Invited Paper

HEALTH IMPLICATIONS OF HYDROPOWER DEVELOPMENT

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Abstract

HEALTH IMPLICATIONS OF HYDROPOWER DEVELOPMENT.

Hydropower development had been neglected in many countries during the past few decades, but the situation dramatically changed during the 1970s owing to the constantly increasing costs of electricity generation by fossil-fuel and nuclear power plants. Currently, hydroelectric generation accounts for approximately 23% of total global electricity supply. Much of the hydropower potential in developing countries of Africa, Asia and Latin America still remains to be exploited. Like any other source of energy, hydropower development has several health impacts. Conceptually, health implications of hydropower development can be divided into two broad categories: short-term and long-term problems. Short-term health impacts occur during the planning, construction and immediate post-construction phases, whereas long-term impacts stem from the presence of large man-made lakes, development of extensive canal systems, alteration of the ecosystem of the area, and changing socio-economic conditions. Longer-term impacts are further classified into two categories: introduction of new diseases and/or intensification of existing ones due to the improvements of the habitats of disease-carrying vectors, and health problems arising from resettlement of the people whose homes and land-holdings are inundated by the reservoirs. All these impacts are discussed in detail. Health impacts of hydropower developments have not yet been studied extensively. It is often implicitly assumed that health impacts of major dams are minor compared with other social and environmental impacts. Future studies could possibly reverse this assumption.

1. INTRODUCTION

Use of water power is not a new phenomenon: it has been used in one form or another for some two thousand years. Earlier attempts to harness energy from water were small-scale and for specific purposes only. The situation has dramatically changed during the past hundred years owing to major scientific and technological innovations.

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Hydropower development was somewhat neglected in many countries during the 1960s, mainly because it was economically more advantageous to generate electricity by using oil, which was cheap and plentiful. Although operating costs of hydropower plants are low, capital costs are high, and accordingly more emphasis was placed on power plants operating with fossil fuels. The events of October 1973 started to change this situation, when constantly escalating oil prices ended the era of cheap energy and forced most countries to explore alternative ways of generating cheaper electricity. Since hydropower is the only renewable form of energy that can be used extensively in most countries for large-scale generation of electricity and can be developed with indigenous expertise, it started to attract increasing attention in the 1970s. Since the dams and various structures built are also invariably used for other purposes like irrigation, flood control, navigation, recreation, aquaculture, etc., such comprehensive developments have become increasingly attractive for many countries. For developing countries in particular, water resource developments could successfully contribute to the solution of two major crises facing them today: energy and food. Furthermore, if the construction processes are planned carefully so as to use extensive labour-intensive technology, employment could be provided for a large number of unskilled labourers -- the main type of labour force unemployed -- for several years [1].

According to the survey of energy resources presented at the World Energy Conference, Munich, in September 1980, hydroelectric generation currently accounts for approximately 23% of total global electricity supply. This is an average figure: for many countries hydropower is the principal means of electricity generation. For countries like Brazil, Canada, Morocco, Norway and Sri Lanka, hydropower currently accounts for 70--100% of all electricity generated [2].

While potential for hydropower development has been exploited to a considerable extent in the advanced industrialized countries of North America and Europe, including the USSR, a vast potential in many countries of Africa, Asia and Latin America still remains to be developed. Annual hydroelectric potentials for different regions of the world, as provided during the World Energy Conference of 1980, are shown in Table I. It should be pointed out that during the preparation for the UN Conference on New and Renewable Sources of Energy at Nairobi in August 1981 it was felt that the estimates provided for Asia may not include data from the People's Republic of China. The theoretical potential for the People's Republic of China is currently estimated at 6×10^{12} kW·h, with technically usable potential of 1.9×10^{12} kW·h. At the end of 1979, the total operating potential was 0.05×10^{12} kW·h and potential under construction was 0.0517×10^{12} kW·h.

