generate hydropower. The huge quantum of water to be stored in the three dams could play havoc in the Northern Areas of Pakistan, if the reservoirs either collapse, for any reason, or New Delhi, intentionally or unintentionally, releases the huge quantity of water. It was decided that the matter should be taken up at government-level with India, and if the dispute remains unresolved by both the governments, then a neutral expert should be moved. Pakistan had suffered a loss exceeding five billion rupees in paddy crop production only due to water shortage after India stopped Chenab water to fill its Baglihar Dam during the month of September 2008.

India is violating Indus Water Treaty, and the objective seems to be India's attempt to dry up Pakistan. India's think-tanks have been working on river-diversion plans, with a view to creating acute water-shortage in Pakistan, which could lead to acute shortage of wheat and other crops and also result in inter-provincial conflicts over distribution of water. But those who think that India could make Pakistan a desert, through river-diversion plans, do not understand that although there is no war on Kashmir, there could be a "water-war" between two nuclear states, which could be disastrous for both the countries.

8. OTHER TROUBLE SPOTS

Other instances of conflicts based on sharing of water resources are quoted below:

- There exists strong tensions around Amon-Daria and Syr-Daria between Uzbekistan, Tajikistan, Kyrgystan and Kazakistan.
- Border incidents between Mauritania and Senegal have multiplied for the control of the river Senegal.
- To a lesser extent, there is a problem between Mexico and United States, regarding the waters of the Colorado, a ghost of a river because of over exploitation and pollution (Gleick P.H., 1988 and 1990).

9. CONCLUSIONS

Water has always played an important role in the growth and development of civilization and thus the use of water has a geopolitical dimension. Water moves from upstream to downstream users, and withdrawals and type of use in one place may affect the quantity or quality of supplies downstream. There are also historical, cultural, economic and social aspects of water-use. To some, water is a gift from God, and should not be priced, while others, such as the World Bank, have pushed for full marginal cost pricing of water.

- Water scarcity is a function of supply and demand. The demand is increasing at an alarming rate in some regions, through population-growth and increasing per-capita use. In many water-scarce countries, there is no obvious and inexpensive way to increase the water supply, and tensions among different water-users are likely to result. In other countries, improvements in water- efficiency, moving away from water-intensive crops, or importing water from nearby countries may offer reasonable solutions.

- The lack of a suitable legal framework for resolving international water-resource disputes presents another problem. *Sovereignty over international rivers generally invokes one of four doctrines:* (i) absolute territorial sovereignty, which implies that riparian states may use water resources in any way they please, even to the detriment of other nations; (ii) absolute territorial integrity, which suggests that riparian use of a river should not negatively affect downstream riparians; (iii) limited territorial sovereignty, which invokes a combination of the two within a framework of equitable use by all parties; and (iv) community of co-riparian states, which promotes integrated management of river basins.

- There is little question that water scarcity will be a problem in some regions of the world in the future. Global warming is likely to alter rainfall patterns in many regions, and long-term planning for water-supply must take this into consideration. There is also little question that water will cost more, as it becomes increasingly scarce. This will necessitate improvements in water-use efficiency and possibly the restructuring of economies away from water-intensive sectors.

- Is there likely to be violent conflict over water in the future? Past experience suggests that this is unlikely. However, many claim that the probability of conflict is increasing. The basis for most projections for future conflicts is that, with the growth of demand, the decline in freshwater availability (through groundwater mining and pollution), and the adverse health-effects from poor water-quality and scarcity will result in violence and water wars. Yet fighting over water makes very little sense, economically or politically. Most certainly, water-scarcity will be at the forefront of the international agenda for decades to come. In some cases, water may even be a contributing factor in international conflict. A member of the Israeli negotiating team to the Middle East Peace Process, Hydrology Professor, Uri Shamir, once noted: 'If there is a political will for peace, water will not be a hindrance. If you want reasons to fight, water will give you ample opportunities'.

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LOW-COST MUNICIPAL WASTEWATER TREATMENT OPTIONS FOR USE IN PAKISTAN – A REVIEW

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ABSTRACT

Pakistan has now essentially exhausted its available water-resources and is on the verge of becoming a water-deficit country. The per-capita water availability has dropped from 5,600 m^3 to 1,000 m^3. The public water-requirement has risen manifolds, as population is increasing, industry is growing and we are bringing more area under cultivation to meet the increasing demand for agriculture-products. The quality of groundwater and surface-water is low and is further deteriorating because of unchecked disposal of untreated municipal and industrial wastewater and excessive use of fertilizers and insecticides. This paper presents an overview of various low-cost treatment options for the treatment of municipal wastewater-treatment.

