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# Quality of Groundwater in Eastern Osaka, Japan, and its Hydrogeological Interpretation[*]

Michiji TSURUMAKI

(With 4 Tables and 10 Figuses)

## Introduction

The area studied is located in the east of geographic center of Osaka Prefecture, and is bounded on the west by Uemachi Upland, having the Yodo River as a northern border, and limited on the east by the Ikoma Range, with an edge of the Yamato River on the south (Fig. 1). In the area, called the Eastern Osaka, land subsidence has been remarkably increasing during a few recent years. Owing to the parallelism between the progress of the subsidence and the rapid increase of wells for industrial and municipal water sypply, the use of groundwater beeing gradually regulated and substituted for the use of surface water. Under the circumstances, it is pushed on to throw light upon the hydrogeological conditions of the Eastern Osaka.

This report is based on the work supported by a research grant from Osaka Prefectural Government, and started in 1965 and extended to 1969. The work has been concentrated principally on water quality problems, with secondary attention given on hydrogeology of the area. The primary purpose of this report is to elucidate the distribution pattern of the main constituents in water, and then to illustrate the chemical character of water in connection with the occurrence of it. However, a general sketch on the geology of the area is included in order to give the background necessary for some interpretation of the water quality.

The measurement of natural tritium ($^3H$) content in well water can give a valuable information about groundwater hydrology (BEGEMAN & LIBBY, 957). In recent years, the term "tritium hydrology" is mentioned in literature (GRANT-TAYLER & TAYLER, 1967). The use of tritium dating was carried out for the study of groundwater hydrology in Kanto Plain in this countory (OCHIAI, 1968). Since 1967, in this research, the measurement of natural tritium in well water has been put into practice by courtesy of Dr. T. OCHIAI at the laboratory of Agricultural Engineering Research Station. A fuller discussion of the chemical data gathered during the study will be presented later to this Journal after obtaining the data of tritium dating.

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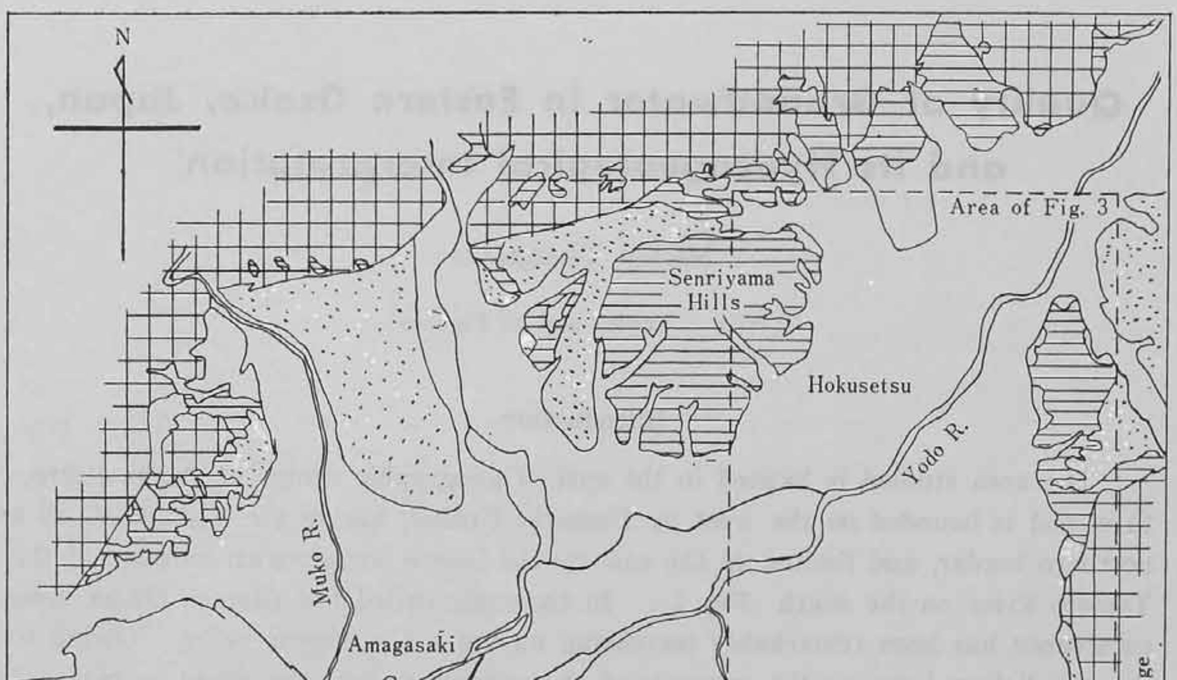

Fig. 1. Geological map (after IKEBE and TAKENAKA, 1969; modified).

## General Sketch of Geology

Geology of the Osaka basin and the surroundings is summarized as the following table (IKEBE & TAKENAKA, 1969), and the simplified geologic map is shown in Fig. 1.

| | |
|---|---|
| Recent Alluvium | (Umeda formation) |
| Uppler Pleistocene formation | Younger (Lower) terraee<br>Middle tarrace<br>Older (Higher) terrace |
| Osaka group (Late Pliocene–Early Pleistocene) | Upper part<br>Lower part<br>Lowest part |
| Infra-Osaka group (Pliocene) | |
| Kobe group (Miocene) | |
| Pre-Neogene basement | |

The concept of a groundwater basin has become important for leading basin wide planning and development of groundwater (Todd, 1959). It is evident from the geological map that the Osaka basin consists a groundwater basin, but Uemachi Upland which lies in the middle part of the basin divides it into two areas,

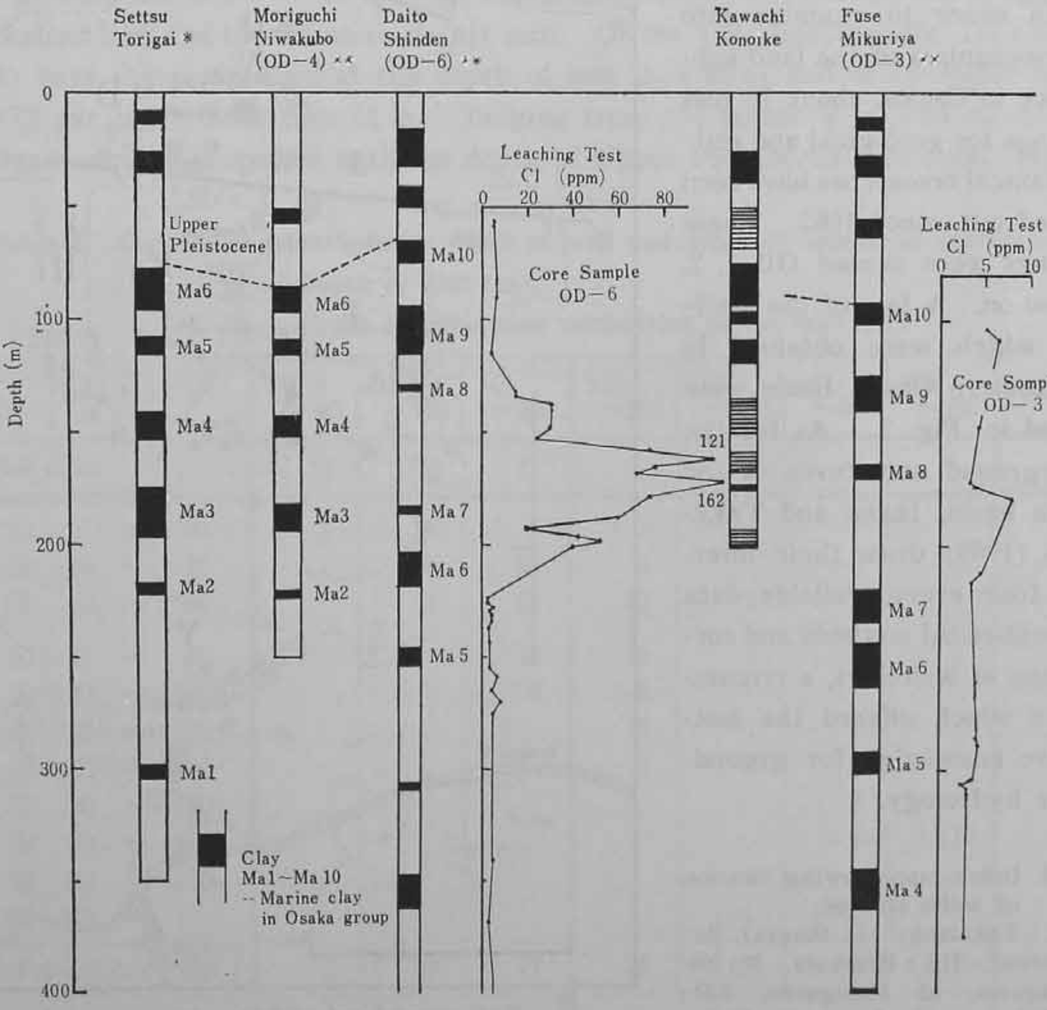

Fig. 2. Well logs and results of leaching test.
* after Inai and Ishida (1966)
** after Matsushita (1960, 1967)