With the present constantly changing energy price scenarios, and since hydropower is a good source of indigenous energy, it is highly likely that an increasing

TABLE I. ANNUAL HYDROELECTRIC POTENTIAL OF DIFFERENT REGIONS

Region	Theoretical potential	Technical usable potential	Operating potential	Potential under construction	Planned potential
	←		(10^{12} kW·h)		→
Africa	10.118	3.14	0.151	0.047	0.201
North America	6.15	3.12	1.129	0.303	0.342
Latin America	5.67	3.78	0.299	0.355	0.809
Asia (excluding USSR)	16.486	5.34	0.465	0.080	0.368
Oceania	1.5	0.39	0.059	0.020	0.032
Europe	4.36	1.43	0.842	0.094	0.197
USSR	3.94	2.19	0.265	0.191	0.17[a]
Total	44.28	19.39	3.207	1.090	2.12

[a] Estimated.

number of countries will encourage intensive development of their hydropower potentials. Estimates of probable hydroelectric development during the period 1976–2020, as provided during the 1980 World Energy Conference, are shown in Table II, which indicates that the total annual energy from installed hydroelectric facilities from all regions of the world is likely to increase five-fold during these 44 years.

2. HEALTH IMPLICATIONS

Like any other form of energy, hydropower development has several health implications. It is important, however, to note a major distinction between hydropower and fossil-fuel or nuclear power plants that generate electricity. In the case of fossil-fuel or nuclear power plants, health impacts can be considered exclusively as a direct consequence of energy development, but for hydropower the situation is somewhat different. Since very few water development projects have been constructed solely for hydroelectric generation, it can be argued that the health impacts of hydropower are actually due to the water resources development process itself, and thus it is difficult to attribute them to hydropower, per se. In other words, if a dam is constructed, its health implications will remain very

TABLE II. ESTIMATED PROBABLE HYDROPOWER DEVELOPMENT, 1976–2020

Country groupings	Potential energy in exajoules (1 EJ = 10^{18} J)			
	1976	1985	2000	2020
OECD countries	3.78	4.49	5.37	7.80
Countries with centrally planned economies	0.72	1.20	2.88	8.70
Developing countries	1.17	1.97	4.49	11.80
World total	5.67	7.66	12.74	28.30

similar irrespective of whether hydropower is or is not a reason for the development. It is not always easy, and at certain times it is impossible, to ascribe the different health implications to specific purposes of water development, i.e. irrigation, power generation, navigation, etc.

Conceptually, health implications of hydropower developments can be divided into two broad categories: short-term and long-term problems. Short-term health impacts occur during the planning, construction and immediate post-construction phases during the filling of the reservoirs [3–6]. Longer-term health impacts stem from the presence of large man-made lakes, development of perennial irrigation instead of seasonal irrigation, alteration in the ecosystem of the area, and the changing socio-economic situation.

2.1. Short-term health impacts

Since water resources development projects require major constructions such as dams, spillways, diversion works, etc., they create new employment opportunities, and new workers of different categories move into the areas near construction sites in large numbers. Since dams are often built in remote, undeveloped regions, they lack suitable housing, sanitation and other infrastructural facilities. Even when they are not in remote regions, host communities are seldom able to absorb large numbers of immigrant workers without encountering serious social problems.

In developing countries, labour-intensive technology is often used to construct such large structures, and this invariably means that a large number of unskilled, uneducated labourers arrive at construction sites in search of employment. It is often not possible to satisfy labour requirements locally. For example, during the construction of the Aswan Dam, contractors were forced to transport labourers from neighbouring governorates to the construction sites. Similarly, for the Bhakra-Nangal Project in India, as many as 60% of the workers had to be imported from other provinces [2].

The construction of large water development projects often stretches over a decade, and the daily labour force engaged fluctuates tremendously not only from one year to another but also within any year. For example, the peak labour strength for the Sarda Sahayak Project in India varied from a low of 4000 in 1969–1970 to over 140 000 during 1975–1977. Minimum labour engaged in any year could vary from only 5% to 20% of the peak strength of that year. There is also a high staff turnover.

