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Original Paper

THE BEHAVIOR OF ^{210}PB OFF COAST ULSAN, GAMPO AND POHANG WATERS, KOREA

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ABSTRACT

During summer of August 2000, the behavior of ^{210}Pb was studied in off coast Ulsan, Gampo and Pohang waters, Korea as an area potentially upwelling occur. Water samples were collected vertically inshore and offshore at each station. The highest of ^{210}Pb activity occurred in the surface layer as derivate from atmosphere and then decreased with increasing depth. The lower ^{210}Pb activity in bottom layer was caused by scavenging of particulate matter and strong affinity of unsupported ^{210}Pb to soil and sediment particles. In middle layer of the water column activity of ^{210}Pb fluctuated due to water masses of North Korea Cold Water (NKCW) that flows in this layer. The water mass of NKCW also affect on increasing dissolved oxygen (DO), where the highest of DO concentration occurred in this middle layer. The vertical distribution of ^{210}Pb in the study area was generally not different between inshore and offshore, and the activity of ^{210}Pb that determine also was not significant different with previous studies.

Key words*: ^{210}Pb, behavior, scavenging, strong affinity*

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INTRODUCTION

^{210}Pb (half life 22.3 years) naturally occurs as a particle-reactive radionuclide of the ^{238}U decay series and has been widely used as marine tracers of particle/water transport and particulate scavenging (Zuo and Eisma, 1993; Wei and Murray, 1994), and of course, sediment accumulation Studies in various conditions have shown the behavior of ^{210}Pb activity. ^{210}Pb is rapidly scavenged from the surface by organisms and subsequently transported to the deeper waters, where it redissolves and disappears trough radioactive decay during the long residence time at depth. Goslar *et al*. (2000) stated that the ^{210}Pb activity in the bottom water is the lowest because it is probably scavenged by adsorption into sinking particulate-material from the surface and then burial in sediment. In addition, it is due to source term for ^{210}Pb isotopes obtained only as a function of the parametric upwelling velocity and wet deposition (Murray *et al*., 2005). Yang *et al*. (1996) found that ^{210}Pb activities in the Korean East Sea were generally high at surface water and gradually decrease with depth, and the excess ^{210}Pb generally decrease with increasing density between depth 50 m and 100 m, suggesting stability ^{210}Pb concentrations in this water column.

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MATERIALS AND METHODS

Sampling area

Ulsan, Gampo and Pohang waters in the east coast of Korea is a part of the Korean East Sea (Japan Sea) (**Fig. 1**) and known as an upwelling area, especially during summer. The East Sea is a typical example of marginal seas and backarc basin in the western Pacific (Hong *et al*., 1999). The East Sea is a large, almost enclosed sea between the Japanese islands, Sakhalin islands, the Siberian coast and Korea with 3900 m maximum depth and distinct water masses. There are three deep basins; Japan, Yamato and Ulleung. The sea floor in each basin is relatively flat with a few seamounts and hills. The shelf breaks occur at ca. 150 m water depths off the western and eastern coasts, and the boundary between the continental slope and the basin plain occurs at about 2000 m in Ulleung basin (Watanabe *et al*., 2001). Recent sediments appear to be primarily of a hemipelagic source. No major rivers drain along the coast of the Korean Peninsula, whereas several Japanese rivers supply significant amount of sediments (Hong *et al*., 1997).

Primary productivity ranges from 70 to 100 $gCm^{-2}yr^{-1}$ and tend to increase along the Korean coast. Near bottom waters in the East Sea are highly oxygenated. In the oxygenated surface sediments, excess ^{210}Pb activity profiles would reflect a combination of net sediment accumulation, radioactive decay, and physical or biological mixing of the sediments. The cold water mass of 12 – 15^{o}C and several kilometers wide occurs almost every summer in the southern part of the Korean East Sea (Han *et al*., 1998).

