# PROCEEDINGS OF THE SEMINAR

## Inaugural Session

The seminar was inaugurated by the Federal Minister for Kashmir Affairs and Northern Areas, Mr. Mohammad Afzal Khan on the morning of October 26, 1994. In his introductory speech, **Dr. A.A. Junejo, MMHP Project Coordinator, ICIMOD**, Nepal, presented information on the background of ICIMOD and its activities in the Hindu Kush-Himalayan region. He informed the participants that ICIMOD has been a serious contributor to the development of appropriate energy resources particularly indigenous ones, in mountain areas. This seminar was a part of the project on MMHP in the Hindu Kush-Himalayan region, financed by the Norwegian Agency for Development Cooperation (NORAD) and implemented by ICIMOD. The main objective of this project was to collect information about status, policies, impact, and problems of the MMHP within the Region and to review and analyse this information to arrive at suggestions and proposals unanimously for the propagation of MMHP as a viable and sustainable energy option. Concluding his introductory address, Dr. Junejo thanked the Ministry of Science & Technology and PCAT for collaborating with ICIMOD in organising the seminar and providing significant and valuable inputs. He assured the full commitment of ICIMOD towards the development of remote and underdeveloped mountainous areas through the provision of appropriate inputs such as information packages, training programmes, and other such materials.

The welcome address was delivered by the **Chairman, PCAT, Mr. Shehryar Khan**. In his address, Mr. Khan briefed the audience about the MHP programme of PCAT. Highlighting its salient features, he stated that PCAT has been installing low-cost and indigenously designed and fabricated MHP plants in the difficult mountainous regions of Pakistan for the last 18 years. In addition to the generation of electricity, motive power from some of these plants was used during the day to run cottage-level industrial and agroprocessing units, providing income-generating opportunities. The remarkable feature of the MHP programme of PCAT was the participation of local communities to the maximum extent, from planning and construction to operation and maintenance. He stated that PCAT has installed a total of 181 MHP plants with a cumulative power generation capacity of 2.5 MW. Mr. Khan added that recently the public representatives of the area have allocated some rural electrification funds to PCAT for the installation of MHP plants.

Delivering the message of **Sardar Talib Hasan, Parliamentary Secretary for Science and Technology**, Mr. Abdul Rashid, Joint Technological Adviser, Ministry of Science & Technology, stated that the occasion reflected the continuity of a joint effort by PCAT and ICIMOD to bring on socioeconomic development in the region.

Emphasising the importance and need of indigenous low-cost technology, Mr. Rashid stated that this makes the technology easy to understand and maintain in remote and far-flung areas with scarcely skilled manpower. He highlighted the development of MHP and the activities of PCAT in this respect. He also appreciated the fact that the cost of installation and generation of MHP plants by PCAT were remarkably low compared to those installed by international donors. He expressed the hope that during the Eighth Five Year Plan, the MHP programme would be further enhanced with assistance from the Government of Pakistan, as well as from international donor agencies.

**Mr. Parvez Ahmad Butt, Secretary, Ministry of Science & Technology**, in his address, highlighted the importance of small hydropower for isolated and remote areas. Appreciating the efforts of PCAT and ICIMOD in organising the seminar, he stated that the MHP programme of PCAT benefits the low-income segment of the population and is, in fact, a real service to the rural people in terms of poverty alleviation through science and technology. He emphasised the need for adopting an integrated approach in providing energy to households and focussed on its productive use through cottage-level industries. Mr. Butt was of the view that efforts should also be made to exploit canal falls using low-head, high-discharge technology. He assured the participants of the full and continued support of the Ministry of Science and Technology for the MHP project of PCAT.

The **Chief Guest, Mr. Mohammad Afzal Khan, Federal Minister for Kashmir Affairs and the Northern Areas**, in his inaugural address, appreciated the efforts of ICIMOD in accumulating a wealth of information from the HKH Region in the field of mini-and micro-hydropower through preparation of country reports, case studies, and through the consultative meeting of experts held in Kathmandu in June 1994. He also lauded the efforts of PCAT in promoting MHP technology in the country's mountainous areas. Highlighting the efforts of the government in the power sector by involving the private sector in power generation projects, he stated that special attention was paid to the development of small hydropower plants and incentives offered to private entrepreneurs to invest in this field. Mr. Khan congratulated PCAT and ICIMOD for jointly organising this seminar.

