MANAGING EMISSIONS OF GREEN HOUSE GASES IN MULTIPURPOSE PROJECTS WITH SPECIAL REFERENCE TO LARGE STORAGE PROJECTS IN INDIA

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ABSTRACT

The hydrological regime characterized by the natural flow of rivers upon modification through reservoirs exerts physico-chemical influences, leading to modification on microbiological scale. The regulatory structures, dams/reservoirs, exerts profound effect on water, land & air bringing chemical, biological and physical changes and in their interrelationships. The stress generated on various components of water, land & air can't be readily modelled, yet have to be taken into consideration while creating the storages. When fluviatile biocoenoses are succeeded by lentic ones, it leads to changes in the nutrient contents, among which the most important for the growth of vegetation are based on carbon, nitrogen and phosphorus. Run off from the command area of the upstream projects may carry ~~with it~~ increased load of pesticides and insecticides, organic loading of the reservoir from industries and habitation in the catchments. Thus triggering a series of adverse reactions. After the first filling or at each rise in the water level, the biomass which gets destroyed by submersion, leads to an increase of the concentration of carbon, nitrogen and phosphorus, which is likely to cause~~s~~ extensive development of bacteria and then of algae in shallow areas. The organic enrichment under halocline thermo cline formations and anoxic conditions triggers anaerobosis which is catastrophic for aquatic ecosystem as these conditions leads to production of methane gas specially in those parts of the reservoirs deficient in sunlight and oxygen. This coupled with increase in organic and in-organic solutes availability of increased fertilizer through wash off nutrients from surrounding habitats causes' eutrophication. Left unattended the development of aquatic vegetation in the reservoir, may endanger aquatic life ,shelter diseases carrying organism and shall also alter the water quality making it unfit for the intended uses besides release of green house gases. Bacterial action changes the physico chemical environment leading to eutrophication impacting feeding of aquatic flora & fauna besides rendering the water unfit for consumption. The extensive release of sulphuretted hydrogen & corrosive phenomena on the metal part of the dam resulting from sulphato-reducing & sulpho oxidating anaerobic & aerobic bacteria, shall be more problematic in a deep storage reservoirs. The detrimental consequences of the reservoir development on aquatic ecosystem are many and each of them was considered on merit. However the present paper examines the phenomenon arising out of emissions of green house gases from the tropical reservoirs and measures for containing these emissions within critical threshold levels. This communication is not intended to be a complete & detailed exposition of all aspect of these parameters or the numerous interrelationship or the interaction. It is attempted to provide brief insight to the issues related with effects of water quality due to storages and managing emissions of green house gasses in tropical reservoir with special reference some Indian cases. Indian river systems like Ganga and Narmada are seeing large and medium storages being created over the years. There is an apprehension in the minds of environmentalists that these storages may degrade the water quality and create green house effects. These concerns are required to be adequately addressed through systematic studies of water quality parameters, sediment behavior etc. en-route the flow before and after construction of dams and storages. In case of Narmada, the plans are devised for keeping the negative influences, including flooding of biomass trapping of the sediments and nutrients, agricultural fertilizers, sewage and industrial pollution, fluctuations in water level, physico-chemical changes in the basin in the catchment benthic environment, water column & consequent impact on food chain, influence of terrigenous nutrients & the related ecological risks, under manageable limits through a large number of studies and translation of studies into action plans. Studies on water quality assessment for Ganga river in the Himalayan region have been considered to establish post storage water quality.

INTRODUCTION

Rivers play an important role in , cycling of carbon, nitrogen,and silicon and help regulate the concentration of CO_2 in the atmosphere. Damming of the river interrupts these cycles causing wide range of impacts including emissions of green house gasses. Such as methane (CH_4) and CO_2 and the potent greenhouse gas nitrous oxide (N_2O). The gases are formed by the decomposition in the reservoir of dissolved and particulate organic carbon (DOC /POC).The main sources of this carbon are the vegetation and soils flooded when the reservoir is first filled, the organic matter washed into the reservoir from upstream (which may be from natural or farmed ecosystems, or sewage from cities), the plankton and aquatic plants which grow and die in the reservoir, and the vegetation that grows on the "drawdown" land temporarily exposed during low reservoir periods. The gases mostly CO_2 are released via diffusion across the water surface and in bubbles that rise from the river/reservoir bottom.

