MANGALORE UNIVERSITY

FINAL REPORT

UGC Major Research Project

UGC APPROVAL LETTER NO.: No. F. No. 41-878/2012 (SR) dated July 26, 2012.

Studies on the sedimentation rate of fresh water reservoirs of South West Coast of India by ^{137}Cs and ^{210}Pb techniques

Submitted by

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DETAILS OF THE PROJECT

1.	Title of the Project	:	**Studies on the sedimentation rate of fresh water reservoirs of West Coast of India by ^{137}Cs and ^{210}Pb techniques**
2.	NAME AND ADDRESS OF THE PRINCIPAL INVESTIGATOR	:	**DR. KARUNAKARA. N.** **ASSOCIATE PROFESSOR** **University Science Instrumentation Centre** **Mangalore University** **Mangalagangotri – 574 199** **D. K. Karnataka**
3.	NAME AND ADDRESS OF THE INSTITUTION	:	**MANGALORE UNIVERSITY** **Mangalagangotri – 574 199** **D. K. Karnataka**
4.	UGC APPROVAL LETTER NO. AND DATE	:	**UGC Sanction No. F. No. 41-878/2012 (SR) dated July 26, 2012.**
5.	DATE OF IMPLEMENTATION	:	**Aug, 2012.**
6.	TENURE OF THE PROJECT	:	**3 years (2012-2015)** **But terminated after firs year**
7.	TOTAL GRANT ALLOCATED	:	**Rs.**
8.	TOTAL GRANT RECEIVED	:	**Rs. 8,79,500=00**
9.	FINAL EXPENDITURE	:	**Rs. 8,58,521=00**

FINAL REPORT

1. Project title:

Studies on the sedimentation rate of fresh water reservoirs of West Coast of India by ^{137}Cs and ^{210}Pb techniques

2. Origin of research problem

Soil erosion and associated sedimentation are major environmental problems worldwide. Soil erosion, a consequence of deforestation and inadequate agricultural practices, causes not only on-site degradation of a non-renewable natural source but also off-site problems such as downstream sediment deposition in fields, floodplains and water bodies. In view of their great impact on sustainable agricultural production and environmental conservation there is an urgent need to assemble quantitative data on the extent, magnitude and actual rates of erosion and sedimentation as well on their economic and environmental consequences. There is increasing recognition of the importance of soil erosion and the transport of fine sediment in river systems as environmental problems. World's reservoirs are currently losing storage at a rate of 50 km^3 per year as a result of sedimentation[1]. Taking account of the central importance of reservoirs for domestic and industrial water supply, for irrigation schemes, and for power production (hydropower and nuclear power), and thus for economic progress of the county, such loss of storage area are of considerable concern. It is therefore important that we should develop an improved understanding of the mobilization, transfer and fate of fine sediment within fluvial systems and to construct sediment and sediment-associated contaminated budgets for river basins.

Many methods, including models for predictions have been developed and used to obtain qualitative and quantitative data on pattern and rates of erosion/deposition. The existing classical techniques have significant limitations. Measurements of soil erosion on the landscape using classical erosion technique are difficult, time consuming and expensive. Most classical methods for estimating soil erosion are based on measuring soil loss from plots or at the edge of a field. They do not give unbiased measurements of actual soil movement, and, more importantly, they do not address spatial patterns of erosion and redeposition within fields. Mathematical models have same limitations. There is a need to develop a method capable of making measurements at any location

1. Mahmood, K. Reservoir Sedimentation – Impact, Extent and Mitigation, The World Bank, Washington DC, 1987.

on the landscape, especially in areas where other erosion data are not available and where long-term experiments have not, nor cannot be, established. Classical erosion measurement techniques and mathematical models cannot meet these criteria. Tracer technique has the potential to provide the necessary type of data. However, this technique can be difficult if tracer must be added to the environment. A tracer is needed that is naturally distributed across the landscape, easily measured, and readily absorbed to soil particles.