## SESSION I

Mini- and Micro-Hydropower Development in the Hindu Kush-Himalayan Region -- Achievements, Impact and Future Prospects

The first paper of Session I, presented by Dr. A. A. Junejo, MMHP Project Coordinator, ICIMOD, Nepal, described the present status of MMHP in the HKH region. Despite the considerable progress made in this field, the share of MMHP in the total energy generation of the countries in the region was still very low. China has exploited about 20 per cent of the potential, whereas in other countries, the exploitation rate is about one per cent. This is due to the fact that MMHP programmes in

Nepal, Pakistan, and India started only about two decades ago, whereas China has been working in this field for the last four decades. In China, there are 48,284 existing SHP/MMHP plants ( of up to 25 MW in capacity), having a total capacity of 15,055 MW, of which 45,645 plants are in the mini/micro range (below 500 kW). In Nepal, about 735 private MMHP plants have been installed so far. In Pakistan, the number of private sector informal MHP plants is about 190, Bhutan has 19 MMHP plants with a capacity of 3.4 MW, and India has installed 145 SHP/MMHP plants with a total generating capacity of 106 MW.

MHP development in Pakistan is predominantly carried out by public sector agencies. In Nepal, the private informal sector leads the installation programmes, and, in India, China, and Bhutan, almost all the plants have been installed by various government agencies.

In Pakistan and Nepal, the cross-flow type turbine is used predominantly in MHP plants. Chinese plants are equipped with a variety of turbines, ranging from the Francis to Turgo, whereas India manufactures a range of different hydropower turbines of up to three MW in capacity.

The support for MMHP in the region generally comes from the respective national governments, whereas some international agencies have also been providing technical assistance. The energy from MMHP plants in the region is primarily used for domestic lighting, however, many installations in Nepal also use this energy for cottage-level industrial activities such as agroprocessing, paper making, saw milling, etc. Plant factors are quite low in all cases, ranging from 10 to 30 per cent, except in China where the plants are relatively bigger, more sophisticated, and the electricity supply is more reliable, which stimulates industrial and commercial use.

The installation costs of MMHP plants vary from country to country. In Pakistan the installation costs per kW are US$ 330-500, compared to US$ 800-2,000 in the case of Nepal. The economic returns from MHP plants are quite low, and returns can be improved by diversifying the end uses, especially the productive ones.

MMHP technology has achieved significant success in the region, the most success being achieved in China where more than one-third of the total country now relies on electricity generated from SHP/MMHP plants. Private MHP installations have also made considerable inroads in Pakistan and Nepal. However, there is a dire need for enhancing the pace of MHP installations in the rest of the region, keeping in mind the tremendous potential and demand. Also, the new plants need to perform better in order to supply reliable electricity which can be used for productive purposes by the rural industrial sector.

The Micro-Hydropower Programme of
Pakistan Council of Appropriate Technology -- An Overview

The second paper, presented by Dr. M. Abdullah, Consultant to PCAT on MHP, highlighted achievements in MHP installation and future plans. The objectives of PCAT are to survey and assess the needs and accordingly design and adapt appliances or technologies for common use. With this objective in mind, PCAT, formerly known as the Appropriate Technology Development Organisation (ATDO), started MHP programme in 1975 by installing the first plant with a three kW capacity. Since then, PCAT has installed a total of 181 MHP plants with an overall generating capacity of about 2,500 kW. The objective of PCAT's MHP programme is to provide electricity to the poorer segments of the population and to inculcate the concept of self-help and self-reliance in terms of installation, operation, and management of plants on a community basis. The plants are installed in the far-flung and isolated communities by distributing simple and inexpensive technology.

