Application of self-absorption correction method in gamma spectroscopy for $^{210}$Pb and $^{137}$Cs sediment chronology on the continental slope off NW Africa

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Introduction

Climatological background

Life in the semi-arid Sahel belt of tropical North Africa strongly depends on the availability of water and has been repeatedly affected by shifts to more or less arid climate. The most recent drought occurred in the early 1970’s and 1980’s, with partial recovery during the late 1990’s. High resolution fluorite sediments off Senegal offer the opportunity to study the history of the Sahel drought and to assess its imprint on the composition of terrestrial materials deposited at the sea floor, if the material can be accurately dated on historical time scales.

Sediment chronology

With the background of the upper mentioned project, we present $^{210}$Pb and $^{137}$Cs data from the high resolution multi-core GeoB9501-4 recovered during METEOR-Cruise M65/1 on the continental slope off NW Africa (Senegal Mudbelt, northern rim of Mauritian Canyon, depth 330 m). The uppermost 50 cm of the multi-core has been used for improving routine technique of $^{210}$Pb and $^{137}$Cs sediment chronology in the Radioactivity Measurement Laboratory of Bremen University.

Self attenuation

Since attenuation of emitted low-energy gamma radiation in voluminous bulk samples is an obstruction for determining $^{210}$Pb (46.5 keV; $\gamma$ 4.25%) quantitatively by means of multidetector gamma spectrometry, the method must be taken into account. Two basic approaches have been applied for solving the problem of self attenuation in volume samples: experimental [1, 2] and mathematical – using Monte Carlo simulations [3]. The approach combining both experimental measurements and mathematical MC simulations was proposed by other authors [4, 5].

Methods

Gamma spectroscopy

Hardware: coaxial HPGe detector Canberra Industries (50% rel. efficiency) housed in a 10 cm Pb shielding with Cu and plastic lining

Software: Genie 2000 software was used for low level, low background gamma spectroscopy.

Self-attenuation correction: applying efficiencies calculated using LabSOCS™ (Laboratory Sourceless Calibration System), Genie 2000 software calibration tool [6], validated by self-absorption measurements of different materials.

Material test

To validate the efficiency calibration generated by LabSOCS, a transmission experiment was realized for different absorbers.

Emitters: point sources of gamma energies of 46.5 keV ($^{210}$Pb) and 661.6 keV ($^{137}$Cs) with reported activity (Buchler) on a holder 15 cm above the absorber, which was placed directly on the detector (Fig. 1).

Absorbers: five different materials with various chemical composition and densities, all of them were sediment in cylindrical plastic containers (round dishes) with diameter of 70 mm and height of 20 mm (the same containers were used for sediment samples).

Results and conclusions

Treatment and measurement of the sediment samples

Wet sediment slices from each 1 cm interval of multi-core GeoB9501-4 were put into plastic round dishes with diameter of 70 mm and height of 20 mm, the containers were filled with the samples into different heights. For determination of $^{210}$Pb activity, $^{210}$Pb activity (determined via the 351.9 keV line of $^{210}$Pb after establishing of Rn progeny equilibrium) was subtracted from the $^{210}$Pb signal. The spectra were analyzed using efficiencies generated by LabSOCS for different sample geometries and constant sediment composition.

$^{210}$Pb and $^{137}$Cs dating

$^{210}$Pb chronology: The age of the core has been estimated using CRS model [7]. The model assumes a constant rate of supply of unsupported $^{210}$Pb to the sediment per unit time and considers a variable sedimentation rate resulting from human activity. Absolute ages were calculated with assumption the uppermost slice of the core corresponds to 2005 AD.

$^{137}$Cs: is present in the sediments due to the global fallout after nuclear bomb testing. It first appeared in the atmosphere in 1945 and peaked in 1963 at the northern hemisphere and can be therefore used for additional calibration of the age.

Acknowledgement

The travelling cost were co-financed by the PIP, Physics international postgraduate school, University of Bremen.

References