ON GEOGRAPHICAL RELATIONSHIP BETWEEN THE CHEMICAL NATURE OF RIVER WATER AND DEATH-RATE FROM APOPLEXY

(Preliminary Report)

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INTRODUCTION

According to Watanabe (1953), Statistic Investigation Department, Welfare Minister's Office, Japan may be called an apoplexy country. He shows that the death-rate from apoplexy in Japan, compared with those in U.S.A., Britain and Germany, is extraordinary high; it is 4—8 times and 3—6 times as high for forty- agers and fifty- agers, respectively. And, it has now become the biggest cause of death in our country after the World War II, as the death-rate from tuberculosis has rapidly decreased while the death-rate from apoplexy has rather increased. It is noted also that there is a marked difference in different parts of Japan: the highest is Akita Prefecture where it is 2.29 times the average rate for fifty-agers in Japan, which is followed by Iwate and Yamagata Prefectures. Fukui Prefecture, on the other hand, is the lowest and is only 0.66 times the average. It is 0.32 times in Okinawa and 0.28 times in Formosa, although they are not Japanese territory now. Thus, the geographical difference is very marked, and the death-rate even in Fukui Prefecture is higher than those in Europe and America, but those in Okinawa and Formosa are about the same as those in Europe and America.

The notable geographical difference in the death-rate from this disease appears to be due to the environmental difference rather than the racial or heritable one. Some investigators tried to attribute this to the climatic influence, effect of such staple food as the polished rice or vitamin deficiency without statistical evidence. It has never been known as yet about the cause of the geographical difference.

The writer has been engaged in the study of the nature of irrigation water from the agricultural standpoint since 1942 and has made clear the chemical nature of more than 600 important rivers in Japan. In this study the writer found out the fact that there is a close relationship between the chemical compositions of river water and the death-rate from apoplexy.

RIVER WATER OF ABNORMAL-TYPE IN JAPAN

River water, as the result of weathering of rocks and soils of the basin, contains various kinds of inorganic matter. The substances dissolved are different according to the geological nature of the catchment area.

However, inorganic substances mostly found in river water are composed of four cations, i. e. Calcium (Ca), Magnesium (Mg), Sodium (Na) and Potassium (K) and three anions, i. e. Carbonate (CO_3), Sulfate (SO_4) and Chloride (Cl), and Silica (SiO_2). Besides those components, Iron (Fe), Ammonium (NH_4), Nitrate (NO_3) and Phosphate (PO_4) and others, though by far smaller in quantity, are found in it. Below is shown a table indicating average composition of the inorganic substances dissolved in the river water of the world calculated by Clarke.

TABLE 1.

The average composition of solid dissolved in river water of the world. (F. W. Clarke, 1924)

Ca^{++}	20.39%
Mg^{++}	3.41
Na^{+}	5.79
K^{+}	2.12
CO_3^{--}	35.15
SO_4^{--}	12.14
Cl^{-}	5.68
NO_3^{-}	0.90
SiO_2	11.67
$(Fe, Al)_2O_3$	2.75
Total	100.00

According to this table, the percentages of the important cations, Ca, Mg, Na and K of the total solids are 20.39, 3.41, 5.79 and 2.12, respectively. The content of calcium is the highest of them. As for anions, CO_3 is 35.15 %, SO_4 12.14% and Cl 5.68%. The percentage of carbonate is remarkably higher than that of sulfate or chloride. Naturally, calcium carbonate occupies the major part of solids dissolved in river water, and it is considered as normal when its content is far more than those of any other salts. As calcium carbonate is an alkaline substance, the river water in its normal state has some neutralizing power against acidity. When boiled to expel carbon dioxide gas, river water indicates a strong alkaline reaction.