The programme is beneficial for local communities in a number of ways, including supply of electricity and motive power for domestic lighting and cottage-level industrial purposes. It requires little capital and stimulates socioeconomic development in the area. The costs of PCAT's MHP plants are in the range of PRs 10,000-15,000 (US$ 330-500) per kW installed and cost per kWh delivered is estimated to be PRs 1.55 and PRs 1.09, for 10 kW and 20 kW plants respectively. The MHP programme of PCAT is funded by the Government of Pakistan, and plants are installed by providing a subsidy of about 40-50 per cent. The plants are operated, managed, and maintained by a management committee constituted by the representatives of local communities.



Community Participation in Micro-Hydropower Development

This paper, presented by Mr. Ghulam Saeed Khan, Regional Programme Engineer, Aga Khan Rural Support Programme (AKRSP), Gilgit, described the AKRSP approach involving local communities in its MHP programme. The AKRSP started its programme in 1986, and plants were distributed to the selected village organisations (VOs). The rural development methodology of the AKRSP is based on intervening in rural society by holding a dialogue with community members/leaders and through the formation of a VO which acts as an interest group.

Once a VO is formed and enters into a partnership with AKRSP, a project is then identified. The basis of the project is that it should provide service /benefits to at least 75 per cent of the VO members. The members develop a financial system through collections, donations, and savings, and then one member is trained in the operation of the MHP plant and to manage the project. AKRSP provides technical assistance and plant equipment, whereas the labour and construction materials are provided locally by the VO. Once a project is completed, it is handed over to the VO for management, operation, and maintenance.

Larger VOs with bigger projects constitute an Electricity Committee for the management of project affairs, while smaller projects are supervised by the VO manager. The committees are responsible for all the affairs of the plants such as appointment of staff, collection of tariffs, and operation and maintenance of the plants. These management committees are responsible to the general body of the VO.

The installation of MHP plants stimulates community development, plays an important role in socioeconomic development of the area and provides entrepreneurial vision to VO members.

*Discussion*: On a query from one of the participants regarding the status of 28 MHP plants installed by the AKRSP, the author stated that all plants installed in Gilgit and Baltistan were in working condition, whereas the figure in case of plants installed in Chitral district was not readily available.

Selection of Turbines for Micro-Hydropower Schemes

Mr. Samiullah Khattak, Assistant Director, PCAT, presented his paper on the selection of turbines for MHP schemes. Each turbine type is best suited to a certain range of pressure heads and flow rates and has an associated numerical value called *specific speed*. The *specific speed* relates the power output of the turbine to its running speed and head, but does not depend on the size of turbine. A well-designed turbine has always the smallest runner permissible within the limit to handle the flow passing through it. The propeller, Kaplan, and Francis turbines are suitable for low head ranges, cross-flow turbines are suitable for low to medium head ranges, whereas Pelton turbines are mostly used in high head range applications. Cost comparison of various turbines types indicates that cross-flow turbines could be the cheapest, whereas propeller and Francis turbines cost more.

PCAT's experience indicates that cross-flow turbines can be fabricated in small workshops, are easy to repair and maintain, and are cheapest. The cross-flow turbine is manufactured with simple fabrication techniques, i.e., cutting, welding, and grinding only, and no casting work is involved. Sheet metal and readily available pipes are used to fabricate the blades of the turbine which are then welded with metal plates to form the runner. These turbines are manufactured at a small local workshop. Efforts are, however, underway to manufacture improved quality turbines by using precision manufacturing techniques.

*Discussion:* A query was raised regarding the testing facility for the turbines in the local workshop. It was felt by one of the participants that details of the power output of the turbine are not adequately covered. The author explained that, at a new workshop, which is being established by PCAT in Peshawar, turbine balancing and testing facilities would become available. In the selection of turbine criteria, only short cuts have been followed and engineering calculations/inputs have not been taken into account.