In large tropical reservoirs, the light is not able to penetrate the bottom layer of water which therefore gets seriously depleted of oxygen. Methane emissions occur due to bacteria that decompose organic matter in oxygen-poor water. Some methane bubbles are oxidized to carbon dioxide as they rise to the reservoir surface. Obviously shallow tropical reservoirs where bubbles have less time to become oxidized give rise to more methane emissions.

Among the factors influencing degassing emissions are the concentrations of methane at different reservoir depths, the depth of turbine and spillway intakes, and the type of spillway design. Surface emissions vary widely among different parts of the same reservoir (largely due to changes in depth, exposure to wind and sun, and growth of aquatic plants), and from year to year, season to season, and between night and day A range of factors effecting production of undesired gases from large reservoirs could be summarized as follows.

1. Depth of reservoir
2. Quality and quantity of Forest/ vegetation being submerged during progressive impoundment
3. Organic loading by tributaries, rivulets etc from the surrounding catchment
4. Organic enrichment by pollutants fertilizers/pesticides from upstream command, Municipal & industrial wastes etc impacting river metabolism
5. Duration of initial and progressive filling of the reservoirs
6. Rate of flushing i.e. inflow and outflow during impoundment
7. Dissipation of heat energy in water column and other physico chemical features
8. Pattern of impounding
9. Terrain being impounded
10. Anthropogenic activities.

Increase in organic and in-organic solutes and further increase in fertiliser through wash off nutrients from surrounding habitats leads to eutrophication. Left unattended the development of aquatic vegetation in the reservoir creates problem in fishing, shelter diseases carrying organism and shall also alter the water quality making it unfit for the intended uses besides release of green house gases. Bacterial action change the physico chemical environment impacting feeding of aquatic flora & fauna besides rendering the water unfit for consumption, enhances eutrophication. The extensive release of sulphuretted hydrogen & corrosive phenomena on the metal part of the dam resulting from sulphato-reducing & sulpho oxidating anaerobic & aerobic bacteria, shall be more problematic in a deep reservoir and has to be addressed suitably. Conditions prevailing in Narmada Projects and for that matter all other similar reservoirs located in mega-diversity countries may emit harmful gases and might contribute to global warming, for the reasons enumerated above, only if required safeguards, in supervision of qualified vigilant personals, are not put in-place in time.

Case history of Sardar Sarovar project is well above the rest, where possibility of developing thermal stratification /eutrophication/ emission of green houses was managed with well laid out plans executed with utmost care and planning

MANAGING NARMADA RIVER SCENARIO: MULTIPLE LAKE ENVIRONMENT

Fifth largest west flowing river which is 1312 km long and enters gulf of Cambay on the Arabian sea, originates from the eastern highlands of the Vindhya ranges which are much older than the Himalayas and is rain fed. Its basin largely remained untapped but currently is undergoing compound impounding. The Narmada River valley has unique location for construction of reservoirs on main stem of river and it's tributaries. The foundation of a master plan to harness of water resources was devised in 1979. Accordingly 30 major projects are planned. Of the main reservoirs under construction on the main river Narmada four each are multi purpose and hydel and two are for Irrigation.

Due to construction of these reservoirs the free flow regime of water will be disturbed. Most of these project are for hydro power and irrigational use therefore though the original flow in this main river will be disrupted but for the generation of hydro power the continuous flow of water will be maintained and the river will remain perennial. Thus the riverine and eaustrine character shall co-exists.

CASE STUDY

The Sardar Sarovar Project, a terminal project on main stem of a least polluted of Indian river , shall tap its virgin river flow . It would attain a maximum depth of 138.68 meters at FRL and with commencement of impounding in 1994 has already attained a height of 121.92 meters by 2005.

Many studies under taken have confirmed that according to Hora,s hypothesis, but for the anthropogenic activities, its vegetation was linked with that of the North-Eastern Himalaya. It will submerge about 37500 ha area of which 13386 ha is forest land. Basin is neither much developed nor many industries are located in its catchment. Similarly not many polluting drains discharge their effluent in to it. Narmada river water even without conventional treatment, remained potable at some of its stretches.