As the present writer has often reported (1951, 54, 55), the rivers in our country are characterized by scantiness of calcium carbonate, i. e. alkalinity. And in some districts of eastern Japan, there are many rivers containing larger quantity of sulfate or sulfuric acid (acid substance) than carbonate (alkaline substance). Such a river may be called abnormal one in the sense that it is markedly different from the rivers most prevalent in the world. According to my investigation, in western Japan including Kinki, Chūgoku, Shikoku and Kyūshū districts, there are 24 sulfate-type rivers and 261 carbonate-type or normal-type rivers ; in Kantō district, 18 sulfate-type rivers and 46 carbonate-type rivers ; in Tōhoku district 37 sulfate-type rivers and 38 carbonate-

TABLE 2. Comparative table of nature of water and

No.	Name of river	Place of sampling	Ca %	Mg %	Na %
1	Iwakigawa	Gosyogawara City, Aomori Pref.	8.56	2.78	12.00
2	Kitakamigawa	Esashi District, Iwate Pref.	10.17	2.33	5.92
3	Yoneshirogawa	Takanosu Town, Akita Pref.	9.83	2.31	8.15
4	Omonogawa	Nishisenboku Town, Akita Pref.	9.05	2.73	11.32
5	Tamagawa	Shiraiwa Village, Akita Pref.	9.97	2.57	9.00
6	Mogamigawa	Kamigō Village, Yamagata Pref.	8.66	2.48	11.55
7	Abukumagawa	Marumori Town, Miyagi Pref.	11.46	2.42	8.46
8	Nakagawa	Kuroiso Town, Tochigi Pref.	12.39	3.34	5.26
9	Tonegawa	Sawara City, Chiba Pref.	14.21	3.03	8.33
10	Arakawa	Kumagaya City, Saitama Pref.	22.34	2.71	5.23
11	Tamagawa	Haijima Village, Tōkyō Metropolis	21.66	2.35	5.00
12	Sagamigawa	Sagamihara Town, Kanagawa Pref.	13.45	3.60	5.75
13	Shinanogawa	Ojiya Town, Nīgata Pref.	11.57	3.47	9.22
14	Kurobegawa	Aimoto Village, Toyama Pref.	17.45	2.08	9.85
15	Kuzuryūgawa	Shimoshihi Village, Fukui Pref.	17.83	3.59	8.46
16	Fujigawa	Iwamatsu Village, Shizuoka Pref.	16.06	2.51	6.69
17	Yahagigawa	Koromo City, Aichi Pref.	11.07	1.42	8.80
18	Tenryūgawa	Futamata Town, Shizuoka Pref.	19.95	3.55	5.71
19	Kisogawa	Kaneyama Town, Gifu Pref.	12.56	1.72	7.59
20	Nagaragawa	Kaisai Village, Gifu Pref.	18.85	3.90	6.65
21	Yodogawa	Hirakata City, Ōsaka Pref.	15.67	4.43	13.74
22	Kinokawa	Iwaide Town, Wakayama Pref.	17.59	3.67	10.26
23	Kumanogawa	Shingū City, Wakayama Pref.	12.26	4.94	11.77
24	Sendaigawa	Kawahara Town, Tottori Pref.	19.68	4.16	5.31
25	Takahashigawa	Kurashiki City, Okayama Pref.	17.59	2.33	6.85
26	Gōgawa	Kawamoto Town, Shimane Pref.	8.85	3.64	16.84
27	Ōtagawa	Yagi Village, Hiroshima Pref.	10.96	3.05	14.09
28	Nishikigawa	Iwakuni City, Yamaguchi Pref.	16.40	4.52	9.76
29	Yoshinogawa	Hayashi Town, Tokushima Pref.	19.88	4.79	7.23
30	Niyodogawa	Kōnotani Village, Kōchi Pref.	21.75	4.69	7.42
31	Chikugogawa	Ōzeki Village, Fukuoka Pref.	8.93	2.22	7.57
32	Ōitagawa	Hazama Village, Ōita Pref.	9.23	1.88	7.83
33	Kumagawa	Yashiro City, Kumamoto Pref.	17.33	3.12	6.84
34	Ōyodogawa	Miyazaki City, Miyazaki Pref.	9.12	3.82	6.53
35	Sendaigawa	Sendai City, Kagoshima Pref.	8.78	2.60	6.62
General average of 75 rivers in the Tōhoku districts			10.45	2.11	8.48
General average of 64 rivers in the Kantō districts			13.48	2.93	6.32
General average of 70 rivers in the Kyūshū districts			10.50	3.20	9.01
St. Lawrence river		Ogdensburg, U. S. A.	23.66	5.49	
Amazon river		Obidos, South America	14.69	1.40	4.24
Nile		Cairo, Africa	13.31	7.39	13.14
Rhine		Cologne, Germany	26.48	6.15	2.73
Thames		Thames Ditton, England	30.10	1.95	2.26
Clarke's general average of the world (Table 1)					