that is to say, Western Osaka and Eastern Osaka. Owing to the concept of the groundwater basin, this reseach comrpises the Hokusetsu area extending to north of the Yodo River, and the combined area of the Hokusetsu area and the Eastern Osaka is designated as the Eastern Osaka Basin. The chemical quality of groundwater in the Western Osaka was discussed by the auther with special reference to the intrusion of sea water (TSURUMAKI, 1962).

In order to examine into the mechanism of the land subsidence in Osaka, about 10 test drillings for geological and soil-mechanical researches have deen carried out, since 1963. These drillings were named OD-1, 2, and so on. A few of the well-logs which were obtained in the Eastern Osaka basin were quated in Fig. 2. As for the underground structures of the Osaka basin, IKEBE and TAKENAKA (1969) draw their inference from every available data of geophysical metheds and correlation of well-logs, a circumstance which offered the instructive knowledge for groundwater hydrology.

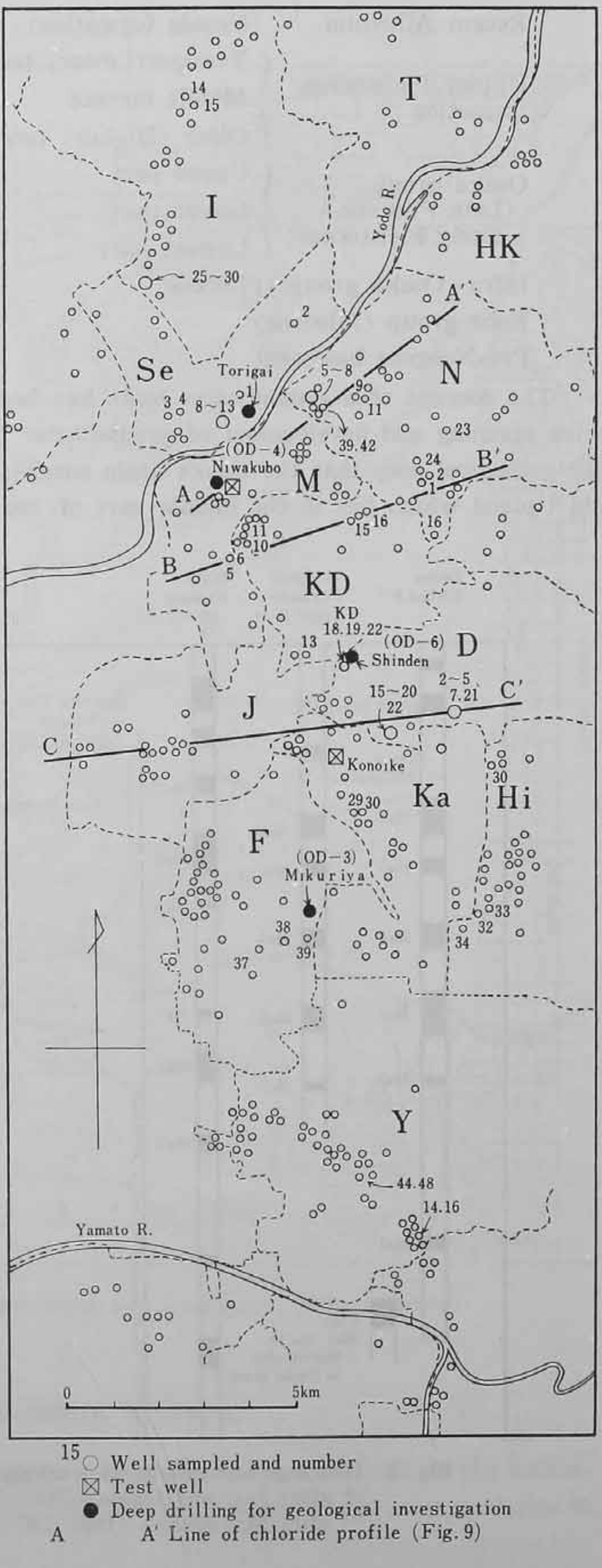

Fig. 3. Index map showing location of wells studied.
T: Takatsuki, I: Ibaraki, Se: Settsu, HK: Hirakata, N: Neyagawa, M: Moriguchi, KD: Kadoma, J: Joto, D: Daito, Hi: Hiraoka, Ka: Kawachi, F: Fuse, Y: Yao,

## Conditions of Well

Fig. 3 shows the location of the well studied. To each of the wells a numbar is assigned at every district. In this text, each well is called by the number with the combination of an initial of the name of district; for example, N-10 and KD-20. The water-samples were taken from the wells which are deep, high-capacity and constructed by drilling. Most of the deep wells in this area have well screens or other opening in the casing at several different depths, accordingly, determination of the depth zone at which water can enter the well is a troublesome work. As an example, the depth of well and the perforated portion of the well casing are shown in Fig. 9.

On the whole of wells studied in the Eastern Osaka, the relation between the depth of well and the depth of the uppermost perforated portion was examined and the result is shown in table 1. Out of total of 188 wells, 84 wells lack for their casing records. For the convenience of examination, the wells are divided into two groups, the depth of 20 to 150 m and 151 to 350 m; the former are designated as *shallow well* and the latter as *deeper well.* Of the 132 *shallow wells,* 117 (89 per cent) have the perforation at the depth of less than 60 m, and of 72 *deeper wells,* 53 (73 per cent) more than 61 m. Judging from the tendency of well completion of this area, and compared with the depth of Upper Pleistocene formation (Fig. 2),

Table 1. Correlation table between depth of well and depth of uppermost perforation

A……Depth of well (m)

B……Depth of uppermost perforation of the well (m)

| B \ A | 20 ~ 50 | 51 ~100 | 101 ~150 | 151 ~200 | 201 ~250 | 251 ~300 | 301 ~350 | Total |
|---|---|---|---|---|---|---|---|---|
| Not cloar | 13 | 40 | 21 | 7 | 3 | | | 84 |
| ① ~ 20 | 3 | 16 | 6 | 1 | | | | 26 |
| ② 21 ~ 40 | 1 | 28 | 28 | 4 | | | | 61 |
| ③ 41 ~ 60 | | 13 | 22 | 12 | 2 | | | 49 |
| ④ 61 ~ 80 | | | 12 | 13 | 3 | | 1 | 29 |
| ⑤ 81 ~ 100 | | | 3 | 9 | 4 | | | 16 |
| ⑥ 101 ~ 120 | | | | 5 | 1 | | | 6 |
| ⑦ 121 ~ 140 | | | | 1 | 6 | | | 7 |
| ⑧ 141 ~ 160 | | | | | | 2 | | 2 |
| ⑨ 161 ~ 180 | | | | | | 2 | 1 | 3 |
| ⑩ 181 ~ 200 | | | | | 2 | | | 1 |
| ⑪ 201 ~ | | | | | 1 | 1 | 1 | 3 |
| Total ① ~ ⑪ | 4 | 57 | 71 | 45 | 19 | 5 | 3 | |
| Total ① ~ ③ | 117 | | | 19 | | | | 288 |
| Total ④ ~ ⑪ | 15 | | | 53 | | | | |

it may be said that the *shallow wells* are supplied from the aquifers of the Upper Pleistocene, and *deeper wells* from those of Upper and/or Lower Part of Osaka group.