The use of radionuclides in soil erosion/deposition research overcomes many of the problems associated with the traditional approaches and they have been used successfully in several developed countries. Of particular relevance is the use of fallout radionuclides in these studies. Among these, the ^{137}Cs and ^{210}Pb technique allows the assessment of both soil loss and deposition in the same watershed without the need of long-term financial commitments. Recognizing this potential the International Atomic Energy Agency (IAEA) started in 1995 the implementation of two internationally coordinated research projects on soil erosion and sedimentation, respectively, using the ^{137}Cs and ^{210}Pb techniques. Under these projects the process of validation and refinement of the ^{137}Cs and ^{210}Pb techniques for documenting soil erosion and sedimentation rate was undertaken by a network comprising 25 scientists on a word-wide basis.

Fallout ^{137}Cs from atmospheric nuclear weapons tests of the 1950s and 1960s is a unique tracer for the erosion and deposition cycle because no natural sources of ^{137}Cs are in the environment. The chemistry of this unique tracer is well understood. Once ^{137}Cs reaches the soil surfaces it is strongly and quickly adsorbed by clay particles, and is essentially non-exchangeable in most environments. Thus, ^{137}Cs becomes an effective tracer of the movement of surface soil. Distribution of ^{137}Cs in soil profiles at undistributed sites shows an exponential decrease with depth, whereas plowed soil show uniform distribution throughout the soil layer. In soil erosion studies, the challenge is to elucidate the changing patterns of distribution of ^{137}Cs-tagged soil particles on the landscape. The redistribution of ^{137}Cs between and within landscape elements provides information on soil erosion rates and patterns. Thus, measurement of ^{137}Cs redistribution on the landscape provides estimates of long-term soil loss.

Large scale industries are being setup along the West Coast region of India and this region is identified as the special economic zone. There are several major rivers and other reservoirs in the West Coast region of India which are considered as life lines of this region. Due to deforestation and larges scale construction activities in the catchments areas of major rivers of this region there is a possibility of increased soil erosion and sedimentation accumulation in all reservoirs of the region.

This would results in the loss of water storage capacity of the reservoir. It is extremely important that we take necessary steps to see that the process of rapid industrialization of this region does not affect the rivers and reservoirs seriously. Hence we need to develop an improved understanding of the mobilization, transfer and fate of fine sediment within fluvial systems and construct sediment and sediment-associated contaminated budgets for river basins and water reservoirs of this region. It should be noted that such detailed studies are non-existent for this region and the baseline database required for Environmental Impact Assessment (EIA) are not available. Therefore, this project proposal aims to initiate a detailed study to estimate the sedimentation rate of fresh water reservoirs of West Coast region of India by ^{137}Cs and ^{210}Pb techniques.

Our earlier extensive studies[2,3,4] on the distribution of natural and artificial radionuclides in the environment of West Coast of India have shown the presence of significantly higher activities of ^{137}Cs and ^{210}Pb in soils and sediment of the region. A comparison of the ^{137}Cs and ^{210}Pb concentrations observed in this region with those reported for other parts of the country show that the concentration of these radionuclides in this region is significantly higher. The presence of higher concentrations of ^{137}Cs and ^{210}Pb provides a unique opportunity to undertake a systematic study on soil erosion and sedimentation rate measurements by ^{137}Cs and ^{210}Pb techniques.

3. Interdisciplinary relevance and Significance of the study

The use of ^{137}Cs and ^{210}Pb techniques for sedimentation rate estimation and sediment catchment budget estimation are interdisciplinary in nature and involve Physics, Instrumentation and Geology to a large extent and Chemistry to lesser extent. Hence, faculty from Instrumentation, Physics and chemistry were involved in this project proposal. While scientist from Physics worked on development of methodology, sample collection and measurement of ^{137}Cs and ^{210}Pb concentrations by nuclear counting technique, the scientist with Geological background helped help in identification of location for sample collection and in interpretation of the results of the

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2. Karunakara N, Avadhani D N, Mahesh H M, Somashekarappa H M, Narayana Y and Siddappa K. ^{137}Cs Concentration in Environment of Kaiga in the south West Coast of India, *Health Physics*, USA, Vol. 81, No 2, pp 148-155, 2001.

