

Supporting information:

Supplementary information:

Table S1. The activities of ^{223}Ra , ^{224}Ra and ^{226}Ra in the surface seawater and bottom seawater of the Yellow River Estuary.

Table S2. Depth (m), pH, temperature ($^{\circ}\text{C}$), salinity, DO (mg/L), turbidity (FTU), DIP (mol/L), DIN (mol/L), DSi (mol/L) of bottom water at sample sites for the Yellow River Estuary.

Table S3. Zonation, pH, temperature ($^{\circ}\text{C}$), salinity, DO (mg/L), turbidity (FTU), DIP (mol/L), DIN (mol/L), DSi (mol/L) of surface water at sample sites for the Yellow River Estuary.

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Tables include the original data collected from the 2014 cruise in the Yellow River Estuary. Table S1 presents the activities of Ra in surface and bottom seawater. Table S2 and S3 presents the depths and zonation information of the sites and the geochemistry characters in bottom seawater and surface seawater.

Table S1. The activities of ^{223}Ra , ^{224}Ra and ^{226}Ra in the surface seawater and bottom seawater of the Yellow River Estuary

Station ID	Longitude	Latitude	Surface water(dpm100L ⁻¹)			Bottom water(dpm100L ⁻¹)		
			^{223}Ra	ex ^{224}Ra	^{226}Ra	^{223}Ra	ex ^{224}Ra	^{226}Ra
1-T16	119.27	37.87	1.26±0.25	31.6±3.9	49.1±1.1	1.64±0.31	35.8±3.7	48.8±0.9
1-T17	119.26	37.89	1.70±0.31	51.8±3.6	33.5±0.7	2.68±0.51	46.4±3.1	55.6±1.7
1-T18	119.28	37.94	1.55±0.30	28.5±3.2	46.2±1.4	2.24±0.48	30.1±2.7	51.5±1.0
1-T19	119.28	37.86	1.34±0.28	12.3±2.1	43.9±1.1	1.08±0.26	8.9±2.2	46.1±1.6
1-T20	119.29	37.88	0.95±0.21	9.7±2.5	25.4±0.7	0.77±0.34	46.6±3.9	35.8±0.8
1-T21	119.31	37.93	1.22±0.25	31.7±3.4	52.1±1.2	1.76±0.34	32.1±3.7	58±1.6
1-T22	119.29	37.85	0.89±0.18	34.1±4.1	46.6±1.5	2.94±0.37	82±5.8	55.8±1.7
1-T23	119.31	37.87	1.28±0.27	4.9±1.7	38.5±1.1	1.64±0.29	30±3.4	51.4±1.6
1-T24	119.35	37.90	1.23±0.25	2.8±1.8	38.1±1.2	1.10±0.26	7.3±2.1	41.9±0.9
1-T25	119.29	37.98	0.86±0.21	6.4±1.7	16.4±0.5	1.09±0.26	9.6±2.2	41.4±1.1
1-T26	119.34	37.97	2.41±0.35	51.1±4.7	55.2±1.7	2.08±0.28	64.4±4.7	56.3±1.0
1-T27	119.38	37.94	1.00±0.18	27.0±3.5	49.2±1.7	1.68±0.26	29.5±3.7	49.8±1.4
1-T28	119.30	38.02	1.13±0.27	23.3±2.6	45.3±1.1	1.11±0.23	38.2±3.3	52±1.6
1-T29	119.36	38.01	0.43±0.10	3.4±3.4	38.1±1.1	1.03±0.22	5.5±2.0	43.9±1.1
1-T30	119.42	37.97	1.89±0.36	5.1±2.2	40.5±1.3	1.67±0.27	16.7±2.5	51.2±1.0
1-T31	119.30	37.82	2.63±0.25	49.9±4.9	55.2±1	2.15±0.28	61.6±4.8	57.9±1.4
1-T32	119.33	37.85	1.54±0.25	25.1±2.9	47.2±1.1	1.63±0.28	20.3±2.6	41.1±0.8
1-T33	119.37	37.88	0.93±0.20	5.5±1.6	33.6±0.9	0.91±0.18	6.5±1.8	41.9±1.2

