

APPLYING SEDIMENT CORES AND NUCLEAR TECHNIQUES FOR POLLUTION ASSESSMENT IN THE BONNY/NEW CALABAR RIVER ESTUARY, NIGER DELTA, NIGERIA

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Abstract

Sediment cores were collected from the Bonny Estuary in August 2011 to archive pollution records over the last 80 years. Three sampling locations were selected and used for assessing the extent of pollution in the estuary. Alpha and gamma spectrometer in conjunction with the constant rate of supply model (CRS) were deployed to establish the age of the sediment and the data were validated using ¹³⁷Cs profiles and events that occurred within the region. The results of the activities of naturally occurring radionuclides (²²⁶Ra, ²²⁸Ra and ⁴⁰K) ranged from 15 ± 2 - 34 ± 3 Bq·kg⁻¹; 32 ± 5 - 48 ± 6 Bq·kg⁻¹ and 264 ± 29 - 462 ± 36 Bq·kg⁻¹ respectively. The results obtained for the core profiles of stations 1 and 2 exhibited a relatively constant activity but that of station 3 exhibited significant decrease with depth which was appropriate for radiometric dating. CRS model displayed increase in bulk sediment accumulation over the past 80 years with special reference to 1938, 1955, 1973, 1997 and 2004. Cesium-137 profiles were in agreement with the CRS established ages. The sedimentation rates obtained ranged from 0.019 to 0.034 g·cm⁻²·y⁻¹. The data further revealed that minimum and maximum environmental perturbations occurred in the early 1970s and late 1990s respectively. Core profiles of total hydrocarbon content ranged from 0.001 to 130.80 ppm and total phosphorus 0.01 to 0.499 mg/g. The observed profiles had peaks corresponding chronologically to severe environmental perturbations resulting from massive oil spills and substantial delivery of phosphorus from agricultural runoffs between early 1970s and early 2000s. It is therefore surmised that since the advent of industrial activities the estuary has been subject to perturbations and contamination from human activities which has resulted to fluctuations in environment conditions.

Keywords: Pollution archiving, total hydrocarbon content, ¹³⁷Cs, radiometric dating, CRS model

INTRODUCTION

Nigeria has experienced remarkable increase in industrial activities; particularly in its oil and gas sector. These activities which are centred mainly in the Niger Delta area have generated massive wealth for the nation. The Niger delta is bounded to the south by the Atlantic Ocean and covers about 50% of the total length of the Nigerian Coastline and it is situated in the Gulf of Guinea, located between 5° E to 8° E longitude and 4° N to 6° N latitude.

The coastal areas of Nigeria, particularly the Niger Delta Basin have suffered debilitating environmental degradation and pollution from human activities such as oil industry operations, manufacturing and municipal discharges. These activities became heightened following the discovery of crude oil in the late 1950s but have assumed even greater dimensions since the early 1970s when oil prospecting became the mainstay of the Nigerian economy. This scenario has undermined basic ecosystem services such as water quality and land productivity (NDES, 1999). The consequences of this have been the decline in health conditions, standard of living, socio-economic well-being and loss of income of the indigenous populace.

However, the government has demonstrated concern for environmental protection and resource conservation but unfortunately, empirical data providing evidence of pollution stocks over the last 80 years is lacking. Thus, in order to maintain and improve the quality of the unique environmental resource endowment and the physical characteristics of the coastal areas, assessing pollution stocks using sediment cores and nuclear techniques is essential.

The objectives of this research paper are to evaluate profiles of pollution stocks dating back some 80 years, identify peaks in the disturbances, and identify possible sources of pollution.

MATERIALS AND METHODS

Sample Collection and Preparation

Sediment cores were retrieved from shallow marginal areas at three stations (Fig. 1) belonging to the upper Bonny Estuary in August 2011 using an Uwitec gravity corer of 10 cm internal diameter. Three cores, 32; 30 and 20 cm depth were collected from station 1 (St-1); station 2 (St-2) and station 3 (St-3) respectively. In addition, sediment surface samples (6 cm depth) were also collected, from the three stations during different months (August, October and December 2011, and February and May 2012) covering rainy and dry seasons.



