SOCIAL AND ECONOMIC BENEFITS OF WEATHER, CLIMATE AND WATER SERVICES

By

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1. Introduction

The environmental problem facing us seems huge that our attempt to bury our heads under the duvet would not work and for secure and sustainable living on our Planet we urgently need to change the way we live to ensure a future for our children. Their tomorrow depends on our today. So, we need to tackle the problems of poverty, climate change and environmental devastation to build a sustainable future on Planet Earth.

To achieve this sustainability we need to use Planet resources in most effective way. One way to achieve secure and sustainable living is to understand the social and economic benefits of weather, climate and water services provided by National Meteorological Services (NMS).

Across the world, many NMSs expend large amounts of funds on meteorological observation systems, forecasting and prediction efforts and research programs to improve and expand the capability to provide a range of meteorological services to a variety of users.

It is important to recognize that many of the substantial economic impacts of various weather events are well documented (Cornford 2002). However, the economic value and the benefits of many of the meteorological services such as the existing weather forecasting systems are seldom fully understood or recognized. Furthermore, there are only a few comprehensive studies of the economic value of various meteorological services to their users, although it is widely assumed that the benefits far exceed the costs. Moreover, there is even less information on the economic value to users of potential improvements to or changes in current meteorological services (Katz and Murphy 1997, Lazo and Chestnut 2002). Hence, there is a growing demand for more rigorous and more broadly base ' demonstration of the economic value of meteorological services.

2. Economic characteristics of meteorological services

Current and potential users and/or beneficiaries of meteorological services include individuals, households, firms, government organizations, economic sectors, regions, national economies, etc. Virtually every sector of every country makes some direct or indirect use of basic and/or special (user specific) meteorological services. These sectors include agriculture, aviation, banking and financial services, construction industries, disaster management, energy generation and supply, environmental protection, fisheries, forestry, health, insurance, leisure, manufacturing, military, port and harbour management, transport, urban planning, and water resource planning and management (Freebairn and Zillman 2002a).

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On the basis of the major user groups and the key product/service characteristics, the meteorological information provided by the NMS can be categorized into two broad groups: basic meteorological services and special meteorological services. The basic services are those made freely available to the broader community generally through the mass media (including the world-wide web), in the public interest. Examples include public weather forecasts and severe weather warnings etc. In general, the basic meteorological services constitute what, in economic terms, are referred to as public goods. Use of these services by one user does not reduce their availability to others. Furthermore, once the service is available, it is available to all and it would be impossible or very costly to exclude potential users from accessing the service and using it for their own benefit. Nor would it be efficient to charge for the basic services since the marginal cost of serving an additional user is close to zero. Basic services with public good characteristics account for between 70 to 90 per cent of the total volume of meteorological services provided by the NMS. Special meteorological services include the provision of value added services to meet the specific needs of particular users. Examples include weather services to airlines, industries and wind power forms etc.

3. Value of meteorological information

Meteorological information can be viewed as a factor in the decision making process that can be used by decision-makers (ranging from individuals, farmers, businesses, and public sector agencies such as emergency services) to reduce uncertainty and improve their economic and other decisions. For example, assume that a farmer has an 'intuitive feeling' (subjective estimate) of the 'likelihood' (probability distribution) for a particular meteorological event (e.g. rainfall). The rainfall forecast provided by the NMS to the decision-making and planning process of the farmer provides a basis for altering the subjective probability distribution. The value of rainfall information at the individual farmer level is then a translation of the change in revenue generated from improved decisions associated with the additional meteorological information. This implies that meteorological information acquires value when use of such information changes the behaviour of the user.

In the case of individuals, an accurate one-to-three day weather forecast is valuable in helping plan outdoor activities, travel and a range of other activities. Energy companies can maximize the availability of power plants and distribution of power with better weather forecasts. Public emergency services can preposition personnel and equipment to minimize, for example, storm damage based on timely and accurate weather forecasts.

In each case, the economic value or benefit of the forecasts is the improvement in economic and related outcomes resulting from the use of weather forecasts. Similar considerations can be extended to climate-related products and services.

In addition, the economic valuation of meteorological and related information also includes consideration of "lost opportunities" from improper and/or inadequate use of the pertinent information and the associated products and services.

Typically meteorological services are not used on their own but in conjunction with other 'products/services'. For example, some individuals in deciding whether to put their cars under cover may use general weather forecasts for the following day. Similarly, farmers in deciding whether to irrigate a crop, use a warning of an approaching storm. In other words, factors such as protection of property and the level of economic activity could influence the demand for meteorological services. As a result, the demand for meteorological services is based on the demand for these related 'products/services'. In other words, the demand for meteorological services is a derived demand.

In general the demand for, and hence the value of, meteorological information is likely to be influenced by their quality, accuracy, user friendliness and timeliness. It is important to recognize that the value of meteorological information to users is not related to the quality of the information alone. In assessing the value of meteorological information, it is important to recognize the 'complete process' of transforming the improvements in the accuracy, quality, user friendliness and the timeliness of such information into the users' values. In providing a simple framework for such a 'complete process', Hooke and Pielke (2000) identify three parallel sub-processes (prediction, communication and use) with significant feedbacks and interrelationships between them.

The complete process' of transforming meteorological information to users' value contains multiple elements. According to Hooke and Pielke (2000), at the interfaces of these multiple elements lie a number of questions that ought to be asked and answered in an effective 'complete process'. For example, between prediction and use, the key questions are: what ought to be predicted? how are predictions actually used? Between prediction and communication, the relevant questions are: what does the prediction mean in operational terms? how reliable is the prediction, and how is uncertainty conveyed? The important questions between communication and use are: what information does the decision maker require? what content or form of communication leads to the desired response?

No single element of the 'complete process' captures the users' value of meteorological information. Instead multiple measures are required to assess the technical, communication and decision dimensions of meteorological information. In general, different groups focus on different aspects of the 'complete process' to assess the value of meteorological information. For example, policy makers examine the economics of meteorological information. On the other hand, social scientists focus on the communication processes and the scientists assess meteorological information based on technical criteria such as skill scores. In better understanding the relationship between, say, the weather forecasting process and the broader society of which it is a part, what is required is integration of evaluation tasks with a more comprehensive perspective of the overall picture of the complete process of transforming meteorological information to users' value.

An understanding of the 'communication' process is necessary to convey information to users of any potential changes in meteorological services. It is also important to understand how different users perceive and use meteorological information in order to properly interpret and elicit values for different products and services.

An operator of a ski resort may benefit from additional snow, whereas the operator of a fishing lodge – downstream from the ski resort – may incur reduced business with such a prospect. An economy wide approach to analyzing the value of information is required under such circumstances to estimate the overall value of such information.

4. Sectoral Assessment of Benefits

All socio-economic sectors are affected by weather, climate and water events that routinely occur in virtually all climate regimes. Many of these sectors are extremely vulnerable or climatically sensitive on some or all timescales, and this vulnerability is increasing with real-time economic exchanges and the growing numbers and severity of extreme weather events. In a multi-factor, multi-sector context, the issue of valuing the effect of meteorological information services is complex, given the inter-sectoral linkages both on the producer side as well as the consumer side. For example, it is possible that the same meteorological event could generate benefits to some while incurring losses to others. Briefly following major socio-economic sector driving the benefit of Meteorological Service in Pakistan has been discussed:

- Aviation
- Agriculture
- Human Health
- Tourism
- Energy
- Water sector and flood management etc.
- Disaster management, tropical cyclone etc.

4.1 Aviation

The aviation industry stands to benefit greatly from better weather information. The main impacts of meteorological services for aviation can be grouped as follow:

- Safety of airlines operation
- Fuel saving, as flight altitude, routes, and alternate airports can be fine tuned
- Avoidable weather related delays
- Passenger time value from avoidable weather related delays
- Avoidable repair costs from not flying into volcanic ash plumes

Pakistan Meteorological Department (PMD) is the designated Aeronautical Meteorological Authority in Pakistan which has Meteorological Offices at all the international and local airports in the country. These offices provide up-to-date weather information and forecast and documentations round the clock to the airlines operating in Pakistan.

Safety & Fuel Saving

For airlines operators accurate weather information provide better safety and higher reliability of airlines operations. But beside safety the meteorological information and forecast offer possible for fuel saving, as flight altitude, routes, and alternate airports can be fine-tuned with en-route wind and weather conditions in mind. The main reasons

behind fuel saving when utilizing meteorological information can be further explained as follow. The first is the possibility to find a better situated alternate airport, and this way to avoid extra fuel load – this is not unusual in exceptional situation when the planned arrival airport is unavailable (because of technical reasons, weather etc.). The second is possibility to find tail winds for long distance flights. The conservative estimates suggest that the saving in fuel consumption for flights originating from Pakistan alone are in the range of one to one-and-half billion rupees per annum.

Avoidable weather related delays

There is hardly a need to re-emphasis the importance of accurate weather information for efficient airlines operation. The rough estimates and discussion with airlines operators in Pakistan suggest that at least 5-10% weather related delays are avoided because of accurate weather information. The cost saving to the airlines operating in Pakistan that are achieved by avoiding weather related delays due to better weather forecasting are estimated to be around rupees 500 million per annum. The cost estimate of value of passenger time saved due to avoiding delays as a result of better weather forecasting is difficult to quantify.

Avoiding volcanic ash

Airplanes can suffer significant damage from flying into volcanic ash plumes. Meteorological offices provide the information warning about the areas of volcanic ash plumes and the airlines are greatly benefited by avoiding volcanic ash plumes and the associated repair cost of flying aircraft into such a plumes.

.2 Agriculture

The most weather prone sector in our societies is agriculture. Land use, crop selection, and farming practices are all directly dependent on the prevailing local climate. Major parts of the farming produce are very vulnerable for unfavourable weather conditions and thus the value of meteorological information can be considered significant. Climate variability and climate change have large impacts in crop growth and development, crop yields, and activities such as shift in cropping periods, crop rotations, and modifications of cropping systems. We are facing new threats through deforestation, wind erosion and water erosion, more agricultural use of sloping lands, migration into vulnerable areas, and new insect pests. Climate variability and change, in all contexts, represents a factor of risk, which can have the dimensions of disaster in fragile and more vulnerable environments. Agro-meteorology can help us to cope with these environmental hazards and mitigate their negative impacts.

Given the fact that weather affects every stage of farming activities in one way or another, the benefits gained by the specialized weather forecasts for farmers are quite obvious. The benefits may be direct economic savings in production costs for instance accurate weather forecast can contribute to more efficient irrigation of crops – resulting in water savings, energy saving by not pumping water etc. Reliable and frequently updated weather forecasts make also decision-making on farming activities and planning of these activities significantly easier.

At the beginning of the growing season correct timing of sowing is essential. Five-day weather forecasts are then of crucial importance for work planning; the time of e.g. surface harrowing is virtually dependant on the rain, air temperature and air humidity

expected. In the dry early summers, irrigation results in a substantial increase in yield as well as an improvement in the quality of yield. Reliable weather forecasts are also crucial for the quality and quantity of the yield during harvesting.

Agro-meteorological services are provided by the PMD as a part of their daily service. This service includes meteorological information given on radio, television and in daily newspapers. Meteorological services for agriculture are also available on Internet web sites maintained by PMD (www.pakmet.com.pk).

The meteorological information is needed to guarantee that the agricultural production is as effective as possible and to ensure high quality of agricultural products. The benefits that can be gained by effective agro-meteorological services encourage to maintain and to further develop these services. An effective use of meteorological information helps to optimize the use of fertilizers and pesticides, which benefits in lower costs for farmers and it also has highly favourable effects on environmental protection too.

The most commonly used techniques to estimate the value of meteorological information are normative or prescriptive models. The approach in these models is to view meteorological information as a factor in the decision-making process that can be used by decision-makers to reduce uncertainty. This approach is based on Bayesian decision theory (Johnson and Holt 1997).

In 1997, at the request of Federal Agriculture Ministry, PMD started regular issuance of advisories for cotton growers about the appropriate dry periods suitable for pesticides sprays on cotton crops. Because in the absence of these advisories growers had to suffer huge economic losses if the rain occurs immediately after the pesticides applied on the crop.

Federal Agriculture Ministry acknowledged in writing that the cotton growers have saved about Rupees 70-80 crores (0.70 billion rupees) on account of pesticide sprayed on cotton crops, because of the precise and timely weather forecast / advisories of Met office.

4.3 Human health

There is clear evidence that environmental factors are key determinants of human health. In particular, weather and climate parameters are crucially linked, both directly and indirectly, to a large number of health issues, such as vector-borne diseases malaria, meningitis, malnutrition, cardiovascular and respiratory diseases, and skin cancer. Climate change is exacerbating these problems significantly in many parts of the Pakistan. A multidisciplinary understanding of the relevant issues, as well as the development of appropriate tools and end-to-end systems, is crucial for public health sustainable development and poverty reduction.

