VERTICAL AND HORIZONTAL FLUXES OF SELECTED RADIONUCLIDES AND
TRACE METALS OFF THE COAST OF SOUTHERN CALIFORNIA

ANNUAL (AND FINAL) REPORT
FOR THE PERIOD

15 NOVEMBER 1990-14 NOVEMBER 1991 (EXTENDED TO 14 MAY 1992)

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U.S. DEPARTMENT OF ENERGY
ECOLOGICAL RESEARCH DIVISION
OFFICE OF ENERGY RESEARCH
UNDER GRANT DE-FG06-89ER60819

Received by OCTI
JUN 15 1992

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I. INTRODUCTION

This is the final technical report for our trace metal and radionuclide studies during Phase II of the California Basin Study (CaBS) program sponsored by the Ecological Research Division of the U.S. Department of Energy. I have participated in the CaBS Program since its inception on 15 May 1985. There were two phases in the program, with Phase I lasting the first four years. During Phase I, semiannual reports (including renewal proposals) were made. The CaBS Phase II program, started on 15 May 1989 and ended on 14 November 1991, was broken down into three project/budget periods as follows:

Period 1: 15 May 1989 - 14 November 1989

Period 2: 15 November 1989 - 14 November 1990

Period 3: 15 November 1990 - 14 November 1991

Annual progress reports were made and submitted to DOE immediately at the end of each period, except for Period 3. Because a 6-month no-cost extension was requested to provide logistic and administrative support needed for my graduate student Mr. Lei Yu to finish his thesis work, this third and final report is deferred until now.

Included in this report are: (1) a reprise of our objectives in the CaBS Program, (2) a report of our progress, with special reference to work performed during the last budget period, (3) an updated list of publications resulting from this work, and (4) three appendices: a journal article, a meeting abstract, and a graduate student's Master's thesis.

II. OBJECTIVES - A REPRISE

The overall objective of our research, within the structure of the CaBS program, was to understand the transport pathways and mass balances of some metabolically-active and inactive chemical species in the Santa Monica/San Pedro (SM/SP) Basin. Our focus is to examine selected trace metals and radionuclides in seawater, sediment trap material, and bottom sediments. Knowledge of the inventories, fluxes, and routes of these nuclides and metals in or among these reservoirs should lead to a cogent model for these elements in SM/SP Basin, which in turn should shed light on the fate and effects of energy-related by-products in a coastal region heavily impacted by human activities.

Specific scientific objectives (and the approaches) are:

- (1) To unravel the history of deposition and quantify the burial fluxes of selected trace metals, radionuclides and biogenic components in the SM/SP Basin (by sediment core studies);
- (2) To quantify, on seasonal and annual timescales, the fluxes of these components through the water column (by sediment trap deployments and studies);
- (3) To delineate the sources and transport pathways of these chemical materials, and determine factors that control spatial and temporal variations in fluxes (by a collective analysis of sediment core, sediment trap, transmissometer, and current meter data);
- (4) To construct a one-dimensional model to interpret the overall results (by using thorium

isotopes as proxy tracers).

III. REPORT OF WORK PERFORMED

Since the beginning of the CaBS Phase I program in May, 1985, I have participated in ten cruises and collected a large number of sediment core, sediment pore water, sediment trap, and water column samples for our studies of the system. During Phase I, six semi-annual progress reports were made and submitted to DOE, five papers were published in journals, and one meeting abstract was presented. During Phase II, three annual progress reports (including this one) were made, two journal articles were published (or in print), and one conference abstract was presented. In this final technical report, I shall once again update and summarize the results of our work. As in the past 8 reports, I shall only briefly summarize the results, as given in the following sections, with more detailed documentation of work accomplished in the final project period.

1. Radiochemical Studies of Sediment Cores

Twenty-one sediment cores were collected from the SM/SP and Santa Cruz Basins during the CaBS program, as listed in Table 1 and shown in Fig. 1. In the SM/SP Basin, the cores fall primarily along two transects: an offshore transect from the eastern slope toward the deep SM/SP Basin, and a longshore transect along the axis of the SM/SP Basin and the sill passages in a NW-SE direction. Results on the cores from the offshore transect was published as our first CaBS contribution (Huh *et al.*, 1987). We have since then completed the analysis of other SM/SP Basin cores and the integrated results were published in *Continental Shelf Research* (Huh *et al.*, 1990) and *Progress in Oceanography* (Huh *et al.*, in press; Appendix I). In addition, we have also studied two cores collected from the Santa Cruz Basin to evaluate horizontal transport of anthropogenic materials out of the SM/SP Basin into the outer basins and the California Current system.