## Methods for Collection and Analysis of Water-sample

### A. Collection of water-sample.

The major parts of the water-samples were collected from the wells whose records of construction had been preserved. In the region not having proper distribution of wells, the samples were taken from the wells even lacking the records. The sample was taken from such a well as was able to be pumped up directly and not through pressure tank or any other distribution systems, because the water was in artesian condition. After the measurements in field, water-sample was collected in a polyethylen bottle. All bottles were washed with hot hydrochloric acid and rinsed with tap water in the laboratory, and they were rinsed again with the water to be sampled.

### B. Field determinations.

Temperature, pH and electrical conductivity were determined simultaneously with sampling, and the addition of the reagents necessary for colorimetric determination of ferrous ion was performed.

(1) Temperature: Temperature measurement was made with mercury thermometer graduated per 0. 2 °C.

(2) pH: A pH determination was made colorimetrically through addition of bromthymol blue or phenol red solution as indicator in comparison with standard color series.

(3) Electrical conductivity: A preliminary step in each analysis was the determination of electrical conductivity in micromhos ($\mu\mho$) with a portable conductivity meter, model CM-3M fabricated in TOA Electronics Ltd.. Accuracy and sensitivity of the meter are ±10% and 2. 5% respectively. The electrical conductivity is related to the concentration of ionized substance in water; therefore, a conductivity reading gives the analyst an idea as to the concentration of ions, and this speeds up the analytical procedures. Also the conductivity in micromhos at 18 °C was used as a check on the chemical determinations (LOGAN, 1961. TSURUMAKI, 1969).

### C. Laboratory tests.

Alkalinity, nitrite, phosphate and ferrous ion were determined on the same day of collection, and then others in succesion within a week. Analytical procedures were based mainly on "Testing Methods for Industrial Water (JIS K 0101)" published by Japanese Standards Association and partly on "Standard Methods (1965)" published by American Public Health Assoc. and American Water Works Assoc..

(1) Alkalinity: Titrated with 0.02N sulfuric acid in use of mixed bromcresol green-methyl red indicator. The value is considered to represent the amount of bicarbonate because of the absence of P. alkalinity in all of the water-samples.

(2) Chloride: Volumetric methods using mercuric nitrate and silver nitrate were adopted to meet the concentration of chloride.

(3) Sulfate: Turbidimetric method and colorimetric barium chromate method were adopted.

(4) Nitrate: Photometrically determined in use of phenoldisulfonic acid, excepting the specimen with higher content of chloride. For the specimen of high chloride, brucine method (AWWA, p 198, 1965) or 2, 4- xylenol method (NAGASAWA, 1966) were used tentatively.

(5) Nitrite: Photometrically determined in use of G. R. reagent.

(6) Phosphate: Colorimetrically determined through stannous chloride method.

(7) Ammonia: After distillation colorimetrically determined by nesslerrization.

(8) Calcium and Megnesium: EDTA titrimetric methods were adopted.

(9) Sodium and potassium: The measurements were preformed with atomic absorption and flame emission spectrophotometer, model AA-1E fabricated in Nippon Jarrell-Ash Co., Ltd..

(10) Silica (soluble): Colorimetrically determined by molybdosilicate method.

(11) Ferrous iron: Ferrous ion was determined colorimetrically with the specimen treated in the field using o-phenanthroline method.

(12) Total iron: Colorimetrically determined through thiocyanate method after oxidizing the specimen.

(13) Manganese: Colorimetrically determined through persulfate method.

### D. Expression of result.

The result of chemical determination was expressed in parts per million (ppm) and in terms of equivalents per million (epm). Epm can be obtained from ppm by dividing the ppm by the equivalent weight of the ion. As regard silica, the expression by epm was not adopted, for the silica in most waters is present as the particles of subcolloidal size (Hem, 1959, p. 56).

When a complete analysis was made, the totals of anions and cations expressed in epm should be equal. Difference between them can be used to check for the possible error in analytical procedurs. Table 2 shows the results of analysis for the representative water-samples, as well as the totals of anions and cations, and the ratios of some important constituents.

In order to estimate the range of variation in the chemical quality, the water-samples of two groups of wells were taken and analyzed repeatedly from 1966 to 1969 once or twice in a year. One group locates at the western Neyagawa and consists of four *shallow wells* (N-5, 6, 7, 8) and one *deeper well* (N-39), and the other group locates at the southwest Daito and consists of five *deeper wells* (D-16, 17, 18, 19, 20).

## Regional Distribution of Water Quality

Fig. 4 and 5 are the maps showing the regional distribution of the quality of water-samples taken from the *shallow wells*. There are two reasons why we adopted the *shallow wells* as the examination of regional distribution. (1) The depth zones from which water can enter the *shallow wells* are in the limited range of depth as seen in Table 1. (2) The range of seasonal or annual variation of the quality of the *shallow well* is smaller than that of *deeper well* as seen from the comparison of the analyses of N-5, 6, 7, 8 and D-16, 17, 18, 19 (Table 2-3, 2-6 and 2-7).

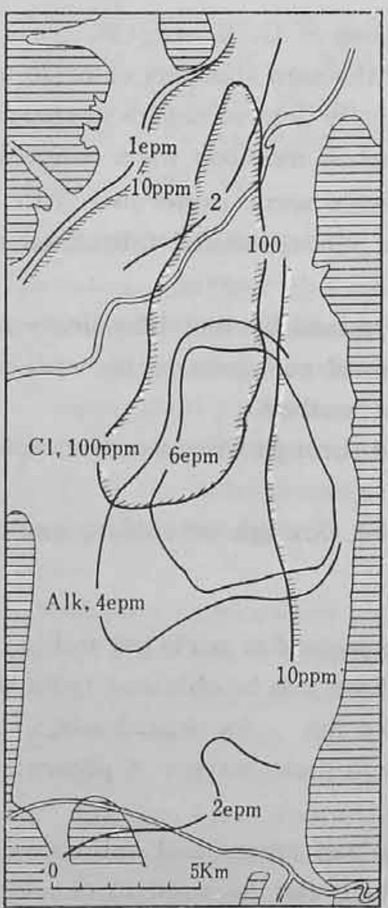

Fig. 4. Generalized alkalinity and chloride map of the *shallow well*.

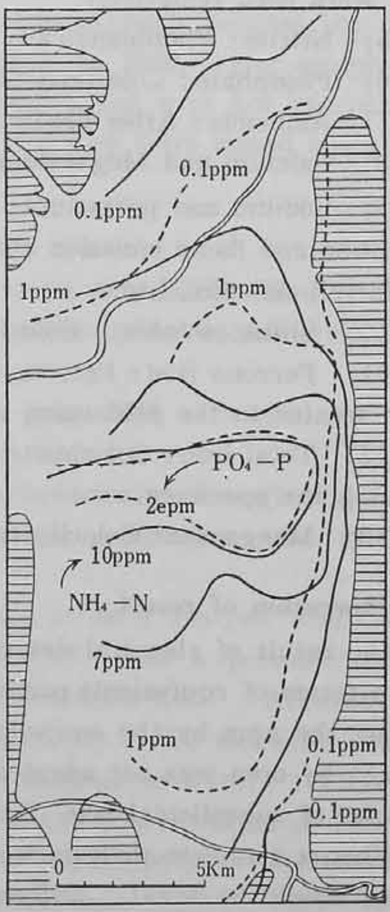

Fig. 5. Generalized ammonia and phosphate map of the *shallow well*.