Keywords: *Biological Treatment, Low-cost Treatment, Municipal Wastewater, Water Availability*

1. INTRODUCTION

Pakistan's current population of 170 million is expected to grow up to about 221 million by the year 2025. This increase in population will have a direct impact on the water-sector for meeting the domestic, industrial and agricultural needs. Pakistan has now essentially exhausted its available water-resources and is on the verge of becoming a water-deficit country. The per-capita water availability has dropped from 5,600 m^3 to 1,000 m^3. The quality of groundwater and surface-water is low and is further deteriorating because of unchecked disposal of untreated municipal and industrial wastewater and excessive use of fertilizers and insecticides. Water quality monitoring and information management is lacking, even though it's crucial to any water-quality improvement programme.

Results from various investigations and surveys indicate that water-pollution has significantly increased in Pakistan. The pollution-levels are higher particularly in and around the big cities of the country where clusters of industries have been established. The water-quality deterioration problems are caused by the discharge of hazardous industrial wastes, including persistent toxic synthetic organic chemicals, heavy metals, pesticides and municipal wastes and untreated sewage water into natural water-bodies. These substances mixed with water then cause widespread water-borne and water-washed diseases (Chandio and Abdullah, 1998).

According to Chandio and Abdullah (ibid), the public water-requirement has risen manifolds as a result of population increase, industrial growth and bringing more area under cultivation, to meet the increasing demand for agriculture-products. All the above factors forced the water-managers to explore the quality of existing freshwater- resources. It has been estimated that about 27% of world population does not have access to clean drinking water.

The conditions become more adverse in developing countries, where there is lack of resources and the water-protection schemes are given least priorities. A study by Zahid and Baig (1997) concluded that about 80% people living in the main cities of Pakistan lack access to really clean, potable water. The environmental profile of Pakistan indicates that about 40% of deaths are related to waterborne diseases that spread by water-pollution that is caused mainly due to the sewage and industrial wastewater contamination of drinking-water distribution systems.

Continuing urbanization, growing populations and increasing industrialization have increased water-consumption, correspondingly generating higher volumes of wastewater. Untreated wastewater and poor solid-waste management are threats to human health and natural environment. Regrettably, the public-and the private-sectors, in developing countries, including Pakistan, are not focusing on the wastewater-treatment practices at domestic and industrial level. Lack of interest even extends to controlling water-borne diseases, which causes severe environmental and health problems. Most of the wastewater is not treated and, with the expansion of urban settlements without wastewater-treatment facilities, it will continue to adversely impact the natural environment and public health. The worst impact is evident in areas that are close to industrial sites.

Saeed and Bahzad (2006), had reported that more than 28 m^3/sec wastewater was being disposed off into the River Ravi without any treatment from Lahore, the second largest city of Pakistan. The river pollution is frequently associated with the disposal of untreated effluents from municipal, industrial and agricultural wastes into the natural streams, which is always considered as an easy way to dispose off many kinds of effluents. The people's psychology is that the wastes are washed away and are not visible after dumping.

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A study (by Balfours, 1987) revealed that about 18 m^3/sec of wastewater from Lahore city was being disposed off into the River Ravi and it is estimated that wastewater flow would increase to 35m^3/sec by the year 2017. This wastewater is accompanied by a biochemical oxygen demand (BOD) of upto 240 mg/L.

It is difficult to propose conventional systems of wastewater-treatment to apply for the treatment of municipal wastewater in Pakistan, because there is no separate drainage system for domestic and industrial wastewater. All types of wastewater are moving towards to single drain. Therefore, there is a tremendous need to select a most economical treatment-system that should be able to treat municipal wastewater containing industrial wastewater as well. There are many options to use; natural biological, CEPT and AOP need so as to be tested to select one most appropriate and economical system. The problem with such kind of wastewater is variations in COD and BOD from 200 to 2000 mg/L. Sometimes, simple CEPT, direct treatment with hydrogen peroxide, hydrogen peroxide/UV and anaerobic treatment process may be required individually, or with combination, to overcome the high variation in COD in municipal wastewater stream. Separate installation of treatment-facility at each source may not be feasible to overcome this problem, at present status.