Major observations based on ^{210}Pb and ^{234}Th data are summarized below:

- (1) In the Santa Monica Basin, sedimentation rates decrease offshore over the basin slope (from $\sim 80 \text{ mg/cm}^2/\text{yr}$ at the upper slope to $\sim 30 \text{ mg/cm}^2/\text{yr}$) in the vast basin floor. In the Santa Cruz Basin, the southern core accumulated at a rate of $\sim 10 \text{ mg/cm}^2/\text{yr}$, and the northern core accumulated at a much higher rate of $\sim 100 \text{ mg/cm}^2/\text{yr}$, probably caused by enhanced supply from the nearby northern canyons or the sill passage between Santa Monica and Santa Cruz Basins.
- (2) Detailed examination of ^{210}Pb profiles downcore reveals that sedimentation rates have been decreasing during the past one to two centuries, probably resulting from (i) the expansion and intensification of the anoxia in the deep basin, and (ii) increasing urbanization and flood control of the natural drainage.
- (3) Based on ^{210}Pb chronology, turbidites found in some of the cores can be dated at hundreds of years B.P. (before present) to within a decade B.P. The ages of younger turbidites (< 20 years) can be correlated to major storms recorded in modern history.

Table 1. Sediment cores collected and studied

Cruise name	Box core number	Location		Depth (m)	Date of collection (mo/day/yr)
CaBS-I	BC-12	33°50.1'N,	118°41.3'W	750	10/08/85
	BC-40	33°51.1'N,	118°38.13'W	398	10/09/85
	BC-89	33°41.5'N,	118°56.3'W	908	10/12/85
	BC-102	33°44.8'N,	118°50.3'W	910	10/14/85
	BC-113	33°50.64'N,	118°38.9'W	572	10/16/85
CaBS-III	BC-31	33°45.47'N,	118°49.57'W	910	5/18/86
	BC-1	33°44.58'N,	118°50.79'W	910	5/19/86
CaBS-V	BC-3	33°44.15'N,	118°53.75'W	906	4/08/87
	BC-6	33°46.18'N,	118°42.00'W	910	4/11/87
	BC-7	33°45.22'N,	118°47.45'W	910	4/12/87
	BC-8	33°49.96'N,	119°05.10'W	880	4/13/87
	BC-9	33°30.07'N,	118°20.39'W	896	4/14/87
CaBS-X	BC-2	33°50'N,	119°00'W	870	9/28/88
	BC-3	33°50'N,	118°45'W	890	9/28/88
	BC-4	33°45'N	119°28'W	1910	9/30/88
	BC-5	33°35'N	119°30'W	1985	9/30/88
CaBS-XI	BC-1	33°45.54'N	118°50.88'W	904	1/26/90
	BC-10	33°56.96'N	118°44.87'W	535	1/26/90
	BC-13	33°48.47'N	118°55.08'W	904	1/26/90
	BC-4	33°41.78'N	118°30.78'W	780	1/27/90
	BC-3	33°46.4'N	118°41.5'W	905	2/2/90

Figure 1. Locations of box cores (solid squares).

(4) Cores from the oxic basin slope indicated substantial sediment mixing in the upper 2-4 cm. Those in the anoxic deep basin showed annual varves, with very minor mixing (mixing coefficient = $0.2\text{-}4\text{ cm}^2/\text{yr}$) restricted only to the top $\sim 1\text{ cm}$.

2. Chemical Studies of Sediment Cores

On selected key cores, we have performed elemental analysis (major, minor and trace metals, organic carbon and carbonate carbon). Based on data of three SM/SP Basin cores we have published two papers to update the history of heavy metal pollution in the Southern California Bight (Finney and Huh, 1989a, b). Profiles of all anthropogenic metals, except Ba, are characterized by increases above their background levels since the onset of the century and pronounced subsurface maxima reflecting peak contamination during the interval 1960-70 (Finney and Huh, 1989a, b). In CaBS Phase II, we studied nine more cores and the expanded data were used to calculate the budgets and discuss depositional and transport processes of selected elements more thoroughly. Some of the results were presented in 1992 AGU Spring Meeting in Montreal (Huh, 1992; Appendix II), and a paper was written up and will soon be published in *Progress in Oceanography* (Huh *et al.*, 1992). A most significant conclusion from this study is that the majority of most sewage metals discharged along the coastline has been transported out of the inner basins and into the California Current. We estimated that the percentages of sewage metals (e.g. Cr, Zn, Pb, etc.) retained on the shelf, trapped in the basin, and exported out of the basin are 12-20%, 2-7% and 73-86%, respectively.