Figure 1: The study area showing the sampling locations.

The sediment cores were immediately transported after retrieval to the laboratory for pre-treatment and conditioning prior to radiometric analyses. Each core was sectioned into 2 cm slices and wet sub-samples were weighed and then dried in an oven, using a constant temperature of 80°C during 24 h. Dry samples were weighed again and the content of water in each stratigraphic level was calculated for the three cores. Bulk densities were determined from water content and particle density of each slice. Finally, dried sediment was ground in a mortar to fine powder and homogenised for subsequent alpha and gamma emitters analyses. Organic matter content was calculated as the difference in weight between the dried sediment and the ash obtained following ignition at 550°C for 24 h.

Radiometric Measurements:

The activity of ²¹⁰Pb was determined using alpha-ray spectrometry using silicon surface barrier detectors (EG&G) coupled to a PC running MaestroTM data acquisition software while gamma emitting radionuclides [²²⁸Ac(²²⁸Ra), ²¹⁴Bi(²²⁶Ra), ²¹²Pb(²²⁸Th) and ⁴⁰K] were measured using gamma-ray spectrometer.

Total Hydrocarbon and Total Phosphorus Analyses:

All samples were analyzed as described in Standard Methods for the Examination of Water and Wastewater (APHA, 2001).

Trends of Naturally Occurring Radionuclides

Spatial and Temporal Trends

The activities of naturally occurring radionuclides ²²⁶Ra, ²²⁸Ra, and ⁴⁰K, were all in the range of the values reported for coastal regions. The spatial and temporal variations displayed fairly uniform distribution with ²²⁶Ra while ²²⁸Ra displayed some variability with lowest activities during the dry season than wet season