Indigenous Development and Manufacturing of Very Low Head Micro- Hydel Power Plants

This paper, written by Mr. Aftab Sarwar and Dr. S. M. Bhutta, was presented by Dr. Bhutta. The paper briefly described the water resources of Pakistan and the rural electrification programme of the government. The theoretical design of a very low head micro hydropower unit was presented in the paper based on a flow of five cusecs and with a head of three feet. The speed of the turbine is calculated, the runner diameter has been worked out, and it is confirmed that a turbine with a runner diameter of 10 inches with the above parameters would generate 1.0 kW of electric power.

Development stages of commercial plants include research and development, assessment, and other aspects such as engineering, industrial, commercial, managerial, economic, and financial. All these aspects have a strong interplay and are essential for successful manufacturing. The first step in manufacturing a plant is to build a prototype plant. This involves analytical investigations and research and development, in addition to identifying critical technical and economic parameters. During this stage, the design is evaluated; parameters adjusted; physical operation is confirmed; and equipment, material and apparatus are fabricated.

The next step in this process is the demonstration of the prototype technology in the field. There could be many concepts and designs for building prototypes, but only a few go on to demonstration and then into the commercial stage. The evaluation of the demonstration unit is made both in technical as well as in economic terms. After successful practical demonstration of the technology and its technical and economic feasibility, manufacturing of such plants on a commercial scale can be undertaken by the private sector.

These micro-hydropower plants can prove to be a viable service for the people in remote areas and can be self sustainable. The approach also offers several advantages over the centralised electricity supply systems. The economic analysis indicates that the cost per unit from thermal power plants for rural areas becomes PRs 3.50 whereas, in the case of MHP plants, it is PRs. 1.30.

*Discussion.* Replying to a question, the speaker stated that only about 15 per cent of the country's hydropower potential has been utilised, and sites with low-head potential have been completely ignored. The total length of canals in Pakistan is 58,500 km, and there are thousands of small waterfalls on these canals. There are 150,000 villages in far-flung areas, out of which 50,000 enjoy the facility of electricity. A question was raised regarding poor support from the government for the promotion of MHP technology. The speaker observed that high failure rates due to lack of repair and maintenance facilities have been giving a bad name to the technology.

Management of Micro-Hydropower Plants in Pakistan

This paper, presented by Dr. Habib Gul, Deputy Director, PCAT, detailed the management system of MHP plants adopted by PCAT. Applications for installation of MHP plants from the local people received by PCAT are accepted with the pre-condition that the applicants should be a group of four to six local people. In most cases, these applications are duly recommended by the elected public representatives of the respective areas. After surveying the site and determining its technical and social feasibility, the final decision to install a plant is taken by PCAT.

A management committee of four to six prominent persons is formed, and a written agreement is signed by the PCAT with this committee. In this agreement, the committee is clearly apprised of its responsibilities, which include the provision of free labour and materials for construction of the project, purchase of distribution wires, and subsequent operation and maintenance of the plant.

The plants are installed in close association with the community and the involvement of most of the villagers. Once the plant is installed, one or two operators identified by the committee are trained in its operation and maintenance. This on-the-job training is provided by the PCAT staff for seven days. Consequently, the plant is handed over to the management committee for operation and maintenance. The committee fixes the monthly tariff usually on a per bulb basis and arranges for collection. This amount is used to pay the salary of the operator and for routine operation and maintenance. In the case of major breakdowns, the recipients approach PCAT to provide technical assistance and also contribute the amount for this repair.

Discussion. The total contribution made by PCAT for the provision of energy to rural areas was questioned. The Chairman of PCAT responded that, despite the limited resources and manpower, the staff of PCAT has been working hard in the isolated and far-flung areas in order to serve the public. Efforts were being made to depute some additional staff to the PCAT Field Office, Peshawar, in order to accelerate the pace of installations. One participant was of the opinion that PCAT should chalk out an integrated and comprehensive long-term plan for MHP development. The PCAT staff should also be given due incentives to improve performance.