Although not enough data are available for detailed maps, there are enough so that the pattern can be drawn with some confidence. The main feature of the pattern is a gradual increase in each of the constituents from low values in the surrounding hilly lands to high values in the area of central low land.

(1) Alkalinity (Fig. 4) : In the southern area, low alkalinity line of 2 epm stretches from the junction of the Yamato and Ishi rivers to the northwest. The

pattern suggests that the river-bed water of the rivers is supplying the groundwater to the Upper Pleistocene formations of this area. The Yamato River, the downstream of which was excavated in recent times, had been flowing to the north in former times. As for the northern area, such type of replenishment of groundwater as is infered in the southern area has not been defined. A few words may be said about the circumstance: (1) The alkalinity map in the northern area and the low content of natural tritium (ref. Table 2-10, N-50 m and N-100 m) make it possible to deny the replenishment. (2) Low silica content, for example, of 25-30 ppm (ref. Table 2-3, Group-B) suggests the likelihood of the replenishment, on the contrary. The analyses of surface waters of the Yodo, Yamato, and Ishi rivers are shown in Table 2-11.

There are pronounced high values of alkalinity (4~6 epm) in the central reagions of this area. A marked tendency to increase alkalinity with groundwater flow is well accepted, and the alkalinity which shows the concentration of bicarbonate ion is produced by the decomposition of organic matter in ground (FOSTER, 1950: SUGISAKI, 1962). Accordingly, the groundwater flow in those regions must be very slow or stagnant. It seems that the pumping up of such groundwater plays one reason of a severe ground subsidence in this area.

(2) Chloride (Fig. 4): The zone of high chloride water shown by the isochlor pattern of 100 ppm lies along north to south trend in the northern part of central Eastern Osaka. The higher values of chloride appered within the isochlor are ranged from 500 to 800 ppm. Chloride in this area is not supposed to be depend on the sea water intrusion because of the following reasons. (1) High chloride zone does not connected with the western area. (2) Chloride does not increase year after year. (3) Groundwater with high chloride sometimes occurs in a deeper stratum. (4) Alteartion of water quality due to the contanination of sea water recognized with the grondwater in Western Osaka (TSURUMAKI, 1962) is not seen in this area. (5) Contents of natural tritium in the high chloride groundwater in this area are usually low (1. 9, 2. 7, 4. 0 in T.U. unit). As a result, it can be said that the source of chloride in this area is connate sea water. Chloride may be present in resistates as the result of inclusion of connate water, and is to be expected in any incompletely leached deposit laid down under the sea or in a closed basin where chloride was present (HEM, 1959, p. 104). Accordingly, the distribution of chloride in groundwater may offer some interesting explanation for the underground structure of the basin. More detailed consideration of the chloride distribution will be dealt presently in the later chapter.

(3) Ammonium and phosphate (Fig. 5): The general pattern of the two ions is that of a progressive increase from the marginal regions to the central region. Nitrogen and phosphorus are regarded as to be derived from decomposition of organic matter contained in the marine clayey stratum. Therefore,these maps represent the distribution of the younger marine formations in this area.

## Distribution of Chloride with Depth

Of the various ions analyzed, chloride has proved the most useful for three reasons. (1) From geochemical point of view, chloride ion is not complicated by exchange reaction or by precipitation from solution. (2) From geological point of view, chloride has interesting meaning as described above. (3) Water containing much chloride is poor for all sides of utilization.

### A. Introductory research.

(1) Relations among depth, temperature, and chloride.

In order to investigate chloride distribution with depth, it is necessary to determine the depth zone in which water enters the well. The relationships between the depth zone which was identified from the casing record and water temperature, the temperature and chloride content of the water-sample taken from the well were examined for five reagions in this area, and then the general features of chloride profiles were drawn in 1967 (TSURUMAKI).

(2) Electric log.

Electric log is a useful method for locating salt-water leaks in water wells. Resistivity logs were performed at two localities with the different electrode spacings, one of which is nearly equal to the diameter of the bore hole and the other is three times of it. The results are shown in Fig. 6. The log of western Neyagawa indicates that the salty water locates at the depth of 60 m, and southern Kawachi at 150~200 m.

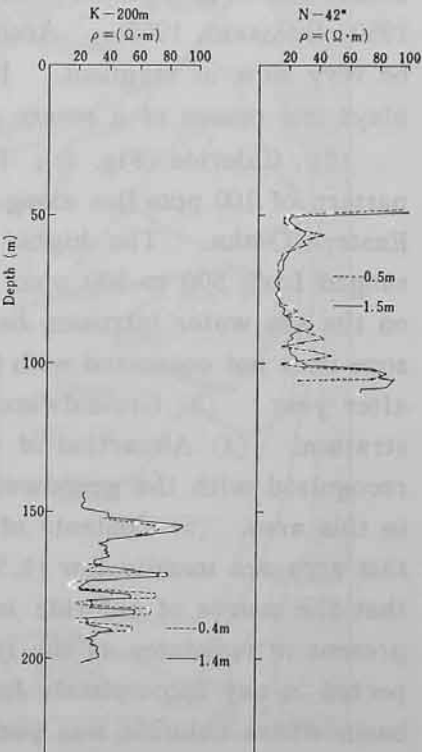

Fig. 6. Resistivity logs.
* measured by Nippon Sakusen Tanko Co.,

(3) Leaching test of core-sample.

The boring core samples taken by the double core tube and carefully stored must preserve the pore water at the depth of sample. Extraction and analysis of chloride ion in the sandy samples obtained from the test holes named OD-3 and OD-6 were performed with the following procedure. Sample in wet state was treated with 0.5N potasium nitrate solution of the same weight for 2 hours at a room temperature. After standing with several times of stirring, the suspension was filtered off, and the filtrate was submitted for analysis. Colorimetric method using mercuric nitrate and VOLHARD's titrimetric method were adopted in accordance with concentration. The resulte were expressed in ppm of chloride of the filrate, and shown in Fig. 2. OD-6 had the samples contained high chloride at the depth of

150 to 180 m, whereas none of the samples of high chloride appeared in OD-3.

(4) Variation of chloride with time.

Seasonal or annual variations of the water quality observed at the well group of southwest Daito suggested the chloride variation with depth. Fig. 7 shows the variation of chloride and water temperature. The variation are often observed after the repair of well by swabbing. In the case of the wells of D-16, 17, 18, and 19, increment of chloride is accompanied by rising temperature. In contrast, well of D-20 shows decrement of chloride in close accordance with rising temperature. These wells have screens at several different depths ranging from 60 to 290 m as shown in line-C of Fig. 9, and so, the well water is the mixture of groundwaters of different depths, and the ratios of mixing are variable in every well and at an interval of time. The study of the relations makes it possible to allocate the waters of high and low chloride to the three zones as following; the shallow zone is low, the middle zone is high, and the deeper zone is low in chloride content.

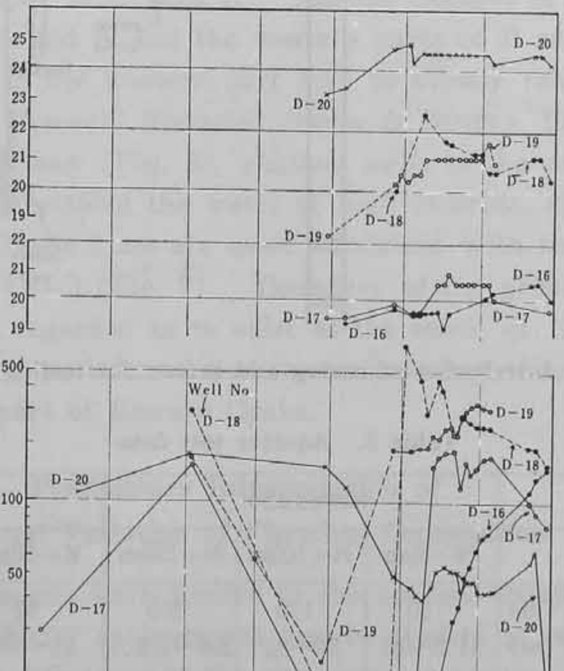

Fig. 7. Variation of chloride and temperature with time, at Daito well group.