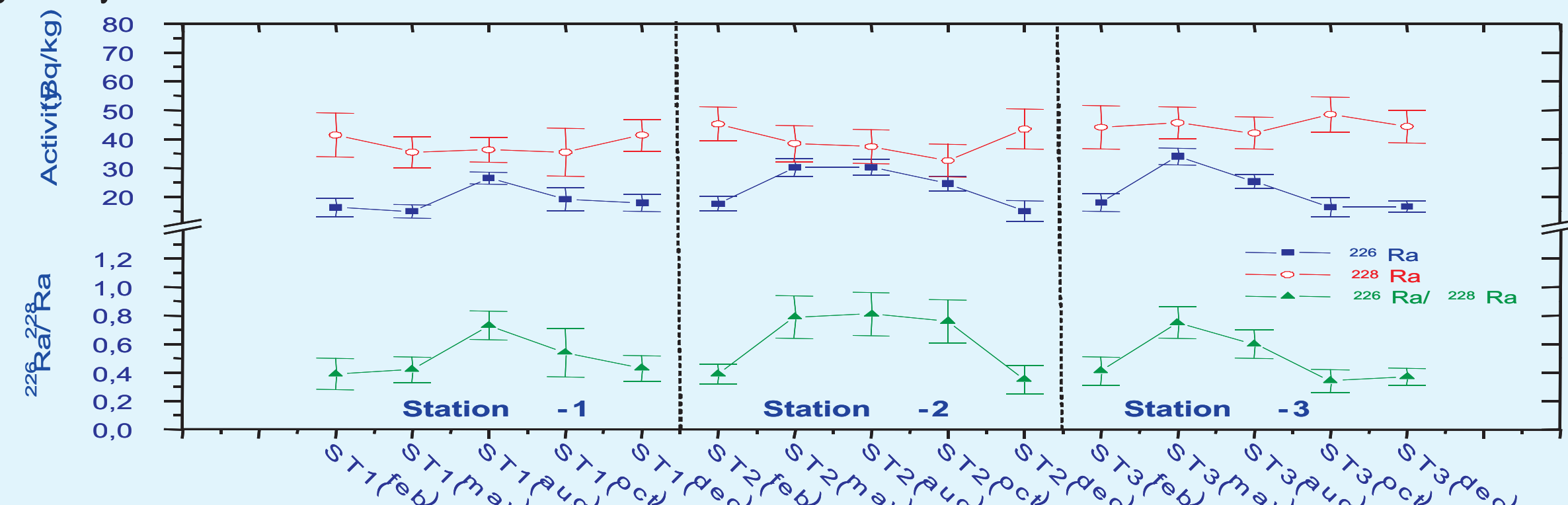


Figure 2: Activity concentrations of ²²⁶Ra and ²²⁸Ra in different months at the three stations. Activities are in Bq·kg⁻¹ dry weight and uncertainties are 1-σ statistical errors. Variation of ²²⁶Ra to ²²⁸Ra ratio is also plotted

Vertical Distributions

Core profiles of ²²⁸Ra ²¹⁰Pb and ⁴⁰K displayed fairly homogenous distributions throughout the cores with the only exception for ⁴⁰K in St-3. A relatively visible increase of this radionuclide concentration in the basal 6-cm of the core was observed. This enhancement of ⁴⁰K may be attributed to the different origin of particles present in the deepest layers of the core that may contain more fine-grained clay sediment than the rest of the core. In addition, vertical distributions of organic matter content are also depicted in Fig. 3 for each coring site.