Over a billion people around the world lack access to safe drinking-water, when around 80% of all diseases are due to poor drinking-water quality in developing countries; this lead to 1.7 million deaths annually (UNDP, 1996). In Pakistan, water availability has already fallen from 5,000 m^3 per capita to 1,100 m^3 in 2005. According to government statistics, 88% of the districts (urban population) and 62% of rural residents have access to water supply. But, in fact, only 33% people has water supply at their homes and 67% rely on outdoor sources. The water-quality analysis report 2005-06 says: 55% samples were found with coliform contamination (IUCN, 2009). Accordingly, we present a Review of some low-cost options for water-treatments. Some of that more sophisticated ones are suitable only for use in the larger metropolitan cities.

2. LOW-COST TREATMENT OPTIONS FOR PAKISTAN

2.1 Sewage-treatment

Sewage-treatment, or domestic wastewater treatment, is the process of removing contaminants from wastewater and household sewage, both runoff (effluents) and domestic. It includes physical, chemical, and biological processes, to remove physical, chemical and biological contaminants. Its objective is to produce a waste-stream (or treated effluent) and a solid waste or sludge suitable for discharge or reuse back into the environment. This material is often inadvertently contaminated with many toxic organic and inorganic compounds (Nidal, 2008).

2.2 Process Overview

Sewage can be treated close to where it is generated (in septic tanks, bio-filters or aerobic treatment systems), or collected and transported via a network of pipes and pumping stations to a municipal treatment plant. Sewage collection and treatment is typically subject to local, state and federal regulations and standards.

Conventional sewage-treatment may involve three stages, called primary, secondary and tertiary treatment. Primary treatment consists of temporarily holding the sewage in a quiescent basin, where heavy solids can settle to the bottom while oil, grease and lighter solids float to the surface. The settled and floating materials are removed and the remaining liquid may be discharged or subjected to secondary treatment.

Secondary treatment removes dissolved and suspended biological matter. This treatment is typically performed by indigenous, water-borne micro-organisms in a managed habitat. The treatment may require a separation-process, to remove the micro-organisms from the treated water, prior to discharge or tertiary treatment.

Tertiary treatment is sometimes defined as anything more than primary and secondary treatment. Treated water is sometimes disinfected chemically or physically (for example, by lagoons and micro-filtration) prior to discharge into a stream, river, bay, lagoon or wetland, or it can be used for the irrigation of a golf course, green way or park. If it is sufficiently clean, it can also be used for groundwater recharge or agricultural purposes (Roland, 1997).

2.3 Pre-treatment

Pre-treatment removes materials that can easily be collected from the raw wastewater, before they damage or clog the pumps and skimmers of primary treatment clarifiers. Pre-treatment includes the

following steps:

2.3.1 Screening: The influent sewage-water is strained to remove all large objects carried in the sewage stream, such as rags, sticks, tampons, cans, fruit, etc. This is most commonly done with an automated mechanically raked bar screen, in modern plants serving large populations, whilst in smaller or less modern plants a manually cleaned screen may be used. The raking action of a mechanical bar screen is typically paced according to the accumulation on the bar screens and/or flow-rate. The solids are collected and later disposed off in a land-fill or incinerated (Hammer, 2004; Roland, 1997).

2.3.2 Grit removal: Pre-treatment may include a sand or grit channel or chamber (sometimes called a de-gritter) where the velocity of the incoming wastewater is carefully controlled to allow sand, grit and stones to settle, while keeping the majority of the suspended organic material in the water-column. Sometimes there is a sand washer (grit classifier), followed by a conveyor that transports the sand to a container for disposal. The contents from the sand-catcher may be fed into the incinerator in a sludge-processing plant, but in many cases, the sand and grit is sent to a land-fill.

2.3.3 Primary treatment: In the primary sedimentation stage, sewage flows through large tanks, commonly called "primary clarifiers" or "primary sedimentation tanks". The tanks are large enough so that the sludge can settle and floating material, such as grease and oils, can rise to the surface and be skimmed off. The main purpose of the primary sedimentation stage is to produce both a generally homogeneous liquid capable of being treated biologically and a sludge that can be separately treated or processed. Primary settling tanks are usually equipped with mechanically driven scrapers that continually drive the collected sludge towards a hopper in the base of the tank, from where it can be pumped to further sludge-treatment stages (Hammer, 2004; Roland, 1997).