Studies on mechanism and chemical properties of this phenomenon have been studied intensively (Yang *et al*., 1994; Lie *et al*., 1995; Han *et al.,* 1998). A cold water mass is known to occur along the southeastern coast of Korea Peninsula in every summer (Han *et al.,* 1998). Yang *et al.* (1994) showed the data of radium isotope from North Korean Cold Water (NKCW) were suggesting the cold water with temperature of 2-6^{o}C

The water quality characteristic in the East Sea Korea also have been investigated in many aspects of radionuclides such as the distribution of ^{137}Cs, ^{90}Sr and ^{226}Ra in the surface water (Hirose *et al*., 1999; Muslim. 2006, 2009). These water masses were characterized by activity of water temperature and dissolved oxygen (Muslim, 2009). The present study was carried out at East Coast of Korea, especially in the east coast of Ulsan, Gampo and Pohang. The major objectives of the study were to investigate the behavior of ^{210}Pb in the close to the coastal area (inshore) and in the offshore area and to highlight any changes in ^{210}Pb on different depth.

Water sampling

Water samples were collected during the cruises of R/V Tamyang on August 2000. The stations of these study divided into 2 groups, that are on station 2 and station 7 or 6 each line with several different depths range to distinguish between the stations that close to the coastal (inshore) and offshore (**Fig. 1**).

Pb Analysis

Seawater for analyzing ^{210}Pb was treated integrated with ^{210}Po analysis. The flow chart for ^{210}Pb and ^{210}Po analyzing is shown in the (**Fig. 2**). The ^{210}Po data result is shown in another publication.

RESULTS AND DISCUSSION

Vertical distribution of ^{210}Pb

The activity and vertical distribution of ^{210}Pb is given in the **Table. 1** and **Fig. 3**.

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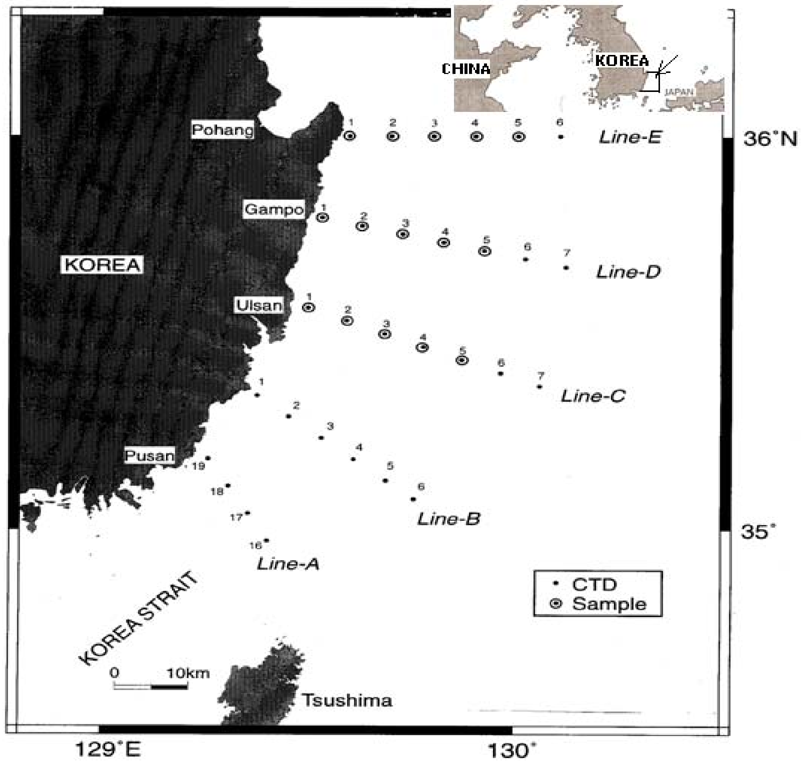

Fig 1. The field trip of "R/V Tamyang" during summer season in 2000. The collecting water samples of this study only were done in Line C, D and E