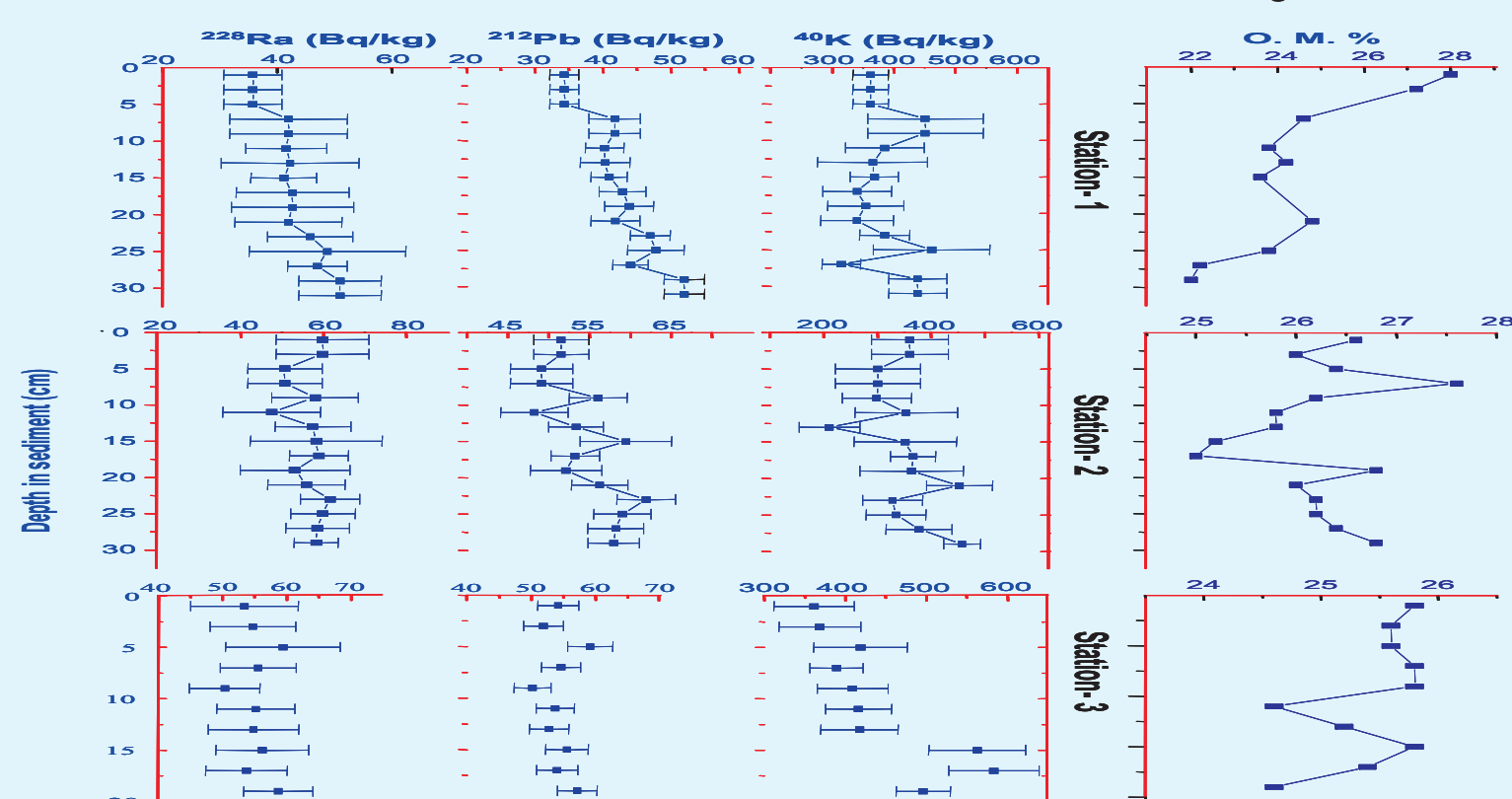


Figure 3: Vertical distributions of ²²⁶Ra, ²¹⁰Pb and ⁴⁰K in the three sediment cores collected from the Bonny Estuary. Activities are in Bq·kg⁻¹ dry weight and errors are 1-σ statistical uncertainties

Radiometric Dating

Radiometric dating was achieved for station 3 with the unsupported ²¹⁰Pb exhibiting significant decrease with depth while stations 1 and 2 did not exhibit significant decrease in ²¹⁰Pb with depth, but rather relatively constant activities with discrete maxima and minima. Therefore, these cores (St-1 and St-2) were qualified as incomplete and disturbed, and were excluded from calculations of sedimentation rates, ages and total inventories of ²¹⁰Pb.