2.3.4 Secondary treatment: Secondary treatment is designed to substantially degrade the biological content of the sewage, such as the ones derived from human waste, food waste, soaps and detergent. The majority of municipal plants treat the settled sewage-liquor, using aerobic biological processes. For this to be effective, the biota requires both oxygen and a substrate on which to live. There are a number of ways in which this is done. In all these methods, the bacteria and protozoa consume bio-degradable soluble organic contaminants (e.g. sugars, fats, organic short-chain carbon molecules, etc.) and bind much of the less soluble fractions into flock. On the basis of biomass present, secondary treatment systems are classified as:

- Fixed-film or;
- Suspended-growth.

Fixed-film or attached-growth system treatment process, including trickling filter and rotating biological contactors where the biomass grows on media and the sewage passes over its surface.

In suspended-growth systems, such as activated sludge, the biomass is well-mixed with the sewage and can be operated in a smaller space than fixed-film systems that treat the same amount of water. However, fixed-film systems are more able to cope with drastic changes in the amount of biological material and can provide higher removal-rates for organic material and suspended solids than suspended-growth systems.

Roughing filters are intended to treat particularly strong or variable organic loads, typically industrial, to allow them to then be treated by conventional secondary treatment-processes. Its characteristics include typically tall, circular filters, filled with open synthetic filter media to which wastewater is applied at a relatively high-rate. They are designed to allow high hydraulic loading and a high flow-through of air. On larger installations, air is forced through the media using blowers. The resultant wastewater is usually within the normal range for conventional treatment processes. The final step in the secondary treatment-stage is to settle out the biological floc or filter material and produce sewage water containing very low levels of organic material and suspended matter.

2.3.5 Up-flow anaerobic treatment reactor: Up-flow anaerobic treatment reactor has been successfully used to treat a variety of industrial as well as domestic wastewaters. It can briefly be described as a process in which substrate in water passes through sludge-bed containing biomass. This sludge is present in the form of granular or

flocculent form. Influent enters into the system from bottom of the reactor and leaves from upper side of the reactor. Uplift velocity of the influent is very critical to allow sufficient time to uptake the substrate through the biomass without uplifting the sludge-granules. This is the most attractive treatment-system due to its no-sludge excess sludge-production because substrate convert into biogas (Ghangrekar, 2005).

2.4 Bioreactors

2.4.1 Membrane bioreactors: Membrane bioreactors (MBR) combine activated sludge-treatment with a membrane liquid-solid separation process. The membrane component uses low-pressure micro-filtration or ultra-filtration membranes and eliminates the need for clarification and tertiary filtration. The membranes are typically immersed in the aeration tank (however, some applications utilize a separate membrane tank). One of the key benefits of a MBR system is that it effectively overcomes the limitations associated with poor settling of sludge in conventional activated system (CAS) processes. The technology permits bioreactor operation with considerably higher mixed-liquor suspended solids (MLSS) concentration than CAS systems, which are limited by sludge-settling. The process is typically operated at MLSS in the range of 8,000–12,000 mg/L, while CAS is operated in the range of 2,000–3,000 mg/L. The elevated biomass concentration in the MBR process allows for very effective removal of both soluble and particulate biodegradable materials at higher loading rates. Thus increased Sludge Retention Times (SRTs)—usually exceeding 15 days—ensure complete nitrification, even in extremely cold weather.

The cost of building and operating a MBR is usually higher than conventional wastewater-treatment, however, as the technology has become increasingly popular and has gained wider acceptance throughout the industry, the life-cycle costs have been steadily decreasing. The small footprint of MBR systems and the high-quality effluent produced, makes them particularly useful for water-reuse applications (Judd, 2006; Verstraete, 2005).

2.4.2 Rotating biological contactors: Rotating biological contactors (RBCs) are mechanical secondary-treatment systems, which are robust and capable of withstanding surges in organic load. RBCs were first installed in Germany in 1960 and have since been developed and refined into a reliable operating unit. The rotating disks support the growth of bacteria and micro-organisms present in the sewage, which breakdown and stabilize organic pollutants. To be successful, micro-organisms need both oxygen to live and food to grow. Oxygen is obtained from the atmosphere as the disks rotate. As the micro-organisms grow, they build up on the media until they are sloughed off due to shear forces provided by the rotating discs in the sewage. Effluent from the RBC is then passed through the final clarifiers, where the micro-organisms in suspension settle as sludge. The sludge is withdrawn from the clarifier for further treatment.