Sardar Sarovar Project is a terminal reservoir in chain of lakes to be created on river Narmada and is referred to here. This is an interstate project submerging part areas of Gujarat, Madhya Pradesh & Maharashtra areas of Indian Union. On completion, this project will create a reservoir extending about 214 Km in Narmada valley submerging an area of 37500 ha with a width of 1.77 Km and depth at the dam site 120.68 M. The maximum fluctuation in water level will be about 28.04 M. Creation of Sardar Sarovar Project would change the lotic (free flowing) character of the river to lentic (stagnant)character. This would submerge 13386 ha of forest land and would bring a change in natural vegetation due to the reasons of the submergence and micro climatic changes. Land use pattern would also undergo changes. Zoological imbalances would manifest.

In accordance with Government regulations, the SSP was subjected to Environmental Impact Assessment (EIA), which called for actions so that no unmanageable adverse environmental effects are caused. The Ministry of Environment and Forests (MEF) cleared the project In 1987. Certain conditions were attached to this clearance, as they had been to the World Bank Loan Agreement in 1985, relating to the Implementation of environmental safeguards and to Resettlement and Rehabilitation (R&R) of project affected people (PAPs). The Narmada Control Authority (NCA) was assigned the task to ensure that proper environmental safeguards were adopted where necessary and that the project adheres to all relevant environmental controls and regulations.

The environmental studies amongst others identified the following key areas which were addressed in planned manner.

- To compensate the loss of forest land not even forest, compensatory plantations in 3 ha area against each ha diverted for the project were planned and executed . The project authorities have arranged for afforestation of an equal area of non-forest land and the reforestation of double the area of degraded forest. It has been calculated that massive plantations under plantation/ social forestry, catchment treatment agricultural crops would increase the leaf area index many fold thus would result in greater carbon sequestration than has been estimated.

- Catchment Area Treatment refers to measures to prevent erosion and conserve soil mantle and aims to check erosion and assist soil and moisture conservation in the catchment area and also within the immediate vicinity of the reservoir. This was achieved both by stabilising soil surfaces with vegetation and by engineering measures to reduce the velocity of run-off of rain water and to interrupt the erosion process, thus greatly reducing trapping of carbon in the reservoir. As a condition of the environmental clearance for the project, a phased treatment programme drawn up and completed ahead of reservoir filling.

- Terrestrial Ecology : Conservation of terrestrial flora and fauna. Creation of a reservoir in the present water deficit terrestrial ecology is going to significantly modify the moisture regime. The river & reservoir bank areas which remain dry on high lands will be most benefited both In the upstream and downstream by the changed moisture regime as well as greater water availability round the year. The impoundment of water will provide new scope for revitalisation and rebuilding of a better and more productive eco-system and opportunity for recreating healthier forests. Besides further improvement provided by the SSP was the creation or enhancement of areas of wildlife sanctuaries in all three States. The function of these sanctuaries is to provide habitats for fauna following submergence and to encourage development of a diverse wildlife. Detailed plan were drawn for development of Shoolpaneshwar wildlife sanctuary, plan for Improvement to the Nal Sarovar, Wild Ass and Black Buck sanctuaries in the Command Area. these plans are under advance stage of implementation. This will greatly enhance the capacity fixation of carbon and will reduce global warming

- **Upstream Aquatic Environment** : the conservation of important natural fauna. The SSP dam will create round the year a narrow lake upstream In place of the free-flowing river with highly variable flow that exists currently. There are therefore, anticipated changes to the aquatic environment which are being managed through proper planning. Several studies on pre-and post-impoundment hydro-biological aspects were undertaken to establish the physico-chemical and ecological status of the Narmada and consequent water development plans. These plans provide specific measure for prevention of eutrophication and reduction in emission of Green House Gases.

- **Command Area and downstream :** The SSP will provide irrigation water for a Cultivable Command Area of 1.9 million hectares in Gujarat. The introduction of fresh water to the drought-prone areas of Gujarat will create obvious benefits for the farming communities. In order to safeguard these benefits, control and monitoring is being exercised in key areas to protect and safeguard the environment to make it deliver goods for a larger population on a sustainable basis. This adds up the leaf area several fold to serve fixation of carbon and towards reduction in emission of green house gases.