3. Karunakara N, Avadhani D N, Mahesh H M, Somashekarappa H M, Narayana Y and Siddappa K. Distribution and enrichment of ^{210}Po in the environment of Kaiga in south India, *Journal of Environmental Radioactivity*, UK, 51, pp. 349-362, 2000.

4. Karunakara N, Avadhani D N, Mahesh H M, Somashekarappa H M, Narayana Y and Siddappa K. ^{226}Ra, ^{40}K and ^{7}Be activity concentration in plants in the environment of Kaiga, India. , *Journal of Environmental Radioactivity*, UK, 65, pp. 255-266, 2003

measurement, and faculty from Chemistry helped in radiochemical separation of ^{137}Cs and ^{210}Pb from the sediment core samples .

4. Review of research and development in the subject

International Status

On the basis of application of ^{137}Cs technique in the UK, USA, Australia and other countries[5] it is identified that (i) the technique permits retrospective assessment of medium-term erosion rates, (ii) the application of the technique requires only one field visit, and the results can be provided within a relatively short time, (iii) the rates estimated represent the sum of all erosive processes, (iv) both rate and pattern of soil redistribution may be quantitatively assessed, (v) range of erosion rate estimates may be obtained, including mean rate of erosion and deposition and net rates of soil export from the field, and (vi) estimates are location specific and can be made with minimum disturbance to study sites, giving both spatial patterns and rates of erosion from single visit.

Recognizing this potential of this technique International Atomic Energy Agency (IAEA) initiated a detailed study in 1995 through two internationally coordinated research projects on soil erosion and sedimentation, respectively, using the ^{137}Cs and ^{210}Pb techniques. Under these projects the process of validation and refinement of the ^{137}Cs and ^{210}Pb techniques for documenting soil erosion and sedimentation rate was undertaken by a network comprising about 25 countries on a word-wide basis. Subsequently, all European Countries, some of the countries of Africa, USA, South American countries, Australia have undertaken details studies on this technique and now it is established technique in these countries

National status

Although the ^{137}Cs and ^{210}Pb techniques are well established techniques and are used widely in developed countries application of these technique are very sparse in India. Only limited attempt has been made to study the sedimentation rate by ^{210}Pb and use of ^{137}Cs is almost non-existent. The studies proposed under this project would be a pioneering effort in this direction.

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5. Acta Geologica Hispanica. Ed. Queralt, Zapata F and Garcia Agudo E. Vol 35, No. 3-4. 2000.

5. Significance of the study

The country as a whole and the West Coast region of India in particular, is experiencing an unprecedented growth in industry. Many major industries, such as, thermal power stations, petrochemical complexes, nuclear power stations, mining and processing industries are being set up in this region. While industrialization is essential for strengthening countries economy, it is equally important to ensure that the rapid industrialization do not degrade the environment irreversibly. One of the main environmental problems associated with industrialization is deforestation that results in soil erosion and downstream sediment deposition in fields, floodplains and siltation of water reservoirs. World's reservoirs are currently losing storage capacity at a rate of 50 km^3/year as a result of sedimentation. Considering the central importance of reservoirs for domestic and industrial water supply, irrigation, electricity generation, and thus for economic progress of the country, such loss of storage area is of concern.

There are several major rivers and other reservoirs in the West Coast region of India, which is now experience rapid industrialization. It is extremely important that we take necessary steps to see that the process of rapid industrialization of this region does not affect the rivers and reservoirs seriously. Therefore, it is important that we develop an improved understanding of the mobilization, transfer and fate of fine sediment within fluvial systems and construct sediment and sediment-associated contaminated budgets for river basins and water reservoirs of this region. Such study would be a pioneering effort in generating standardized and reliable database essential for EIA of industrial activities. For any industry being established on the West Coast of India the data would be readily available, thereby facilitating the rapid growth of industry and also the country. It should be noted that such detailed studies are non-existent for this region and the baseline database required for Environmental Impact Assessment (EIA) are not available.