A functionally similar biological filtering system has become popular as part of home aquarium filtration and purification. The aquarium-water is drawn up out of the tank and then cascaded over a freely spinning corrugated fiber-mesh wheel, before passing through a media-filter and back into the aquarium. The spinning mesh wheel develops a biofilm coating of micro-organisms that feed on the suspended wastes in the aquarium water and are also exposed to the atmosphere as the wheel rotates. This is especially good for removing waste urea and ammonia urinated into the aquarium water by the fish and other animals (Leslie et al. 1998).

2.4.3 Lagooning: Lagooning provides settlement and further biological improvement through storage in large man-made ponds or lagoons. These lagoons are highly aerobic and colonization by native macrophytes, especially reeds, is often encouraged. Small filter-feeding invertebrates, such as Daphnia and species of Rotifer, greatly assist the treatment by removing fine particulates (Hammer, 2004).

2.4.4 Constructed wetlands: Constructed wetlands include engineered reed-beds and a range of similar methodologies, all of which provide a high degree of aerobic biological improvement and can often be used instead of secondary treatment for small communities. Constructed wetland is fed in at the inlet and moved in laminar regime through porous medium, until it reaches the outlet zone where it is collected before the outlet. During this flow-regime wastewater is in contact with aerobic, anoxic and

anaerobic zones. Rhizomes and plant roots release the oxygen and develop aerobic conditions. Constructed wetlands have long been used for domestic and municipal wastewater (Vymazal, 2009; Cooper et al., 1996; Brix et al., 1987).

2.4.5 Nutrient removal: Wastewater may contain high levels of the nutrients nitrogen and phosphorus. Excessive release of waste-water to the environment can lead to a build-up of nutrients, called eutrophication, which can in turn encourage the overgrowth of weeds, algae, and cyanobacteria (blue-green algae). This may cause an algal bloom, a rapid growth in the population of algae. The algae numbers are unsustainable and eventually most of them die. The decomposition of the algae, by bacteria, uses up so much of oxygen in the water that most or all of the animals die, which creates more organic matter for the bacteria to decompose. In addition to deoxygenatoin, some algal species produce toxins that contaminate drinking-water supplies. Different treatment-processes are required to remove nitrogen and phosphorus. Removal of nutrients has been studied for different reactors. Sequential-batch reactor, for biological nutrient removal from municipal wastewater, was found very effective in reducing BOD_5, TSS and ammonium nitrogen upto 98, 90 and 89 % at 12 hours cycle time. It consists of a sequencing operation, including the steps of "fill, react, settle, decant and idle" (Kargi and Uygur, 2003).

2.4.5.1 Nitrogen removal: The removal of nitrogen is effected through the biological oxidation of nitrogen from ammonia (nitrification) to nitrate, followed by denitrification the reduction of nitrate to nitrogen gas. Nitrogen gas is released to the atmosphere and thus removed from the water.

Nitrification itself is a two-step aerobic process, each step facilitated by a different type of bacteria. The oxidation of ammonia (NH_3) to nitrite (NO_2^-) is most often facilitated by Nitrosomonas sp. Nitrite oxidation to nitrate (NO_3^-), though traditionally believed to be facilitated by Nitrobacter sp., is now known to be facilitated in the environment almost exclusively by Nitrospira sp. (Verstraete, 2004).

Denitrification requires anoxic conditions to encourage the appropriate biological communities to form. It is facilitated by a wide diversity of bacteria. Sand filters, lagooning and reed-beds can all be used to reduce nitrogen, but the activated-sludge process, membrane-aerated biofilm reactor (MABR) (if designed well) can do the job most easily. Since denitrification is the reduction of nitrate to di-nitrogen gas, an electron-donor is needed. This can be, depending on the wastewater, organic matter (from faeces), sulfide, or an added donor, like methanol. Sometimes the conversion of toxic ammonia to nitrate alone is referred to as tertiary treatment (Terada et al., 2003).