ratio of SO_4/CO_3 in chief rivers in Japan and abroad.

K %	NH_4 %	CO_3 %	SO_4 %	Cl %	NO_3 %	PO_4 %	SiO_2 %	Fe_2O_3 %	Total %	Salinity mg/l	SO_4 /CO_3
1.46	0.04	15.47	13.31	14.74	2.05	0.03	28.48	1.08	100.00	96.6	0.86
1.03	0.12	10.63	37.05	5.47	1.27	0.01	24.67	1.33	100.00	92.0	3.49
1.12	0.05	4.64	35.66	8.51	1.29	0	26.18	2.26	100.00	99.7	7.69
1.33	0.06	10.35	19.62	16.38	1.49	0.02	26.92	0.73	100.00	65.7	1.90
1.25	0.07	4.76	26.32	17.70	1.07	0	27.20	0.09	100.00	57.3	5.53
1.82	0.11	10.94	25.03	12.11	1.82	0.01	24.59	0.88	100.00	71.4	2.29
1.48	0.15	13.99	27.49	6.10	1.84	0.04	26.16	0.41	100.00	89.5	1.96
1.04	0.08	7.94	35.33	6.47	0.24	0.01	27.85	0.05	100.00	127.1	4.45
1.65	0.16	20.39	20.16	8.85	0.73	0.02	21.94	0.53	100.00	94.9	0.99
0.85	0.02	34.29	19.75	2.57	0.97	0.03	11.23	0.01	100.00	95.8	0.58
1.20	0.05	34.93	12.58	3.04	2.16	0.01	17.02	0	100.00	82.8	0.36
1.14	0.18	26.89	10.00	2.41	1.62	0.08	34.61	0.27	100.00	89.1	0.37
2.60	0.13	21.28	17.58	7.69	1.71	0.07	24.25	0.43	100.00	70.0	0.83
1.45	0.13	26.63	12.29	8.16	1.27	0.01	20.60	0.08	100.00	47.8	0.46
1.18	0.10	32.91	6.22	6.82	1.49	0.02	21.28	0.10	100.00	52.8	0.19
1.33	0.06	27.45	12.50	3.20	1.20	0.08	28.34	0.58	100.00	99.9	0.46
2.39	0.22	24.86	3.56	3.50	1.90	0	42.02	0.26	100.00	34.3	0.14
1.78	0.10	31.89	11.98	3.23	1.54	0.01	19.66	0.60	100.00	65.6	0.38
2.45	0.10	25.59	4.28	3.10	2.81	0.02	39.47	0.31	100.00	41.0	0.17
1.60	0.07	33.88	6.76	3.59	2.29	0.07	22.16	0.18	100.00	54.6	0.20
2.71	0.17	28.83	9.47	9.24	1.33	0.08	13.45	0.88	100.00	53.6	0.33
1.72	0.04	28.71	12.39	7.06	1.64	0.03	16.64	0.25	100.00	75.2	0.43
1.86	0.09	19.86	18.87	5.02	0.67	0.01	24.56	0.09	100.00	46.4	0.95
1.02	0.05	37.40	7.04	3.64	1.04	0.03	20.63	0	100.00	70.8	0.19
1.45	0.08	33.75	8.94	5.23	2.06	0.03	21.68	0.01	100.00	67.9	0.26
1.85	0.07	18.49	5.49	18.01	1.11	0.01	25.36	0.28	100.00	57.2	0.30
2.26	0.06	21.07	3.68	11.06	1.57	0.02	31.97	0.21	100.00	36.7	0.17
1.97	0.03	26.38	8.86	5.92	1.08	0.01	25.00	0.07	100.00	50.0	0.34
1.49	0.05	30.10	14.12	4.39	1.06	0	16.80	0.09	100.00	53.3	0.47
0.90	0.04	35.71	6.17	4.57	1.26	0.02	17.39	0.08	100.00	52.7	0.17
2.48	0.07	16.25	11.66	6.83	0.83	0.06	42.62	0.48	100.00	102.8	0.72
2.23	0.04	22.01	8.28	4.55	1.02	0.05	42.73	0.15	100.00	124.4	0.38
1.51	0.09	31.21	6.08	3.69	0.69	0.03	29.40	0.01	100.00	58.6	0.19
2.22	0.03	22.10	8.46	4.36	1.01	0.02	42.25	0.08	100.00	94.2	0.38
2.18	0.05	17.89	11.00	5.22	0.64	0.02	44.85	0.15	100.00	84.9	0.61
1.23	0.09	14.52	24.37	8.57	1.22	0.02	28.26	0.68	100.00	76.7	1.68
1.43	0.10	20.73	20.53	8.05	1.25	0.07	24.76	0.35	100.00	97.4	0.99
2.02	0.07	21.10	13.94	5.90	1.04	0.06	32.97	0.19	100.00	94.0	0.66
4.81	—	45.70	9.15	5.87	0.23	—	5.03	0.06	100.00	134	0.20
4.76	—	24.15	2.26	6.94	—	—	28.59	12.97*	100.00	37	0.09
3.26	—	36.02	3.93	2.83	—	0.59	16.88	2.65	100.00	119	0.11
0.02	—	46.96	12.95	4.22	—	0.24	0.15	0.10*	100.00	190	0.28
2.25	—	41.86	11.82	5.20	0.84	—	3.26	0.46*	100.00	272	0.28
											0.35