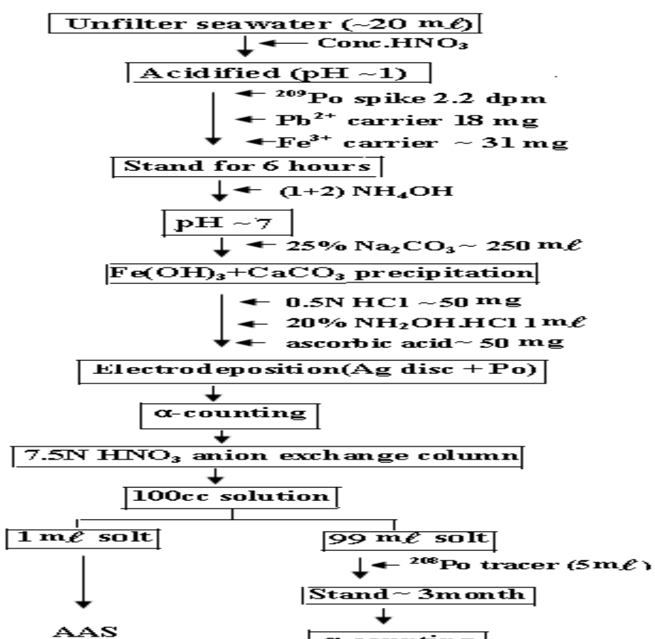

Fig 2. Chemical procedure for analysis of ^{210}Po and ^{210}Pb (After Nozaki and Tsunogai, 1973)

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The range activities of ^{210}Pb were 5.05-19.14 dpm/100ℓ. Showing comparable values with the previous studied ranging 6.07-16.05 dpm/100ℓ) in the station E during April 1994 (Lee, 1996).

Table 1. Values of depth, temperature, salinity, DO and activity of ^{210}Pb in the off coast of Ulsan, Gampo and Pohang.

Station. No.	Depth (m)	Temp. (□)	Sal. (psu)	DO (mg/ℓ)	^{210}Pb dpm/100ℓ
C2	0	23.22	33.30	5.35	15.13
	10	22.72	33.32	5.32	10.86
	20	18.00	33.75	5.27	12.78
	30	14.57	34.25	4.68	9.01
	40	13.09	34.31	5.09	6.70
	50	10.60	34.28	5.57	6.39
	60	8.82	34.23	6.09	7.48
	70	7.90	34.19	6.30	7.25
	80	6.66	34.13	6.42	8.89
	90	4.84	34.07	6.35	6.08
	100	4.57	34.08	6.19	8.76
C7	0	23.18	33.21	5.07	13.60
	10	21.50	33.48	5.41	15.12
	20	18.54	33.77	5.67	10.81
	30	14.56	33.99	4.86	10.14
	40	12.63	34.23	4.34	8.81
	50	10.65	34.22	4.68	6.91
	60	8.63	34.22	5.02	7.45
	70	4.15	34.10	6.01	7.65
	80	3.50	34.10	6.32	9.05
	90	3.06	34.09	6.49	7.63
	100	2.53	34.07	6.74	6.07
D2	0	22.75	32.74	5.12	14.98
	10	19.19	33.28	6.19	12.47
	20	15.92	34.04	4.87	10.04
	30	13.81	34.27	4.79	10.51
	40	12.32	34.29	5.02	9.05
	50	10.58	34.31	5.28	7.65
	60	8.94	34.26	5.71	7.63
	70	7.00	34.19	5.85	6.07
	80	6.18	34.13	6.49	6.48
	90	6.10	34.12	6.64	6.76
	100	5.90	34.11	6.63	7.12
D7	0	24.17	32.92	4.88	16.05
	10	19.81	33.58	5.95	13.38
	20	14.06	34.36	4.52	15.46
	30	12.41	34.34	5.00	12.28
	40	10.93	34.30	5.24	10.58
	50	7.95	34.18	6.50	7.89
	60	6.59	34.12	6.80	7.97

