

Investigations on the water pollution around the river Tae Hwa and the coastal area of Ulsan city.

Yoo, Kwang-Sik, Park, Sang Youn, Hur, Hwang

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<Abstract>

Some polluting components of stream and seawater around Ulsan coastal area have been determined by atomic absorption spectrophotometry and classical methods.

All the water samples for the determination of metal contents were concentrated by the ion-exchange technique.

Lead and cadmium contents were at least 100 times higher than the one in ocean. Other heavy metals, Cu, Zn, and Fe were shown reasonably high values.

울산시 연안지역의 해수및 태화강물의 오염도에 관한 조사 연구

유광식 · 박상윤 · 허 황

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<요 약>

울산 연안지역의 해수및 태화강의 오염 성분들을 원자흡수 분광법에 의하여 분석하였다.

모든 물시료들의 금속성분은 이온교환 방법에 의하여 농축시킨 다음에 분석하였다. 납과 카드뮴 함량은 대양에서의 값보다 약 100배 이상 높았으며 구리, 아연 및 철과 같은 다른 중금속들은 약간 높은 것으로 나타났다.

I. Introduction

Environmental systems undergo constant internal change. A stream can safely absorb some waste material, but a steady deposit of raw garbage will turn the stream into an open sewer. Ecologically, the breakdown of the environment is the consequence of changes effected by man that exceed optimum activity levels in various parts of his surroundings⁽¹⁾. The pollution of river and coastal water of Ulsan city has been rapidly increased by the founda-

tion of the industrial complex including the petrochemical combinat and nonferrouse metal complex in Onsan. In recent years, concern has been expressed in many quarters over the level of exposure of the general population to heavy metals in the environment^(2,3).

The mode of introduction of pollutant metal into the environment are in general so different. Chemical influence of the heavy metals upon health is difficult to evaluate because the toxin will act variably upon genetically, socially, nutritionally, and geographically diverse people.

Over 20 metals, Al, Sb, As, Ba, Be, Bi, Cd, Co, Cu, Ce, In, Pb, Hg, Mo, Ag, Te, Tl, Sn, Ti, W, U, and Zn are known to be important in industrial medicine and theoretical, could be environmental hazards⁽⁴⁾. H.W. Nurnberg⁽⁵⁾ has reported the work on the environmental research and surveillance of toxic metals. He mentioned the most hazardous metals as Cd, Hg, Pb, and As and employed the most versatile polarographic and voltammetric methods for the analysis of the trace metals such as Cd, Pb, Cu in the Mediterranean.

Various atomic spectroscopic techniques seem to be the most reliable methods at the low cadmium concentrations⁽⁶⁾, mercury⁽⁷⁾, lead, cadmium and copper in foods⁽⁸⁾, and iron, manganese, copper, zinc, and nickel in a coastal sea water⁽⁹⁾.

A common kind of water pollution is caused by heavy concentrations of nitrogen and phosphorus, which are used by plants for growth. The widespread use of agricultural fertilizers, household detergents, insecticides, herbicides, fungicides, rodenticides, and etc that drain into water are a source of pollution and also a source of danger to man and wildlife alike.

A comprehensive plan to reduce the pollutants is immediately required to prevent the environmental deterioration.

The analytical work of the contaminants, however, require rapid treatment of the samples, and is so enormous heavy duty to work out regularly. Therefore, the limited number of pollutants can only be found in reports.^{13,14}

We, authors decided to carry out the environmental research continuously for years and set up the analytical data of the pollutants in order to use it for the estimation of water pollution as the most valuable materials. The sampling station is restricted to the Ulsan coastal area and the river Tae Hwa.

II. Experimental

1. Sampling

The seasonal samples were taken at the depth of 2m from the surface of sea water using our own sampling bottle.

The river samples were collected from shore at 50cm under the surface of water. The sampling dates were on 22 August 1980 for the first and on 15 May 1981 for the 2nd time. Sampling points were fixed by map as to permit their identification by other person without personal guidance (See Fig.1). Before filling, the sample bottles were rinsed out three times with the water to be collected.

2. Experimental method

The constituents of the sample were analysed mainly by instrumental methods using atomic absorption spectrometry for metals and by classical methods for the others.