- **The Estuary :** The river and estuary below the Sardar Sarovar dam will be subjected to changes in fresh water flows and in patterns of erosion and sedimentation during progressive filling of the reservoir. These will be more pronounced when the reservoir becomes operational. There may also be Indirect effect due to increased agricultural activity leading to presence of more agrochemical pollutants in return flows from the Command Area. Changes in aquatic ecology can affect the environment both in the estuary and deep sea. Several studies have been conducted to assess modification to river flow, sedimentation & floods. Their effects on flora & fauna have been studied, plans are being drawn up to safeguard the environment on a sustainable basis. This included several measures including release of compensatory flows for the environment downstream, plantation of mangrove trees etc. Mangrove forests are one of the most diverse habitats of tropical coastline and estuaries and their preservation is an Issue of global importance specially with regards to biodiversity conservation and carbon sequestration. Plans to reconstitute the mangroves through a series of pilot projects, are under implementation.

SPECIFIC MEASURES FOR CONSERVATION OF LAKE ENVIRONMENT: CONTAINING EMISSION OF GHG

In case of Sardar Sarovar Project the plans are devised for keeping the negative influences of the issues involved, including flooding of biomass trapping of the sediments and nutrients, agricultural fertilizers, sewage and industrial pollution in the dead storage, fluctuations in water level, physico-chemical changes in the basin in the catchment benthic environment, water column & consequent impact on food chain, influence of terrigenous nutrients & the related ecological risks in Sardar Sarovar (Narmada) project in India, under manageable limits through a large number of studies and consequential plans. The detrimental consequences of the reservoir development on aquatic ecosystem are many and each of them was considered on merit. However the present paper discusses mostly the concern arising out of emissions of green house gasses from the tropical reservoirs and means and ways for containing these emissions within critical threshold levels. This communication is not intended to be a complete & detailed exposition of all aspect of these parameters or the numerous interrelationship or the interaction. This is rather an attempt to provide brief insight to the issues related with managing emissions of green house gasses in tropical reservoir with special reference large storage project in India

It is estimated that the Sardar Sarovar reservoir area will fluctuate between 11000 ha in May-June to 35000 ha in be November with an average water spread of 23000 ha. The most important condition to achieve benefits was its proper management. Under tropical conditions consequent to impoundment three trophic phases are observed. The first phase known as trophic burst is characterised by increased fertility of water by washing off nutrients from the catchment area and submergence of the new soil. The decomposition of the large quantity of organic matter was also expected to increase the food reserves. Clearance of woody vegetation from inundation zone prior to flooding, provision of weed control measures, harvest of weeds for compost, fodder or biogas, regulation of water discharge and manipulation of water levels to discourage weed growth, provision of multi-level releases to avoid discharge of anoxic water besides, control of land uses, waste water discharges and agricultural chemical use in watershed and limiting retention time of water ,in reservoir, help in controlling negative influences of impoundment including reduction in emission of GHG.

- The flood plain area of the Narmada is very small, depth of soil is also very low besides major dams on the main stem of the river would also help reduce the siltation. Soil conservation works in the areas spread to 1,80000 ha, close to the shore land of the reservoir would minimise siltation and its ill effects

- Baseline studies of the forest to be submerged have been done in all three states and results to date suggested that most of the submergence areas were characterised by highly degraded, low productivity forest. However project authorities were directed to remove all vegetation growth and to clear the reservoir bowl of any vegetation before submergence. Felling of trees was delayed until commencement of impoundment. In the areas where felling was carried out in anticipation of impoundment which could not eventually be synchronised, project authorities were directed to remove all coppice crop from the submergence areas. This was aimed to ensure that there was least vegetation material available for decomposition and consequent production of GHG.

- The stage of trophic burst is to be utilised properly with stocking of appropriate species of fish so that trash species should not multiply and establish in the reservoir and is being addressed scientifically under the guidance of a High Level expert Group on Fisheries Development and Conservation . Accordingly the Sardar Sarovar reservoir is being stocked with economic species which are compatible with endemic fauna and form a part of holistic approach to niche colonisation To utilise tropic burst stage and to realise optimum fishery, rational management program was considered essential. The rational management program focused on establishing feasible prey-predator relationship and Forge/consumer ratio and other similar considerations. Besides, introduction of herbivore, detritivore and malacovore is aimed to guide development of neo-ecosystem to betterment . Development of phyto -plankton / algae and other primary producers would consume/ stored carbon and release oxygen. The population of fishes present upon their scientific management would help intensive growth of ictheomass and complex and precious protein help overcome food security. This would prevent formation of hydro-sulphuric sludge/ europhication and eventually reduce emission of GHG.