(5) Test well.

The results mentioned above have formed a fundamental guiding data for solving the chloride distribution with depth, but do not clarify the actual chloride concentration of groundwater which lies in ground. They reveal only the comparative values of each of the zones. In order to ensure the chemical quality and the hydraulic characteristic of the aquifer individually, two groups of test wells which were constructed so that water could enter from a specified aquifer were established at Niwakubo and Konoike, and they were named N-50m, -100m, -250m, and K-50m, -100m, -200m. Driller's well logs and casing records are illustrated in Fig. 2 and 8, and the results of analysis and pumping test are shown in Table 2-10, and 3, respectively. Niwakubo test wells located in northern Moriguchi may be looked upon as representative of the northern part of this area, and Konoike test wells

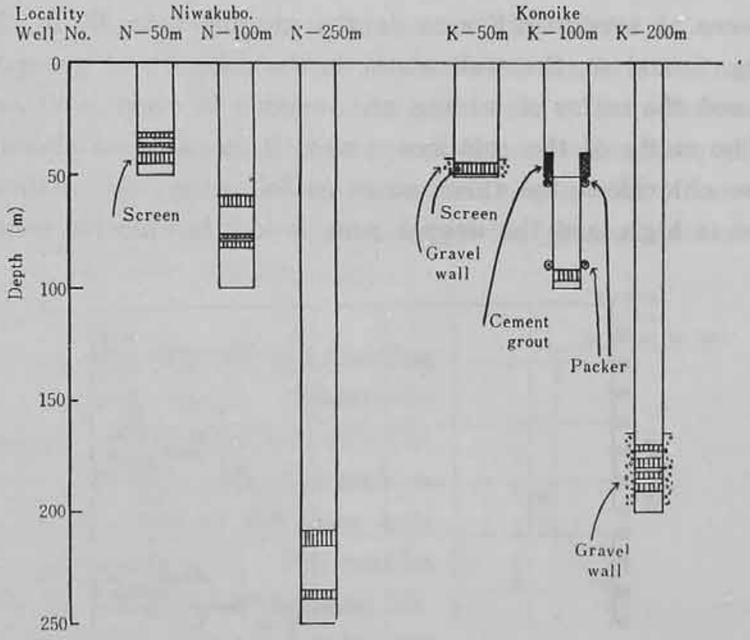

Fig. 8. Installation of casing and screen for testing wells.

Table 3. Aquifer test data

| Locality | Niwakubo | | | Konoike | | |
|---|---|---|---|---|---|---|
| Well No. | N—50m | N—100m | N—250m | K—50m | K—100m | K—200m |
| Total Depth (m) | 50 | 100 | 250 | 51 | 100 | 200 |
| Depth of Perforation (m) | 31.5∼45 | 59∼82 | 208∼238.5 | 45∼50 | 92∼97 | 175∼193 |
| Length of Perforation (m) | 10 | 10 | 11·5 | 5 | 5 | 13 |
| Static Level (m) | 30.46 | 32.07 | 27.06 | 33.37 | 41.72 | 42.70 |
| Pumping Level (m) | 34.40 | 35.02 | 30.05 | 40.53 | 48.31 | 45.05 |
| Specific Capacity ($m^3$/day/m) | 150 | 200 | 170 | 100 | 30 | 300 |
| Coefficient of Transmissibility | | | | | | |
| Drawdown ($m^2$/sec) | $3.1\times10^{-3}$ | $5.4\times10^{-3}$ | $5.9\times10^{-3}$ | $8\times10^{-4}$ | $3.8\times10^{-4}$ | $1.3\times10^{-2}$ |
| Recovery | $2.9\times10^{-3}$ | $8.3\times10^{-3}$ | $5.1\times10^{-3}$ | $5.6\times10^{-4}$ | $3.4\times10^{-4}$ | $8.8\times10^{-3}$ |
| Coefficient of Permeability (m/sec) | $3.0\times10^{-4}$ | $6.8\times10^{-4}$ | $4.8\times10^{-4}$ | $1.1\times10^{-4}$ | $7.2\times10^{-5}$ | $8.5\times10^{-4}$ |
| Date of Test | Dec. 1967 | | | Mar. 1968 | | |

as that of the central part of it. The N-50m and −100m wells at Niwakubo and the K-200 m well at Konoike yielded the water of high chloride, concentration of which were ranged from 160 to 210 ppm.

### B. Profile of chloride.

Fig. 9 shows three profiles of chloride content in groundwater.

(1) Line-A is a profile along the south of the Yodo River. The groundwater of high chloride prevails at the depth zone of 40 to 80m. The zone coincides with the Uper Pleistocene formations distributed in this region as recognized from Fig. 2. At the northeastern part of this line, high chloride water is not seen in the shallow zone, but the deeper well (N-31) whose record of casing is not clear, yields the high chloride.

(2) Line-B shows the profile along Keihan railway line.

(3) Line-C is the profile along Katamachi railway line.

There are some similarities between the profiles of B and C, but the depth of high chloride zone is deeper in C than B. Abrupt changes of chloride are seen at the eastern parts of A and B, and the western parts of B and C. The discontinuity of water quality in the western part may be closely related with the geological structure called Uemachi Elevation (IKEBE & HUZITA. 1966).

As shown in chloride map (Fig. 6), *shallow wells* in the southern regions of Eastern Osaka have never yielded the water of high chloride, and this holds true for the *deeper wells*. Those facts are quite consistent with the leaching test of core sample taken from OD-3 (Fig. 2). Boundary of the groundwater bodies of low and high chloride is regarded as to exist at the south of line-C. Owing to the discontinuity, it would be inferred that the tectonic line of northeast trend lies water of in the central part of Eastern Osaka.

## Preliminary Interpretation of Regional Variation of Chemical Composition

The foregoing discussions were limited to the spacial distribution of selected constituents in water. Water analyses can also be studied in various ways to demonstrate similarity and difference of the chemical composition. In this chapter the dominant ions present in the water are examined and interpreted using the most prevailing method of illustration for chemical-quality data.

Trilinear plotting system proposed by PIPER (1944) is one of the efficient methods which enable to illustrate a large number of chemical analyses. The trilinear diagram illustrates the various percentages of anions and cations in the two triangular fields and a combined position of all major ions in the diamond-shaped field. Percentages of anions and cations are based on total equivalents per million of the major ions. In the PIPER's original diagram, the diamond-shaped field indicates the character of water as represented by the relationships among $Na+K$, $Ca+Mg$, $CO_3+HCO_3$, and $Cl+SO_4$ ions. The waters in this area, however, contain