6. Aim and Objectives

The aims and objectives of the research project are:

- To estimate the sediment accumulation rate in major fresh water reservoir of West Coast region of India by ^{210}Pb and ^{137}Cs techniques,

- To estimate the sediment input to reservoirs by using ^{137}Cs technique, and

- To demonstrate the use of radionuclides to study environmental problems, in general, and in estimating the sedimentation rates of reservoirs in particular.

7. Procurement of the equipment for the project

The following instruments were sanctioned for the project and was procured and installed:

- **Low background beta counting with detector, electronics and lead shield**
  Suppliers details: M/s. Nucleonix, Phase II, IDA Cherlapally, Hyderabad – 500 051
  Cost of the instrument: Rs. 4,95,000 + Tax

A view of the low background beta counting system

- **Sediment core sampler**
  Suppliers details : M/s. NORINCO Private Limited, Chennai, Park View Apartment, No-13, Nagendra Nagar, Velachery Main Road, Velachery, Velachery Main Road, Chennai, Tamil Nadu - 600042
  Cost of the instrument: Rs. 2,55,524 + Tax

A view of the sediment core sampler

Note : Procurement of the custom made instruments consumed significant time of the first year of the project. Further, significant time was also spent on calibration of the instrument using IAEA reference and standard materials.

8. Methodology

Studies on Soil Erosion and Sedimentation Rates

The potential for using ^{137}Cs measurements to investigate rates and patterns of soil loss and the basis of the approach is now well documented[6]. In brief the approach is founded on the fact that ^{137}Cs released into the stratosphere as a by-product of past atmospheric testing of thermonuclear weapons during the 1950's and 1960's reached the land surface as fallout and was in most environments rapidly and strongly adsorbed by the surface soil. Its subsequent redistribution can be attributed to the erosion, transport and deposition of soil particles and measurements of the current distribution of ^{137}Cs within the landscape provide a means of establishing rates of erosion and

6. Ritchie, C. Jerry and McHenry Roger, J. Application of radioactive fallout Cesium-137 for measuring soil erosion and sediment accumulation rates and patters: A review. *Journal of Environment*, Vol. 19, No. 2, 215-233, 1990.

deposition, and spatial patterns involved, during the period since the main phase of atmospheric fallout. Assessment of ^{137}Cs redistribution is commonly based on comparison of the measured inventories (total activity per unit area) at individual sampling points, with an equivalent estimate of the inventory representing the cumulative atmospheric fallout at the site, taking due account of the different behavior in cultivated and non-cultivated soils. Because direct long-term measurements of atmospheric fallout are rarely available, the cumulative input or reference inventory is usually established by sampling adjacent undisturbed, uneroded locations, which can provide an estimate of total fallout inputs. The magnitude and direction of measured deviations from the local reference level provide qualitative assessment of sediment redistribution. To derive quantitative estimates of the rates of erosion and aggradation involved, it is necessary to establish a relationship between the magnitude of the deviation from the reference inventory and the extent of soil loss or gain. Since empirical calibration data are rarely available, many workers have favoured the use of theoretical relationship or models to provide the necessary calibration function. Such models can be used to simulate the effect of a range of long term erosion and aggradation rates upon the ^{137}Cs inventory of soil profiles, and the resultant data can be used to derive the calibration relationship[7,8].