- Another key factor relevant to prevention of production of Green House Gases from Sardar Sarovar Reservoir relates to thermal Startification, which is unlikely to occur due to drawing of water from Hypo liminionic layer for generation of power. However, to avoid formation of hydrosulphuric sludge which may corrode turbines and produce the fish kill is being cleared of vegetation at the time of the initial impoundment . This was considered of key importance particularly in view of the experiences of Brokopendo lake which submerged 1500 Km2 intact forest in Surinam. The submerged vegetation afterwards exerted negative impacts and was cleaned up later on. This after thought caused the project authorities a loss of 7% of the total cost of the project. Similar experiences from Gandhi Sagar reservoir in India where also forest growth could not be cleared before filling was cleared up partly by the fisheries department and partly by the fishermen themselves when it started damaging not only boats and nets but also life and property and was degrading the lake environment.

- In Narmada river system existing load of pollutions from domestic waste water, industrial affluent and agriculture run-off get disbursed and has not posed any problem. Yet in view of the planned development upstream, hydro-biological monitoring is being taken up on a regular basis. The results obtained showed abundance of total phyto-planktons, spurts of diatoms and blue green and decline in benthic community (Annelids/ Dipetrians/ Molluscans) indicating transformation into lake environment and development of columnar increase with progressive impoundment. Manifold increase in aquatic vegetation, acting as energy sink causing negative channelization of the energy was recorded . Though this is detrimental to fisheries as it consums the available nutrients but also prevented emission of GHG

- Availability of higher levels of Phosphates, Nitrates and Silicates recorded from the Sardar Sarovar Dam, showed rich status of productivity. Biotic communities such as diatoms requiring silica shall bloom and contribute sequestration of the carbon from the reservoir. The organic carbon ranged from .46 to 1.5% and free calcium carbonate ranged from 16.0 to 18.0%. Study of organic production indicated prevalence of autotrophic condition favorable for secondary production

- Water Quality parameters studied confirmed alkaline nature (8.05 to 8.6) with Dissolved Oxygen (DO) values of 6.08 to 7.6 mgl-1,favoured biological productivity levels of the Sardar Sarovar Dam. Higher specific conductivity levels and total dissolved solid regime further reconfirmed higher biological productivity. Absence of free Amonia , indicated that Sardar Sarovar was free from organic pollutants. Most notable feature was complete absence of free CO2. This confirmed that all the CO2 produced was utilized by the producers during photosynthesis. Further absence of free CO2 ruled out possibility of Methane Emissions from the Sardar Sarovar Dam.

Analysis of the studies on water quality assessment for Ganga river in the Himalayan region also revealed similar findings regarding post storage water quality.

DISCUSSIONS

Assertions that all/ scientifically managed wetlands are a significant global source of methane emissions are variously irrelevant, incomplete or simply wrong. Estimates by Ivan Lima and colleagues from Brazil 's National Institute for Space Research (INPE) that Indian dams are the largest global warming contributors compared to all other nations, published recently lacked credibility as these ignored the scientific researches and contributions made by the scientists working to blend development with conservation approach. They appear to be ignorant of the large number of Impact assessment studies and the plan for management of negative consequences under implementation. Indian regulatory regime is well developed in this regard

The independent scientific studies in case of Sardar Sarovar Projects on river Narmada and Ganga river in the Himalayan region with actual measurement of carbon di oxide gas emission on the surface of reservoir amply demonstrated that tropical reservoirs managed scientifically do not emit any GHG. Studies quoted in support of production of GHG from Indian reservoirs are derived from ill conceived hypothesis where emission of CO_2 was based on the presumption that standing trees were allowed to be submerged or   decomposed parts of flooded trees remain above the reservoir surface. Similarly assertions that, with the rise and fall of the water level in the reservoir alternately flooding and submerging large areas of land around the shore reservoirs become virtual methane factories. As it allowed quick growth of soft green vegetation on the exposed mud and decomposition of it under anaerobic conditions at the bottom of the reservoir when the water rises again, converting atmospheric carbon dioxide into methane, with a much higher impact on global warming than the CO_2,is ill conceived and ill founded for the same reasons enumerated above.