The instruments used for this study were as follows: Atomspect (Atomic absorption spectrometer) (Hilger & Watts, H 1170, England), uv-vis. spectrophotometer (Spectronic 20), pH meter (EIL, England), portable pH meter, Nephelometer (Corning-EIL, England), portable oxygen meter (EIL, 1520, England), even heat oven (Townson & Mercer, England), electric furnace (Carbolite Co, England).

(1) An outline of the analytical methods used.

Dissolved oxygen¹⁰: It was measured either on the spot by using the portable oxygen meter or by iodometric method in the analytical laboratory. The sample was brought to the laboratory by the BOD bottle of 296ml for the latter case. The results were the same for both cases.

BOD₅¹⁰: The sample in the standard BOD bottle (296ml) was dipped in the water bath at

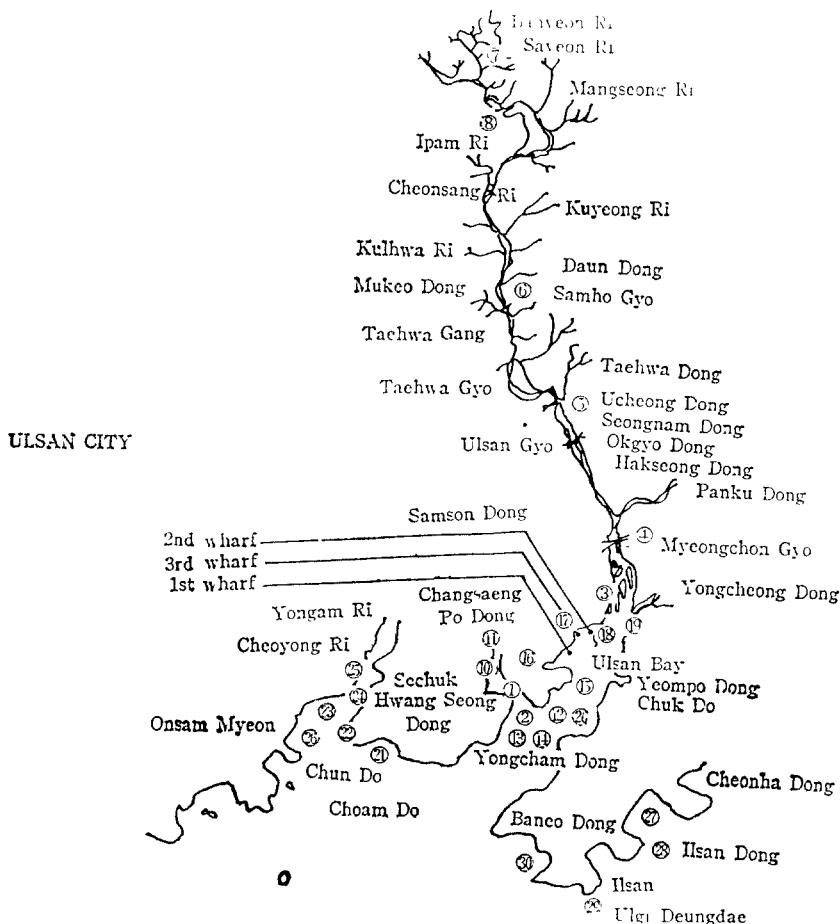


Fig.1 Regional map of Ulsan

* No. indicates sampling station

20°C for 5 days. Then, the remained oxygen in the sample was determined by Winkler method or oxygen meter.

PH and temperature: Those properites were directly measured on the spot by using portable pH meter and thermometer, respectively.

Total hardness⁽¹⁰⁾: The sample with pH at 10 was titrated with 0.02M EDTA solution using EBT as the indicator. The result was converted to the corresponding CaCO₃ppm.

Turbidity⁽¹⁰⁾: it was determined using the Nephelometer. Standard turbidity suspension was prepared by diluting the stock turbidity

suspension (400 units) which is the mixture of 5ml of 1% hydrazine sulphate, (NH₂)₂-H₂SO₄ aqueous solution and 5ml of 10% hexamethylenetetramine aqueous solution in 100ml distilled water and was allowed to stand 24hr at 25±3°C.