*.........$(Fe, Al)_2O_3$

type rivers. Thus, the rate of sulfate-type rivers increases as we go to eastern part of Japan. A detailed study reveals that Akita Prefecture, which has 26 sulfate-type rivers but only 5 carbonate-type ones, is top ranked of all prefectures in Japan as to the number of abnormal-type river.

As the examples of rivers containing extremely large quantity of sulfuric acid, among abnormal type rivers, can be cited such inorganic acid rivers as the Tamagawa and the Takamatsugawa in Akita Prefecture, the Sukawa and the Matsukawa in Yamagata Prefecture, the Arakawa in Aomori Prefecture, the Agatsumagawa in Gumma Prefecture, etc. In some cases they indicate so strong acid reaction as pH 3—4 and give fatal injuries to crops and fishes. They are generally called natural poisonous water ; they taste strongly bitter and are apparently injurious to health. Such acid rivers are peculiar to Japan, especially to her north-eastern part of the main land; and two acid rivers, the Yukawa originating from Yatsugatake volcano in Nagano Prefecture and the Agatsumagawa originating from Kusatsu-Shirane volcano in Gumma Prefecture are on the western border of the part.

With respect to the nature of water, especially the ratio of sulfate to carbonate, some typical rivers in Japan are compared with those of foreign countries, and the results are shown in Table 2.