The Management of Indian reservoir from Environmental considerations provided measures for improving biological pump further by way of plantations, plantations of man grooves , compensatory/ environmental flows requirements towards down stream, channel morphology etc through well orchestered execution of measures designed to offset any such possibilities as brought out above.

Consequent to impoundment, there is an initial high pulse of emissions in the first few years after reservoir filling because of the huge amounts of carbon in the biomass and soils in the area flooded, only if needed safeguard measures are not put in place in time, as was the case where studies were conducted. Even in these cases the emission levels varied widely between reservoirs depending upon such factors as the area and type of ecosystems flooded, reservoir depth and shape, the local climate, the area of the reservoir covered in aquatic plants, water quality(especially pH and nutrient content), the way in which the dam was operated, and the ecological, physical and socio-economic characteristics of the dammed river basin. This required careful consideration of the issues of eutrophication, on merit in each case rather than making a sweeping statement, as brought out and propagated by international river network based on estimates from a limited set of samples measured at specific points in the reservoir during specific time periods. In these cases also the confidence in the measurements was also hampered by the different results obtained through different measuring equipment and techniques, and disagreements over which measuring methods could be considered appropriate. Besides the CO_2 emissions included in calculations were those which would result from the decay of the parts of flooded trees left standing above the reservoir level, which is not true in most of the cases. Natural lakes and rivers in their pristine quality usually are not the sources of CO_2 and CH_4 , except when terrestrial carbon is loaded into these therefore more research is needed to be able to accurately quantify the extent of these emissions, especially of methane, if any to substantiate.

CONCLUSION

The science is very preliminary/young and because of its many complexities and uncertainties and also because very little has been published on it ,the issue remained to be resolved. The main trend in reservoir emission science has been toward increasing recognition of the complexity of the pathways through which emissions are produced and released. Measurements have been made at only a tiny percentage of the world's half million or so freshwater reservoirs and are therefore inconclusive, especially in well managed reservoirs. Carbon fixation achieved from scenario with or without reservoir would need detailed estimation of carbon fixed by various project activities

Though the reservoir emissions were recognized as an issue of concern in early 2006 by the governing board of the Clean Development Mechanism, the Kyoto Protocol's main carbon trading system. Simultaneously the IPCC also recognized in its 2006 guidelines on greenhouse gas inventories that reservoirs are a source of emissions. However the ecological setting of the Indian river system presents a well studied and managed case of Narmada & Ganga rivers which underline the assumption that multipurpose hydropower dam(s) is suitable and conducive for best utilization, with little or no net emissions whatsoever. Efforts for initiating sequential steps to prevent degradation of the reservoir from synergetic influence of a number of stresses is designed to enhance the productivity of the reservoir on a sustainable basis & that this may form a model for conservation of lake environment for all future projects worldwide.

FURTHER READINGS:

1. Ackerman, W.C., et al : "Man made Lakes : their problems & environmental effects"; Geophysical Monograph series. American Geophysical Union Vol 17; 1973.

2. Anon : Sociological Survey of the fishing families of the Narmada River NCA/CICFRI, Barrackpore, W.B. India; 1991.

3. Aquatic Fauna (Fish) Studies in Indira Sagar Submergence Area, prepared by the Friends of Nature Society in 1991 on behalf on the NVDA reported on the fish fauna of the Narmada.

4. Dubey, G.P. and S.N. Chatterjee : Case Study of Gandhi Sagar Reservoir, Madhya Pradesh, India IPFC/76/Sym/21 FAO; 1976.

5. Eco-Environmental and Wildlife Management Studies in the Sardar Sarovar Area in Gujarat, 1992, by MSU.

6. Fish conservational and hydro biological perspectives of river Narmada with reference to Sardar Sarovar Project(2007) Study by CICFRI for Government of Maharashtra .

7. Hei de, V.V.:" Lake Brokopendo - filling phase limnology of a man made lake in the humid tropics". Offset drukkerykanters. B.V. Albatrosserdam ;1982.