Phenolphthalein acidity⁽¹¹⁾: 3 drops of phenolphthalein indicator was added to a sample of suitable size, 50.0ml. The soultion was titrated with 0.02N standard sodium chloride to light pink corresponding to pH 8.3.

Total alkalinity(methyl orange alkalinity)^(11, 12): The term, methyl orange alkalinity repr-

resents the sum of free hydroxide, carbonate and other organic and inorganic substances neutralized at pH 8.3 (phenolphthalein alkalinity), plus a major portion of the alkalinity due to weak organic and inorganic bases. The mixed indicator which was prepared by dissolving both of 0.02g of methyl red and 0.1g of bromocresol green in 100ml of 95% ethyl alcohol. 3 drops of the mixed indicator was added to a sample of suitable size, 50.0ml and titrated with 0.02N standard hydrochloric acid to pH 4.6, light pink.

Total alkalinity as mg/l CaCO_3

$$= \frac{V_{\text{HCl}} \times N_{\text{HCl}} \times 50,000}{\text{ml sample}}$$

Total residue on evaporation: 100ml of sample in a ignited and tared disk was evaporated and dried for 1hr at 105°C. The weight of the residue was reported as total residue (g/l).

Nitrogen (organic and ammonia): The sample of 250ml was transferred into a 500ml Kjeldahl flask and 50ml hydroxide-thiosulphate reagent⁽¹⁰⁾ (which is prepared by dissolving 500g NaOH and 25g $\text{Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$ in 1 liter of ammonia free distilled water) was carefully added to the sample solution. Connect the flask to the steamed out distillation flask and shake the flasks to insure complete mixing. The 200 ml distillate collected in 50ml boric acid containing 3 drops of mixed indicator (0.2% methyl red and 0.1% methylene blue in 95% ethylalcohol) was titrated with 0.02N sulphuric acid solution to pale lavender.

Sulphate⁽¹⁰⁾: 25ml of water sample was adjusted to pH 4.5–5.0 using hydrochloric acid and boiled after the addition of 2ml HCl(1:1). 10ml of boiling BaCl_2 solution was added to the acidified sample solution and kept at 80–90°C for 3 hours. After the filtration, the precipitate was ignited at 800°C for 1 hour and weighed.

(2) Metal ions

Ion-exchange technique was employed to concentrate metal ions which are normally present as cationic or anionic form.

1 l of the water sample was passed through a column packed with 10ml of cation exchange resin (Diaion CR 10) and the eluate was directly reached on the bed of 12ml of anion exchange resin (Amberlite 1RA 400C) in a column with the diameter of 1cm at the flow rate of 3ml/min.

The elution was carried out by using 100ml of 2N H_2SO_4 followed by 100ml of distilled water. The solution was evaporated to small volume by heat and made up the volume to 50.00 ml in a calibrated volumetric flask after cooling to room temp. Metals such as, Cu (324.8 nm), Cd(228.8nm), Fe(248.3nm), Pb(217.9nm), Zn(213.9nm), Mg(285.2nm), and Cr(357.9nm) were directly determined by using atomic absorption spectrophotometer by spraying the solution prepared into the flame of acetylene-air whose ratio was recommended by the maker of the instrument.

III. Result and Discussion

Since the establishment of Ulsan industrial complex, several points of coastal area and river seem to be markedly polluted by cooling water from both of industry and urban life. The growth of urban population may obviously be contributed to the problem of environmental pollution. Almost all of the factories invest a lot of money for the treatment of water and the purification of stack gas. Among the pollutants that foul the water ways are untreated garbage and sewage, industrial dyes and other chemicals, and oil slicks. Therefore, the solution of some pollution problems requires cooperation on a regional, a national, and even an international basis.

Some results were obtained from this research work as shown on table 1.