As evident in Table 2, the ratio of sulfate to carbonate is very small in general in the rivers of foreign countries listed, namely, it is 0.20 in the St. Lawrence river at Ogdensburg, U. S. A., 0.09 in the Amazon river, 0.11 in the Nile, and 0.28 in the Rhine and the Thames. In Japan, on the contrary, the ratio is 7.69 in the Yoneshirogawa (at Takanosu Town, Akita Pref.); 5.53 in the Tamagawa (at Shiraiwa Village, Akita Pref.); 4.45 in the Nakagawa (at Kuroiso Town, Tochigi Pref.) ; 3.49 in the Kitakamigawa (at Kitakami City, Iwate, Pref.); 2.29 in the Mogamigawa (at Kamigō Village, Yamagata Pref.) ; 1.96 in the Abukumagawa (at Marumori Town, Miyagi Pref.) and 1.90 in the Omonogawa (at Nishisemboku Town, Akita Pref.). The average of the ratios of 75 rivers in Tōhoku district (north-eastern part of the mainland of Japan) is as high as 1.68, in Kantō district (Tōkyō and its neighborhood) 0.99 and in Kyūshū district 0.66. In the Tonegawa, the biggest river in Japan, it is 0.99 at Sawara City (lower stream) and in the Shinanogawa it is 0.83 at Ojiya Town (middle stream). These big rivers are also considered to be sulfate-surplus. However, we can find out some rivers with low sulfate content in the regions west of Tōkyō. For example, in the Tamagawa the ratio is 0.36 at Haijima Village near Tōkyō, in the Kuzuryūgawa 0.19 (at Shimoshihi Village, Fukui Pref.), in the Kisogawa 0.17 (at Kaneyama Town, Gifu Pref.), in the Takahashigawa 0.26 (at Kurashiki City, Okayama Pref.), in the Ōtagawa 0.16 (at Yagi Village near Hiroshima City), in the Niyodogawa 0.17 (at Kōnotani Village, Kōchi Pref.). In these rivers, running down Chichibu Palaeozoic stratum which is composed of sedimentary rock, the ratios are low and comparable with those in the foreign rivers.

Generally speaking, Japan has many rivers which contain remarkably large quantity of sulfuric radical as compared with carbonic one, the alkaline substance. This is apparently due to the volcanic sulfur-rich nature of the ground in our country. Sulfur contained in sulfur-springs, sulfide ores and in the soil is oxidized to sulfuric acid, which causes the sulfate-rich but carbonate-poor character of the river water.

RELATIONSHIP BETWEEN RIVER WATER OF ABNORMAL-TYPE AND DEATH-RATE FROM APOPLEXY

As stated above, Japan, especially her north-eastern part of the mainland, has some "inorganic acid rivers" which contain sulfuric acid so much as to give apparent injuries to plants and animals, besides many abnormal-type rivers containing more sulfate than carbonate, though the reaction is