Many studies in other countries have been carried out in the area of climate and human health, and these have demonstrated their value in guiding interventions that minimize or prevent the impacts of disease. However, there is a need for a systematic analysis of the impacts of weather and climate anomalies on health in various parts of the Pakistan in order to identify priorities and enhance preparedness. It is also necessary to compile a baseline set of climate, epidemiological and socioeconomic data at the district level

which, coupled with geographic information system tools, can serve as a foundation for developing end-to-end warning systems for different regions of the country and for various climate-related health issues.

The social and economic benefits of warning systems and forecasts need to be quantified and detailed cost-benefit analyses would strengthen the case for further investments. Communication is essential for the provision of warning information systems and for forecast delivery. Collaborative efforts exist at the global level, such as the partnership between WMO and WHO; but, there is a clear gap between meteorological and health services at the national level. Such collaboration is crucial for providing end-users with the health benefits of weather, climate and water services. Specialists in both the meteorological and health communities need to collaborate closely to provide the optimum information to the end-users in a comprehensible form, as well as to provide clear guidance on response options to such information. Education and training programmes for relevant staff is also required. The role of the public broadcast media as a trusted source for transmitting warnings and forecast information is also important.

4.4 Tourism

Tourism is primarily an outdoor activity and very few other activities depend to such an extent on changes in weather and climate. The tourism is currently a significant user of weather and climate forecasts and greatly appreciates the improvements made in the quality and reliability of forecasts and the greater lead time. The tourism sector uses weather and climate services on a range of timescales, as follows:

- Short-term forecasts and nowcasting: These are important for operational planning by tourists to make decisions on which activities to engage in, for health and safety and for financial decisions;
- Monthly and seasonal forecasts: These are important for resort operations and are also likely to become increasingly important in the choice of destination by tourists.
- Longer-term projections: Climate change is a major challenge for the tourism industry, with focus on the development and planning of appropriate facilities, the long-term sustainability of these facilities and their environmental impact.

Further advances from improved data and forecasting systems will lead to better services, with significant benefits for the tourism industry. Climate change is recognized as a major factor influencing tourism. On the one hand, climate change is perceived to have a direct impact on tourism destinations, and, on the other hand, air travel, an integral part of tourism, is a significant and growing contributor to greenhouse gas emissions. In some instances, climate change could enhance the attraction of some tourist destinations (for example, when warmer water temperatures prolong the summer season). However, it is more likely that climate change will have a negative impact on the tourist industry.

4.5 Energy

In Pakistan, 30% power production is from hydro and 70% from other means. The power generation sectors need extensive weather information for operating their power plants and electricity grids optimally and as planned. Security of supply is priority in energy

production and distribution. Reliability is even more important thinking of industrial customers and their production facilities. Energy producers have to foresee possible threats that changing weather conditions may cause.

Hydropower plants are dependent on water availability and they use extensive hydro-meteorological information provided by PMD about the rainfall forecast, snow area coverage and snowmelt information including seasonal water availability projection etc Similarly, thermal power plants also need changing weather information including more accurate temperature forecast for computing improved energy demand expectations and saving in the electricity sector.

The use of tailor-made meteorological services (forecasts, warnings etc.) is one of the key means to control the impacts of changing weather condition and keep the electricity grids stabilized at all times. The main problem created by exceptional weather conditions in Pakistan electricity supply are as follow:

- power supply failures
- damage to building and plants
- increase in maintenance costs for building and plants
- increase energy consumption
- destruction of transmission network (towers/lines) due to wind storms
- drought and flooding have adverse impact on the implementation of generation plans i.e. the pace of completion works related to the construction and maintenance of plants.

The cost of these could be reduced by PMD's additional weather / hydrological information services that could help to overcome such damages. For example:

- precipitation, wind and temperature forecast for plant locations
- communication on expected extraordinary meteorological conditions for the next 1-3 days.
- Seasonal weather forecasts
- Real time hydrological data
- Availability of historical meteorological data
- Hydrological forecasts

One very simple example that how the rain forecast contributed to the huge cost saving by improved energy demand calculations in Pakistan is the acknowledgement by the Power authorities (WAPDA) in writing that the daily weather reports helped their centre in the accurate electricity Load Forecast assessment for the day. Based on Load Forecast demand is placed on IPP's thermal units. On 2nd July, 1998 WAPDA saved Rupees 12.3 million by not demanding HUBCO Unit (Private Power Unit) because Met Office predicted rain at Lahore proved correct.

The above discussion would justify the claim that meteorological services provided by PMD are contributing to energy sector an economic benefit to the tune of above two billion rupees annually.

4.6 Water & Flood Management

Water is an essential requirement in sustaining life. But the same water when it is excess it caused floods and when less it creates droughts. Floods are a natural and inevitable part of life along the rivers in Pakistan.

PMD is charged with the responsibility of issuing flood forecasts and warnings to the nation to help in saving lives and to reduce flood damages. For this purpose, PMD maintains a specialized Flood Forecasting Division (FFD) at Lahore. PMD issues pertinent information on rivers' condition to local, provincial, and federal decision-makers and to general public. However, a flood forecast is only of value if it induces a response from the residents in the threatened area that lead to effective actions. For example, a benefit can acquire through evacuations, flood proofing, flood fighting, or the shutdown of some water channel to reduce potential flood losses. Flash-flood watches and warning, river and flood forecasts and warning, and water supply forecast and water management at major dams are the major hydrological services provided by PMD.

PMD uses many sources of data in developing its hydrological forecasts. Water and Power Development Authority (WAPDA), Provincial Irrigation Authorities are the principal source of data on river depth and flow in Pakistan. PMD collect the precipitation data which is again supplemented by WAPDA and other agencies. All this data in combination with satellite and weather radar data is used to produce hydrological forecast. PMD has developed and use complex mathematical weather and hydrology models to see how Nation's rivers and streams respond to rainfall and snowmelt.

Benefits to Hydrological Forecasts

Benefits associated with hydrologic flood forecast result from a variety of sources. Flood losses can be lessened by regulating upstream reservoirs, emergency actions to flood fight (sand bags, levees, evacuation etc.) and by providing warning to the threatened area. But, in order to compute benefits from hydrologic forecast, damage estimates under natural conditions need to be considered.

PMD through its River and Flood Forecast System obtain economic benefits by issuing forecasts that cause a reaction from the pending natural hazard of flooding. There are three categories of obtaining monetary benefits: optimum reservoir operation, short term forecast and long term forecast. One example of benefit based on PMD's flood forecast is given here. In August 1997, PMD issued an advisory on the flood potential four days in advance and advised Mangla Dam authorities to drawdown the water level in reservoir, which was at the maximum conservation level at that time. So that when the rain/flood starts its water could be accommodated in reservoir. The Dam authorities acted, though reluctantly, and brought down the water level in dam ahead of flood peak arrival in the dam. Subsequently, Pakistan's Federal Flood Commission acknowledged that during August, 1997 Met. Office early warnings and consequent pre-releases from Mangla Dam saved the country from flood damages to the tune of approximately 5 billion rupees".

So far we have focused on the benefits that result from warning issued by PMD during flood events and actions taken to reduce flood damages. The forecasting of both high

and low flows during non-flood conditions also constitute important inputs to the efficient operation of any water resources system: hydropower generation, irrigation, and water supply.

The conservative estimates suggest that the average annual combined economic flood loss reduction benefit and direct benefits of efficient water management in the country from Met. Office hydrometeorological forecasts is around rupees two billion per annum.

4.7 Tropical Cyclones Forecasting

Tropical Cyclones can have significant social and economic impact on society if they approach a coastline and more importantly if they make landfall. The impacts are far reaching, extending from direct impacts (such as property losses associated with wind and water damage and personal injury or death) to secondary impacts e.g. increase in health or disease problems following a tropical cyclone, loss of business and tourism etc.

Pakistan has a coastline of more than thousand kilometers and thus a vulnerable country from Tropical Cyclone prospective. Though during the last 10-years two cyclones had a landfall over Pakistan coast and for which Met. Office issued well in advance timely warning. But there were numerous other cyclones during this period which formed over North Arabian Sea and had landfall over other neighbouring countries. Their monitoring and prediction that they would not affect our coastal areas is also equally important. PMD is maintaining an accurate monitoring and tropical cyclone forecasting system. Effective tropical cyclone monitoring and forecasts cannot prevent the cyclone from making landfall, but they can provide valuable information during the life of the cyclone to assist public and private decision-makers in determining appropriate responses for preparation and evacuation. Decisions based on tropical cyclone forecasts can save lives, reduce property damage, ease the stress placed on government response, and create more efficient commercial response.

One example of benefits based on PMD's Tropical Cyclone Warning is mentioned here. On 22nd June, 2007 Met Office issued the Tropical Cyclone advisory, that cyclone would have a landfall over Balochistan coast after 4-days. Advising evacuation, return of fishermen from open sea, and reduction of discharges in irrigation channels etc. Authorities later confirmed saving of about 20,000 fishermen life (who were in open sea and were recalled back on emergency basis) beside reduction in economic losses to the tune of rupees one billion. Federal Cabinet in its meeting held immediately after the cyclone landfall highly appreciated the precise and timely early warning of PMD.

Conclusion

In this study an attempt has been made to estimate the social and economic benefits of some of the services and products provided by Pakistan Meteorological Department (PMD). In summary, this analysis found the following estimated quantified economic benefits per annum from improved meteorological services for the following five specific types of economic activities:

Aviation

Enhanced aviation weather forecasting resulting improvements in airlines operations in terms of its safety, fuel saving, avoidable weather related delays, avoidable repair cost

from not flying into volcanic ash plumes etc. is benefiting to the tune of approximately rupees one billion per annum to the airlines operating in Pakistan.

Agriculture

Enhanced weather forecasting leading to more efficient irrigation of crops – resulting in water saving and energy saving by not having to pump water, economic gains by effectively using other ago-meteorological services in decision-making process for other agro-related activities including optimize use of fertilizers and pesticides. The conservative estimates indicate that minimum economic gains from meteorological services by agriculture sector in Pakistan are in the range of 2-3 billion rupees per annum.

Energy

Improved meteorological services in Pakistan are contributing to better management in energy sector including reduction in weather related destruction losses, accurate temperature forecast leading to improved energy demand calculations. These gains in economic terms can be estimated to be above two billion rupees per year to the energy sector alone.

Water and Flood Management

Hydro-meteorological services of PMD according to conservative estimates are contributing to annual combined economic flood loss reduction benefits and direct benefit of efficient water management in the country to the tune of two billion rupees.

Tropical Cyclone Forecasting

Effective tropical cyclone monitoring and forecasting system is contributing about half a billion rupees benefit to the nation in terms of reduction in economic and human losses due to timely and accurate cyclone warning etc.

Finally, it is concluded that meteorological services in Pakistan are contributing economic benefits of above eight billion rupees annually to the nation.

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INFLUENCE OF CLIMATE CHANGE ON UPPER INDUS RIVER FLOWS

By

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ABSTRACT

Waters from Upper Indus Basin (UIB) Rivers are of vital importance for the irrigated agriculture of Indus Basin and hydro power generation in Pakistan. Glaciers of Central Karakoram, Western Himalayas act as a reservoir, capturing snow and ice, holding the water and releasing it into the rivers which feed the Indus Plain. About 75% of summer flows of River Indus at Tarbela are contributed by highly glaciated central Karakoram tributaries. Flows from these tributaries are mainly temperature driven with May flows resulting from snow melt while June to August flows dominated by glacier melt originating from the zone between 3800 – 4800 meters above sea level elevation zone. It has been forecasted that there will be a glacier retreat in Upper Indus Basin in the early half of the twenty first century resulting in an increase in river flow and thereafter there will be a permanent decrease of 30% to 40% . But there are contrary reports that the Karakoram Glaciers are stable and some of the large glaciers are growing. In this paper influence of climate change on the UIB Rivers has been examined by analysing flow volume trends of Upper Indus and its major tributaries for the period May to August. This analysis would help to understand the state of UIB glaciers lying in the ablation zone. It has been found that flows from eastern part of Karakorams, gauged at Kachura, show a remarkable rising trend in summer mean monthly flows, a phenomenon attributed to receding glaciers. For western Karakoram tributaries, Gilgit and Hunza, monthly flow volumes show a falling trend during the same period indicating cooling summers. This is in conformity with the June, July and August mean monthly temperature trend for Gilgit, in the western Karakoram. This study corroborates to the views that some of the large Karakoram glaciers are not only stable but are growing.

1. INTRODUCTION

Pakistan is an agrarian country where seventy percent of its rural population is directly associated with agriculture. More than ninety percent of its agriculture output is from the Indus Basin which is located in arid to semi arid region, which necessitates the use of irrigation water to supplement the rain water for crop production. With ever growing population and limited water resources Pakistan has been declared as water stressed country. Although the country is blessed with the huge frozen fresh water reservoir in the form of glaciers located in the North of the country known as Upper Indus Basin (UIB), flows from this resource are reported to be under the threat of the climate change. Intergovernmental Panel on Climate Change, using different weather and flow forecasting models for South Asia region (Rees etal., 2004) has predicted that there will

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be increase in the waters of Upper Indus River at Besham Qila for 30 years (2010 to 2040) during which the glaciers of Upper Indus Basin will be vanished and thereafter there will be permanent reduction of the order of 40 % in River Indus at Besham Qila flows.