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	70	5.67	34.09	6.90	8.02
	80	4.82	34.04	7.29	8.00
	90	3.93	34.05	7.07	7.96
	100	3.39	34.04	6.96	8.76
	150	1.46	34.06	6.79	6.70
	200	1.12	34.06	6.43	6.39
	250	0.91	34.07	6.18	5.88
	300	0.73	34.07	5.87	7.31
	400	0.55	34.07	5.66	6.09
	500	0.43	34.07	5.50	5.24
	750	0.29	34.07	5.21	5.05
E2	0	23.34	33.40	4.90	19.14
	10	19.79	33.56	5.32	10.67
	20	16.96	33.97	5.15	15.29
	30	15.49	34.37	4.54	7.32
	40	12.59	34.34	5.20	9.11
	50	10.97	34.31	5.84	5.24
	60	10.15	34.30	5.53	7.48
	70	9.10	34.27	5.49	6.04
	80	7.98	34.22	5.66	5.95
	90	6.74	34.16	6.09	8.47
	100	5.43	34.11	6.53	6.22
	150	2.57	34.05	6.63	6.40
	200	1.69	34.04	6.80	5.07
E6	0	24.46	32.87	4.79	14.25
	10	20.08	33.39	5.34	18.76
	20	14.92	34.17	4.28	11.33
	30	14.20	34.24	4.21	8.42
	40	11.64	34.28	4.70	13.57
	50	9.94	34.26	5.59	10.00
	60	8.58	34.23	5.70	9.38
	70	5.63	34.11	6.40	6.54
	80	4.91	34.08	6.80	7.49
	90	4.18	34.05	7.02	6.77
	100	3.60	34.04	7.07	6.18
	150	1.83	34.06	6.43	5.53
	200	1.11	34.06	6.29	8.21
	250	0.83	34.07	6.05	10.41
	300	0.69	34.07	5.74	5.37
	400	0.51	34.07	5.49	5.48
	500	0.41	34.07	5.38	5.24
	750	0.27	34.07	5.23	6.06
	1000	0.21	34.07	5.10	5.11

Note:
psu = practical salinity unit.
dpm = disintegration per minute.

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The profiles of ^{210}Pb varied from area to another of the sampling site, but tend to decrease towards deeper waters with extreme drop at the surface layer (0-10 m, **Fig. 3**). This surface maximum type is generally an indication of substances of atmospheric origin, and subsequently decreased smoothly with increasing depth due to scavenging from sub surface waters by particulate matter, since behavior of unsupported ^{210}Pb were strong affinity to soil and sediment particles (He and Walling, 1996) and its call as particle reactive (Murray *et al*., 2005). Thus, in general from the surface of water up to about 50 m depth both inshore and offshore where the thermocline occurred, the ^{210}Pb concentration tends to decrease. The deposition of ^{210}Pb occurs primarily in association with precipitation and was buried in sediment (Murray *et al*., 2005). It was same in previous study by Lee *et al.,* (1996) that ^{210}Pb activity from the surface up to 100 m depth decreased with increasing depth. However, in this study at about 50 m to 100 m depth the activity of ^{210}Pb showed relative fluctuation. It may be caused by the varying responses of physical, physico-chemical and biological processes, which in turn will result in temporal changes in the radionuclide distribution in the vertical water profile as effect of increasing DO. According to Yang *et al.* (1994) in the depth between 75 m to 150 m the water masses of NKCW (North Korea Cold Water) flows in this layer with ranged temperature 1–7^{o}C. The water mass also affected on dissolved oxygen (**Fig.5**) and temperature. The condition indicates that upwelling occurred, because according to Walker and Villanoy (2001) is typically of upwelling areas and can be identified at the surface water based on their anomaly in their physical properties of the sea water (e.g. temperature, salinity, density, water color), chemical (e.g. oxygen, nutrients), and biological (e.g. chlorophyll, plankton) characters. This process would be reflected as combination of net sediment accumulation, radioactive decay, physical or biological mixing of the sediments and also on excess ^{210}Pb activity profiles. Moreover, the cold water mass of 12 – 15^{o}C flows several kilometers wide occurs almost every summer in the southern part of the Korean East Sea (Han *et al.*, 1998) also will affect.

The ^{210}Pb activity, temperature and DO value under NKCW flow were relatively constant to the bottom waters. This condition had clearly occurred in station E2 as inshore station, D7 and E6 as offshore. This fact can be assumed that in the time of upwelling event didn't distribute or effect to the bottom. These data had been confirmed by using NOAA-14 remote sensing image during the same period (August, 2000) in which upwelling event does not occur strongly yet (Kim, 2002). Thus, the activity of ^{210}Pb in this layer was supported by dominant decay of ^{226}Ra concentration as ^{210}Pb parents, since the ^{226}Ra concentration was relative constant to depth (Muslim, 2009).