1-T34	119.30	37.81	0.68±0.17	10.2±2.5	39.7±1.3	0.37±0.12	4.1±2.0	39.6±1.1
1-T35	119.35	37.84	0.62±0.16	4.9±1.6	25.9±0.8	0.75±0.16	11.2±2.0	40.4±1.7
1-T36	119.40	37.86	1.51±0.18	48.6±3.9	48.9±1	1.91±0.36	43.5±4.0	55.7±1.3
1-T37	119.31	37.80	1.49±0.23	21.4±2.6	48.6±1.2	1.65±0.28	26.7±2.9	45.8±1.2
1-T38	119.36	37.82	1.15±0.22	11.3±2.7	43.9±1.2	1.12±0.26	15.6±2.2	43.5±1.1
1-T39	119.42	37.83	0.87±0.20	9.0±1.7	41.2±1.2	0.94±0.20	12.0±2.0	41±1.2
1-T40	119.32	37.79	0.68±0.18	7.3±1.9	44.9±1.5	1.01±0.21	18.7±2.2	45.6±1.1
1-T41	119.38	37.80	1.58±0.34	37.8±4.0	47.4±0.9	1.67±0.36	55.6±3.9	57.5±1.4
1-T42	119.43	37.80	3.20±0.49	37.2±3.0	44.3±1.1	2.45±0.34	44.0±4.4	50±1.8
1-T43	119.42	37.91	1.90±0.30	24.3±3.0	45±2.3	1.43±0.26	28.2±2.8	45.5±1.7
1-T44	119.44	37.88	0.74±0.18	3.1±1.6	38.3±0.9	0.73±0.11	25.5±3.1	38.9±1.3
1-T45	119.47	37.85	0.63±0.20	3.9±1.7	40.9±1.1	0.39±0.14	17.3±2.2	37.8±1.2
1-T46	119.49	37.81	1.58±0.35	44.2±3.8	49.1±1.2	1.81±0.36	59.6±3.7	50.6±1.4
1-T47	119.46	37.94	1.44±0.31	25.8±2.5	41.3±1.1	1.99±0.42	44.2±3.6	44.0±1.2
1-T48	119.49	37.91	1.76±0.22	14.0±2.5	40.1±1.1	1.54±0.35	32.9±3.3	41.9±1.2
1-T49	119.52	37.86	0.94±0.21	15.1±2.0	37.9±1.1	1.57±0.30	30.8±3.2	39.9±1.1
1-T50	119.55	37.82	0.39±0.13	7.2±1.5	29.1±1.3	1.50±0.31	46.3±4.8	34.4±1
Groundwater			²²³ Ra		ex ²²⁴ Ra		²²⁶ Ra	
G1	118.92	37.54		73.89±19.08		1.86×10 ³ ±135.1		112.8±5.3
G2	118.98	37.63		27.24±7.55		1.95 ×10 ³ ±117.5		140.2±7.1
G3	119.21	37.73		59.83±14.10		2.37 ×10 ³ ±124.6		219.5±8.0
G4	119.24	37.73		42.83±15.14		1.99 ×10 ³ ±126.6		184.9±10.4
G5	119.09	37.82		31.49±9.96		1.35 ×10 ³ ±76.5		63.0±3.5
G6	119.09	37.89		9.79±3.70		483.3±37.3		66.1±3.4
G7	119.10	37.85		7.29±2.98		376.4±26.7		73.4±3.5

Table S2 Depth(m), pH, Temperature(°C), Salinity(‰), DO(mg/L), Turbidity(FTU), DIP(μmol/L), DIN(μmol/L), DSi(μmol/L) of bottom water at sample sites for the Yellow River Estuary