The Basis of the ^{137}Cs Technique in soil erosion studies

In brief, the basis of the ^{137}Cs technique may be defined as follows:

- The ^{137}Cs was deposited as fallout primarily during the late 1950s and the 1960s and in most environments was rapidly and strongly adsorbed by soil particles at the ground surface
- Subsequent redistribution of the ^{137}Cs reflects the movement of soil particle since the ^{137}Cs remains adsorbed and moves in association with the soil particles
- It is assumed that the initial distribution of the ^{137}Cs fallout input was uniform, then deviations in the measured distribution of ^{137}Cs from the local fallout inventory represent the net impact of soil redistribution during the period since ^{137}Cs deposition
- If a relationship between ^{137}Cs loss and gain and soil loss and gain can be established, it will be possible to estimate rates of soil erosion and aggradation from ^{137}Cs measurements.

The important stages involved in the erosion assessment using ^{137}Cs measurements are:

- Establishment of a reference site for the study area which represents the total fallout input of

7. Walling, D. E. and Quine, T. A. Calibration of Cesium-137 measurements to provide quantitative erosion rate data, Land Degrad Rehabilitat, 2, 161-175, 1990.

8. Quine, T. A. Estimation of erosion rates from Cesium-137 data the calibration question. Sediment and Water Quality in River Catchments, Wiley, Chichester, 307-329, 1995.

^{137}Cs at an undisturbed site experiencing no erosion or deposition and establishment of the reference ^{137}Cs inventory

- Extensive sampling in the study area and measurement of ^{137}Cs to find the spatial distribution of ^{137}Cs inventories at the study site
- Evaluation of the pattern of ^{137}Cs redistribution at the study site
- Estimation of soil erosion/deposition rates using a comparison of the reference ^{137}Cs inventory with the inventories measured for the study area, using models based upon relationship between ^{137}Cs loss or gain and soil erosion or deposition.

The basis of ^{210}Pb technique in reservoirs sedimentation rate measurements

The ^{210}Pb technique for the measurement of sedimentation rate of reservoirs is very well established. Vertical profiles of ^{210}Pb provide valuable information on the sedimentation accumulation rate in reservoir, rivers, estuaries, lakes, etc. The total ^{210}Pb that is present in the sediment of reservoir has two components, first a minor part in equilibrium with ^{226}Ra fixed to the sediment from ^{238}U decay. Second, ^{210}Pb have a major part that is associated to the particulate matter, named ^{210}Pb in excess ($^{210}Pb_{excess}$). This $^{210}Pb_{excess}$ is formed in the atmosphere after ^{222}Rn decay and is deposited on the sediment surface with the particle material, so the exponential decrease of the accumulated $^{210}Pb_{excess}$ can be used to estimate the sediment accumulation rate. The sedimentation rate or accumulation rate or age of different horizons in a sediment core is determined from the unsupported ^{210}Pb activity ($^{210}Pb_{excess}$= ^{210}Pb - ^{226}Ra) based on the following assumptions: (i) loss of ^{210}Pb from the sediment depth horizons is only by radioactive decay (i.e. there is no mixing of various layers and there is no chemical mobility of ^{210}Pb after deposition), (ii) the radionuclide flux at the sediment-water interface is constant, and (iii) the in-situ concentration of ^{210}Pb supported by ^{226}Ra in the sediment is constant. With the above conditions, the sedimentation rate from the vertical profiles of $^{210}Pb_{excess}$ can be obtained from the relation

$$^{210}Pb_{excess}(Z) = {}^{210}Pb_{excess}(Z_0)\, e^{-\lambda z/\omega}$$

Where $^{210}Pb_{excess}$ (Z) is the activity of $^{210}Pb_{excess}$ at any depth Z from the sediment-water interface, $^{210}Pb_{excess}(Z_0)$ is the $^{210}Pb_{excess}$ activity in the freshly deposited sediment at depth Z=0. λ is the decay constant of ^{210}Pb and ω is the sedimentation rate (cm y^{-1}).

Sample collection

Two important river basins of the West Coast region of India were selected for the studies. They are (i) Kali river basin, and (ii) Sharavathi river basin, both in the North Canara dist. After the selection of the study sites and establishing the reference sites, reconnaissance soil sampling was carried out. Both bulk sampling (collection of samples which contain a complete soil profile to a depth sufficient to encompass all of the ^{137}Cs present) and depth incremental sampling (collection of samples at predetermined intervals) was carried out. After defining the optimum sampling strategy, comprehensive sampling would be carried out based on either individual slope transects or grid frameworks. Core samples of sediments were collected from different locations of different reservoirs using a gravity corer to estimate the sedimentation rate of reservoirs. The collected samples were be processed employing standard methods[9].