Problems Associated with Private/Decentralised Mini- and Micro-Hydropower Plants and Some Possible Redressals

This paper by Dr. A.A. Junejo identified the problems associated with private or decentralised MMHP systems in the HKH Region and possible remedies. Funding has been pinpointed as one of the major constraints for the distribution of MMHP plants. Lack of coordination among various implementing agencies is also a major problem with regard to policies, planning, and execution of MMHP schemes. Systems for plant performance evaluation are almost non-existent in the Region, and there is no integration of MMHP schemes with the national rural electrification schemes of the governments, except in China. MMHP technology is not recognised at national level as a viable and cheap source of energy for remote and isolated mountainous areas, and generally a commitment to develop MMHP at national level is lacking on the part of governments and related authorities.

The people associated with private/decentralised MHP programmes need to be adequately trained in various aspects of technology, including planning, community development, survey, design, construction, supervision, operation, maintenance, and in case of breakdown. In the specific context of Pakistan, major problems relating to MHP development include non-recognition of MHP by the government as an important source of energy supply, lack of coordination between various implementing agencies, the low level of indigenous technology development, and lack of training facilities for personnel involved in the implementation of MHP schemes.

The solutions to some of these problems include enhanced funding by the government and donor agencies for MHP programmes, dedicated government policies, and establishment of suitable liaison institutions to coordinate the implementing agencies, thereby avoiding duplication and overlapping. The cost of indigenously produced equipment also needs to be lowered, research and development activities need to be enhanced, and appropriate training facilities need to be established.

*Discussion.* It was pointed out that the tariff system in Nepal was based on connected power, rather than energy used. In the Pakistan context, concern was also expressed about the 200 pending applications with PCAT, responsibility for which was placed on government agencies. It was felt that the economic and living conditions of the recipients need to be improved by installing more MHP plants and government and non-government agencies should take the initiative. Private entrepreneurs need to be involved in power generation as was the case in India. A participant pointed out that the presence of 200 applications indicates the success of the PCAT programme.

Socioeconomic Impact of Micro-Hydropower Plants

Mr. Ghulam Umar Sarhandi presented this paper on behalf of the authors. Bringing a new source of energy into a hitherto inadequately supplied area results in a profound impact on the social and economic framework in a particular locality. This effect is the direct impact of the existence of the plant, its construction, and operation. It brings on employment, availability of a service, and stimulation of the economic activity. The indirect impact of electrification would probably be the same whatever the source of energy supply may be, although the price of the electricity and its price stability would be important for many consumers, and, here, hydropower appears to have a distinct advantage. It is difficult to conceive that any electricity supply can have a negative impact. The primary impact is limited to the consumers, and electrification supports the transformation of a subsistence economy to a monetary economy, which leads to an increase in national productivity and reduces the drain on national resources.

The main benefits of MHP in rural development, in general, include promotion of local industry, increase in the income of the rural poor, agricultural modernisation, mitigation of rural-urban migration, replacement of kerosene lamps, improvement in living standards, more job opportunities, and reduced damage to the environment.

The Tyson Turbine-Another Remote Area Power Supply and Water Pumping System:

Mr. Fazal Rehman presented this paper on behalf of the authors. The concept of the Tyson turbine, named after its Australian inventor, is based on harnessing the energy of moving water in a canal, stream, or river by the use of a turbine and without any use of civil works such as dams, reservoirs, etc. This turbine can pump water for irrigation purposes and generate a reasonable electricity supply for domestic use at low operating cost. Unlike conventional hydropower plants, this turbine operates on a zero head and utilises the river flow for the generation of power. The turbine is similar to the horizontal windmill and is the exact reverse of the ship propulsion system with propeller type blades operating in a set of mutually perpendicular axes to the river flow.

The runner of the turbine is made from polyethylene moulded material, either 1.5 or two metres in diametre. This runner can sustain the impacts of floating debris in water and is also highly corrosion-resistant. The pumping system of the turbine consists of a simple pump at very low head, and its output can exceed five litres per second. It can pump water up to a height of 100 metres. Alternatively, power of up to five kW can also be produced.