In these difficult circumstances, and in view of the lack of adequate medical assistance in most developing countries, it is impossible to provide appropriate medical and sanitation facilities to the majority of the workers who, as mentioned earlier, are poor, unskilled and illiterate, and thus lack any political power base. While a certain amount of medical facilities are available for skilled, salaried and educated workers, the unskilled workers are employed primarily as daily labourers without job security and are mostly on their own so far as health services are concerned. In addition, those who live in the new settlement but are not directly employed in the project often do not have access to medical facilities. The presence of large numbers of workers within a limited area, living in unsanitary conditions and without adequate medical facilities, is conducive to the prevalence of diseases like malaria, filariasis, poliomyelitis, venereal and skin diseases, tuberculosis, leishmaniasis (*espundia* of Kala-azar), etc. Furthermore, in some countries, for example Pakistan, groups of labourers exist who travel all over the country working from one construction site to another [2]. Such movements have one important and undesirable side-effect: they tend to increase disease transmission rates.

2.2. Longer-term health implications

As is to be expected, longer-term health implications of hydropower development are more serious than short-term impacts. The longer-term impacts could be broadly classified into two types: (a) introduction of new diseases and/or intensification of existing ones due to the improvement of the habitats of disease-carrying vectors, and (b) health problems arising from resettlement of the people whose homes and land-holdings are inundated by the reservoirs. These two are somewhat interrelated.

2.2.1. Diseases due to improvement of vector habitats

So far as diseases are concerned, probably the most widespread and important one is schistosomiasis. This disease, however, occurs only in tropical and semi-tropical countries and not in temperate regions. Even in countries like China, with a wide variety of climatic regions, schistosomiasis can be observed only in areas where warmer climates are prevalent. While the spread of schistosomiasis is common in most tropical climates owing to dam constructions, the situation becomes far worse if extensive canal systems are developed for irrigation. In other words, increases in schistosomiasis depend more on whether the water development project had irrigation as a primary focus rather than on hydropower per se.

Schistosomiasis is not new: it was known during Pharaonic times. The unprecedented expansion of water resources development, especially the introduction of perennial irrigation systems, has introduced this disease into previously uncontaminated areas [7, 8]. The disease is contracted percutaneously from water infected by cercaria released by snails, and the victims are debilitated by progressive urinary or intestinal infections, reducing labour productivity by some 30–50% [9–10]. The victims also become progressively more vulnerable to other diseases; they face difficult and unpleasant treatments, which are often not available, especially in rural areas of developing countries. The disease is currently endemic in over 70 countries and affects over 200 million people. Prior to development of the present extensive irrigation networks, and when agriculture depended primarily on seasonal rainfall, the relationship between snail host, schistosome parasite and human host was somewhat stabilized, and infection rates were low. Snail populations increased during the rainy season, when agriculture was possible, and this provided the contact between man and parasites. During dry periods, however, there was a lull in infection. With the stabilization of water resource systems due to the development of reservoirs and extensive canal systems, the habitats for snails were vastly improved and extended, and they also had a prolonged breeding phase which substantially increased their population. More human contacts with parasites were provided, which not only raised infection rates but also greatly increased worm load per person. The incidence and extension of these diseases can be directly related to the proliferation of water development schemes, the stabilization of the aquatic biotope, and subsequent ecological changes.

The characteristics of snail habitats, as described by Malek [11], are as follows: *"They breed in many different sites, the essential conditions being the presence of water, relatively solid surfaces for egg deposition, and some source of food. These conditions are met by a large variety of habitats: streams, irrigation canals, ponds, borrow-pits, flooded areas, lakes, water-cress fields, and rice fields. Thus in general they inhabit shallow waters with organic content, moderate light penetration, little turbidity, a muddy substratum rich in organic matter, submergent or emergent aquatic vegetation, and abundant micro-flora."* Thus, water resource developments, especially improvements for hydropower, irrigation or fishing industry, are most likely to favour increased propagation and the spread of these snails [12].

Infection rates of 70% or more can often be observed in certain regions of countries with large irrigation development (e.g. Egypt, Kenya and Sudan). The Lake Victoria area of Kenya is hyperendemic, and the infection rate in schools is up to 100% in certain areas associated with irrigation schemes.