^{137}Cs and ^{210}Pb activity and sediment and soil properties

Precise determination of the activities of ^{137}Cs and ^{210}Pb in soil and sediment samples are important for the estimation of soil erosion and sedimentation rates. After processing the samples, the activities of ^{137}Cs and ^{210}Pb was determined by low background beta counting system, which was set up under this project.

The concentration of ^{226}Ra (which is required for estimating unsupported ^{210}Pb activity) in sediment core samples were determined by gamma spectrometry by employing either a 42% relative efficiency n-type (model GR4021) or a 38% relative efficiency p-type (model BE3825) low background HPGe detectors having carbon fibre window and ultra-low background cryostat (Canberra, USA). These detectors can be used for the measurement of gamma ray energies from 5 keV to 10 MeV. The energy resolution of the detector is 2.1 keV at 1.33 MeV. The detectors were enclosed in a 10 cm thick low background graded lead shield to reduce the background. The Canberra DSA-1000 (which consists of HV bias supply, ADC and 16K MCA) and GENIE-2000 software were used for data acquisition and analyses. The detector efficiency calibration was performed using the IAEA quality assurance reference materials (RGU-238, RGTh-232, RGK-1 and SOIL-6). The IAEA quality assurance reference material (IAEA 307, ash of sea plant) was used for efficiency calibration for the measurement of radionuclides concentration in ashed samples of vegetables. Soil samples were counted for 40,000 s and ash samples were counted for 60,000 s. The ^{226}Ra activity concentration was evaluated from the weighted mean activities of three photopeaks of ^{214}Bi (609.3, 1120.3, and 1764.5 keV) and one photopeak of ^{214}Pb (352 keV) after applying Compton corrections. Both standard materials and samples were taken in identical cylindrical

9. EML Procedure Manual. Edited by Herbert L. Volchok and Gail de Planque. 26th Ed., *Environmental Measurement Laboratory*. (1983).

containers so that detection geometry remained the same. These detectors can also very well be used for the measurement of ^{210}Pb in environmental samples.

A view of n-type 42% relative efficiency HPGe gamma spectrometer system

Quality assurance

The following International Atomic Energy Agency (IAEA) reference standards were used for calibration and efficiency determination of different gamma spectrometers and other radiation detecting systems:

- RGU-238
- RGTh-232
- RGK-40
- IAEA Soil-6 for ^{137}Cs as well as natural radionuclides
- IAEA-307, Sea plant ash from Mediterranean sea
- IAEA-314 and IAEA-313, U and trace elements in Stream sediment
- IAEA-414, Radionuclides in Irish and North Seas

The gamma reference standards have been prepared from the above reference materials in different geometries, such as, top hat geometry of different sizes, vial geometry, etc. and are available in the laboratory for counting samples in different geometry.

All the measurements were carried out following the standard methods/procedures/protocols given by IAEA, EML and BARC. Frequent inter-comparison measurements were carried out with ESL, Kaiga. The PI's laboratory is a regular participant in the inter-comparison measurement exercise conducted by IAEA.

Estimating soil erosion and deposition

As discussed earlier, the use of fallout ^{137}Cs to estimate soil erosion and deposition rates is founded upon a comparison between ^{137}Cs inventories for individual sampling points and the local reference inventory. ^{137}Cs inventory less than the local reference value indicates erosion, whilst inventories which are greater indicate deposition. The following theoretical models[10] and related computer software based on above models (provided by IAEA) would be used to estimate the soil erosion from the measured ^{137}Cs inventories.