Table 1. Analytical Result of River and Sea Water

Item	pH	Temp	BOD	DO	Turbidity	Ca	Mg	Cu	Cd	Zn	Fe	Pb	Tot. alkalinity	Phenol & organic acidity	Ca-CO ₃	NH ₃ -N	Ammonia nitrogen	Phosphate	Sulphate	Ignition residue	Tot. rec-duc	Tot. Hardness
Unit		°C	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	%	%	ppm
1	8.4	20.0	3.41	6.3	2.6	351	1,279	0.010	0.019	0.038	0.040	0.013	108.6	16.0	2.90	0.28	2,418	2.63	2.95	5,889	2.95	5,889
2	8.1	14.0	2.35	8.5	1.3	383	1,320	0.011	0.022	0.041	0.035	0.037	117.8	5.0	3.00	0.25	-	-	-	-	-	6,183
2	8.4	19.0	3.25	6.5	0.6	351	1,230	-	-	-	-	-	110.6	17.0	1.17	0.39	2,484	3.23	3.62	6,104	3.62	6,104
3	8.3	14.3	2.72	8.4	0.4	372	1,253	-	-	-	-	-	120.1	11.0	1.80	0.18	-	-	-	-	-	6,159
1	8.2	23.5	3.80	7.8	5.25	273	875	-	-	-	-	-	82.1	14.0	0.89	0.26	1,795	2.16	2.41	4,427	2.41	4,427
2	8.5	17.5	3.60	7.2	3.10	361	372	-	-	-	-	-	95.8	7.0	1.18	0.18	-	-	-	-	-	5,341
1	6.6	26.5	3.45	6.7	14.4	132	87	0.006	0.018	0.032	0.021	0.015	74.5	3.0	1.23	0.49	25.92	0.021	0.026	3,692	0.026	3,692
2	7.3	20.0	3.87	6.99	1.33	153	103	0.011	0.023	0.048	0.073	0.073	88.9	2.0	1.99	0.35	-	-	-	-	-	3,987
1	6.5	26.5	3.97	7.2	22.9	9.6	3.3	0.009	0.017	0.030	0.054	0.016	20.3	4.0	2.30	0.22	9.05	0.012	0.014	37.6	0.014	37.6
2	8.5	21.0	6.23	9.20	10.22	10.2	6.9	0.018	0.023	0.113	0.275	0.030	40.7	1.0	0.91	0.08	-	-	-	-	-	121.2
1	6.9	26.0	0.97	7.6	8.5	9.4	3.3	-	-	-	-	-	24.1	6.0	2.12	0.24	9.88	0.0051	0.0075	37.0	0.0075	37.0
2	8.3	20.2	1.12	9.00	11.56	11.3	6.2	-	-	-	-	-	37.3	3.0	0.08	0.05	-	-	-	-	-	103.2
1	8.3	27.0	1.10	7.4	2.1	7.8	2.3	-	-	-	-	-	22.5	3.6	1.79	0.24	8.61	0.0030	0.0054	29.0	0.0054	29.0
2	7.7	20.0	2.20	8.70	3.56	6.5	12.5	-	-	-	-	-	74.8	1.9	0.42	0.08	-	-	-	-	-	114.6
1	7.0	25.5	0.97	7.2	6.6	8.7	2.9	-	-	-	-	-	23.1	4.0	1.45	0.32	10.70	0.0470	0.0072	34.0	0.0072	34.0
2	8.2	18.0	0.72	8.10	4.89	9.2	7.5	-	-	-	-	-	34.7	1.0	nd	0.080	-	-	-	-	-	93.3
1	8.6	23.5	3.45	8.2	0.20	327	1,155	-	-	-	-	-	115.2	11.0	2.06	0.22	2,251	2.85	3.28	5,731	3.28	5,731
2	8.3	13.5	2.50	9.96	0.44	351	1,280	-	-	-	-	-	120.0	8.0	0.33	0.14	-	-	-	-	-	6,260
1	8.5	24.0	3.10	7.4	0.21	346	1,160	-	-	-	-	-	1,150	4.0	1.90	0.26	2,419	2.88	3.34	5,758	3.34	5,758
2	8.3	13.5	3.10	9.24	0.44	381	1,260	-	-	-	-	-	120.4	3.0	1.08	0.08	-	-	-	-	-	6,220