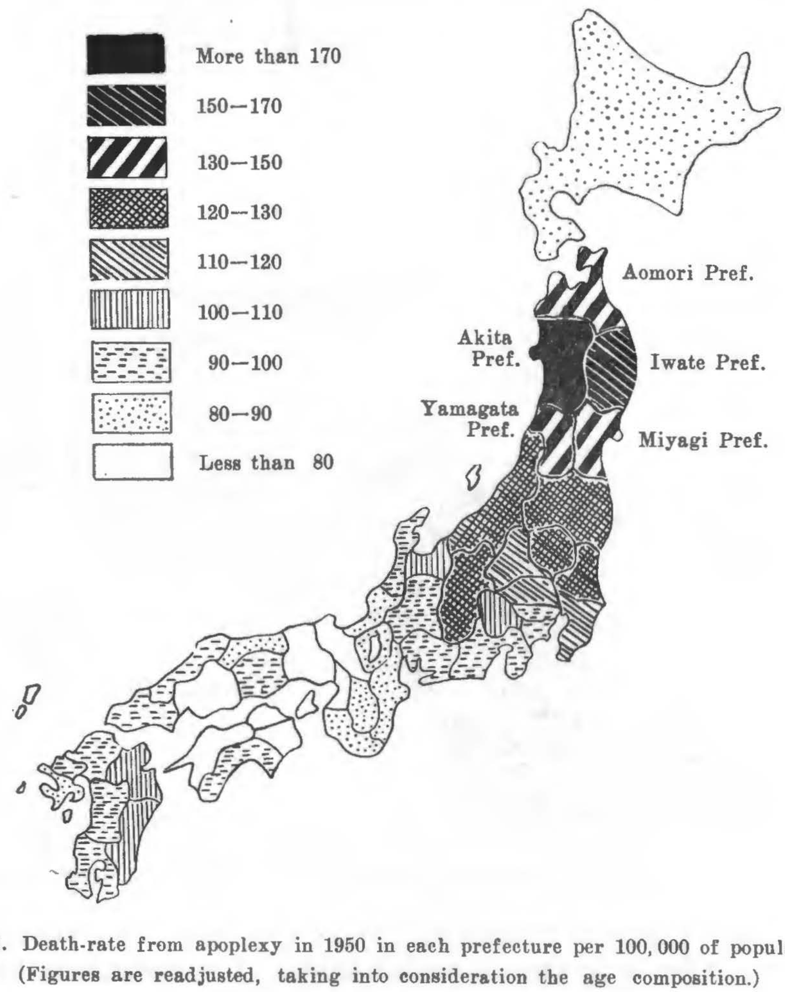


Fig. 1. Death-rate from apoplexy in 1950 in each prefecture per 100,000 of population. (Figures are readjusted, taking into consideration the age composition.)

not acid. Comparing the geographical distribution of rivers of abnormal-type in Japan with that of death-rate from apoplexy, the writer is aware of the fact that there exists a close relationship between the both cases.

The death-rate from apoplexy in 1950 published by Analysis Section, Statistic Department, Welfare Minister's Office, is shown in Fig. 1.

Akita Prefecture occupies the top rank, and next comes Iwate Prefecture. Aomori, Miyagi, Yamagata, Fukushima, Nīgata, Tochigi, Ibaragi and Nagano Prefectures are also very high, while in districts west of Tōkyō, it is low in general.

As shown in Fig. 2 and Table 3, Akita Prefecture ranks atop with respect to the ratio of sulfate to carbonate, and next come Iwate, Aomori,