The present study attempts to describe the variability in the flows of Upper River Indus and its selected tributaries especially which are located in Karakoram Range and have glacier melt as dominant portion. The tributaries located in the western part of Karakoram are River Hunza and River Gilgit, which are gauged at Dainyour and Alam Bridge respectively. The tributaries which are located in the eastern part of Karakoram are Indus (main), Shyok and Shigar which are collectively gauged at Kachura. The flows of both eastern and western tributaries are collectively gauged at Partab Bridge. They all constitute about 75% percent of River Indus summer inflows to Tarbela Dam. Maximum flows in these tributaries are during May, June, July and August with May flows dominated by snow melt and June - August flows dominated by glacier melt. (Hewitt, 2007).

2. STUDY AREA

Upper Indus Basin consists of the catchment area drained by the Indus River upstream of Tarbela Reservoir, the Jhelum River upstream of Mangla Reservoir and Kabul River. This area is located in the Northern Pakistan and includes three major mountain ranges, the Himalaya, Karakorams and the Hindukush. While some of the headwaters of the Indus River lie within China and India, most of the Indus Basin lies within Pakistan. (Figure 1.).

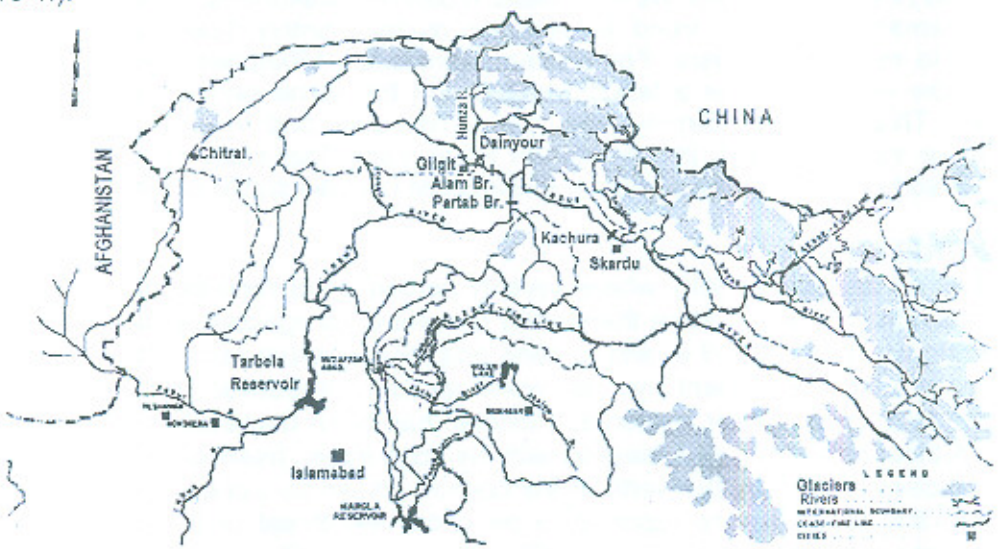


Figure 1. Stream gauging network and glaciers in Upper Indus Basin.

The Upper Indus Basin consists of series of mountain ranges of extreme ruggedness and exceptionally high elevations. With hundreds of peaks in excess of 6000 meters elevation, it consists of a wide range of mountain ridges and high valleys. There are more than 5000 glaciers in River Indus catchment with total ice reserve of 850.4 km^3

(Qin 2002). The glaciers of Karakoram within Pakistan cover an area of about 13000Km^2 (Mercer, 1975). The largest 23 glaciers account for about 60% of the glacier area (Hewitt, 1985). It is the ablation zone of these large glaciers, which produce the bulk of glacier ice melt.

3. CLIMATE OF KARAKORAM

3.1 Precipitation

There are two principal sources of precipitation in Upper Indus Basin. The major moisture source during the winter months is depressions coming from the West. A secondary summer accumulation season at high elevation in the Karakoram and Hindukush usually derives from the same source. These westerly sources provide the dominant nourishment for the glacier systems of the Karakoram.

The second source of precipitation is probably the monsoon, bringing storm systems from the South from late July through September. Mayweski et al. (1980) have shown that in some years the monsoon is strong enough to break through the Frontal Ranges and can deliver substantial precipitation to the Central Karakoram region, but generally it has a little impact on the flows of Upper Indus tributaries especially lying north of River Indus.

The bulk of all UIB precipitation occurs in an altitudinal zone of 2500 m and 6000-m elevation. The elevation of maximum precipitation is probably about 5000 m in the western Karakorams, 6000 m in the eastern Karakoram and in the order of 1000 – 1800 mm of Snow Water Equivalent (Hewitt, 1989).

3.2 Temperature

Surface air temperature exhibits extreme spatial variability dependent primarily on elevation but with strong seasonal and diurnal cycles. Valley bottom temperatures experience local thermal circulation effects, and areas above 5000 meters above sea level (m.a.s.l.) usually remain under sub freezing conditions. Active melting zone for glaciers is between 3500 - 4800 m.a.s.l and that too during June, July and August when temperatures are suitable for ice melting. The glaciers at 4800 m.a.s.l. hardly receive two weeks of melting temperatures (Hewitt, 2001).

4. DATA USED

4.1 Stream flow

The Upper Indus Basin remained inaccessible for many years for common people due to its inhospitable weather, difficult roads and long distance from the nearby cities. The first hydro-meteorological network was established in the valley bottoms in nineteen sixties by Water and Power Development Authority of Pakistan. Whereas this network was good for discharge measurements of main Upper River Indus stem and its major tributaries at various gauging stations, the weather stations installed lacked the catchment representativeness due their location in valley bottom- (Hewitt, Wake 1989). However data trends from these stations could be an indicator of the direction of change, if any. The gauging stations (Figure-1) discharge data used for mean monthly trend analysis in this study are from River Indus at Partab for 42 years (1964 - 2005), River

Indus at Kachura for 36 years (1970 - 2005), River Hunza at Dainyour for 39 years (1966 - 2004) and River Gilgit at Alam Bridge for 40 years (1966 - 2005).

4.2 Temperature

Pakistan Meteorological Department (PMD) has established its network in the Northern Areas of Pakistan for air traffic navigation. A valley weather station at Gilgit is located in the western Karakorams, 47 years (1960 -2006) of temperature data was available from this station which was used for summer months temperature trend analysis..

4.3 Precipitation

PMD station at Skardu is located in the eastern Karakorams. Mean monthly precipitation data for the available period of 54 years (1951 – 2005) from this station has been used for analyzing impact of monsoon rain in Karakoram Region.

5. MATERIALS AND METHODS

To identify trend in hydrologic data of UIB stations, the Mann – Kendall trend test has been applied. This is a non - parametric test, suggested by Mann (1945) which can be applied to any time series. It has been extensively used in the analysis of environmental time series data.

Mann-Kendall test is based on statistic **S**. Each pair of observed values y_i, y_j ($i > j$) or random variable is inspected to find out whether $y_i > y_j$ or $y_i < y_j$. Let the number for former type be P (Positive), and the number for later type be N (Negative). Then **S** is defined as

$$\mathbf{S} = P - N \qquad (1)$$

There is a correction factor for ties when $y_i = y_j$ (Salas, 1993).
Under the null hypothesis H_0, that there is no trend displayed by the time series, the distribution of **S** is then expected to have a zero-mean and variance

$$\text{var}(\mathbf{S}) = [n\,(n-1)\,(2n+5)] / 18\,, \qquad (2)$$

where n is the number of values in data set. Then the Kendall Statistics Zo is given as

$$Zo = \begin{cases} (\mathbf{S} - 1) / \sqrt{\text{var}(\mathbf{S})} & \text{if } \mathbf{S} > 0, \\ 0 & \mathbf{S} = 0, \\ (\mathbf{S} + 1) / \sqrt{\text{var}(\mathbf{S})} & \text{if } \mathbf{S} < 0 \end{cases} \qquad (3)$$

The magnitude of trend is given as

$$\beta = \textit{Median}\,[(y_i - y_j) / (i - j)] \qquad (4)$$

In which $1 < j < i < n$. A positive value of β indicates an upward trend and a negative value of β indicates a downward trend.

The Mann – Kendall test is given as:

Null Hypothesis Ho: $\beta = 0$, i.e. there is no trend, P = N or **S** = 0

Rejected Ho : $|Zo| > Z_{1-\alpha/2}$ there is a trend at significance level, α .

In which $\pm Z_{1-\alpha/2}$ are the standard normal deviates, and α is the significance level for the test. The hypothesis that there is no trend is rejected when the |Zo | value computed by above equation is greater than the tabulated value $Z_{1-\alpha/2}$. Conversely α value or confidence level (1 - α) in percentage can be computed at which the hypothesis is rejected and significance of trend is established.

The Mann – Kendall test is expected to be less affected by the outliers because its statistics is based on the sign of differences, not directly on the values of the random variables.

6. RESULTS AND DISCUSSION

The meteorological network installed in UIB in sixties is very sparse, located in the valley bottom and is prone to local thermal effects. Therefore this cannot represent temperatures in higher mountain environment, especially in the glacier ablation zones. Although a high elevation automated meteorological network was installed in mid nineties, the length of record from this network is short for trend analysis. During summers flows from Upper Indus Basin region are mainly from snow and glacier melt driven mainly by summer temperature with May flows mainly representing snow melt. August temperatures, which are highest during summer temperatures, represent totally glacier melt. The state of UIB glaciers and changes in climate has been examined by analysing mean monthly flows trend of the rivers draining the Karakoram and Hindukush regions. For the purpose of this study, the rivers draining the western and eastern region of Karakoram are analysed separately for their mean monthly summer flows trend. Flows from both these regions are collectively gauged at Partab Bridge, which were also analysed for trend.

6.1 Eastern Karakorams

River Indus gauged at Kachura, with catchment area of 112665 Km^2 and comprising the eastern Karakoram, is examined for the available record of 36 years (1970 – 2005). Summer flow volumes (May, June, July and August) at this gauging station are more than 74% of annual flow volumes. Kachura flows represent about 60% of River Indus at Partab Bridge annual flow volume. The watershed of Kachura comprises the Shyok basin (having longest 73 Km Siachen glacier of the region), Shigar basin (which has an important 68Km long Biafo glacier in addition to numerous other glaciers), and the Indus (main) with considerable snow melt contribution. The river Indus at Kachura rises in April with snow melt as dominant component and peaks during August with glacier melt as dominant component.

Figure 2 shows a continuous rising trend in summer months June, July and August flows at Kachura at the significance level above 99%. The rising trend in summer flows of River Indus at Kachura with very high significance level indicates warmer summers in eastern Karakoram. The significant rising trend in flows is also visible during snow melt period of May, which accounts for 6% of the annual flow volume at Kachura.

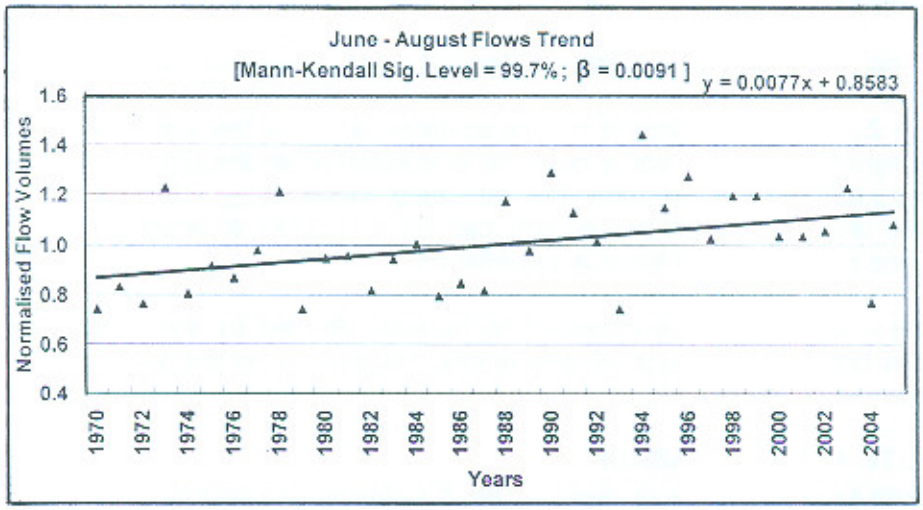


Figure 2. Significant rising trend in flows of River Indus at Kachura during glacier melt period (June to August)

Mann – Kendall Test parameters for various stations for snow and glacier- melt months are given in Table 1.