3. Water Column Studies

(1) Radiochemical and chemical analyses of sediment trap samples

Radiochemical and chemical analyses of sediment trap samples collected by the PMEL sequentially-rotating traps and Scripps long-term traps were done in CaBS Phase I, and the results were summarized in a paper published in *Continental Shelf Research* (Huh *et al.*, 1990). During Phase II, efforts were made to analyze seasonal samples collected using Vertex traps deployed by Dr. Mike Landry. Results from this later analysis form the basis of Mr. Lei Yu's M.S. thesis, which is attached as Appendix III.

(2) Th isotopes in the water column

In the first year of the CaBS program, we measured the distribution of Th isotopes (^{234}Th , ^{232}Th , ^{230}Th) between dissolved and particulate forms in a water column at the central SM Basin, and a surface transect of ^{234}Th across the SM Basin. The water column data was published in *Earth and Planetary Science Letters* (Huh and Beasley, 1987). The surface transect data show that dissolved ^{234}Th generally increased, while particulate ^{234}Th decreased, offshore. The scavenging residence time of Th varied from 21 days (inshore) to 72 days (offshore).

IV. PUBLICATIONS RESULTING FROM THE PROJECT

Below is a complete list of papers and meeting abstracts written under the full or partial support of the CaBS program. Because all references cited above can be found in the list, no separate bibliography for this report is necessary. Items 1-9 have been submitted along with previous progress reports and renewal proposals, and they are already in public domain. Items 10-12 are products of the last budget period, and are appended in this final report.

- (1) Huh, C.-A., D. L. Zahnle, L. F. Small and V. E. Noshkin (1987) Budgets and behaviors of uranium and thorium series isotopes in Santa Monica Basin sediments. *Geochim. Cosmochim. Acta*, 51 1743-1754.
- (2) Huh, C.-A. and T. M. Beasley (1987) Profiles of dissolved and particulate thorium isotopes in the water column of coastal Southern California. *Earth Planet. Sci. Lett.*, 85, 1-10.
- (3) Huh, C.-A. (1987) Profiles of ^{230}Th and ^{232}Th measured on small-volume seawater samples by mass spectrometry. *EOS, Trans. Am. Geophys. Union*, 68, 331.
- (4) Finney, B. P. and C.-A. Huh (1987) Profiles of heavy metals, organic carbon and other elements in sediment cores from the Santa Monica Basin, California, *EOS, Trans. Am. Geophys. Union*, 68, 1325.
- (5) Huh, C.-A. (1988) Determination of thorium in seawater by neutron activation analysis and mass spectrometry. In: *Radionuclides: A Tool for Oceanography* (eds. J. C. Guary, P. Guegueniat and R. J. Pentreath). p. 84-91, Elsevier Applied Science.
- (6) Finney, B. P. and C.-A. Huh (1989a) History of metal pollution in the Southern California Bight: An update. *Environmental Science and Technology*, 23(3), 294-303.
- (7) Finney, B. P. and C.-A. Huh (1989b) High resolution sedimentary records of heavy metals from the Santa Monica and San Pedro Basins, California. *Marine Pollution Bulletin*, 20, 181-187.
- (8) Jackson, J. A., F. Azam, A. F. Carlucci, R. W. Eppley, P. M. Williams, B. Finney, C.-A. Huh, L. F. Small, D. S. Gorsline, B. Hickey, R. A. Jahnke, I. R. Kaplan, M. I. Venkatesan, M. R. Landry, K. M. Wong (1989) Elemental cycling and fluxes off Southern California. *EOS, Trans. Am. Geophys. Union*, 70, 146-149, 154-155.
- (9) Huh, C.-A., L. F. Small, S. Niemi, B. P. Finney, B. M. Hickey, N. B. Kachel, D. S. Gorsline and P. M. Williams (1990) Sedimentation dynamics in the Santa Monica-San Pedro Basin off Los Angeles: radiochemical, sediment trap and transmissometer studies. *Continental Shelf Research*, 10, 137-164.
- (10) Huh, C.-A., B. P. Finney and J. K. Stull (1992) Anthropogenic inputs of several heavy metals to nearshore basins off Los Angeles. *Progress in Oceanography* (in press; Appendix I).
- (11) Huh, C.-A. (1992) Anthropogenic versus natural fluxes of metals and radionuclides in the Southern California Bight. *EOS, Trans. Am. Geophys. Union*, 73, 162 (Appendix II).
- (12) Yu, L. (1992) Budgets and behaviors of uranium and thorium series isotopes in the Santa Monica Basin off the California Coast. M.S. thesis, Oregon State University (Appendix III).

V. APPENDICES

Appendix I. Anthropogenic inputs of several heavy metals to nearshore basins off Los Angeles.

Appendix II. Anthropogenic vs. natural fluxes of metals and radionuclides in the Southern California Bight.

Appendix III. Budgets and behaviors of uranium and thorium series isotopes in the Santa Monica Basin off the California coast.

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