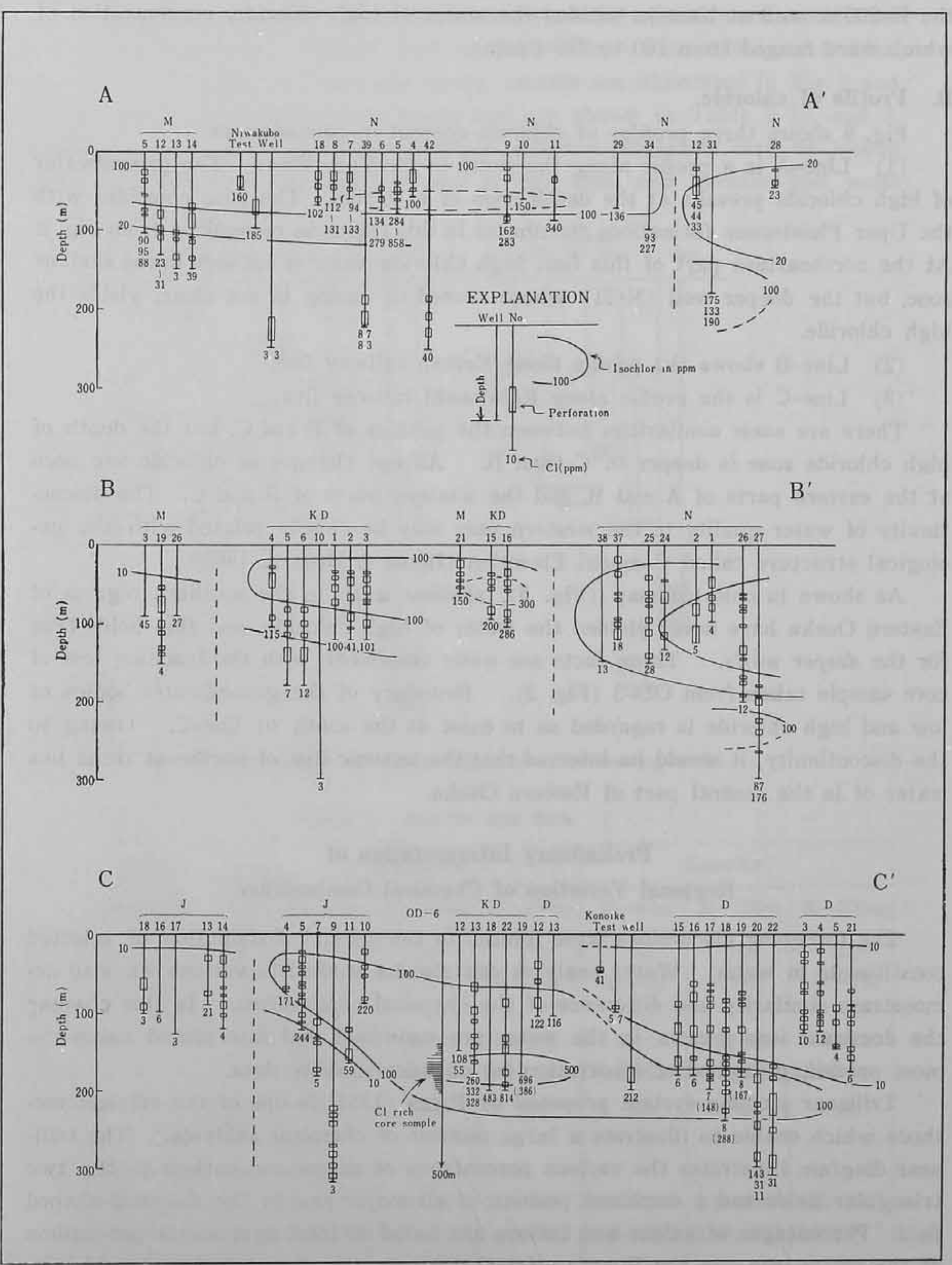

Fig. 9. Profiles of chloride concentration. Location of profiles is shown on Fig. 3.

considerable amounts of phosphate, ammonia, iron and manganese, and these ions should not be overlooked for calculating the total concentration. In this report the relationships are represented by the combination of;

$Na+K+NH_4$, $Ca+\underline{Mg+Fe+Mn}$.
$H\,CO_3$, $Cl+\underline{SO_4+PO_4}$.

Carbonate is not determined in most waters in this area. The combinations of ions underlined are used for the cation and anion triangular fields. The arrangement of constituents mentioned above is a matter of convenience, and has no severe geochemical meaning. The arrangements of Na, Ca and Mg (Sugisaki, 1962), and $Fe^{2+}+NH_4^+$, $Ca^{2+}+Mg^{2+}$ and $Na^++K^+$ (Konishi, 1966) are found in literatures. In the diamond-shaped field concentrations of dissolved matter are usually represented by the circles, the radius of which are proportional to the concentrations. This method of illustration requires considerable space for plotting a single one water-sample, and is inadequate for plotting a number of the analyses of similar composition. Each of the diagrams shown in Fig. 10 contain from 15 to 20 water analyses. The concentrations are indicated by epm unit near by the diagram.

Fig. 10 illustrates the representative water analyses which are obtained from the northern area of Eastern Osaka basin. The water-analysis data are classified into three regions and five groups.

(1) Analyses of waters taken from Hokusetsu area are shown in Diagram-A. Along the foot zone of northern hilly land, both of *shallow* and *deeper wells* yield the waters which are low in total mineral content. The waters are high in the ratio of bivalent cations ($Ca+Mg+\cdots\cdots$) to total cations, and high in sulfate content except for *deeper wells*. This type of water quality is close agreement with that the hills and the foot zone may by phisiographically taken as the intake area of groundwater for this area and, perhaps, partly in Eastern Osaka. In the southern part of this area, Settsu, the concentration of total soluble matters varies widely than the above region. Of them, the waters of high chloride may be accounted for the transitional type between the above type and the type of next group. The waters of low chloride in this region are high in the ratio of monovalent cations ($Na+K+NH_4$) to total cations, which fact means that the waters are soft. Sulfate is scarce in both of the high and low chloride waters and this fact is attributed to the reduction of sulfate accompanied by the inactive flow or stagnation of groundwater (Foster, 1950; Cederstrom, 1946).

(2) The *shallow wells* in northern Moriguchi and western Neyagawa yield the water of high chlaride with a range of 100 to 300 ppm. Water analyses of this region are shown in Diagram-B. Dominant consituents of the water are chloride and sodium.

(3) The *deeper wells* in the same region as above and the *shallows well* in the southern Neyagawa yield the water of low chloride and low alkalinity. The difference in the water quality between them is the cationic composition as seen in Diagram-C. The waters of *deeper well* which are concieved to be drawn from