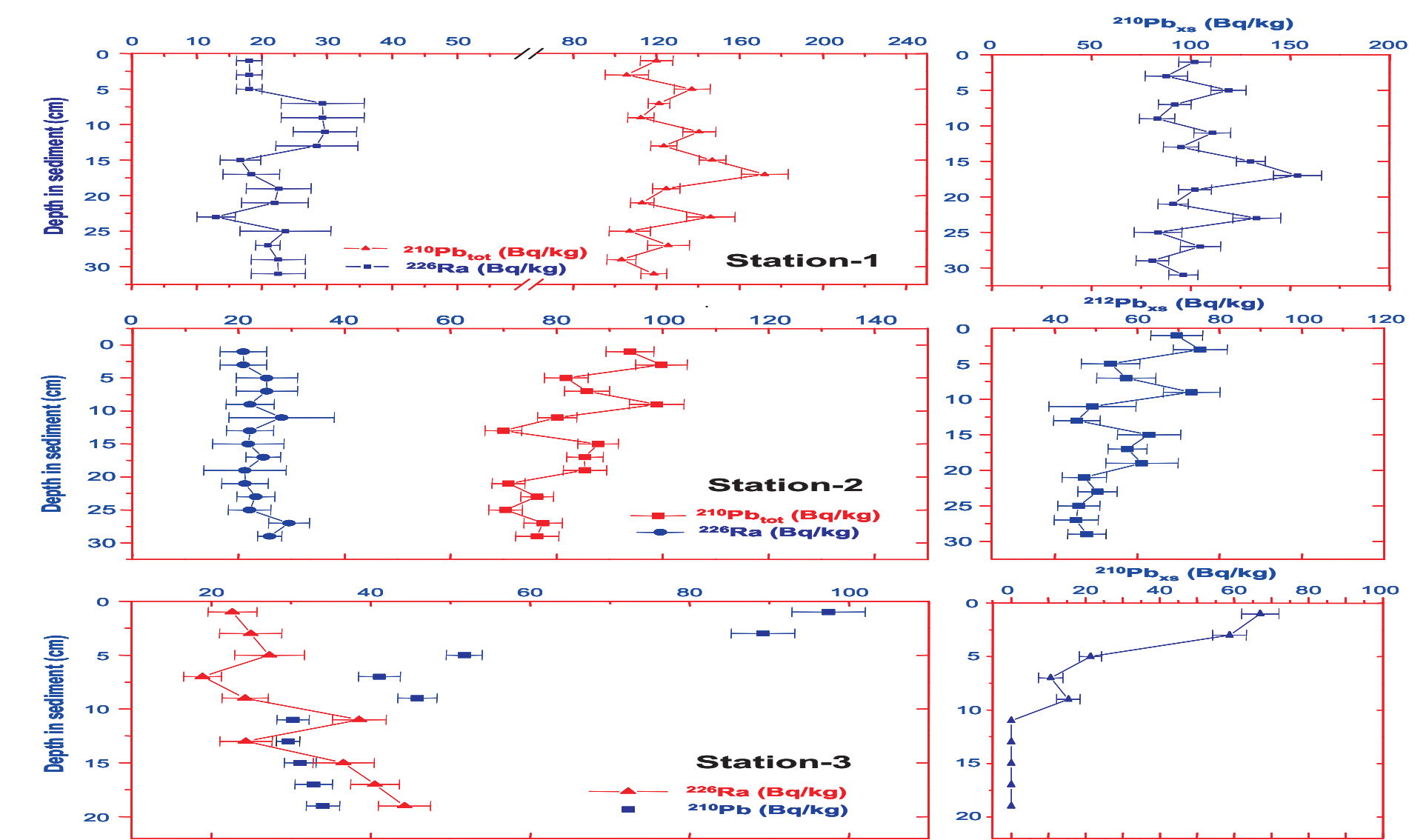


Figure 4: ²²⁶Ra, total ²¹⁰Pb and ²¹⁰Pb activity profiles in the sediment cores collected from the Bonny Estuary. Activities, with 1-σ statistical errors, are all in Bq·kg⁻¹ dry weight and line are only for guidance

The constant rate of supply (CRS) model displayed increase in bulk sediment accumulation over the past 80 years with special reference to 1938, 1955, 1973, 1997 and 2004. The data were validated using ¹³⁷Cs (Table 1) and were in agreement with the CRS established age.