Classification	pH	Temp °C	BOD ppm	DO ppm	Turbidity				Zn ppm	Fe ppm	Pb ppm	Total Alkalinity		Total Ammonia & Phosphate	Sulphate	Ignition residue %	Total residue %	Total Hardness ppm		
					Ca ppm	Mg ppm	Cu ppm	Cd ppm				CaCO ₃ ppm	CaCO ₃ /NH ₃ ppm						PO ₄ ppm	SO ₄ ppm
12	8.6	23.8	1.45	7.6	0.10	368	1,191	0.028	0.015	0.102	0.080	0.017	108.7	4.4	3.47	0.24	2,391	2.89	3.32	5,834
2	8.3	12.8	1.44	8.74	0.44	352	1,325	0.032	0.020	0.155	0.110	0.038	123.7	6.0	nd	0.15	—	—	—	6,380
13	8.6	24.0	2.25	7.4	0.32	381	1,173	—	—	—	—	—	112.9	4.8	2.68	0.22	2,380	2.88	3.32	5,815
2	8.4	14.0	3.60	10.34	0.44	343	1,307	—	—	—	—	—	117.8	5.3	nd	—	—	—	—	6,150
14	8.5	23.7	0.97	7.5	0.10	381	1,259	0.042	0.089	0.025	0.085	0.012	108.2	0.1	2.57	0.22	2,391	2.86	3.33	5,758
2	8.3	13.0	2.20	9.18	0.44	368	1,320	0.050	0.175	0.038	0.080	0.019	113.7	1.5	0.08	0.16	—	—	—	6,200
15	8.6	23.8	1.97	7.8	0.20	331	1,178	—	—	—	—	—	112.1	3.0	3.13	0.21	2,399	2.90	3.20	5,834
2	8.2	14.5	3.65	8.90	0.89	365	1,280	—	—	—	—	—	117.8	2.1	0.50	0.08	—	—	—	6,380
16	8.2	23.0	3.10	6.3	0.25	346	1,146	0.009	0.014	0.027	0.031	0.018	108.3	6.0	3.69	0.27	2,371	2.88	3.15	5,665
2	8.1	14.0	2.04	8.35	0.44	372	1,288	0.011	0.018	0.045	0.040	0.033	117.8	2.1	0.75	0.25	—	—	—	6,280
17	7.9	23.2	2.65	6.9	0.38	323	1,260	0.008	0.013	0.027	0.090	0.012	109.6	6.1	3.58	0.24	2,372	2.88	3.15	5,740
2	8.2	11.2	4.92	10.01	0.89	353	1,250	0.010	0.015	0.038	0.070	0.030	117.8	3.0	1.41	0.16	—	—	—	6,200
18	8.5	23.7	3.30	7.7	0.50	361	1,160	0.010	0.020	0.038	0.095	0.021	105.4	11.0	3.47	0.22	2,371	2.89	3.19	5,684
2	7.8	16.5	3.10	8.74	0.44	321	1,268	0.014	0.025	0.065	0.090	0.030	108.9	6.2	0.50	0.13	—	—	—	6,236
19	8.7	23.8	1.97	7.8	0.26	368	1,119	—	—	—	—	—	107.6	6.3	3.36	0.22	2,262	2.78	3.06	5,533
2	8.0	17.0	3.10	8.30	5.33	353	1,320	—	—	—	—	—	111.5	2.5	3.90	0.33	—	—	—	6,184
20	8.7	24.0	1.97	7.8	0.50	323	1,187	0.018	0.010	0.032	0.111	0.018	108.4	0.1	2.68	0.22	2,403	2.91	3.01	5,853
2	8.2	14.5	1.61	9.29	0.44	361	1,302	0.022	0.020	0.065	0.120	0.050	117.8	nd	0.08	0.09	—	—	—	6,270
21	8.6	23.8	1.97	7.9	0.48	323	1,200	—	—	—	—	—	111.5	0.1	3.13	0.21	2,451	2.98	3.26	5,909
2	8.3	15.0	3.20	9.80	0.20	335	1,290	—	—	—	—	—	115.4	dn	2.80	0.08	—	—	—	6,252
22	8.6	23.4	3.97	7.6	0.58	346	1,178	0.012	0.010	0.010	0.051	0.012	112.5	0.1	2.35	0.23	2,374	2.89	3.21	5,796
2	8.6	15.5	6.5	10.04	2.67	348	1,280	0.018	0.025	0.013	0.060	0.030	116.3	dn	1.13	0.21	—	—	—	6,462

Investigations on the water pollution around the river Tae Hwa and the coastal area of Ulsan city.