The electrical system of the turbine consists of an electrical generator supplying electricity to a control unit which monitors and controls the charging of a 48-volt battery system. The alternator used is a high efficiency, permanent magnet generator that produces a variable frequency and variable voltage output, which is then rectified to D.C. and used to charge the battery bank. A significant number of Tyson turbines has been delivered for water pumping and electricity generation in various countries.

*Discussion:* A question was raised regarding the cost comparison of the imported versus the indigenous turbine made in the country under a license agreement. Concern was also expressed about possible corrosion problems with the turbine parts. The speaker informed the participants that the cost of imported machines, including government taxes, would be around PRs 515,000. There would be enough demand from the private sector if the cost of the turbine was reduced to PRs 300,000. In the speaker's opinion, the cost of locally manufactured turbines would be around PRs 150,000. Corrosion problems with the turbine parts did not exist since high strength plastics and corrosion resistant materials were used.

Mini-Hydropower Programme of the Northern Areas Public Works' Department

This paper was presented by Mr. Abdul Amir, Executive Engineer, NA-PWD, a government agency which has constructed and commissioned 59 small hydropower and 11 thermal stations in the Northern Areas with a total generating capacity of 26.5 MW. Five plants with a capacity of 29.64 MW are presently being installed, and another five plants with a capacity of 85.3 MW are in the planning stage. About 300 villages, accounting for 40 per cent of the population of the total area, have been electrified through these MMHP/SHP plants. NA-PWD, in collaboration with NORAD, has also established a workshop in Gilgit to cater for repair and maintenance of these power plants.

The electro-mechanical equipment used in the SHP/MMHP plants is procured from the international market, and all the installed units are imported. A variety of turbine types including cross-flow, Francis, and Pelton are used in these power plants. Recently, NA-PWD facilitated an agreement between Heavy Mechanical Complex (HMC),Taxila, and Bi-Water of the UK, under which turbines would be manufactured at HMC through a successive deletion programme.

*Discussion:* Replying to a question on the cost of SHP/MMHP plants, the author stated that installed costs per kW were in the range of PRs 30,000-50,000, whereas cost per kWh was PRs 0.5-0.8. A point was raised about the shortage of water in the winter season and increased demand of electricity. Another question was raised regarding the proportion of equipment locally manufactured. The author stated that the design of plants was undertaken according to the minimum water available during the winter season. Only transformers and transmission lines were locally made. In the near future, turbines manufactured locally by HMC would be used.

Economic Feasibility of a Small Hydropower Station at Lower Bari Doab Canal, Mian Channu, District Khanewal

This paper, presented by Mr. Skaukat Khan, describes the economic feasibility of a low-head small hydropower plant at a canal fall, namely

Lower Bari Doab canal at VR Bridge, District Khanewal. The technical data of the site reveal that out of the total flow of 38.9 $m^3$/sec, about 3.4 $m^3$/sec have already been diverted to power 10 traditional flour grinding mills and about 35.4 $m^3$/sec flow are falling over eight weirs, each of 0.644 m width. Thus, a flow of 28 $m^3$/sec can be utilised to generate power. Eight sub-units (water turbines) with a total theoretical power generation capacity of 640 kW can be installed on the existing weirs.

The total investment cost of the plant would be PRs 32.30 million and annual operation and maintenance costs would be PRs 1.0 million. Assuming a plant life of 20 years, a discount rate of 20 per cent, an inflation rate of 10 per cent, and a yearly electricity production from the units at 3.96 TWh, the cost-benefit ratio varies from 1.19 to 2.99 for four various options with an energy selling price from PRs 1.00 to PRs 2.50 per kWh and a payback period of 19 to six years respectively.

*Discussion:* One participant commented that if the figures reflected in the analysis were correct, the government and private sector agencies should give serious thought to the installation of such power plants. It was agreed that the canal system is very important and useful for hydroelectric power generation, and provincial irrigation departments should be pursued to exploit this source of energy. A question was raised regarding the type of imported turbine/machinery proposed for use in the power plant. The co-author stated that Francis Open, German made flume turbine units with a 90 kW capacity were recommended for this particular site.