Station ID	Depth	Zonation	pH	Temp.	Salinity	DO	Turb.	DIP	DIN	DSi
1-T16	5.9	NWI	8.13	19.35	27.54	4.84	153.37	0.13	31.14	4.36
1-T17	10.7	NWI	8.11	19.50	27.59	4.86	70.44	0.11	56.17	11.82
1-T18	14.2	NWI	8.10	18.76	28.22	4.79	15.14	0.13	43.95	8.46
1-T19	15.5	NWII	8.11	18.18	28.47	4.92	11.14	0.13	26.95	4.04
1-T20	16.5	NWIII	8.15	18.14	28.61	5.21	12.06	0.14	31.25	3.07
1-T21	2.5	NWI	8.12	19.91	26.41	5.18	45.85	0.14	41.24	6.76
1-T22	11.8	NWI	8.09	18.91	27.91	4.94	61.05	0.11	59.23	16.20
1-T23	14.8	NWI	8.10	18.32	28.37	4.74	26.27	0.15	30.69	3.77
1-T24	16.5	NWII	8.12	17.99	28.53	4.98	45.16	0.13	32.18	3.42
1-T25	16.9	NWIII	8.14	17.89	28.76	5.12	31.13	0.13	27.84	2.71

1-T26	3.0	NWI	8.10	19.81	26.47	5.05	59.29	0.13	50.21	14.57
1-T27	11	NWI	8.11	19.02	27.82	4.72	138.51	0.10	24.62	6.44
1-T28	14.5	NWI	8.11	18.65	28.27	4.68	41.77	0.09	26.80	5.77
1-T29	16.1	NWII	8.11	18.17	28.48	4.82	10.15	0.11	25.59	3.21
1-T30	17.2	NWIII	8.10	17.68	28.63	4.83	6.09	0.13	26.26	3.69
Northwest zone average(n=15)			8.11	18.69	28.00	4.91	48.50	0.12	35.61	6.55
1-T31	2.7	SEI	8.16	22.37	24.49	5.41	47.76	0.11	50.24	13.69
1-T32	11	SEI	8.14	20.24	27.32	5.06	77.39	0.08	26.71	6.12
1-T33	14.8	SEI	8.14	19.63	28.31	5.04	16.96	0.08	24.76	2.70
1-T34	16.6	SEII	8.13	18.65	28.44	5.01	10.38	0.16	26.12	3.07
1-T35	17.6	SEIII	8.12	17.78	28.57	4.91	16.94	0.16	27.33	2.76
1-T36	3.3	SEI	8.14	20.83	26.20	5.29	138.59	0.11	35.61	9.14
1-T37	11	SEI	8.11	19.49	27.60	4.83	138.51	0.12	29.61	6.23
1-T38	15	SEI	8.12	19.17	28.35	4.82	46.84	0.11	27.96	2.92
1-T39	16.6	SEII	8.12	18.32	28.48	4.80	6.32	0.09	24.67	3.39
1-T40	17.4	SEIII	8.11	17.94	28.55	4.81	6.78	0.07	21.70	4.05
1-T41	5.3	SEI	8.14	20.84	26.55	5.02	127.52	0.09	38.23	6.72
1-T42	12.2	SEI	8.13	20.92	27.39	5.11	138.57	0.13	26.41	4.89
1-T43	14.6	SEI	8.13	19.74	28.28	4.97	98.62	0.08	23.61	4.81
1-T44	16.1	SEII	8.13	18.99	28.46	4.97	27.67	0.12	20.93	2.60
1-T45	16.9	SEIII	8.14	18.46	28.58	5.00	6.23	0.14	24.31	2.84
1-T46	5.9	SEI	8.15	21.18	26.69	5.11	130.44	0.17	41.92	6.84
1-T47	11.8	SEI	8.13	21.31	27.61	4.97	21.95	0.13	30.14	4.25
1-T48	14.6	SEI	8.14	21.00	28.02	5.15	9.39	0.12	28.90	3.33
1-T49	15.4	SEII	8.15	20.71	28.21	5.22	4.89	0.11	26.78	3.03
1-T50	16.2	SEIII	8.13	19.81	28.55	4.99	5.96	0.13	18.26	3.12
Southeast zone average(n=20)			8.13	19.87	27.73	5.02	53.89	0.11	28.71	4.82

Table S3 pH, Temperature(°C), Salinity(‰), DO(mg/L), Turbdaty(FTU), DIP(μmol/L), DIN(μmol/L), DSi(μmol/L) of surface water at sample sites for the Yellow River Estuary