2.4.5.2 Phosphorus removal: Phosphorus removal is important, as it is a limiting nutrient for algae growth in many fresh-water systems (for negative effects of algae, see Nutrient removal). It is also particularly important for water-reuse systems where high phosphorus concentrations may lead to fouling of downstream equipment, such as reverse osmosis (Landner, 1976).

Phosphorus can be removed biologically in a process called 'enhanced biological phosphorus-removal'. In this process, specific bacteria, called polyphosphate-accumulating organisms (PAOs), are selectively enriched and accumulated large quantities of phosphorus within their cells (up to 20% of their mass). When the biomass enriched in these bacteria is separated from the treated water, these biosolids have a high fertilizer value (Verstraete, 2004).

Phosphorus removal can also be achieved by chemical precipitation, usually with salts of iron (e.g. ferric chloride), aluminum (e.g. alum), or lime. This may lead to excessive sludge-productions, as hydroxides precipitates, and the added chemicals can be expensive. Chemical phosphorus-removal requires significantly smaller equipment-footprint than biological removal, is easier to operate and is often more reliable than biological phosphorus-removal. Once removed, phosphorus, in the form of a phosphate-rich sludge, may be stored in a land-fill or resold for use in fertilizer (Tchobanoglous et al., 2003).

2.5 Tertiary treatment

The purpose of tertiary treatment is to provide a final treatment stage, to raise the effluent-quality before it is discharged to the receiving environment (sea, river, lake, ground, etc.). More than one tertiary treatment-process may be used at any treatment plant. If disinfection is practiced, it is always the final process. It is also called "effluent polishing". It includes micron filtration, ozonation, reverse osmosis and UV treatment (IBWA, 1995).

2.5.1 Filtration: Sand filtration removes much of the residual suspended matter. Filtration over activated carbon removes residual toxins.

2.5.2 Disinfection: The purpose of disinfection in the treatment of wastewater is to substantially reduce the number of micro-organisms in the water to be discharged back into the environment. The effectiveness of disinfection depends on the quality of water being treated (e.g., cloudiness, pH, etc.), the type of disinfection being used, the disinfectant dosage (concentration and time), and other environmental variables. Cloudy water will be treated less successfully, since solid matter can shield organisms, especially from ultra-violet light or if contact-times are low. Generally, short contact-times, low doses and high flows all militate against effective disinfection. Common methods of disinfection include ozone, chlorine, or ultra-violet light. Chloramine, which is used for drinking water, is not used in wastewater-treatment because of its persistence. Chlorination remains the most common form of wastewater-disinfection in North America, due to its low cost and long-term history of effectiveness. One disadvantage is that chlorination of residual organic material can generate chlorinated-organic compounds that may be carcinogenic or harmful to the environment. Residual chlorine or chloramines may also be capable of chlorinating organic material in the natural aquatic environment. Further, because residual chlorine is toxic to aquatic species, the treated effluent must also be chemically dechlorinated, adding to the complexity and cost of treatment.

Ultra-violet (UV) light can be used instead of chlorine, iodine, or other chemicals. Because no chemicals are used, the treated water has no adverse effect on organisms that later consume it, as may be the case with other methods. UV radiation causes damage to the genetic structure of bacteria, viruses, and other pathogens, making them incapable of reproduction. The key-disadvantages of UV disinfection are the need for frequent lamp-maintenance and replacement, and the need for a highly treated effluent to ensure that the target micro-organisms are not shielded from the UV radiation (i.e., any solids present in the treated effluent may protect micro-organisms from the UV light). In the United Kingdom, light is becoming the most common means of disinfection, because of the concerns about the impacts of chlorine in chlorinating residual organics in the wastewater and in chlorinating organics in the receiving water (IBWA, 1995).

Ozone (O_3) is generated by passing oxygen (O_2) through a high-voltage potential, resulting in a third oxygen atom becoming attached and forming O_3. Ozone is very unstable and reactive and oxidizes most organic material it comes in contact with, thereby destroying many pathogenic micro-organisms. Ozone is considered to be safer than chlorine because, unlike chlorine, which has to be stored on-site (highly poisonous in the event of an accidental release), ozone is generated onsite as needed. Ozonation also produces fewer disinfection by-products than chlorination. A disadvantage of ozone disinfection is the high cost of the ozone-generation equipment and the requirements for special operators (Pillai, et al., 2009).

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