- ***The proportional model***: The most widely used theoretical model for estimating soil erosion rates on cultivated land from ^{137}Cs inventories.
- ***The profile distribution model***: The most widely used theoretical model for estimating soil erosion rates on uncultivated land from ^{137}Cs inventories. This model is based upon the characteristic exponential decline of ^{137}Cs in an undisturbed soil profile.
- ***Mass balance model***: Used to estimate the soil erosion on cultivated land and this model overcomes some of the limitations of the proportional model.

9. Year wise plan of work and targets achieved

The tenure of the project (3 years) would be divided into 3 equal phases and the work plan for each phase is as under:

Research Plan for each year	**Deliverables for the first year and targets achieved**
I Year • Project formulation meeting (PI, PC & DC) to discuss the modalities for the implementation of the project	• Availability of equipment for the research work • Well planned protocol for the work to be

[10]. Walling, D. E. and He, Q. Improved models for estimating soil erosion rates from Cesium-137 measurement. *Journal of Environmental Quality*, Vol. 28, pp. 611-622, 1999.

• Recruitment of staff for the project • Procurement of major equipments, standards, chemicals, consumable and sample collection tools, such as, core samplers, grab samplers, etc. • Literature survey and field reconnaissance, selection of sampling stations, reconnaissance survey, topographic map and other site information gathering, and . • Extensive collection of sediment samples from the reservoirs and analyses of the samples for sedimentation rate measurements by ^{210}Pb and ^{137}Cs techniques. • Preparation of the first year progress report.	carried under the research project. • Preliminary data on sedimentation rate of major reservoirs of West Coast of India. **Targets achieved :** All the above Targets were achieved
II year • Continuation of the work initiated in the first year • Periodical re-sampling of soil and sediment • Analyses of the samples for ^{137}Cs and ^{210}Pb for estimation of sedimentation rates, respectively • Data processing and preliminary interpretation to rectify, if required, the field work strategies • Analysis of the data collected • Preparation of second year progress report of the project.	• Reliable data and sedimentation rates of major reservoirs of West Coast of India • Research papers in national seminar/conference • Second Progress report of the project **Targets achieved:** All target could not be achieved as project was terminated since the reviewers felt that the progress was not satisfactory as we could not publish a research paper in the first year. **However, studies are being continued on research interest and these have yielded important results**

10. WHETHER OBJECTIVES WERE ACHIEVED (GIVE DETAILS)

Objectives were partially achieved. This is due to the fact that the project was terminated after one year. The area of study undertaken in the project was innovative in nature and involved procurement, installation, and calibration of the instruments, extensive field work in different fresh water reservoirs of the West Coast of India, hiring the boat, collection of sediment core samples. Subsequent analyses of the samples demands processing of the samples, separation of Cs-137 and Pb-210 through radiochemical analyses and analyses of the samples using nuclear detectors. Analyses using the nuclear detectors, such as, low background beta counting system, HPGe gamma spectrometry and NaI(Tl) gamma spectrometry often involved long counting time (typically 48 hrs. for a sample). Procurement of the custom made instrument and calibration of them for measurement of radionuclides present in very low level demands significant time frame. Further, protocols for the methodology to be followed for the studies were to be developed and this also required significant item. After these were completed, field visits were performed and sediment cores samples were collected and analyses of the samples were in full swing at the end of the first year. Since data on sedimentation rate was not available at the end of the first year in view of the above cited reasons, research papers could not be published. However, the review committee insisted for the research papers and opinioned that the progress was not satisfactory.

11. ACHIEVEMENTS FROM THE PROJECT

- Through this project we could develop collaboration with Wayne State University, USA.

- Establishment of a very good NaI(Tl) gamma spectrometry laboratory for the analyses of sediment core samples for Cs-137 and Pb-210. This laboratory is now extending the facilities for users from other neighboring institutions.

- Setting up of very good very good sediment gravity core sampler.

- Development of standard protocols for identification of sampling locations, analyses of samples, opitimisation and interpretation of the results.