Table 1. Mann – Kendall Trend Test Statistics for Upper Indus and its tributaries

Station Name	Study Period	Snow Melt Month (May)			Glacier Melt Months (June, July, August)		
		M – K **Zo**	Sig. Level	β	M – K **Zo**	Sig. Level	B
Summer Flows							
Indus at Kachura	1970 2005	1.8661	93.8%	0.0079	2.9285	99.7%	0.0091
Hunza at Dainyour	1966 2004	0.5280	40.3%	0.0027	-3.319	99.9%	-0.0128
Gilgit at Alam Br.	1966 2005	1.6595	90.3%	0.0063	-2.388	98.3%	-0.0075
Indus at Partab	1964 2005	4.053	100%	0.0151	0.6874	50.8%	0.0011
Summer Temperatures							
Gilgit	1960 2006	1.5957	88.9%	0.0728	-2.256	97.6%	0.004

6.2 Western Karakorams

River Hunza gauged at Dainyour, located in western Karakoram, is examined for the available record of 39 years (1966 – 2004). Summer flow volumes of River Hunza are more than 76% of its annual flow volumes and contribute about 17.5% of flows at Partab Bridge. This gauging station has a catchment area of 13157 Km^2. About 30% area lying above 5000 meters is heavily glaciated with numerous glaciers including two prominent 60Km Batura and 53 Km Hispar glaciers. River Hunza has typical glacial melt flow behaviour; it rises in May with snow melt as dominant component, and peak flows occur during August with glacier melt as dominant component. Hunza River shows a falling trend during high temperature glacier melting months June, July and August, at M-K significance level more than 99%. This falling trend for Hunza flows is in sharp contrast to the rising trends in summer flows of the rivers draining eastern region of Karakoram Mountains. This shows that summers are cooling in this part of the region. This may corroborate to the findings that some of the large Karakoram glaciers are not only stable but are growing (Hewitt, 2005; Ding et al. 2006).

River Gilgit is gauged at Alam Bridge and is also located in western Karakoram. This gauging station has a catchment area of 26159 Km^2 and includes river Hunza catchment. Trend analysis for this station has been carried out by using the available record of 40 years (1966 – 2005). Summer flow volume of River Gilgit is more than 74% of its annual flow volumes and constitutes about 35.6% of flows at Partab Bridge. River Gilgit summer flow trend is shown in Figure 3, which indicates significant continuous falling trend in June, July and August at more than 98% M-K significance level.

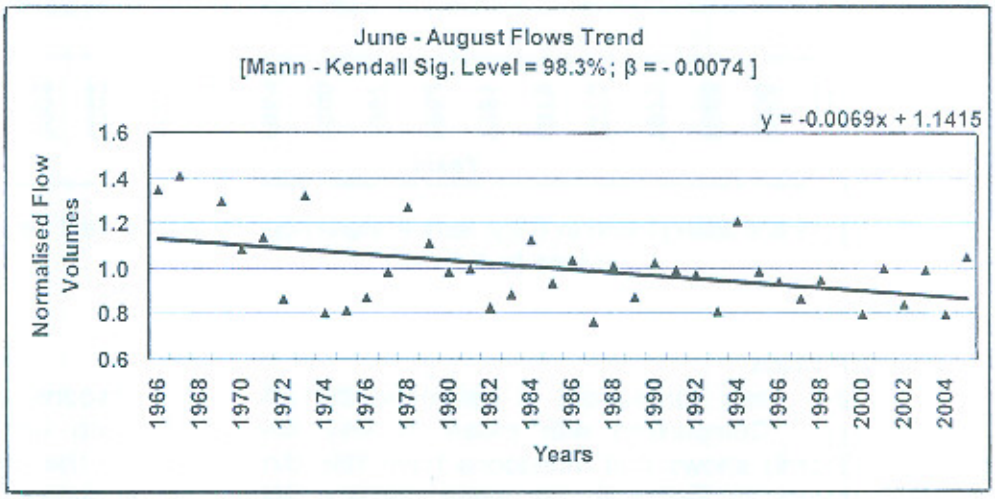


Figure 3. Significant falling trend in flows of River Gilgit at Alam Bridge during glacier melt period (June to August).

This falling trend implies that summers are cooling in this part of the region. These effects are consistent with the mean summer temperature trends at Gilgit which is located in the western Karakorams (Table -1).

6.3 Eastern and Western Karakorams Combined

River Indus at Partab Bridge drains a catchment area of 142709 Km^2 and includes all the flows arising from the eastern as well as western part of Karakoram Mountains. The available record of 42 years (1964 – 2005) of Partab has been analysed for trend. Flows for this gauging station reflect the combined influence of both the eastern and western regions of Karakoram. The trend for the snow-melt month May shows a dominant impact of Kachura flows at this gauging station with rising trend at very high M-K test significance level of 100% (Table -1). The trends for rest of summer month flows are mix with low M-K significance level due to the combination of flows from the rivers draining eastern and western Karakorams having opposite mean monthly flow trends.

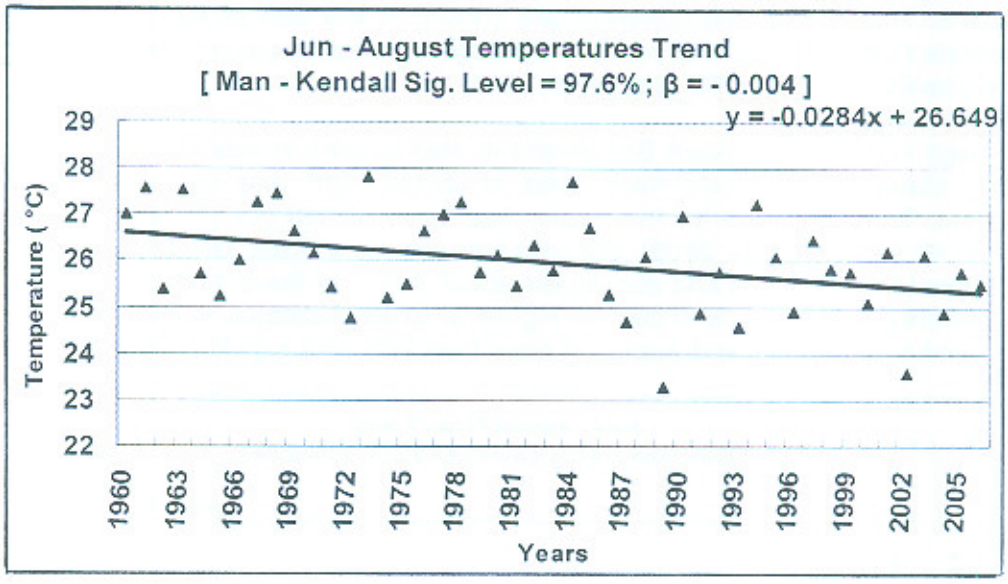


Figure 4. Significant falling trend in Gilgit temperatures during glacier melt period (June to August).

6.4 Monsoon Effect

Many studies have been carried out to determine the effect of monsoons on the Karakoram Ranges. Comparison with mean monthly flow at Kachura and total precipitation at Skardu shows that monsoons have little direct effect on the flows of Karakoram tributaries. In Figure 5. the mean (1970 – 2005) for the monthly total precipitation at Skardu is plotted along the mean monthly flow volumes of River Indus at Kachura (1970 – 2005). This clearly demonstrates that for very high July and August flows and the corresponding precipitation is quite low, indicating little correlation between the two.

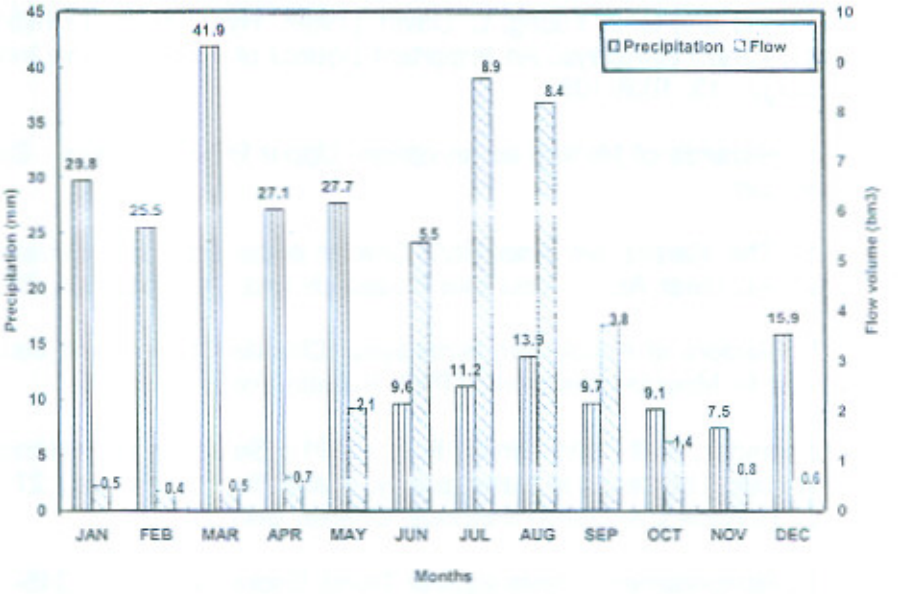


Figure 5. Mean monthly total precipitation at Skardu and mean monthly flow volume at Kachura showing no correlation

7. CONCLUSIONS

Upper Indus Basin has extensive accumulation of glaciers which are vulnerable to climate change. The expected increase in the climate parameters (temperature and precipitation) due to global warming cannot be estimated as the metrological stations network measuring these parameters is sparse and located in valley bottom, and therefore influenced by local thermal effects. However, the summer flows trend from this glaciated area can serve as a good indicator of temperature changes in the glacier ablation zones (3500 - 4800 m.a.s.l).

To estimate the trend from the mean summer flows, Mann- Kendall test has been used. The results show positive trend at more than 99% of Mann-Kendall test significance level during summer months for eastern tributaries collectively gauged at Kachura, indicating warmer summers. In sharp contrast, the mean summer flows of western tributaries show a significant falling trend at more than 98% of Mann-Kendall test significance level indicating cooling summers.

This opposite flow trends in the western and eastern side of Karakoram requires further studies for better understanding of effects of climate change on the water resources lying in Upper Indus Basin. Long term monitoring of snow and glaciers using modern techniques of remote sensing and GIS supported by ground verification of debris covered glaciers can help in achieving this end.

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VEHICULAR EMISSIONS AND THEIR IMPACTS ON HUMAN HEALTH - A CASE STUDY IN KARACHI

By

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Key Words: Vehicular Emissions, Human Health, Traffic Corridors, Air Pollution

ABSTRACT

The environmental degradation provoked by the operation of vehicular traffic has caused enormous health impacts including variations in blood picture of the vulnerable community. This study was carried out in Karachi in coordination with the Transport & Communication Department (TCD), City District Government Karachi (CDGK). This study determines the pollution level and health impact of motor vehicle emissions on the residents, workers and others who are making their living near major automobile traffic corridors in Karachi. Levels of pollutants injected into air by the operation of motor vehicles were measured round the clock for 48 hours (on each point) near highly congested nodes on five main traffic corridors of Karachi. According to the results the average SO_2 measured in air varied from 20 ppb at Tibet Center to 27 ppb in Empress Market, while **NOx** varied from 79 to 127 ppb at Empress Market to Burns Road respectively whereas, **CO** varied from 5 ppm at Karimabad to 10 ppm at Empress Market, while **CO_2** varied from 329 to 422 ppm at Empress Market and Karimabad area, respectively. Average PM10 concentration varied from 210 $\mu g.m^{-3}$ recorded at North Nazimabad to 309 $\mu g.m^{-3}$ at Tibet Center, Gul Bai Intersection areas, respectively. Noise level varied from 76 to 82 dB (A) which was measured in Nazimabad and Karimabad area, respectively. Higher levels of vehicular emissions have resulted in variation in the Eosinophills, Monocytes, Lymphocytes and Neutrophils in the blood of the exposed individuals indicating viral infections, parasitic infections, chronic bacterial infection and chronic inflammatory diseases.

INTRODUCTION

Extensive scientific studies spanning at least three decades has documented the link between air pollution and negative health impacts on people with asthma including asthma attacks. The pollutants most clearly identified as associated worsening the health of people with asthma were sulfur dioxide (SO_2), ozone (O_3) and particulate matter[1,2]. Motor vehicles are a major source of the criteria pollutants and hazardous air pollutants that are ubiquitous to urban areas [3, 4]. A ten-fold increase in estimated exposure to fine particles have significant effect on admission rates for a subset of respiratory diagnoses (asthma, bronchitis, chronic obstructive pulmonary disease, pneumonia, and upper respiratory tract infection) increasing the risk of admission for these diseases by 24 percent. Motor vehicles emit PM2.5 along with a variety of other pollutants and source apportionment studies in urban areas suggest that motor vehicles

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contribute from 25% to 35% of direct PM2.5 emissions [5, 6]. PM2.5 concentrations near busy roads can be 30% higher than background levels. It is likely therefore, that residence near busy streets results in increased exposure to PM2.5 and consequently poorer respiratory health [7]. The proportion of respiratory illness attributable to such exposure is potentially large, given the prevalence of the exposure [8].