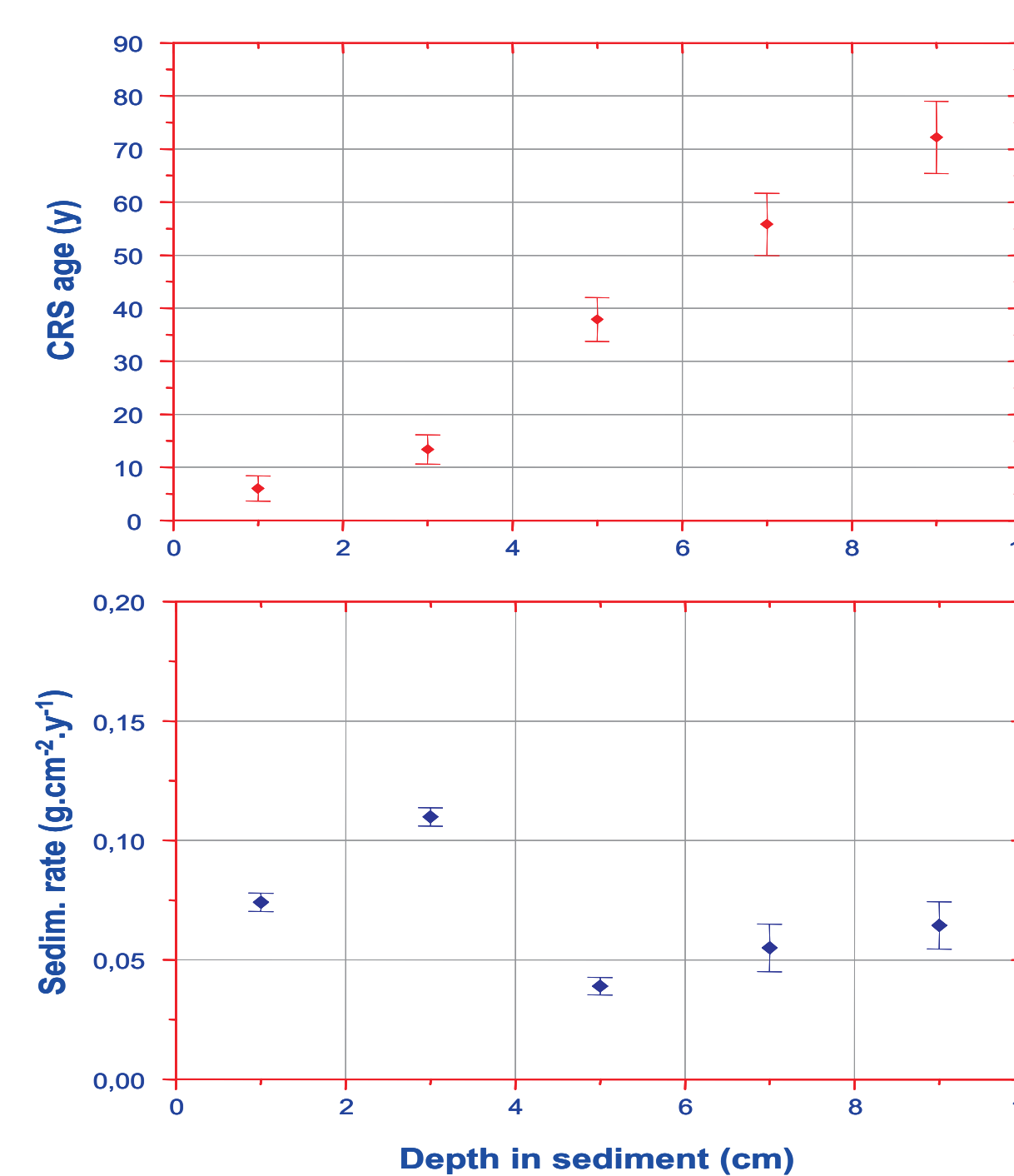


Figure 5: Age/depth and sedimentation rate/depth relationships determined by CRS model for the sediment core at St-3.

Table 1: Validation of ²¹⁰Pb Ages using ¹³⁷Cs. (¹³⁷Cs activities, in Bq·kg⁻¹ dry weight, in the samples of the core collected at St-3. Sample 10-20-cm was obtained by combining all sub-samples of 2-cm thickness).

| Layer | Year | ¹³⁷ Cs Act. (Bq·kg ⁻¹) | LD (Bq·kg ⁻¹) |
|----------|------|---|---------------------------|
| 0-2 | 2004 | <LD | 1,496 |
| 2-4 | 1997 | <LD | 1,521 |
| 4-6 | 1973 | <LD | 1,825 |
| 6-8 | 1955 | 1,416 ± 0,112 | — |
| 8-10 | 1938 | <LD | 1,240 |
| 10-20-cm | | <LD | 0.702 |

Core Profiles of Total Hydrocarbon (THC) Sedimentation rates and Total Phosphorus (TP).

The sedimentation rates obtained revealed that minimal and maximal environmental perturbation occurred in 1973 and 1997 while the single relatively fast sedimentation rate observed was attributed to adverse weather conditions accompanied with flooding.