- Collection of sediment core samples from different fresh water reservoirs. Analyses of these core samples (which are progressing now) would provide valuable data on sedimentation rates of fresh water reservoirs of West Coast of India. The data on this aspect

is very essential in view of the large scale industrialization of the region. Also, the study would demonstrate the use of radionuclides in assessing the environmental problems, in general, and in estimating the sedimentation rates of reservoirs in particular. Although the research project has been terminated, sincere efforts are being made to complete the studies initiated under the project.

12. SUMMARY OF THE FINDINGS

The project did not complete its full 3 years term. From the work carried out from first one year period, the following are the important findings :

i. Low background beta counting with plastic scintillation detectors with graded lead shielding can very well be used for the Cs-137 and Pb-210 activity concentrations very small quantity of sediment samples.

ii. A prior digestion of the sediment samples using microwave digestion and subsequent preconcentration of Cs-137 from the sample using Ammonium Molybdo Phosphate (AMP) provides a better detection levels when used with well type NaI(Tl) gamma spectrometer.

iii. Direct determination of Pb-210 of activity concentration from its 46.5 keV gamma line using the NaI(Tl) gamma spectrometer is difficult. Instead, apha spectrometry provides better results.

iv. The Cs-137 and Pb-210 techniques can be conveniently used for the determination of sedimentation rate of reservoirs, provided undisturbed sediment core samples are obtained.

13. CONTRIBUTION TO THE SOCIETY

The country as a whole and the West Coast region of India in particular, is experiencing an unprecedented growth in industry. Many major industries, such as, thermal power stations, petrochemical complexes, nuclear power stations, mining and processing industries are being set up in this region. While industrialization is essential for strengthening countries economy, it is equally important to ensure that the rapid industrialization do not degrade the environment

irreversibly. One of the main environmental problems associated with industrialization is deforestation that results in soil erosion and downstream sediment deposition in fields, floodplains and siltation of water reservoirs. World's reservoirs are currently losing storage capacity at a rate of 50 km^3/year as a result of sedimentation. Considering the central importance of reservoirs for domestic and industrial water supply, irrigation, electricity generation, and thus for economic progress of the country, such loss of storage area is of concern.

There are several major rivers and other reservoirs in the West Coast region of India, which is now experience rapid industrialization. It is extremely important that we take necessary steps to see that the process of rapid industrialization of this region does not affect the rivers and reservoirs seriously. Therefore, it is important that we develop an improved understanding of the mobilization, transfer and fate of fine sediment within fluvial systems and construct sediment and sediment-associated contaminated budgets for river basins and water reservoirs of this region. This study is a pioneering effort in generating standardized and reliable database essential for EIA of industrial activities. For any industry being established on the West Coast of India the data would be readily available, thereby facilitating the rapid growth of industry and also the country. It should be noted that such detailed studies are non-existent for this region and the baseline database required for Environmental Impact Assessment (EIA) are not available.

14. WHETHER ANY PH.D. ENROLLED/PRODUCED OUT OF THE ROJECT

JRF/Research Assistant position was not sanctioned for the project.

15. NO. OF PUBLICATIONS OUT OF THE PROJECT

The following manuscripts are published/under preparation for publication:

Even though the project was terminated after first year, we could carry out extensive studies and come out with a very good publication in one of the very reputed international journal viz. Journal of Environmental Radioactivity, Elsevier, with an impact factor 3.8.

(i) Problems with the dating of sediment core using excess ^{210}Pb in a freshwater system.
Mark Baskaran, Joseph Nix, and **N. Karunakara**
Journal of Environmental Radioactivity,138, 355-363 (2014)

Copy of the paper is attached to Final Report.

(ii) Sedimentation rates of important fresh water reservoirs of West Coast of India thorugh Cs-137 and Pb-210 techniques (manuscript under preparation for submission for Journal of Environmental Radioactivity, Elsevier, UK)

Name and Signature

a. Dr N Karunakara
Principal Investigator

b. Dr H M Somashekarappa
Co-Investigator