Water mixing and ^{210}Pb isotope

The vertical distribution of seawater temperature profile shows the decrease with increasing depth (**Fig. 4**). From the sea surface waters to 100 m depth had decreased extremely, below 100 m depth decreased slightly and below 200 m relatively constant with increasing depth. The surface seawater temperature shows similar in all stations, both at inshore and offshore. However, it was higher than on samples of June 2000 and similar with August 1999 (Muslim, 2009). The seawater temperature distribution in the study was found different in each time, assuming that the seawater temperature was caused by mixing processes, because in the vicinity of the Korean sea have several water with different properties, such as in Yellow Sea Cold Water (YSCW), the Tsushima Surface Water (TSW), Tsushima Middle Water

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(TMW), Tsushima Warm Water (TWW), Low-Saline Coastal Water of China Continental (CWCC), etc with temporal and spatial variation (Yang *et al.,* 1994).

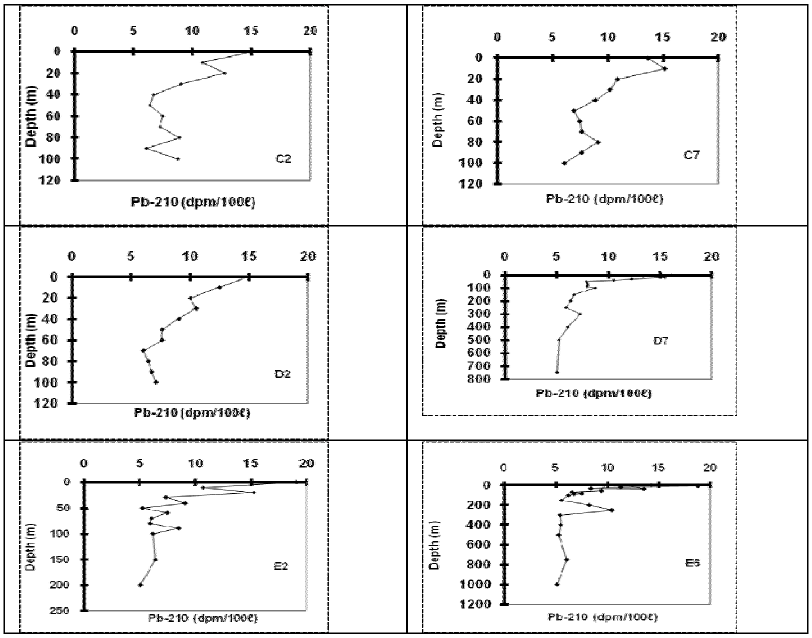

Fig 3. Vertical distribution activity of ^{210}Pb in the Ulsan (C), Gampo (D) and Pohang (E) waters.

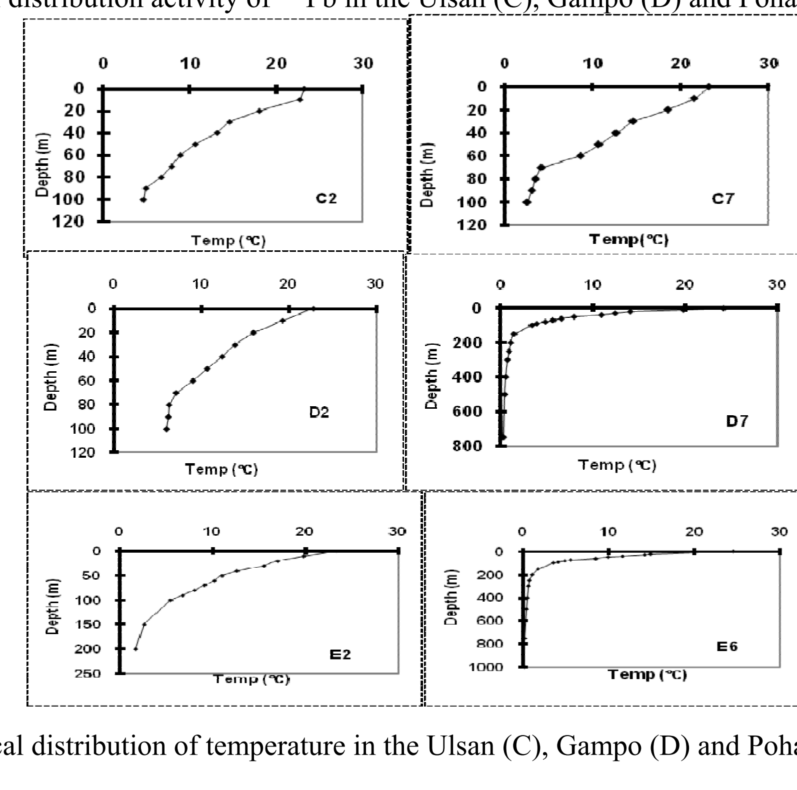

Fig 4. Vertical distribution of temperature in the Ulsan (C), Gampo (D) and Pohang (E) waters.