Studies indicate that part of the increased mortality is attributable to acute cardiac events triggered by high PM levels [9, 10, 11]. PM soot has been linked to a wide variety of serious health impacts from upper and lower respiratory impacts such as asthma attacks and possible asthma onset, to heart attacks and premature death [12]. Similarly studies conducted by Sousa et al. 2008 linked exposure to ambient air pollution to a number of health outcomes, starting from modest transient changes in the respiratory tract and impaired pulmonary function, continuing to restrict activity/reduce performance and to the increase emergency visits, hospital admissions and/or mortality ratio. The increase of allergenic symptoms has been associated with air contaminants such as ozone, particulate matter, fungal spores and pollen [13]. Associations between traffic-related air pollution and birth outcomes were observed in a population-based cohort with relatively low ambient air pollution exposure by Brauer et al 2008[14].

Keeping in view the above studies a study was conducted to measure the pollution level and health impact of motor vehicle emissions on the residents, workers and others who are making their living near major automobile traffic corridors in Karachi.

MATERIALS AND METHODS

Table1: Name and principle of operation of different equipments used during the survey.

Equipment	Make/ Model No	Application	Range	Accuracy	Principal of operation
CO Analyzer	Thermo Environmental Inc., USA Model 48C	Ambient CO Measurement	0–1, 2, 5, 10,20, 50, 100,200,500,1000 ppm	+/- 0.1 ppm	The technique of Gas Filter Correlation (GFC) spectroscopy is based upon comparison of the detailed structure of the infrared absorption spectrum of the measured gas to that of other gases also present in the sample being analyzed. The technique is implemented by using a high concentration sample of the measured gas, i.e., CO, as filter for the infrared radiation transmitted through the analyzer.
CO_2 Analyzer	Thermo Environmental Inc., USA Model 41H	Ambient CO_2 Measurement	0–1,2, 5, 10,20, 50, 100,200, 500,1000 ppm	+/- 0.1 ppm	The technique of Gas Filter Correlation (GFC) spectroscopy is based upon comparison of the detailed structure of the infrared absorption spectrum of the measured gas to that of other gases also present in the sample being analyzed. The technique is implemented by using a high concentration sample of the

					measured gas, i.e., CO_2, as filter for the infrared radiation transmitted through the analyzer.
NOx Analyzer	Thermo Environmental Inc., USA Model 42C	Ambient NO,NO_2 (NO_x) Measurement	0-10, 20, 50, 100, 200, 500, 1,000, 2,000, 5000 ppm 0-20, 50, 100, 200, 500, 1,000, 2,000, 5,000, 10,000 mg/m^3	0.050 ppm	Ambient NOx Monitor based on Chemiluminescent technology is employed to monitor NOx levels. Inside the reaction chamber NO reacts with ozone to form NO2. The NO2 is excited to a higher electronic state. The Chemiluminescence occurs through an optical filter by a photodiode. The modulated hybrid signal from the detector is demodulated to give continuous NOx and NO signals at the same time. The instrument has been designed for continuous monitoring applications with virtually no maintenance except for periodic changes of filters and dryers.
SO_2 Analyzer	Environmental SA Model AF22M	Ambient SO_2 Measurement	Up to 10.0 ppm	+/-0.001 ppm	Ambient SO2 monitor employs the ultraviolet (uv) fluorescent measurement technique. Ultraviolet rays (215 nm) irradiate a sample containing SO2, the sample emits UV rays of a different wavelength (peak 320 nm, 240-420 nm) and excited light is referred to as Fluorescence. The excitation energy or wavelength is selected by means of a highly energy-stable interference filter to minimize interference from fluorescence of other molecules. The interference wavelength selected lies in a narrow band and produces an excited sulphur dioxide molecule with a very short life. Main detector is placed perpendicular to the light directions to distinguish the emitted fluorescence from the excited light.
Particulate Monitoring Instrument C14 BETA	Thermo Environmental Inc., USA Model FH62C14	Continuous Ambient Particulate Monitor	0 to 5,000 µg/m^3 or 0 to 10,000 µg/m^3	<1 µg/m^3 (24-hour average) ; <4 µg/m^3 (1-hour average)	Continuous and simultaneous particulate collection and beta ray attenuation. Uses a single filter-spot position. Does not use a step-wise interval of the filter tape.
Sound Level Meter	Testo816 Germany		30-130 dB		Pre-amplifier detect sound level with the help of microphone.

Levels of pollutants injected into air by the operation of motor vehicles were measured round the clock for 48 hours (on each point) near highly congested nodes on five main traffic corridors of Karachi. The measurements were made using a Mobile Pollution

Laboratory equipped with pre-calibrated automatic analyzers and noise meters as described in table 1. The measurement of noise levels were made at a distance of 7.5 meters from the road side. The video recording of vehicular traffic on road for each traffic corridor was made and later replayed for traffic counting which was carried out by a team of 16 members designated for the task. The vehicles counting were performed as pre-classified into 8-different classes.

During field surveys blood samples were collected. ENT Examination & audiometer test of volunteers from residents, shop owners, traffic police constables, vehicle operators, petrol pump workers including mechanics and denters/painters, school going children and commuters were carried out during the study. Data on incidence and prevalence of diseases related to air and noise pollution from the outpatient departments of the hospitals and clinics was also collected.

For estimating the Impact of air pollution on the health of people, a technique of pathological analysis of blood to study the alteration of blood pictures was adopted. The methodology for doing so was to analyze the blood samples of such persons who spend sufficiently long period of four to six hours in the same environment. The blood analysis of the 200 such volunteers were undertaken to identify the alternation in blood picture due to the inhaling of pollutants in ambient air. For this purpose, such parameters were identified relate to the interaction of above mentioned pollutants in ambient air with blood hemoglobin. The following parameters were found pertinent for arriving at estimates on alterations in blood hemoglobin: HGB – Hemoglobin, MCV - Mean Corpuscular Volume, MCH - Mean Corpuscular Hemoglobin, MCHC - Mean Corpuscular Hemoglobin Concentration, Platelets Count, MPV - Mean Platelet Volume, WBC - White Blood Cell (leukocytes), Neutrophils, Lymphocytes, Monocytes, Eosinophils and Basophils.

RESULTS

The ambient air data for SO_2, NOx, CO and CO_2 were collected and analyzed for the high impact areas. As may be seen in table 2 the average SO_2 varied from 20 ppb at Tibet Center to 27 ppb at Burns road, NOx varied from 79 - 127 ppb which was recorded at Empress Market and Burns Road, respectively whereas CO varied from 5 ppm at Karimabad to 10 ppm at Empress Market while CO_2 varied from 329 to 422 ppm, respectively.

Table-2: Levels of Ambient Air Pollutants at Designated Points

SITES	SO_2 ppb			NOx ppb			CO ppm			CO_2 ppm		
	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg
Empress Market	36	15	22	232	20	79	15	2	10	593	325	422
Karimabad	39	12	22	195	20	84	13	2	5	395	278	329
North Nazimabad	35	18	24	237	27	88	12	3	6	400	300	346
Nazimabad	40	18	25	231	20	90	16	2	7	393	301	355
Drigh Road	36	16	24	222	20	93	14	2	8	450	300	361
Tibet Center	26	15	20	196	30	119	14	2	8	616	296	347
Shaheen Complex	34	15	25	240	23	120	11	3	7	500	317	383
Burns Road	40	13	27	239	21	127	16	2	7	468	304	354
Gul Bai Intersection	34	14	23	247	20	98	13	4	7	464	320	371

Over all minimum PM10 level of 49 $\mu g.m^{-3}$ was recorded in Nazimabad while its maximum level of 135 $\mu g.m^{-3}$ was measured in North Nazimabad area (table 3). While maximum level variations were recorded from 375 to 490 $\mu g.m^{-3}$ recorded at the Drigh Road and North Nazimabad area, respectively. Overall averages PM10 concentration variation were recorded from 210 at North Nazimabad to 309 $\mu g.m^{-3}$ at Tibet Center and Gul Bai Intersection areas, respectively. Average noise levels (table 3) ranged from 76 dB (A) to 82 dB (A) which was recorded at Nazimabad and Karimabad area, respectively.

Table-3: Noise Level at Different Intersections dB (A)

	PM			Noise		
Location	Max	Min	Avg	Max	Min	Avg
Empress Market	426	74	239	85	74	79
Karimabad	435	78	289	94	67	82
North Nazimabad	490	135	210	89	64	77
Nazimabad	375	49	234	88	64	76
Drigh Road	469	90	229	90	65	79
Tibet Center	469	98	309	86	75	81
Shaheen Complex	415	94	228	85	70	78
Burns Road	405	53	222	90	68	80
Gul Bai Intersection	460	81	309	85	69	79

Alteration in blood picture as shown in table 4 which gives an extensive change in the blood picture of the people living for long time on the road side.

Table 4: Alteration in blood picture data collected from the survey

Blood Component	Observed Range	Normal Range
Hemoglobin	9-18	13- 18 g/dl
Red Cell Count	3.7 – 9.1	4.5 – 6.5
PCV	15.4 – 56.7	36 – 54
MCV	21.6 – 111.3 fl	76 -96
MCHC	21.5-35.4 g/dl	30-35g/dl
Platelet Count	7.4-449	150 – 400
Total Leucocytes	2.6 - 17.4	4 -10
Neutrophils	38 – 86	40 – 75
Lymphocytes	5-76%	20-45 %
Eosinophils	1-14%	1-6 %
Monocytes	1-23%	2-10 %
Basophils	1-2%	0-1 %
Lead Levels	0.41-26.5	

Variations of some of the blood parameters of individuals living or making their living near the high congestion points of motor vehicle traffic is graphically shown in the Fig 1 & 2. From these figures it is evident that variation oh MCH eosinophils levels are increased in blood of highly exposed individuals (Fig. 1 & 2). Most of the blood samples

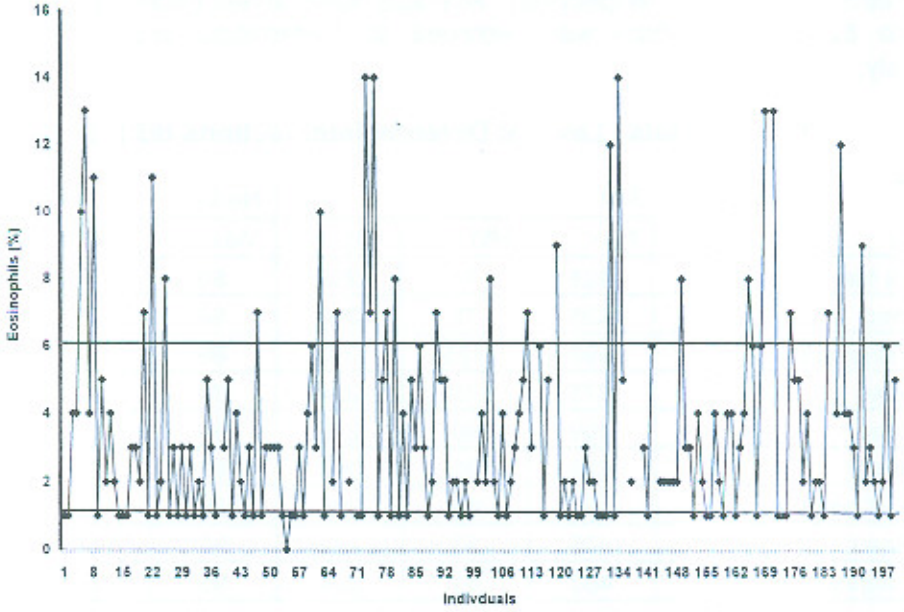


Fig 1: Eosinophils level (normal range 1-6%)

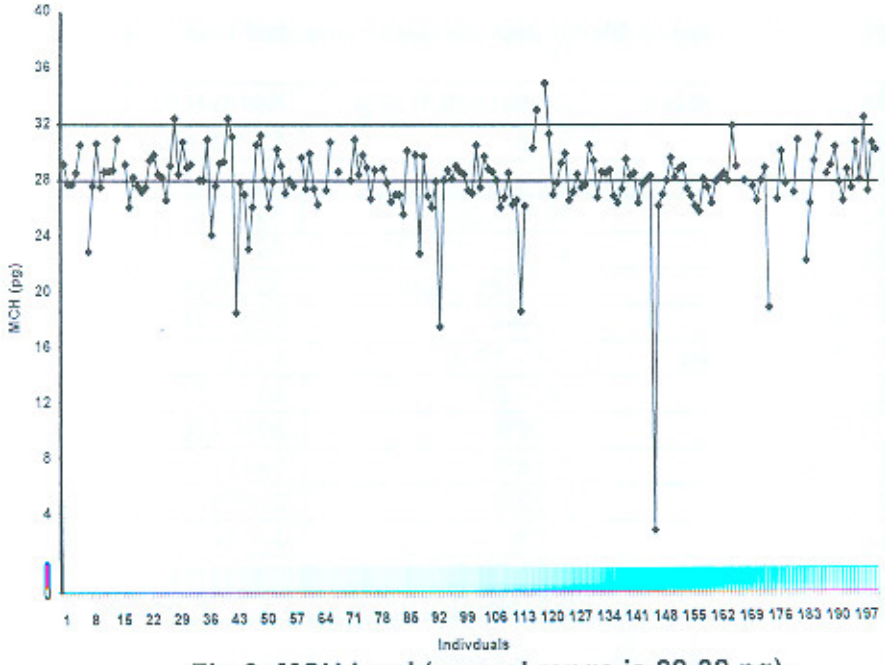


Fig 2: MCH level (normal range is 28-32 pg).

of vulnerable community showed alteration in their blood picture. The plots of blood parameters suggests that the average platelets count, MCH and is on the lower side of the spectrum and that esinophills, monocytes, lymphocytes and neutrophils are on the higher side of the recommended level (Fig. 3).