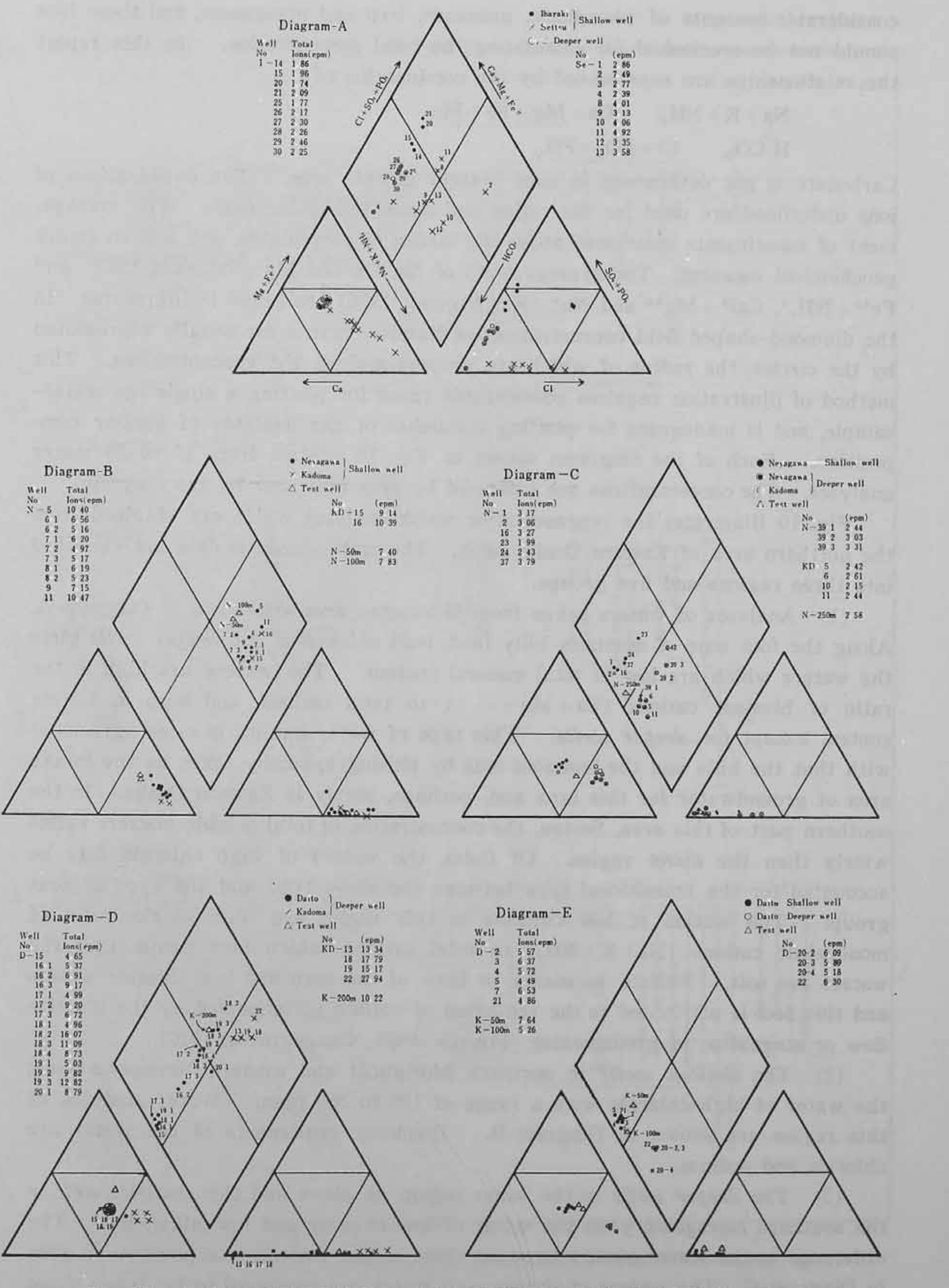

Diagram-A

| Well No | Total Ions(epm) |
|---|---|
| I−14 | 1 86 |
| 15 | 1 96 |
| 20 | 1 74 |
| 21 | 2 09 |
| 25 | 1 77 |
| 26 | 2 17 |
| 27 | 2 30 |
| 28 | 2 26 |
| 29 | 2 46 |
| 30 | 2 25 |

| No | (epm) |
|---|---|
| Se−1 | 2 86 |
| 2 | 7 49 |
| 3 | 2 77 |
| 4 | 2 39 |
| 8 | 4 01 |
| 9 | 3 13 |
| 10 | 4 06 |
| 11 | 4 92 |
| 12 | 3 35 |
| 13 | 3 58 |

Diagram-B

| Well No | Total Ions(epm) |
|---|---|
| N−5 | 10 40 |
| 6 1 | 6 56 |
| 6 2 | 5 16 |
| 7 1 | 6 20 |
| 7 2 | 4 97 |
| 7 3 | 5 17 |
| 8 1 | 6 19 |
| 8 2 | 5 23 |
| 9 | 7 15 |
| 11 | 10 47 |

| No | (epm) |
|---|---|
| KD−15 | 9 14 |
| 16 | 10 39 |
| N−50m | 7 40 |
| N−100m | 7 83 |

Diagram−C

| Well No | Total Ions(epm) |
|---|---|
| N−1 | 3 17 |
| 2 | 3 06 |
| 16 | 3 27 |
| 23 | 1 99 |
| 24 | 2 43 |
| 37 | 3 79 |

| No | (epm) |
|---|---|
| N−39 1 | 2 44 |
| 39 2 | 3 03 |
| 39 3 | 3 31 |
| KD 5 | 2 42 |
| 6 | 2 61 |
| 10 | 2 15 |
| 11 | 2 44 |
| N−250m | 2 58 |

Diagram−D

| Well No | Total Ions(epm) |
|---|---|
| D−15 | 4 65 |
| 16 1 | 5 37 |
| 16 2 | 6 91 |
| 16 3 | 9 17 |
| 17 1 | 4 99 |
| 17 2 | 9 20 |
| 17 3 | 6 72 |
| 18 1 | 4 96 |
| 18 2 | 16 07 |
| 18 3 | 11 09 |
| 18 4 | 8 73 |
| 19 1 | 5 03 |
| 19 2 | 9 82 |
| 19 3 | 12 82 |
| 20 1 | 8 79 |

| No | (epm) |
|---|---|
| KD−13 | 13 34 |
| 18 | 17 79 |
| 19 | 15 17 |
| 22 | 27 94 |
| K−200m | 10 22 |

Diagram−E

| Well No | Total Ions(epm) |
|---|---|
| D−2 | 5 57 |
| 3 | 6 37 |
| 4 | 5 72 |
| 5 | 4 49 |
| 7 | 6 53 |
| 21 | 4 86 |
| K−50m | 7 64 |
| K−100m | 5 26 |

| No | (epm) |
|---|---|
| D−20 2 | 6 09 |
| 20 3 | 5 89 |
| 20 4 | 5 18 |
| 22 | 6 30 |

Fig. 10. Analyses represented by three points plotted in trilinear diagram.

the aquifers correlated to the strata of the Lower Part of Osaka group are soft by comparison with the shallow waters. As for the correlation, it is mentiond that the depth of the uppermost perforation of the wells of N-250m, N-39 and KD-10 is deeper than the depth of the boundary between the Upper and Lower Osaka group at OD-4.

(4) Diagram-D illustrates the chemical analyses of the water samples obtained from the *deeper wells* in the region of southern Kadoma and eastern Daito. The chloride concentration in the water samples of D-16$\sim$20 varies widely with time as already shown (Fig. 9), and in the diamond-shaped uper field the analyses plot on nearly a straight line. When analyses represent two original waters and their mixtures, the analyses will plot on a straight line. On the basis of such informations, it appears well established that the waters are the mixtures of two kinds of groundwaters; namely shallow water of high alkalinity and deeper water of high chloride. In the cationic triangular diagram the analyses plot on a limited field, therefore, those waters are assumed to be similar in cationic composition. The waters taken from the wells of D-16$\sim$20 have higher content of divalent cations than those from the wells of KD-18, 19 and 20, which fact means that the former is harder than the latter. As for the waters of high chloride in this region, it may be said that the deeper the aquifer lies from north to south, the harder the water becomes.

(5) The analyses of six *shallow wells* and two *deeper wells* which have the depth of 300m are illustrated in Diagram-E. All the waters are high in alkalinity

Table 4. Summary of water quality

| Occurrence | | | Water Quality | | |
|---|---|---|---|---|---|
| | | | Total Ions (epm) | Predominant Ions | |
| Region | Group* | Sub-group | | Anions | Cations |
| Hokusetsu | A | Ibaraki | 1.8$\sim$ 2.5 | $HCO_3+SO_4$ | Ca (+Mg+Fe) |
| | | Settsu | 2.4$\sim$ 7.5 | $HCO_3$ or Cl | Na |
| North of Eastern Osaka | B | shallow | 5.0$\sim$10.5 | Cl | Na |
| | C | shallow | 2.0$\sim$ 3.8 | $HCO_3$ | Ca+Mg |
| | | deeper† | 2.2$\sim$ 3.6 | $HCO_3$ | Na |
| Middle of Eastern Osaka | D | deeper | 5.0$\sim$18 | Cl or Cl $\rightleftarrows$ $HCO_3$ | Ca+Mg |
| | E | shallow | 4.5$\sim$ 7.6 | $HCO_3$ | Ca+Mg |
| | | deeper†† | 5.2$\sim$ 6.3 | $HCO_3$ | Na |

* Group name refers to Table 2 (Analytical table) and diagram in Fig. 10.

† The deeper wells are in the same region of group-B.

†† The depth of wells are deeper than the wells of group-D.

and low in chloride. The waters taken from *shallow wells* are harder than those from *deeper wells*, and the fact was seen in Diagram-C also. As for the waters of low chloride, there is a tendency that the hardness in water is lessing with the increase in the depth of aquifer.

Thus the variations in chemical quality derived from the differences in the location and the depth of wells were summarized in Table 4.

## Summary and Conclusion

Groundwater samples taken from the wells in the Hokusetsu and the Eastern Osaka area have been analyzed since 1966.