8. Impact Assessment of Madhya Pradesh Land to be Submerged Under Sardar Sarovar Project and Adjoining Ecosystems. The study was conducted by the State Forest Research Institute (SFRI) in Jabalpur and financed by the NVDA. This study was completed & report was submitted in 1994.

9. L.P. Rosa *et al*. (2002) "First Brazilian Inventory of Anthropogenic Greenhouse Gas Emissions. Background Reports. Carbon Dioxide and Methane Emissions from Brazilian Hydroelectric Reservoirs," Ministry of Science and Technology, Brasília.

10. L.P. Rosa *et al*. (2004) "Greenhouse gas emissions from hydroelectric reservoirs in tropical regions," *Climatic Change* 66; Fearnside (2004).

11. Narmada Basin Water Development Plan: Development of Fisheries, 1987, was prepared by the Narmada Planning Agency, GOMP.

12. Narmada River Basin Development Project: Fisheries Component, 1991 by the German Consultants to the World Bank, GOPA.

13. Note on Sardar Sarovar Project - Preparation of Environmental Work Plan for Forest and Wildlife by the State Forest Department, GOM, 1988.

14. P. Parekh (2004), "A Preliminary Analysis of the Impact of Dam Reservoirs on Carbon Cycling," prepared for International Rivers Network.

15. P.M. Fearnside (1995) "Hydroelectric Dams in the Brazilian Amazon as Sources of 'Greenhouse' Gases," *Environmental Conservation* 22:1.

16. P.M. Fearnside (2002) "Greenhouse gas emissions from a hydroelectric reservoir (Brazil's Tucuruí dam) and the energy policy implications," *Water, Air, and Soil Pollution* 133:1.

17. P.M. Fearnside (2004) "Greenhouse gas emissions from hydroelectric dams: Controversies provide a springboard for rethinking a supposedly 'clean' energy source," *Climatic Change* 66.

18. Pawan-Kumar & A.K.Malhotra: - "An approach to integrated development of Water resources projects with conservation of ecosystem in Environmental Impacts of water resources development ": Tata Mc Graw Hill, New Delhi India; 1994 , pp175-184.

19. Pawan-Kumar & A.K.Malhotra: Overview & Prioritised action plan, Sardar Sarovar Project; ERM, London/NCA, Indore, M.P.,India; 1993.

20. Pawan-Kumar : "Narmada river basin Development : A Strategy for sustainable living and Guidelines for conservation of Species & ecosystem Procc." National Seminar conservation of endangered sp & ecosystem Biotechnological & Ecological approaches : BHU Varanasi, Eco transformation system for Environment & upliftment, New Delhi,India; 1996.

21. Pawan Kumar (1996):Conservation of Eutrophication in man made lakes with special reference to Sardar Sarovar (narmada) Project in India LACAR Argentina.

22. Pre-and Post-Impoundment Limnolo-gical Studies of Narmada Basin, by three universities coordinated by Barkatullah University for the NVDA. (1989-92) Study report was available in 1994.

23. Preliminary Report on First Botanical Exploration and Plant Collection from Narmada Valley by the Botanical Survey of India in 1986.

24. Rapid Reconnaissance Survey of Limnological Aspects Part I, II and III, 1987, were undertaken by the Bhopal, Vikram and Rani Durgavati Universities for GOMP.

25. Report on the Survey of the Narmada Sagar Area by Zoological Survey of India, 1988.

26. Singh, S.N. - Studies on fish conservation in Narmada Sagar Sardar Sarovar & its downstream. Narmada Control Authority - CICFRI, Barrackpore -743101 West Bengal, India ; 1993.

27. Status of Flora and Fauna in and Around Sardar Sarovar Project, Maharashtra is studied by the University of Pune (1992-94).

28. W.E. Dean and E. Gorham (1998) "Magnitude and significance of carbon burial in lakes, reservoirs, and peat lands," *Geology* 26:6.

29. Water quality data collected by the Central Pollution Control Board, Central Water Commission, the State Pollution Control Boards and the National Institute of Oceanography.

30. Wildlife Management Studies in the Submergence and Catchment Area of Narmada Project: With Special Reference to Shoolpaneshwar Wildlife Sanctuary, by the SSNNL, 1992.