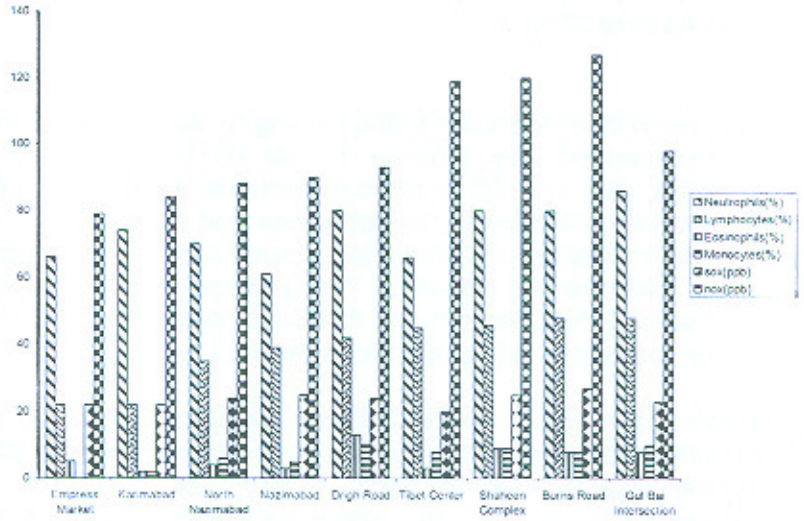


Fig 3: Blood Component levels and Pollutant Levels on Different sites.

Results show that inhaling of increased level of Nox in air has resulted in the high lymphocytes in the blood. A positive correlation exists between average Nox level and maximum value of lymphocyte in the blood of the exposed ones. The high levels of Nox and SO2 in ambient air have caused modification in the esinophill and monocytes in the blood of the vulnerable individuals (Fig. 3).

The data on the patients of the respiratory diseases collected during the study is shown in Fig 4. This data shows increase in the number of patients with respiratory diseases each year from 2000-2004. There is positive correlation of impact of pollution on the human health (Fig-4) i.e. higher the pollution levels more patients are reported.

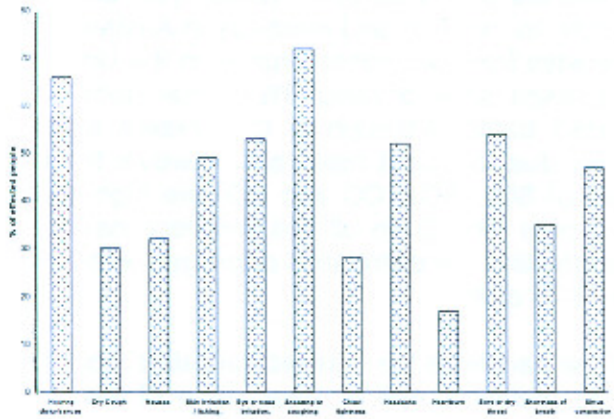


Fig.4: Number of patients admitted to hospitals during 2003-3004.

Information obtained through questionnaires is given percentage wise. On the basis of surveys the impact of pollution on the human health are quantified as hearing disturbance of 66%; dry cough 30%; nausea 32%; skin irritation/itching 49%; eye or nose irritation 53%; sneezing or coughing 72%; chest tightness 28%; headache 52%; heartburn 17%; sore or dry throat 54%; shortness of breath 35%; sinus congestion or runny nose 47% and Asthma 75%.

DISCUSSION

Emissions from the operation of vehicular traffic leading to disturb the natural balance of the atmosphere have caused dire adverse impact on human health in Karachi. Increased levels of NOx, SO_2 and CO in air from vehicular emissions have resulted in variation in the Eosinophills, Monocytes, Lymphocytes and Neutrophils in the blood of the exposed individuals indicating viral infections, parasitic infections, chronic bacterial infection and chronic inflammatory diseases. The average platelets count, MCH and MCH is on the lower side of the spectrum and that esinophills, monocytes, lymphocytes and neutrophils are on the higher side of the recommended level.

The average platelets count, MCH and MCHC has lowered due to the interaction of blood haemoglobin with increased levels beyond above allowable limit of CO, NOx, SO_2 in the blood and living organisms like bacteria. Platelets cells produced by the bone marrow, the interaction of CO, SO_2, and NO_x with them may go far ahead to the impacts of carbonyl / nitrosyl analogues of haemoglobin on the bone marrow processes causing clotting of blood. The alterations in the blood parameters may be different in case the nutritional status and personal habits are accounted for in the study.

Proximity to roads is positively correlated with risk of skeletal abnormalities in Alaskan wood frogs [15] which is also true in the present study. Anthony et all 1998 [16] have related Daily air pollutant level in relation to daily deaths indicating that that several categories of air pollution pose an acute health hazard. In other study conducted by Andy Haines showed that the transport sector accounts for 26% of all carbon dioxide emissions in the European Union, and its con-tribution is rising [17].

In another study conducted by Künzli et al. (2000) [18] assessed the contribution of traffic related air pollution to mortality and morbidity in Austria, France, and Switzerland. They used effect estimates from two cohort studies in the United States and found that particulate matter was responsible for about 6% of total mortality. About half of this was attributable to motorized traffic. Although in the present study data is collected for relatively short duration, due to limited resources, however from that it may be inferred that ambient air levels of SO_2, NOx, CO and CO_2 are high near the road side areas. Average level of 6-10 ppm for CO on all five corridors indicates the prevalence of a reducing atmosphere affecting the distribution of oxygen within the human body. Noise level remained in the 76-78 dBA.

It was observed that the people at the intersections/sites were facing transport and air pollution related health problems and at least some of them were showing positive symptoms of impact on their health.

Karachi being a mega city requires regular monitoring of ambient air levels as people affected from these levels is high in number. Further more roots like Liyari by Pass, and Northern by Pass may be constructed in order to reduce the traffic load on the roads inside the city. There is very much need of public awareness to educate them to use proper mask while working in the busy traffic corridors. Regular medical check up is also recommended for the people who work or make their living near the traffic corridors.

CONCLUSIONS

CO, NOx, SO_2 and noise levels have been measured in the different traffic corridors and found their levels higher than the safe limits all the sites. Traffic load on all the studied corridors is high. The average platelets count, MCH and MCHC values in the reported samples is lower due to the interaction of blood hemoglobin with higher than allowable limit of CO, NOx, SO_2 in the blood and living organisms like bacteria. The findings of the study are based on data of small duration; however the conclusions drawn may be validated by a separate study based on data of longer duration.

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EMISSION INVENTORY OF LAHORE, PAKISTAN-2007

By

B. M. Ghauri* and A. N. Khan**

ABSTRACT

An emission inventory is emission estimates from different major sources of air pollution in a given area for a specified time period. It is an essential element of Air Quality Management (AQM).The principle adopted in this study is "*Key is to establish a baseline with available data*".

Lahore (31°54' N, 74°34' E) is the second most populated city of Pakistan. In present study the emissions from combustion activities, industrial process, transport, wastes and livestock have been estimated using Stockholm Environment Institute (SEI) approach. The estimated pollutants are SO_2, NO_x, CO, NMVOCs, CO_2, NH_3, PM_{10}, $PM_{2.5}$ and CH_4. The main source of air pollutants is combustion of fossil fuels in public electricity &heat, transportation and industry. It contributes about 93% SO_2, 98% NO_x, 99 % CO, 98 % NMVOCs, 92 % CO_2, 23 % PM_{10}, and 22 % $PM_{2.5}$.

KEYWORDS

Emission Inventory, Lahore, Pakistan, Stockholm Environment Institute Approach.

INTRODUCTION

An emission inventory is emission estimates from different major sources of air pollution in a given area for a specified time period.

The emission inventory of Lahore is divided into stationary, mobile, and biogenic sources.

a. Stationary Source Emissions

Stationary sources are further divided into point and area sources.

Point Sources

Combustion Activities

Emissions from different types of fuels (Gasoline, Petrol, Natural Gas, Liquefied Petroleum Gas, Coal etc.) burnt in Public Electricity & Heat, Agriculture, Domestic, Other Govt., Commercial and Industry are estimated under this category.

Industrial Process

There are about 1454 industrial units in Lahore. In this inventory only those industries have been discussed about which both data and emission factor were available and

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emissions have been calculated upon installed capacity of the unit. These include Mineral Products (Brick Manufacturing, Lime), Chemical Industry (Sulphuric Acid, Ammonia), Metal Production (Pig Iron/Steel, Aluminum), Food & Drinks (Bakery Products, Biscuits, Animal Feed (Poultry)), Paper& Pulp and Solvent & other Solvent Use (PVC, Rubber Processing, Paint & Varnishes, Ink and Glue, Solvent Extraction (Edible & non-edible).

Area Sources
Wastes
Emissions from municipal solid waste and liquid waste.

b. Mobile Source Emissions
Mobile sources consist of on-road motor vehicles and other mobile sources.

On-Road Motor Vehicles
On-road motor vehicles are passenger cars, trucks, buses, vans, motorcycles etc.

Emissions from on-road motor vehicles are a major portion of the emission inventory.

Other Mobile Sources
These sources include aircraft, garden, farm and construction equipment.

c. Biogenic Sources
Human excreta and livestock waste.

Importance of Emission Inventory
Emission inventories are an essential element of air quality management programs. They provide a basis for regulatory programs, emission trends analysis and many other program activities.

In Planning
Inventories are critical components of air quality planning. The ultimate goal of the planning process is to identify and achieve emission patterns that exceed ambient air quality standards.

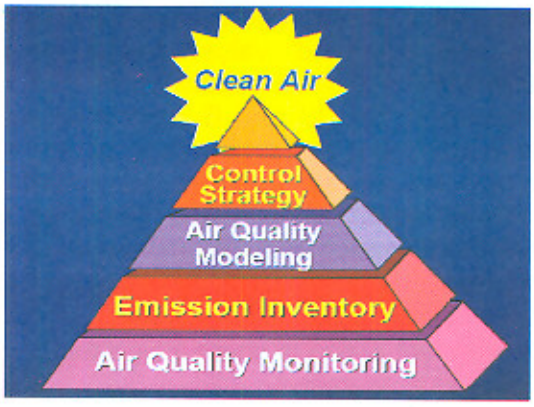
Evaluating the success of emission reduction programs
By conducting an emission inventory, and then a follow-up study we can get an indication of the progress being made to reduce pollution.

Research
Researchers from universities and other institutions and agencies use the inventories as they look into issues like the health and environmental impacts of air pollutants.

Forecasting future emission levels

Projected regional population, economic and development statistics are used to predict future changes in emission levels. These predictions are used to determine which emission areas might require further controls.

Fig.1 Hierarchy of Emission Inventory in Air Quality Management.



Pollutants discussed in this Emission Inventory
The estimated pollutants are, SO_2, NO_x, CO, NMVOCs, CO_2, NH_3, PM_{10}, $PM_{2.5}$ and CH_4.

METHODOLOGY

The method used to calculate different emissions is as follow.

Emissions = Emission Factor **x** Activity Rate

(An emission factor provides emissions per unit activity)

Emission Factors used in this Inventory are the default factors provided in **"The Global Atmospheric Pollution Forum Air Pollutant Emission Inventory Manual, Version 1.2, August 2008"** except for CH_4 (For solid and liquid wastes) which has been calculated from IPCC Guidelines.

Activity and units of emission factors for various sources

The activity of discussed sectors i.e. combustion activities, industrial process, transport, wastes and livestock mean fuel consumption in TJ, tonne of production, Km traveled by vehicle, population; BOD_5; tonne of solid waste produced per year, number of animals and units of emission factors for these sources are Kg/TJ, gm/Km for road vehicles & Kg/LTO for air transport, Kg/tonne of product, Kg/capita/year; Kg/Kg BOD_5; tonne/million litre of waste water and Kg/animal/year respectively.

ASSUMPTIONS/LIMITATIONS

Different assumptions have to be considered in this emission inventory.

- The data about consumption of different fuels in various sectors for Lahore is not available. So, in this inventory the data has been calculated assuming the per capita consumption of TOE from literature about Pakistan and considering some guidance from "Pakistan Energy Yearbook 2007"
- Data about registered vehicles has to be considered.

- Emission estimates for industrial process is calculated on installed capacity rather than actual production of the unit.
- Variations in conditions (fuel properties, operating conditions, vehicle characteristics, etc.) for which segregated data is not available.
- Emission factors are 'averaged' values based on related assumptions to represent characteristics of a given population of sources. Most of the emission factors are developed in the US and European countries, and are, therefore, applicable to these countries, strictly. In many cases, it can be argued that the emission factors are equally applicable to the conditions in Pakistan as well. However, the differences in climatic and operating conditions are likely to introduce uncertainties for which no estimates are available.
- Due to lack of information in the source data/emission factors for various sources of emissions could not be estimated.
- Some institutions were not willing to share their data.