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Classification	pH	Temp °C	BOD ppm	DO ppm	Turbidity ppm	Ca ppm	Mg ppm	Cu ppm	Cd ppm	Zn ppm	Fe ppm	Pb ppm	Total alkalinity		Ammonia & phosphate		Sulphate	Ignition residue	Total residue	Total Hardness
													CaCO ₃ ppm	CaCO ₃ ppm	NH ₃ ppm	PO ₄ ppm				
23	8.6	23.5	3.97	7.4	0.30	331	1,169	0.010	0.008	0.008	0.052	0.016	113.0	4.0	3.02	0.22	2,346	2.87	3.20	5,796
2	8.5	15.5	4.1	9.80	0.44	373	1,315	0.011	0.020	0.065	0.065	0.028	116.3	3.2	1.00	0.22	—	—	—	6,413
1	8.6	23.7	2.15	8.2	0.53	331	1,164	—	—	—	—	—	117.8	3.5	2.95	0.22	2,393	2.59	2.86	5,778
2	8.4	15.5	3.4	8.50	1.78	375	1,290	—	—	—	—	—	121.0	2.6	0.83	0.18	—	—	—	6,151
1	8.7	23.5	2.50	7.8	2.20	346	1,164	0.010	0.008	0.011	0.052	0.014	110.7	2.5	2.50	0.23	2,386	2.86	3.00	5,815
2	8.0	17.2	4.7	5.24	3.66	382	1,400	0.022	0.025	0.073	0.190	0.055	128.3	3.6	5.06	0.15	—	—	—	6,080
1	8.6	23.4	1.97	7.2	0.51	346	1,119	0.012	0.011	0.018	0.048	0.010	109.2	4.0	2.35	0.23	2,246	2.77	3.06	5,552
2	8.6	14.0	1.6	8.70	0.44	363	1,315	0.035	0.035	0.075	0.140	0.205	115.5	5.4	1.18	0.26	—	—	—	6,650
1	8.6	23.2	1.20	8.2	0.30	338	1,196	—	—	—	—	—	114.6	2.0	2.57	0.23	2,470	3.00	3.40	5,928
2	8.5	15.0	2.30	8.5	0.20	372	1,280	—	—	—	—	—	118.5	1.3	2.10	0.18	—	—	—	6,315
1	8.7	23.3	1.10	8.2	0.20	338	1,187	—	—	—	—	—	111.5	5.0	1.90	0.28	2,449	2.97	3.27	5,890
2	8.6	15.1	2.8	8.3	0.10	348	1,292	—	—	—	—	—	120.1	2.7	0.72	0.23	—	—	—	6,203
1	8.7	23.5	0.97	8.1	0.68	353	1,290	—	—	—	—	—	108.0	0.1	0.83	0.24	2,462	3.02	3.36	5,966
2	8.4	14.8	1.50	8.5	0.40	362	1,320	—	—	—	—	—	119.3	0.3	0.63	0.21	—	—	—	6,301
1	8.7	23.3	2.05	8.2	0.73	353	1,196	0.011	0.010	0.031	0.060	0.013	108.1	3.0	2.58	0.23	2,460	2.73	3.01	5,966
2	8.6	15.5	3.20	7.9	0.32	372	1,338	0.013	0.015	0.029	0.037	0.012	116.7	3.2	1.17	0.18	—	—	—	6,309
2	8.7	—	0.19	3.30	0.44	—	—	nd	nd	0.115	0.070	0.020	135.8	nd	nd	0.20	—	—	—	207.1
2	7.8	—	0.11	8.5	2.67	19.5	9.12	0.020	nd	0.060	0.25	0.062	66.9	6.0	nd	0.08	—	—	—	97.8

** NO.1 and 2 on the column of sampling time indicate that the sampling dates which were on 22 Aug. 1980 and 15 May 1981 respectively.