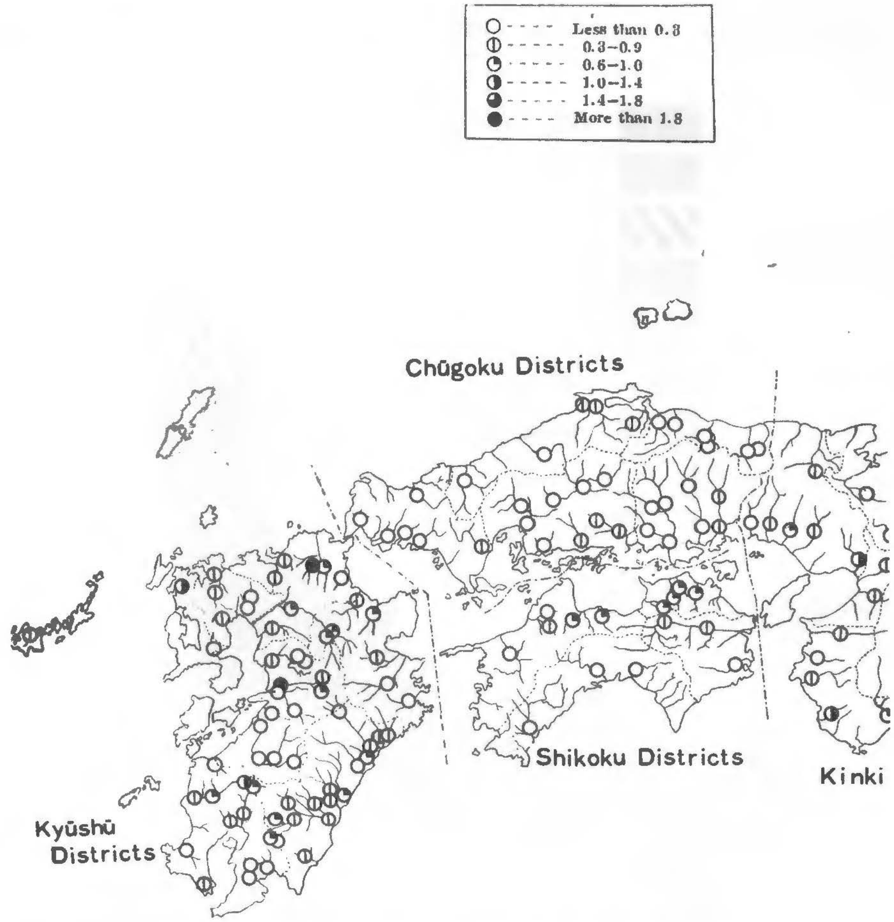
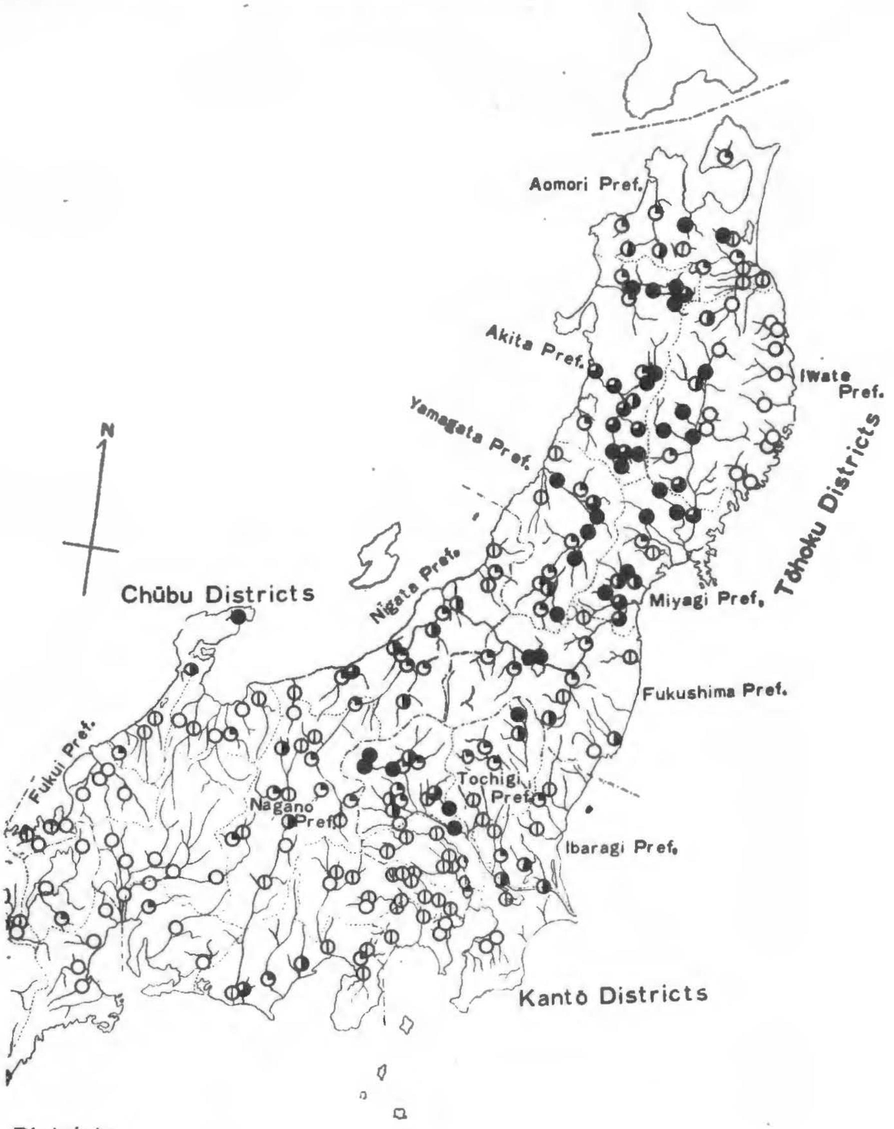


Fig. 2. Distribution chart of ratio of SO_4/CO_3 in rivers of Japan.

Miyagi and Yamagata Prefectures. On the other hand, the ratios are generally low in the Prefectures of western Japan. This suggests us that a high correlation exists between the death-rate indices from apoplexy and the ratio of sulfate to carbonate in river water.



A similar situation is also observable within a Prefecture. In Iwate Prefecture, for example, we can find a striking contrast regarding death-rate as such that people who live in the Kitakamigawa basin show high death-rate from apoplexy while in the eastern Pacific coastal region the rate is very low. In this connection, it is noted from Fig. 2 that a number of rivers of abnormal-type run through the Kitakamigawa basin, whereas the rivers in

TABLE 3. Distribution table of ratio of SO_4/CO_3 in prefectures of Japan in number of rivers.