Experience with malaria has been somewhat mixed. There does not appear to be any resurgence of malaria directly associated with the construction of large dams in Africa, but in India, Pakistan and Sri Lanka the incidence of malaria has increased owing to impoundments. Very few in-depth studies are available on the relationship between water development projects and malaria, and this could possibly explain the anomaly. For example, the environmental impact assessments of the Kamburu-Gtaru Dam in Kenya indicate that *"increase in transmission in Kamburu will move malaria from the presently low mesoendemic towards hyperendemic level"* [13].

Malaria was a problem during the early days of the dams operated by the Tennessee Valley Authority in the USA. By fluctuating reservoir water levels by means of carefully controlled draw-downs, mosquito populations were successfully controlled. However, on a global basis, there are over 100 species of mosquitoes capable of carrying malarial or filarial infections like Bancroftian filariasis (elephantiasis) or arboviruses like dengue, yellow fever, viral encephalitis, etc. The different species of mosquitoes often have different behavioural patterns and prefer different types of habitat, so it is not easy to control all disease-carrying mosquito populations in a specific area by any one technique which may have been used successfully elsewhere. Physical, chemical and biological techniques must often be combined with public education and hygiene for any chance of long-term success. In the final analysis, success will depend very much on the availability and use of knowledge of local conditions.

Gambian trypanosomiasis (sleeping sickness), transmitted by tsetse fly, is prevalent in West Africa. The tsetse fly prefers light forests, which often tend to lie along watercourses. New reservoirs, especially those with irregular shorelines, often increase forest areas and thus provide suitable habitats for tsetse fly to flourish. African trypanosomiasis is a debilitating disease which often proves fatal to both humans and animals. Control of trypanosomiasis is not easy, and it is made more difficult by free movement of people and animals from contaminated to uncontaminated areas.

In contrast to diseases discussed earlier, hydropower developments tend to reduce the incidence of onchocerciasis (river blindness). The intermediate host, *simulium* spp. (blackfly), tends to breed in fast-flowing reaches of rivers with turbulent, and thus well-oxygenated, flow. These areas are often drowned by the construction of dams. However, special care must be taken to ensure that new breeding grounds do not develop, especially immediately downstream of the spillways with fast-flowing waters. Construction of the Volta Dam destroyed the blackfly breeding ground that existed upstream. However, blackfly vectors continue to infest many tributaries, and the benefits initially expected from the construction of the Volta Dam have not yet materialized. Furthermore, the vector can travel as far as 300 km, whereas it was formerly thought to be able only to travel 50 km. This naturally increases their sphere of influence.

2.2.2. Health implications of resettlement

One of the major social problems created by large-scale hydropower developments is the displacement of local inhabitants owing to extensive inundations. The Volta Dam, for example, inundated an area of about 3275 square miles and the resulting lake has a shoreline of over 4000 miles. Consequently some 78 000 people and more than 170 000 animals had to be evacuated from over 700 towns and villages of varying population. Eventually 52 new settlements were developed to house 69 149 people from 12 789 families [1].

Resettlement planning for large dams and, what is more important, the implementation, have seldom been successful in developing countries. Most of the sites selected for resettlements are not ready when the settlers arrive, and lack of potable water and sanitary facilities force people to use lake or river water which could be contaminated. People often store water near dwellings for convenience, and this could become potential breeding grounds for mosquitoes which are carriers of numerous diseases. Medical facilities are often non-existent, and people, mostly illiterate and often nomadic, are unaware of the basic precautions necessary for health. Theoretically, the health of settlers in the new environments should be better than before they were evacuated, but in reality conditions generally turn out to be worse than before. There are several reasons for this:

(a) People are frequently moved from rich, alluvial farming land to areas with less desirable soil and sources of water. Social and institutional infrastructures often do not exist and it is therefore difficult to obtain fundamental agricultural requirements such as seeds, fertilizers and pesticides. (For example, ten years after the resettlement of the refugees from the Volta Dam, their agricultural productivity did not equal the pre-impoundment level.) Agricultural yields diminish and become inadequate. Whereas in earlier locations diet could be supplemented with fish, a common and important source of protein, new areas are often far from water bodies and this source disappears. The settlers are sometimes not familiar with local wild food, and when faced with food shortages they experiment with new types. This was probably what caused the 'Lusitu tragedy' of 1959, when 53 women and children who were resettled owing to the construction of the Kariba Dam were poisoned. World Food Programme had to step in at the Volta Dam and the Aswan Dam to alleviate widespread sufferings.