Table.2 The elemental composition of seawater

Element	Abundance mg/1	Element	Abundance mg/1	Element	Abundance mg/1
C	28	Ge	0.00007	Eu	4.6×10^{-7}
N	0.5	As	0.003	Gd	2.4×10^{-6}
O	857.04	Se	0.004	Tb	—
F	1.3	Br	65	Dy	2.9×10^{-6}
Ne	0.0001	Kr	0.0003	Ho	3.8×10^{-7}
Na	10,500	Rb	0.12	Er	2.4×10^{-6}
Mg	1,350	Si	8	Tm	5.2×10^{-7}
Al	0.01	Y	0.003	Yb	2.0×10^{-6}
Si	3	Zr	—	Lu	4.8×10^{-7}
P	0.07	Nb	0.00001	Hf	—
S	885	Mo	0.01	Ta	—
Cl	19,000	Tc	—	W	0.0001
A	0.6	Ag	0.00004	Re	—
K	380	Cd	0.00011	Os	—
Ca	400	In	0.02	Ir	—
Sc	0.00004	Sn	0.0008	Pt	—
Ti	0.001	Sb	0.0005	Au	0.000004
V	0.002	I	0.06	Hg	0.00003
Cr	0.00005	Xe	0.0001	Tl	0.00001
Mn	0.002	Cs	0.0005	Pb	0.00003
Fe	0.01	Ba	0.03	Bi	0.00002
Co	0.0005	La	1.2×10^{-5}	Rn	0.6×10^{-15}
Ni	0.002	Ce	5.2×10^{-6}	Ra	1.0×10^{-10}
Cu	0.003	Pr	2.6×10^{-6}	Th	0.00005
Zn	0.01	Nd	9.2×10^{-6}	Pa	2.0×10^{-9}
Ga	0.00003	Sm	1.7×10^{-6}	U	0.003

Table.2, the elemental composition of the seawater⁽¹⁵⁾ presented for a short discussion of the result obtained here. In general, heavy metal contents were appeared as remarkably higher value than the one of ocean in table 2. The concentration of calcium and magnesium, however, went down to much lower level probably due to the dilution of the coastal seawater by fresh water from stream.

Although sodium and potassium are present as simple hydrated cations, appreciable fractions of other elements in seawater may form a complex with sulphate, bicarbonate, carbonate and halide⁽¹⁵⁾

In the present study, the water sample was

first passed through the column packed with cation exchange resin in order to concentrate cations on it and then the eluate was directly sent over the column with anion exchange resin to collect metal anions in the form of complex species.

The recovery rate of the process for the metal ions tested was over 85 percent which is good enough for the present purpose using atomic absorption spectrophotometer.

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References

1. J.H. Thomas "Compton's Encyclopedia" vol. 20, p.441 a, F.E. Compton company, Division of Encyclopedia Britannica, Inc. 1980.
2. D. Bryce Smith, Chem. Br., 7, 54, 1971.
3. H.A. Waldron, Chem. Br., 11, 354, 1975.
4. L. Friberg, G.F. Nordberg, and V.B. Vouk, Handbook on toxicology of metals. Elsevier/ North Holland Biomedical press, 1979.
5. H.W. Nurnberg, Electrochimica Acta, 22, 935, 1977.
6. R.G. Michel et al., Analyst (London), 104, 491, 1979.
7. D.D. Siemer, and L. Hageman, Anal. Chem., 52, 105 (1980)
8. M. Feinberg and C. DuCauze, Anal. Chem., 52, 207 (1980)
9. S.S. Berman, J.W. McLaren, and S.N. Willie, Anal. Chem., 52, 488 (1980).
10. American public health association etc., Standard methods for the examination of water and wastewater, 13th ed. 1975.
11. 朴青植, 俞光植譯, 工業用水의 化學的 分析 및 處理, 螢雪出版社, 1974.
12. 權庸杓, 金元滿, 羅和紀, "環境工學", 普成文化社, 1979.

13. 元鍾勳, 朴清吉, 梁漢燮, 蔚山灣 海水中의 水銀 카르뎀, 구리, 납, 亞鉛의 濃度分布, 韓水誌, 9 (3), 177(1976). 1971), 第15號, 釜山, p.22.
14. 國立水產振興院, 水質汚濁調査事業報告(1937- 15. R. A. Horne, "Marine Chemistry, pp.153-155, John Wiley & Sons, Inc. (1969).