District	Prefecture \ SO_4/CO_3	More than 1.8	1.8 – 1.4	1.4 – 1.0	1.0 – 0.6	0.6 – 0.3	Less than 0.3	Total
		(Abnormal-type river water) ←				→ (Normal-type river water)		
Tōhoku	Aomori	2		2	5	5		14
	Akita	18	7	1	5			31
	Iwate	4	1	2	1		13	21
	Yamagata	5	1	1	5	2		14
	Miyagi	5	3	2	1	1		12
	Fukushima	2		2	4	3	1	12
Kantō	Ibaragi			2	2	3		7
	Tochigi	2		1	3	2		8
	Gumma	3	1	3	4	1	1	13
	Saitama	1			1	7		9
	Tōkyō					6		6
	Chiba			1		1	2	4
	Kanagawa					5	2	7
Chūbu	Nīgata		1	4	6	3		14
	Nagano			2	6	6	2	16
	Yamanashi					3	2	5
	Shizuoka		1	1	2	4		8
	Toyama				1	2	3	6
	Ishikawa	1		1	1	2		5
	Fukui					2	6	8
	Gifu						6	6
	Aichi				1		3	4
Kinki	Shiga				11	19	22	52
	Mie				1	5	5	11
	Nara							
	Wakayama			3	3	7	2	15
	Kyōto					5	3	8
	Ōsaka		3	7	12	13	8	43
	Hyōgo	1		1	4	8	3	17
Chūgoku	Tottori						6	6
	Okayama					2	6	8
	Hiroshima					3	6	9
	Shimane					3	2	5
	Yamaguchi					1	5	6
Shikoku	Kagawa				4			4
	Ehime				2	1	2	5
	Kōchi						3	3
	Tokushima					2	1	3
Kyūshū	Fukuoka	1			2	3	1	7
	Ōita				3	2	2	7
	Saga			1	2	3	2	8
	Nagasaki			1		1	1	3
	Kumamoto	1			1	2	9	13
	Miyazaki				5	10	3	18
	Kagoshima			1	2	4	4	11
Total		46	18	39	100	152	137	492

the eastern coastal region are so low in sulfate content as to be regarded as the normal-type ones.

The writer, in his analytical study of the river water of Thailand, found that the rivers there are carbonate-rich and of normal type. The ratios are 0.14 in the Mekong and 0.06 in the Menam Chao Phraya. In this country, cases of apoplexy are scarce in spite of the fact that rice is the staple food of her nation. In Okinawa and Formosa, the cases of apoplexy are also scarce, and the geological construction of these islands enables us to infer that the ratio of sulfate to carbonate of the river waters is low. On the other hand, Italy, a famous volcanic country like Japan, is said to be high in the death-rate from apoplexy, ranking next to Japan in the world.

All of these evidences stated above seem to be in favor of the hypothesis that a high correlation exists between the death-rate from apoplexy and abnormal nature of river water due to the geological construction of the catchment area.

It is apparently premature to conclude from this that higher contents of sulfuric acid or sulfate in river water as compared with alkaline substance (calcium carbonate) should cause apoplexy, since physiological effect of inorganic acid or alkali has never been clarified as yet.

However, the above-mentioned correlation found out by the writer may suggest that the excess of inorganic acid induces apoplexy for some reason, and calcium carbonate prevents the case. The writer will be much pleased if the above facts will give a clue to the solution of the problem of geographic difference in the death-rate from apoplexy.

The writer desires to take this opportunity to thank Dr. Masayoshi Yamaguchi, Director of Public Hygiene Bureau, Welfare Ministry and Dr. Sadamu Watanabe, Statistic Investigation Department, Welfare Minister's Office, who have shown much interest in this subject and supplied statistical materials. The writer also expresses his gratitude to Dr. T. Shimizu, President of our Okayama University for his kind counsel.

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