(b) Relocated people may have no resistance to diseases prevalent in the areas where they are being resettled, and may become more susceptible to certain new forms of diseases.

(c) When people are relocated to totally unfamiliar environments they suffer considerable psychological stress. For example, the 57 000 members of the Tonga tribe who were moved owing to the construction of the Kariba Dam suffered great cultural shock when thrust into communities as different from their own as theirs from Great Britain [14]. Two years were required to clear sufficient land to meet even their subsistence needs. The government had to intervene and establish grain stores to avert famine and very serious hardships. Ironically, this well-intentioned step became one of the most destructive parts of the process: the grain distribution centres became transmission sites of the dreaded sleeping sickness disease.

(d) The displaced population is often neglected by both local governments and international organizations. 'Operation Noah', a much publicized and expensive scheme to resettle only some of the animals threatened with inundation from the rising water levels of Lake Kariba, received more international attention and assistance than the refugees,whose sad plights went unnoticed. Planning and constructing adequate and appropriate housing, provision of basic services, including health, and preparation of land for agricultural development, have seldom been completed in any developing country prior to the arrival of the refugees. In most cases, at least during the initial years, the settlers faced worse facilities than they had enjoyed earlier. In the case of the major African dams, the initial emphasis has so far been placed mainly on constructing 'improved' housing, which has too often turned out to be unsuitable for the people being resettled. Rarely had the infrastructure been developed to provide facilities like health services or means of earning a living. The psychological trauma of enforced resettlement, lack of the type of food to which the evacuees had been accustomed for generations, local resentment of the newcomers, breakdown of social order, and exploitation of the settlers by government officials and local people, all ensured that the refugees were under multidimensional stress for a prolonged period, which in certain cases has extended beyond a decade. In such situations, the people were more susceptible to disease, and consequently their health suffered.

In some cases the situation was better. In Sudan, for example, soon after the relocation of the inhabitants from old Wadi Halfa town to New Halfa owing to the rising water level of Lake Nasser, their general state of health improved. One side-effect was an increase of approximately 30% in the birth rate, which was due partly to better living conditions, more food, and improved medical care, and partly to the return of many absentee husbands to settle in the area [15]. Such improvements, especially during the early years, are somewhat uncommon in most developing countries.

3. CONCLUSIONS

Health implications of hydropower development have thus far been a neglected subject of research. While several studies are available on the overall environmental impacts of hydro-dams, not much in-depth work has been carried out on their impacts on the health of both humans and animals. The general assumption so far has been that the health impacts of major dams are small compared to other social and environmental impacts. However, future studies may very well reverse this assumption.

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DISCUSSION

K.G. VOHRA *(Chairman):* Have you made any quantitative estimates of the health detriment associated with hydroelectric power generation in terms of, for example, fatalities per 1000 MW(e)? This has been done for other methods of generating electricity.

A.K. BISWAS: Not much research has been conducted into the health risks associated with hydropower development, and this is partly due to an erroneous belief that such health risks are minimal and hence can be neglected. Most studies deal with health risks arising from the development of nuclear or fossil fuel plants.

The information available world-wide on the question of health hazards due to the failure of hydroelectric dams is very sketchy[1]. While we are aware of most of the problems created by spectacular failures and/or overtoppings of hydroelectric dams, we have very little information on minor failures, which, as one might expect, are far more numerous than the former. In many cases it is not even reported whether the dams concerned generated hydroelectric power! There has been a tendency in the past to aggregate all the available information on dam failures and then determine the failure risks as if they were all statistically independent events. This is mainly because some of these studies have been conducted by people who have very little knowledge of the design of dams and their behaviour after construction. Such estimates are unreliable and would not even provide 'ball-park' estimates of risks.

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