Temporal Coverage

This emission Inventory has been developed for 2007.

DATA SOURCES

The basic activity data used in the inventory is obtained from yearbooks, surveys, census reports and annual reports published by different Govt. organizations.

Some personal visits were also made to collect data. The other modes of data collections were

E-mails to both national and international experts, telephonic contacts and postal services.

The main sources are:

- Pakistan Energy Yearbook 2007, Prepared by Hydrocarbon Development Institute of Pakistan.
- Punjab Development Statistics, 2007, Bureau of Statistics, Govt. of the Punjab, Lahore.
- National Emission Inventory Program for Pakistan, 2000, under Male declaration.
- EPD, Punjab, Lahore.
- TEPA, Lahore.
- Lahore Chamber of Commerce and Industry, Lahore.
- DO office, Municipal Solid Waste Management, Lahore.
- Economic Survey of Pakistan 2007, Published by Finance Div., Govt. of Pakistan.
- National Transport Research Centre, Islamabad.
- Civil Aviation Authority (CAA), Karachi Airport.

RESULTS: (Tonne per year)

Fuel Combustion Activities

Sector/Fuel	Energy Use (TJ)	Quantity (TOE)	CO_2	SO_2	NO_X	CO	NMVOC	PM_{10}	$PM_{2.5}$	NH_3
Transport	**26554**	**632000**		12600						
Aviation Gasoline	1486	35392	104055							
Motor Gasoline	3265	77736	226264							
Diesel Oil	18156	432288	1345359							
Natural Gas	3612	85992	202633							
Power Generation	**56213**	**1338400**		34800						
Furnace/Heavy Oil	24157	575171	1869759		6000	360	120	520	320	60
Natural Gas	31785	756786	1783138		3300	630	158	90	90	41
Industrial (Combustion)	**43025**	**1024400**		32700						
Furnace/Heavy Oil	44227	1053030	3423185		6400	660	220	110	70	10
Natural Gas	22625	538700	1269285		1200	680	110	-	-	30
Coal	11302	269111	1069226		3400	1700	230	1140	500	0.1
Agriculture	**2142**	**51000**		200						
Diesel Oil	282	6732	20948		37	280	56	-	-	-
Domestic	**20769**	**494500**		30						
Kerosene Oil	299	7120	21498		7	51	1	9	8	-
Natural Gas	11856	282290	665132		440	600	60	-	-	2
LPG	1198	28538	75631		22	400	6	140	130	-
Other / Govt. Sector	**1978**	**47100**		600						
Diesel Oil	910	21680	67468		120	18	4	3	2	-
LPG	34	823	2183		1	1	0.2	-	-	-
Commercial	**3788**	**90200**		900						
Natural Gas	2019	48084	113294		74	100	10	-	-	0.4
LPG	567	13514	35815		19	11	3	-	-	-
Total			**12294878**	**81830**	**35370**	**73590**	**9936**	**2000**	**1120**	**205**

2. Transport
2.1 Road Transport

Description of Vehicle	NOx	CO	NMVOC	NH_3	PM_{10}	$PM_{2.5}$
Motor cycle	2685	282015	134293	26	537	537
Car & Jeep	10220	213700	24622	9	297	297
Station wagon	6780	84863	14044	4	253	253
Passenger Wagon	1453	18193	3010	1	54	54
Bus/Mini Bus	8651	7470	1622	2	832	832
Rickshaw	4531	17261	7551	-	140	140
Taxi	470	1543	324	-	14	14
Pick-up	1180	4496	1967	0.6	140	140
Delivery Van	4209	52691	8720	3	157	157
Truck	5131	4430	962	1	493	493
Others	4070	23161	4876	3	593	593
Total	**49382**	**709825**	**201992**	**52**	**3513**	**3513**

2.2 Air Transport

Aircraft Type	No. of LTOs	SO_2	NOx	CO	NMVOCs	PM_{10}	$PM_{2.5}$
Airbus A310	4,603	7	106	118	23	2	2
Airbus A320	3,432	3	37	60	6	2	2
Airbus A330	828	2	30	17	2	0.4	0.4
Airbus A340	189	0.4	7	9	3	0.1	0.1
Boeing 727	02	0.003	0.02	0.05	0.01	0.001	0.001
Boeing 737	7,976	6	66	94	5	4	4
Boeing 747	3,129	10	177	61	5	1	1
Boeing 757	140	0.2	3	2	0.1	0.07	0.06
Boeing 767	596	1	15	4	0.5	0.3	0.3
Boeing 777	2,443	6	131	150	50	1	1
DC-8	02	0.004	0.03	0.1	0.1	0.001	0.001
DC-9	415	0.4	3.0	2	0.3	0.2	0.2
DC-10	08	0.02	0.3	0.5	0.2	0.004	0.004
MD-82	775	0.8	9	5	1	0.4	0.4
Type Unknown (Average Fleet)	3,815	3	31	45	2	2	2
Total	28353.0	40	617	570	98	15	13

3. Industrial Processes

Industry	Production (Tonne)	SO_2	NO_x	CO	NM-VOCs	NH_3	PM_{10}	$PM_{2.5}$
Mineral Products								
Brick Manufacturing	25,000	NA	NA	NA	NA	NA	17	11
Lime	2,100	NA	NA	NA	NA	NA	46	5
Chemical Industry								
Sulphuric Acid	17,600	299	NA	NA	NA	NA	NA	-
Ammonia	584	0.02	NA	5	3	1.2	NA	NA
Metal Production								
Pig Iron/Steel	4,38,044	1314	33	587	52	NA	22	-
Aluminum	2,012	30	4.	271	0.04	NA	94	-
Food & Drinks								
Bakery Products	29,315	NA	NA	NA	149	NA	-	-
Biscuits	6,135	NA	NA	NA	6	NA	-	-
Animal Feed (Poultry)	3,46,100	NA	NA	NA	103	NA	-	-
Paper & Pulp	2,03,356	773	305	1139	752	NA	18709	16472
Solvent & other Solvent Use								
i) Chemical Products								
PVC	2,280	NA	NA	NA	91	NA	NA	NA
Rubber Processing	6,394	NA	NA	NA	96	NA	NA	NA
Paint & Varnishes	74,585.8	NA	NA	NA	1118	NA	NA	NA
Ink	1,655	NA	NA	NA	49	NA	NA	NA
Glue	250	NA	NA	NA	5	NA	NA	NA
ii) Other Uses								
Solvent Extraction (Edible & non-edible)	18,000	NA	NA	NA	324	NA	NA	NA
Total		**2417**	**343**	**2002**	**2752**	**1.2**	**18889**	**16488**

4. Wastes

Human Excreta

Total NH_3 per year from Human Excreta in Lahore = 0.8*8010000 = 6408000 Kg = **6408 Tonne**

Municipal Solid Waste

Total Methane Emissions per year from Municipal Solid Waste in Lahore = 1898000*0.7*0.8*0.12*0.77*0.5*1.34 = **65800 Tonne**

Liquid Waste

Total CH_4 produced per Year from Waste Water in Lahore = 0.25*8164800 = 2041200 Kg = **2041Tonne**

5. Livestock

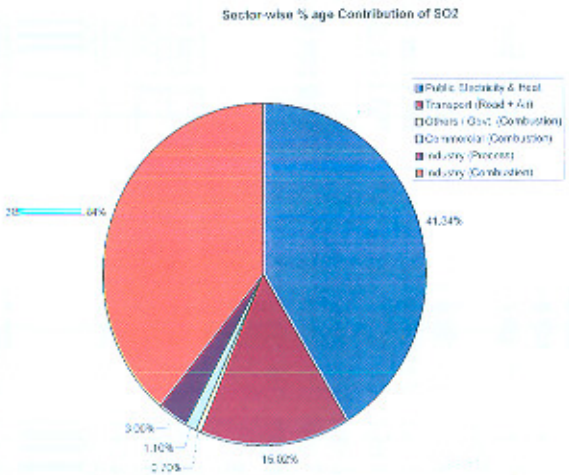
Livestock Type	Total No. (In 2000)	NH_3 Emissions
Buffalo	327000	1733
Sheep	27000	16
Goats	67000	37
Other Cattle	90000	450
Total		2236

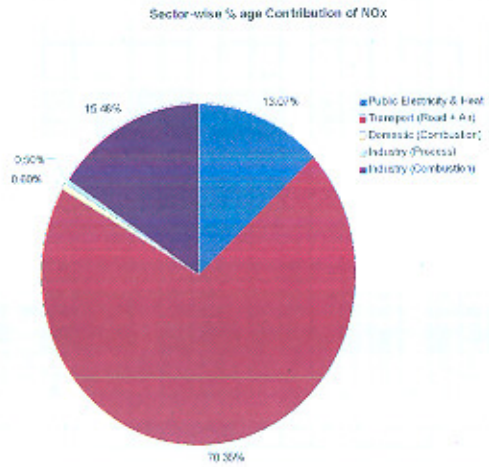
Summary Sheet- Annual Emissions of Each Pollutant by Source/Sector

Table. 1

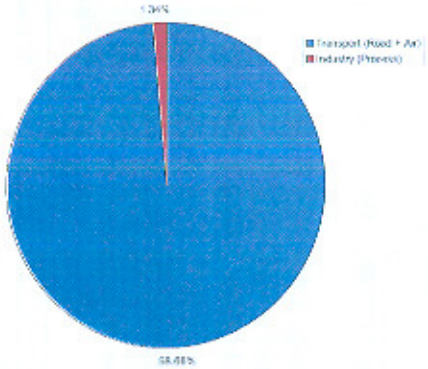
Sector/ Source	Total Emissions (Tonne per Year)								
	SO_2 CH_4	NOx	CO	NMVOCs	NH_3	PM_{10}	$PM_{2.5}$	CO_2	
Public Electricity & Heat	34800	9300	990	278	101	610	410	3652898	-
Transport (Road + Air)	12640	50000	710395	202090	52	3527	3526	1878312	-
Agriculture (Combustion)	200	37	280	56	-	-	-	20948	-
Domestic (Combustion)	30	470	1051	67	2	149	138	762262	-
Others / Govt. (Combustion)	600	121	18	5	-	3	2	69651	-
Commercial (Combustion)	900	93	111	12	0.4	-	-	149109	-
Industry (Process)	2417	343	2002	2752	1	18889	16488	-	-
Industry (Combustion)	3270	11000	3040	560	40	1250	570	5761696	-
Live Stock	-	-	-	-	2236	-	-	-	-
Wastes (Solid, Liquid, Human Excreta)	-	-	-	-	6408	-	-	-	67848
Total	**84287**	**71364**	**717888**	**205821**	**8843**	**24429**	**21135**	**12294877**	**67848**

- = Either Not Applicable or EF not Available

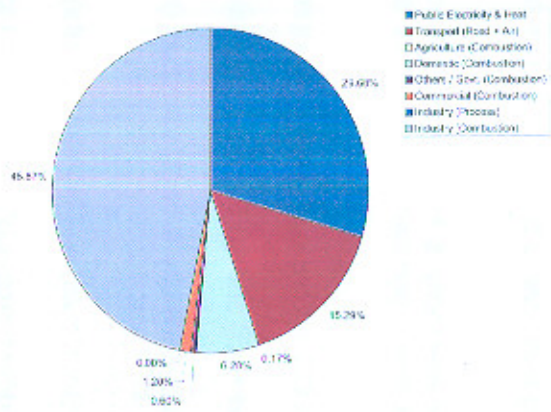




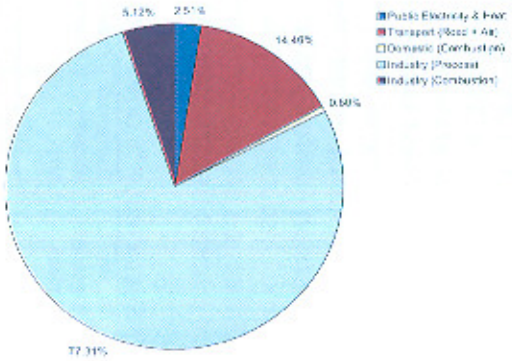
Sector-wise % age Contribution of NMVOCs



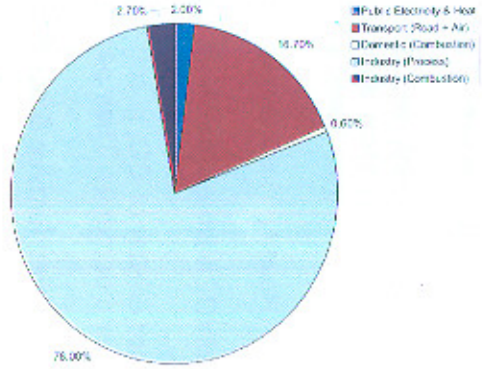
Sector-wise % age Contribution of CO2



Sector-wise % age Contribution of PM10



Sector-wise % age Contribution of PM2.5



Note: The sectors having contribution less than 0.5 % have been ignored.