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The vertical distribution of seawater temperature showed a good correlation to ^{210}Pb (R^2: 0.60-0.95), which is due to fluctuation of the seawater temperature. Seawater temperature and ^{210}Pb activity decreased with increasing depth. It was different with ^{210}Po distribution, generally ^{210}Po showing in correlation to temperature. Some factors such as biological removal, productivity, suspended materials as biogeochemical processes affect on decreasing radionucline in the seawater (Muslim, 2007). The distribution of ^{210}Pb as particle reactive element was influenced considerably by particles as effect of mixing processes of seawater temperature. Beside that ^{210}Pb is quickly removed from the anoxic water column by particle coagulation and settling. Thus, ^{210}Pb decreased in deeper water, because they have strong affinity to suspended particles.

The vertical distribution of dissolved oxygen shows variable. The highest DO usually occurred in about 100m depth (**Fig. 5**). It may be caused by water masses of NKCW (North Korea Cold Water) that it flows cold current (1–7 ^{o}C) in this layer (Yang *et al.*, 1994). However, in the deep layer of offshore such as at station D7 and E6 the DO concentration was very low, this is because of relative of decomposition process in the bottom layer or upwelling event does not occurred in this layer.

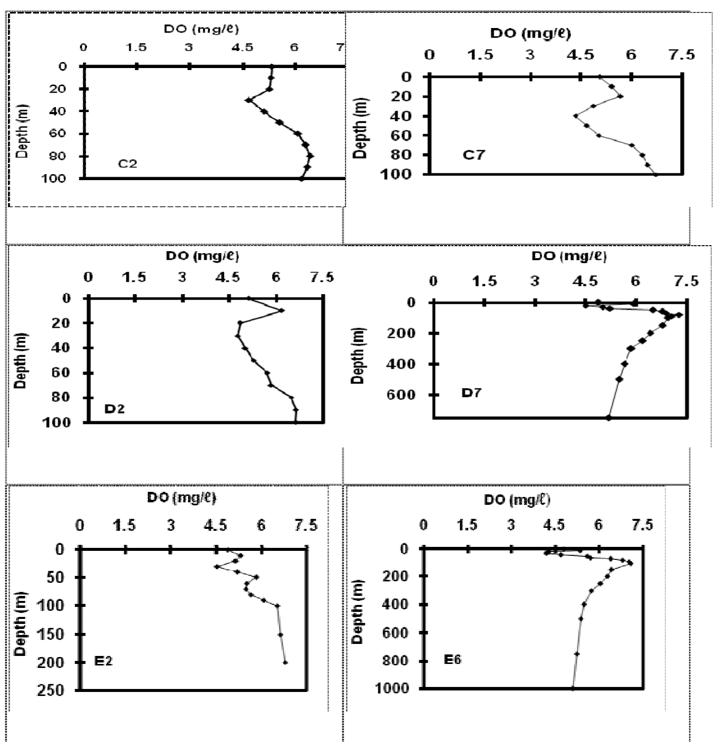

Fig 5. Vertical distribution of dissolved oxygen (DO), seawater temperature in the Ulsan (C), Gampo (D) and Pohang (E) waters.

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CONCLUSION

Tracing water mass mixing which affect on biogeochemical changes processes will contribute on distribution of ^{210}Pb in seawater column. Concentration of ^{210}Pb showed to decrease quickly in the surface layer when thermocline occurred, because scavenged by particles and strong's affinity to particles stimulate the ^{210}Pb to precipitate into the bottom. In the deep water where the temperature was constant and the mixing water mass did not appear the ^{210}Pb showed relative constant with increasing depth, it may be the ^{210}Pb was supported by ^{226}Ra decay as ^{210}Pb grandparent. The highest concentration of ^{210}Pb was in the surface water, it due to the ^{210}Pb was supported by atmosphere.

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