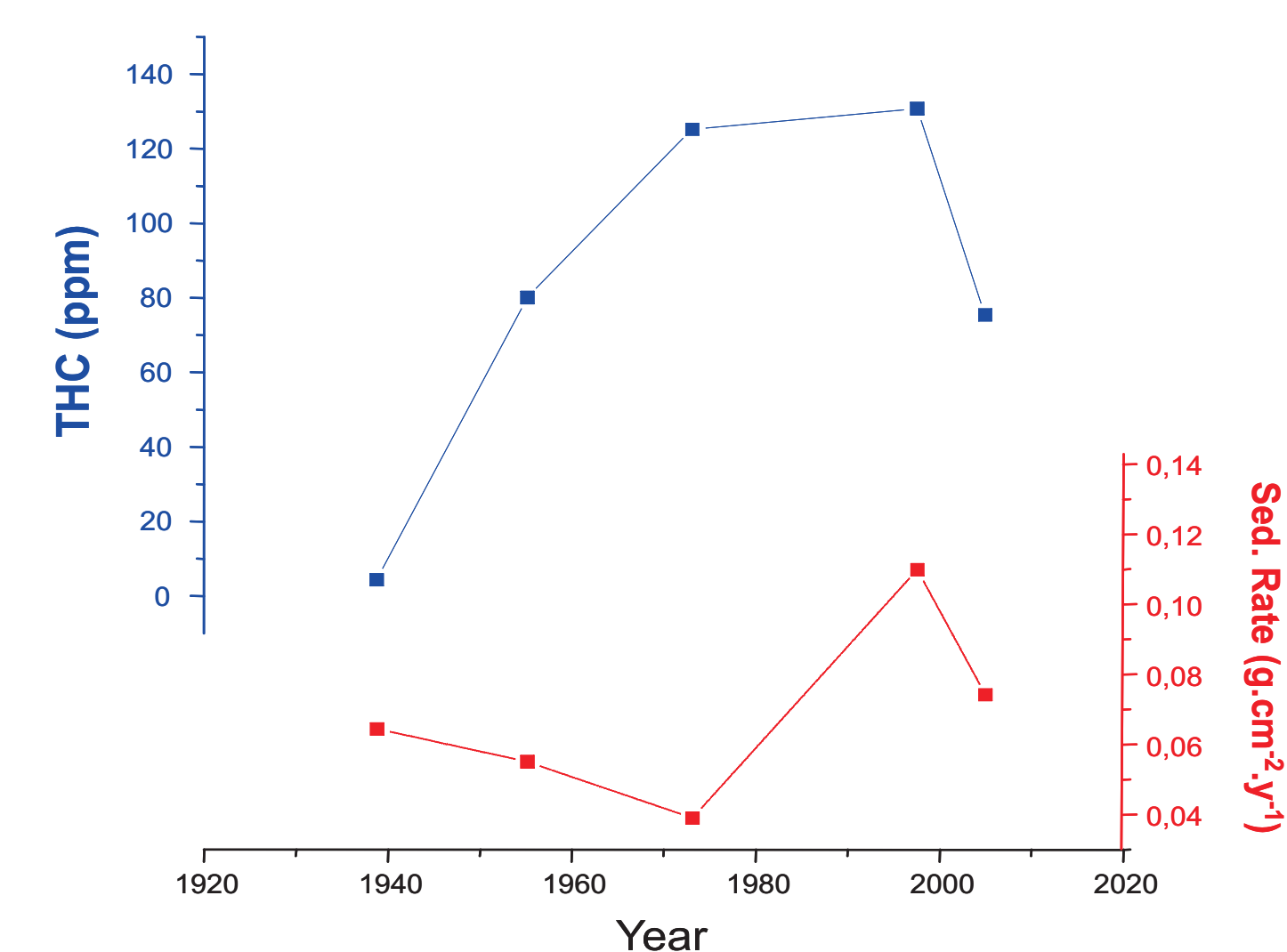


Figure 6: Core Profiles of total hydrocarbon content (THC) and sedimentation rates in sediment

The concentration of THC and TP revealed low concentrations in the late 1930s and high concentrations suggesting massive oil spills and substantial delivery of phosphorus from agricultural runoff from early 1970s to early 2000s.