DISCUSSION

The main source of air pollutants is combustion of fossil fuels in public electricity &heat, transportation and industry. The sectors having less than 0.5 % contribution have been neglected in this discussion. (Table. 1 & 2)

SO_2 and NO_x are mainly produced from public electricity & heat; transport (road + air) and industrial combustion and contribution of these pollutants from these sources is about 95 and 98 % from these sources.

Transport (Road+Air) is the major contributor of CO and its contribution is approx. 99 %.

98 % NMVOCs are emitted from transport (road + air) and1.5 % from industrial process.

The major emitter of CO_2 is combustion in public electricity & heat, transport (road + air) industry and domestic. Their part is 29.7, 15.3, 47.0 and 6.2 % respectively.

NH_3 is estimated for Live Stock and Wastes (Solid, Liquid, and Human Excreta).

PM_{10} and $PM_{2.5}$ are mainly estimated from industrial process of paper & pulp industry and transportation.

CH_4 contribution was calculated for wastes (Solid, Liquid, and Human Excreta)

There are various impacts of being exposed to various discussed pollutants, such as:

- *Effects on human health*

Premature mortality, asthma attacks, respiratory symptoms, chronic bronchitis, oxygen deficiency in blood, eye irritation, and genetic and reproductive damages

- *Effects on vegetation*

Productivity loss and slower photosynthesis for vegetation

- *Effects on material and structure*

Corrosion of metal, accelerated erosion on building and monument

- *Effects on comfort and aesthetics*

Bad smell, reduced vision distance, quick paling of paint on buildings

- *Effects on ecosystem* (atmosphere, soil and water body)

Local (human health), regional (acid rain), and global (climate change)

Table.2 Sector-wise % age contribution of various pollutants

Pollutant / Sector	Public Electricity & Heat	Transport (Road + Air)	Industry (Combustion)	Domestic (Combustion)	Commercial (Combustion)	Others / Govt. (Combustion)	Industry (Process)
SO_2	41.3	15.0	38.8	-	1.1	0.7	3.0
NOx	13.0	70.0	15.4	0.6	-	-	0.5
CO	-	99.0	-	-	-	-	-
NMVOCs	-	98.2	-	-	-	-	1.4
CO_2	29.7	15.3	47.0	6.2	1.2	0.6	-
PM_{10}	2.5	14.4	5.1	0.6	-	-	77.0
$PM_{2.5}$	2.0	16.7	2.7	0.6	-	-	78.0

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CONCLUSION

The study reveals that about 60-70% of energy consumption and emissions are due to combustion of fossil fuels in vehicles, industry and electricity generation.

RECOMMENDATIONS

Improvement in fuel efficiency is required in Pakistan which may be achieved by adopting various options like de-sulfurization of fuels ,scrubbers, catalytic converters, tuning of vehicles and boilers periodically and well established infra structure and implementation of existing laws in true letter and spirit by concerned authorities.

Detailed study to calculate/develop the emission factors with our own socio-economic environment/data and development of national emission inventory involving all sectors is required to be carried out in Pakistan.

ABBREVIATIONS

SO_2	Sulphur Dioxide
NO_X	Oxides of Nitrogen (NO + NO_2)
CH_4	Methane
NH_3	Ammonia
NMVOCs	Non-Methane Volatile Organic Compounds
CO	Carbon Monoxide
PM	Particulate Matter
PM_{10}	Particulate Matter less than 10 µm in diameter
$PM_{2.5}$	Particulate Matter less than 2.5 µm in diameter
TOE	Tonne of Oil Equivalent
TJ	Tera Joule = 10^{12} Joule
LTO	Landing and Take-Off Cycle of an Aircraft
BOD_5	Biological Oxygen Demand (for Five days)
NA	Not Applicable
EF	Emission Factor
CO_2	Carbon Dioxide

ACCOUNTABILITY OF CHEMICAL INDUSTRIES TOWARDS SUSTAINABLE DEVELOPMENT

By

S. E. Benjamin*

By definition sustainable development according to WCED (World Commission on Environment and Development, Oxford University Press, Oxford, 1987) means, "the development that meets the needs of present without compromising the ability of future generations to meet their own needs". Three important points linked to this simple definition is the economics, social impacts and the environment safety. It means that concise efforts are required to preserve the depleting sources and at the same time maximize the remuneration by conservation and working out the most suitable processes based on the best atom economy. The processes adopted must be safer and cleaner to safeguard the eco system and should be sustainable to coop with the dynamic growth of the world population.

This important issue of sustainable development was not addressed when several new processes and technological advancements were taken place until serious consequences e.g., at Bhopal, Madhya Pradesh, India (December 03, 1984) was encountered. A Union carbide pesticide plant released 42 tons of methyl iso cyanate (MIC) gas exposing approximately 520,000 people to toxic gases and 8000 people died within two weeks and several suffered from serious effects. It is now felt with full consciousness that meeting the need today should not be a tragedy of tomorrow.

Industrial growth relates to sustainable development in chemistry and technology to develop industry and economics i.e., requiring both competitive advantage and sustainability. All the countries of the world have some type of chemical industry which may be specific or a supplier of unfinished product to the other down stream industry. The chemical industry is therefore, the key industry. It contributes to all areas of life i.e., from food and clothing, housing, communications, transport till leisure. It encompasses the whole world of materials and therefore, supports the energy sector, information technologies, environmental industries and waste disposal sector. The important areas of drugs and medicine, agriculture and pesticides survive on the chemical industries though differently labeled as pharmaceutical and agrochemical industries. It is therefore, a challenging task that the chemical industries face today to meet all type of demand.

The chemical technologies involve the use of chemical processes such as chemical reactions and refining methods to produce a wide variety of solids, liquids and gaseous materials. Uncontrolled emissions added to air, water and land are not only causing damage locally but are a threat globally. The complexity of the problem is multiplied due to lack of data regarding the amount of hazardous substances being released into the environment during use. The disposal of wastes from chemical processes and interactions are a major threat and require efforts on part of every human being as a member of the global team to participate in combating the this huge amount of task.

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Under the concept of "responsible care", the chemical companies are committed, in all aspects of safety, health and protection of the environment. The chemical industry not on has to keep the demand / production ratios to the mark but these have to consciously improve performance continuously. This works through proper education all staff starting from the raw material selection, via efficient, clean and safe process routes till the use of end product by the customers. Thus, the chemical industries in business crucially need action on part of all people, governments, and organizations around the world.

Over the last ten years Green Chemistry has become recognized as both a culture and a close method of achieving sustainability. The principle of Green Chemistry helps show how this can be achieved. Many of these principle employ e.g., catalysis and increased use of renewable resources. When looking at Green Chemistry from an industrial perspective it is important to take the cost of implementing Green Technology into account. A safe process may not be economically very viable. However, continuous adjustments in solvents and raw materials may lead to a safe and productive environment. If at all, the hazardous economically suitable process is to be adopted, concerted efforts should be placed on safety measures, conservation, limited use, and secured disposal of wastes. The ill attitude of dealing the problem at end / outlet and not killing it at the source must be permanently discarded.

The chemical industry can be catalyst for novel implementations. Various mechanisms exist by which chemical innovations stimulate others. The chemical technologists can achieve implausible goals by the use of nano material investigations i.e., engineering of functional systems at the molecule scale. It refers to the projected ability to construct items from the bottom up with the help of techniques and tools to generate highly advanced products. Nano studies can help achieve standards and quality. It also has serious economic, social environmental and military implications. It offers better built, longer lasting, cleaner safer, and smarter products for the home, for communications, for medicine, for transportation, for agriculture, and for industry in general. Adoption of low weight but strong and though materials through manipulation of functional groups can assist in manufacture of vehicles that are lighter and can be hence, more energy efficient. The same applies to the building materials especially in areas where earthquake threat exists.

Materials technology and knowledge based technology must work hand in hand. The transfer of materials technology to farmers generally involves the production, distribution, and sale of seeds, implements, agrochemicals, and other production inputs. Most materials technology requires technical knowledge so that these products or tools can be used effectively. Hence, the farmers should be continuously educated and provided with up to date knowledge.

Modern technologies like as biotechnology can be effectively engaged in disease prevention therapeutics. This is based on exploiting the genosome. One facet is the production of transgenic organism, bacteria yeast plant, or animals that have been

genetically modified to produce a commercially useful product that might be difficult to manufacture other wise. Pesticides have added to crop production but at the same time it adversely affects the whole eco system. Some chemicals may become a part of food

chain and eventually produce incurable disease in the human beings. This necessitates that biotechnology should be implemented to bring changes in seed make-up chemistry at the gene level so that healthier and more resistant fields to pests are developed.

The leather industry has its valuable place and the local industry is still surviving on use of hazardous chemicals. It is an established fact by now the enzyme treatment of leather can give more effective results and is much more safer to employ. The use of purified enzymes and other type of highly specific catalyst can to carry out several biological manufacturing processes and replace traditional chemical manufacturing processes.

The valuable environmental aspects has been ignored in the Pakistan industry. Whether, consciously or unconsciously, the wonderful fresh waters resources have been polluted, to such an extent, that in some cases, life could not sustain, any longer. It is discouraging to note that several international industries have also taken advantage of the killing freedom and have produced profits ignoring the well being of the surrounding population. In such areas people suffer not from only mal nutrition but also face child deformities for generations to come. Still births are commonly encountered. Congestion and suffocation is widespread. It is depressing to note that introduction of International measures as ISO 9000 that were regrettable taken as steps to kill the 3rd world economy though in reality it contained measures to produce quality goods with safer technologies. The nation has to adopt an attitude so that better technologies should be taken and not the throw away ones which though much cheaper give bereavement later on. No compromise policy has to ensure the future of our country.

Pakistan as a third world country stands at the risk of very deleterious present. The power and energy deficiency from the hydrothermal resources has brought constraints on the natural gas. A dire exists that the benefits from the depleting sources should be optimized. The population burst has placed colossal burden not only on the socio economic balance but has also negatively played with the eco system. Energy efficiency, less use of solvents, less volatile organic matter (VOC's), less hazardous chemicals, all needs minimization. Other sources as LPG should be marketed to a greater extent.

To summarize, several important steps need to be taken for sustainable development as follows :

- Conservation of goods and quality.
- Replacement of poor technologies by cleaner and more efficient technologies. Hence, incorporation of advance technology for sustainable growth.
- Configuration of technology platforms : Technology integration and validation activities should focus on new technology platforms.
- Standards have to be created and enforcement is required.
- Policy debates should frequently occur to press towards sustainable development. Ceaseless effort must be placed upon improving process yield. Adopted strategies should not be static but must respond to changes and trends with both science and society.

- More involvement of low-cost, low weight primary structures.
- Selection of best available component technologies for existing designs and developing advanced designs to reduce NO_x and CO_2 emissions e.g., more efficient scrubber systems or development of new integrated environmental technologies.
- More efficient machines to provide a balanced capability in products.
- Involve system integration and optimize overall energy consumptions.
- The Government must support the transition to more sustainable models of production.
- Identify priority research themes.
- Support potential industrial and academic interest in participating in collaborative research projects in identified areas.
- Adopt effective methodologies for the transformation of research results into operational management procedures covering all segments. This requires development of framework to link knowledge and technology management to sustainable production.
- Strengthen skills for understanding the nature of economic cycles.
- Rebates to the industries adopting sustainable technologies.
- Continuous ceaseless efforts.
- Role of media to ask people to contribute if they see any industry adding pollution in the environment and to which extent.
- Educate people consistently about the subject under discussion. Creation of energy conservation conscious society should be the major aim. Development of culture to feel our responsibility towards the human race.
- Burning of garbage especially in cities should be banned.
- Black plastic bags to be a permanent banned item.
- Installation of new chemical plants should not be allowed unless passed by the environmental acts.
- Government policies must more stringent and harder on the environmental issues. Develop a clears set of rules with predictable consequences in the long run. Products must carry the eco logo.

The role of chemical industries in sustainable development is unquestionable. However, from the perspective of its role in Pakistan several stringent actions are required on part of people, governments, business and organizations. It has to be a shared vision.

All in house small industries must be pooled at one place and should work under rigorous monitoring and measures. Several people enjoy the freedom of doing whatever

suits them to earn them good profits. Their paradise should be our hell. Under hand groups function here and there and recycle dangerous plastic to make cheap items. The thermal treatment of these waste plastics release toxic carcinogenic chemicals in the atmosphere. These injure not only the people living in the near vicinity but travel miles before escaping into the atmosphere. Thus, perils associated with such activities are unlimited.

Effective leadership is not a confined virtue but it rather a personality trait. Such people should be identified and respected and should be rewarded for the training that they give to masses.

The mass communication should place its role. The media should advertise daily about the legislation on poison releasing chemical industries. Even the illiterate should be encouraged to report the Care Taking Government Offices if they know of any chemical dangerous chemical activity in there areas. All human wish to be productive and healthy and safe. "Income of one should not be death for the other". Strong legislative measures must be enforced and mass awareness should be propagated. A lot needs to be done until goals of industrial sustainable development are met.

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