Station ID	Zonation	pH	Temp.	Salinity	DO	Turb.	DIP	DIN	DSi
1-T16	NWI	8.11	19.37	27.59	4.95	49.26	0.11	26.13	5.21
1-T17	NWI	8.18	23.22	24.32	5.14	9.16	0.09	48.28	12.97
1-T18	NWI	8.16	23.29	25.86	5.28	5.67	0.09	40.48	8.91
1-T19	NWII	8.18	23.13	27.41	5.38	2.48	0.11	31.69	4.57
1-T20	NWIII	8.20	23.55	27.50	5.35	1.20	0.10	24.02	3.56
1-T21	NWI	8.15	21.85	21.48	5.16	24.87	0.15	34.48	7.53
1-T22	NWI	8.16	22.22	22.91	5.28	9.95	0.10	71.30	20.48
1-T23	NWI	8.18	22.88	27.64	5.32	1.58	0.07	24.85	4.19
1-T24	NWII	8.20	23.24	27.53	5.38	1.33	0.13	27.06	3.62

1-T25	NWIII	8.18	23.50	27.51	5.31	0.25	0.09	25.67	3.33
1-T26	NWI	8.13	22.30	21.90	5.10	43.50	0.14	85.41	25.39
1-T27	NWI	8.15	20.17	26.50	5.04	9.10	0.08	30.03	7.50
1-T28	NWI	8.19	20.48	26.56	5.26	2.70	0.07	25.45	5.95
1-T29	NWII	8.19	21.75	27.71	5.35	1.23	0.13	25.31	3.29
1-T30	NWIII	8.20	22.03	27.47	5.38	1.23	0.12	27.53	4.43
Northwest zone average(n=15)		8.17	22.20	25.99	5.25	10.90	0.10	36.51	8.06
1-T31	SEI	8.17	22.37	24.48	5.40	44.67	0.07	60.39	13.38
1-T32	SEI	8.17	20.95	27.10	5.30	6.96	0.11	29.87	6.26
1-T33	SEI	8.19	21.47	28.07	5.41	1.00	0.12	24.83	3.49
1-T34	SEII	8.20	21.53	27.86	5.47	1.15	0.11	21.59	3.04
1-T35	SEIII	8.20	21.31	27.92	5.54	1.23	0.11	21.19	2.51
1-T36	SEI	8.16	22.49	24.71	5.28	9.79	0.10	50.57	12.89
1-T37	SEI	8.16	20.94	26.87	5.20	4.84	0.11	29.61	6.37
1-T38	SEI	8.19	21.80	27.78	5.29	2.19	0.13	22.83	2.97
1-T39	SEII	8.20	21.46	27.68	5.35	0.80	0.13	19.77	4.18
1-T40	SEIII	8.19	21.47	27.54	5.36	1.48	0.13	28.69	3.36
1-T41	SEI	8.15	20.83	26.56	4.98	33.47	0.15	45.69	7.05
1-T42	SEI	8.14	21.05	27.31	5.04	12.03	0.08	28.72	5.29
1-T43	SEI	8.14	20.84	27.49	5.04	6.00	0.14	26.06	4.43
1-T44	SEII	8.19	21.12	28.23	5.30	1.66	0.16	29.13	2.21
1-T45	SEIII	8.19	20.77	27.98	5.41	1.15	0.09	16.76	2.58
1-T46	SEI	8.19	22.26	26.34	5.38	9.46	0.11	39.34	7.16
1-T47	SEI	8.18	21.93	27.31	5.30	5.40	0.15	33.30	5.10
1-T48	SEI	8.18	21.91	27.82	5.37	0.21	0.08	20.03	3.04
1-T49	SEII	8.18	21.45	28.02	5.34	2.48	0.14	25.97	2.77
1-T50	SEIII	8.19	21.53	28.24	5.39	2.28	0.16	23.95	3.24
Southeast zone average(n=20)		8.18	21.47	27.27	5.31	7.41	0.12	29.91	5.07