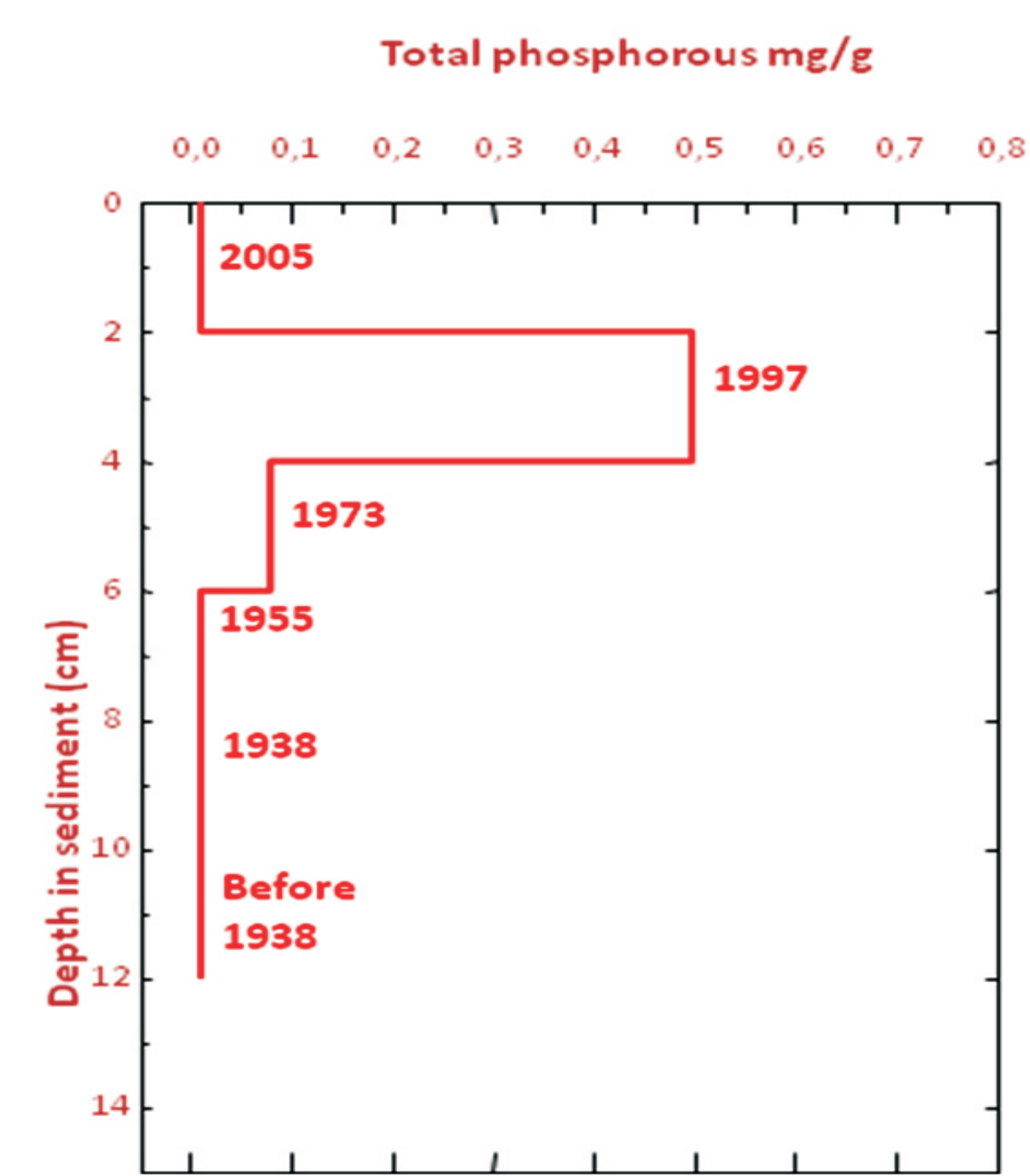


Figure 7: Core Profile of Total Phosphorus in the sediment

Conclusion

The study revealed the pollution records and provided evidence of these conditions in the Niger Delta Basin over the last 80 years. It is therefore surmised that since the advent of industrial activities, the Bonny estuary has been subjected to perturbations and contamination from human activities which has resulted to fluctuations in environment conditions.

References

APHA (2001). Standard Methods For The Examination Of Water And Wastewater, American Public Health Association, 20th edition.

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