Water analyses of the shallow wells the depths of which are less than 150 m are illustrated by the maps showing the regional distribution of alkalinity, chloride, ammonia and phosphate. These maps indicate the career of groundwater as follows; (1) Alkalinity map suggests that the river-bed water of the Yamato and Ishi rivers is supplying the artesian groundwater to the Upper Pleistocene formations in the southern region of Eastern Osaka. (2) Chloride map indicates that the groundwater of the central part of the area is contaminated with connate saline water. (3) Ammonia and phosphate, and alkalinity maps show that the groundwater in the central region is confined by the younger marine formation.

On the basis of the several preliminary reseaches, the profiles of chloride concentration in the groundwater were compiled from the water analyses of the shallow- and deeper wells in the northern regions of the area. The profiles and the chloride map indicate markedly the discontinuities of water quality, and this fact suggestes the existence of two tectonic lines. One which lies in the western region and runs parallel to Uemachi upland is connected with the tectonic movement which produced the upland, and the other lies in the central region, runnig across the basin from northeast to southwest. The latter is merely a matter of surmise, and is not yet connected with any of the tectonic movement. Such an underground structure as this must be restraining the flow of groundwater.

The dominant ions in the water were examined using the trilinear diagram which is wellknown as PIPER'S key diagram and which is extensively used for the comparison of water analyses. As a result, it has led to the clarification of characters of groundwater due to the difference of occurrence, such as region and depth, as follows; (1) Along the foot zone of the Senriyama hills the shallow wells and deeper wells yield the waters characterized by low alkalinity and high sulfate. (2) The waters of high chloride increase their hardness (Ca+Mg) with depth of aquifer. (3) The waters of low chloride increase their sodium and potassium concentrations with depth.

There remains the problem of how to interpret these results geochemically and hydrologically. This article is a preliminary report and a fuller account of the data will be discussed together with the result of tritium measurement.

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In this research, field and laboratory works were carried out through the cooperation by the author and Mr. M. NAGASAWA of Osaka Prefectural University, and each one had his own alloted regions or wells for the research. The analyses accompl shed by NAGASAWA are quoted in Table 2 with the notation of "M. N.". His contribution to this reseach has been very great and the author wishes to express deepest appreciation to him. The author is also very grateful to Dr. T. OCHIAI who is executing the tritium dating.

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## Table 2－1. Chemical analyses of groundwaters from Hokusetsu area ( 1 )

| Group | A | | A | | A | | A | | A | | A | | A | | A | | A | | A | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Well No. | I－14 | | I－15 | | I－20 | | I－21 | | I－25 | | I－26 | | I－27 | | I－28 | | I－29 | | I－30 | |
| Depth of Perforation(m) | 47～116 | | 26～137.5 | | 40～109.5 | | 30～111 | | 50～144 | | 110～172 | | 114～186.5 | | 185～234 | | 201～240 | | 190～276 | |
| Total Depth (m) | 130 | | 140 | | 120 | | 120 | | 154.5 | | 182 | | 188.5 | | 235.5 | | 250 | | 293 | |
| Date of Collection | Mar. 12, '68 | | Mar. 12, '68 | | Mar. 15, '68 | | Mar. 15, '68 | | Mar. 13, '69 | | Mar. 13, '69 | | Mar. 13, '69 | | Mar. 13, '69 | | Mar. 13, '69 | | Mar. 13, '69 | |
| Temp. (℃) | 16.8 | | 16.8 | | 16.1 | | 17.4 | | 16.1 | | 16.1 | | 16.2 | | 17.2 | | 17.2 | | 17.3 | |
| EC. (μ℧.18℃) | 152 | | 167 | | 148 | | 173 | | 137 | | 164 | | 159 | | 162 | | 175 | | 163 | |
| pH | 6.3 | | 6.2 | | 6.1 | | 6.2 | | 6.3 | | 6.4 | | 6.7 | | 6.6 | | 6.6 | | 6.6 | |
| $HCO_3$ | ppm | epm | ppm | epm | ppm | epm | ppm | epm | ppm | epm | ppm | epm | ppm | epm | ppm | epm | ppm | epm | ppm | epm |
| Cl | 63.6 | 1.042 | 64.8 | 1.062 | 47.3 | 0.776 | 53.1 | 0.870 | 70.5 | 1.156 | 88.6 | 1.452 | 96.4 | 1.580 | 103.2 | 1.692 | 105.5 | 1.730 | 104.2 | 1.708 |
| $SO_4$ | 3.69 | 0.104 | 3.19 | 0.090 | 4.41 | 0.124 | 4.96 | 0.140 | 4.58 | 0.129 | 3.69 | 0.104 | 6.77 | 0.141 | 4.20 | 0.119 | 4.34 | 0.122 | 4.20 | 0.118 |
| $NO_3$－N | 33.0 | 0.687 | 39.3 | 0.818 | 40.4 | 0.842 | 52.5 | 1.092 | 22.5 | 0.468 | 29.0 | 0.695 | 28.0 | 0.583 | 21.5 | 0.448 | 29.5 | 0.615 | 20.5 | 0.427 |
| $PO_4$－P | 0.45 | 0.032 | 0.051 | 0.004 | 0.034 | 0.002 | 0.02 | 0.001 | 0.045 | 0.003 | 0.04 | 0.003 | 0.045 | 0.003 | 0.045 | 0.003 | 0.050 | 0.004 | 0 | 0 |
| Total Anions(A) | 0.134 | 0.013 | 0.056 | 0.005 | 0.075 | 0.007 | 0.015 | 0.001 | 0.098 | 0.009 | 0.082 | 0.008 | 0.125 | 0.012 | 0.060 | 0.006 | 0.095 | 0.009 | 0.10 | 0.010 |
| | | 1.878 | | 1.979 | | 1.751 | | 2.104 | | 1.765 | | 2.172 | | 2.319 | | 2.268 | | 2.480 | | 2.263 |
| $NH_4$－N | 0.078 | 0.005 | 0.012 | 0.001 | 0.023 | 0.002 | 0.039 | 0.003 | 0.14 | 0.010 | 0.13 | 0.009 | 0.15 | 0.011 | 0 | 0 | 0.093 | 0.007 | 0.135 | 0.010 |
| Na | 9.7 | 0.422 | 9.4 | 0.408 | 8.6 | 0.374 | 9.3 | 0.403 | 9.7 | 0.421 | 10.8 | 0.470 | 11.8 | 0.513 | 11.7 | 0.508 | 12.8 | 0.557 | 11.7 | 0.508 |
| K | 3.42 | 0.08 | 3.55 | 0.091 | 2.58 | 0.066 | 2.83 | 0.073 | 2.95 | 0.075 | 3.13 | 0.080 | 2.90 | 0.074 | 2.76 | 0.071 | 2.59 | 0.066 | 2.78 | 0.071 |
| Ca | 12.08 | 0.604 | 13.55 | 0.677 | 11.48 | 0.574 | 14.50 | 0.725 | 9.67 | 0.483 | 12.90 | 0.643 | 13.13 | 0.656 | 14.53 | 0.723 | 15.30 | 0.763 | 14.08 | 0.703 |
| Mg | 6.72 | 0.552 | 7.82 | 0.645 | 6.14 | 0.506 | 6.93 | 0.571 | 6.58 | 0.542 | 7.85 | 0.646 | 7.85 | 0.646 | 7.32 | 0.602 | 8.03 | 0.660 | 7.13 | 0.587 |
| FeⅡ | 4.08 | 0.146 | 3.00 | 0.107 | 5.18 | 0.185 | 8.10 | 0.290 | 5.90 | 0.221 | 7.88 | 0.282 | 9.34 | 0.335 | 8.42 | 0.301 | 9.46 | 0.336 | 8.60 | 0.308 |
| Mn | 0.71 | 0.026 | 0.62 | 0.023 | 0.35 | 0.012 | 0.45 | 0.016 | 0.65 | 0.023 | 1.08 | 0.039 | 1.28 | 0.047 | 1.26 | 0.045 | 1.28 | 0.047 | 1.13 | 0.041 |
| Total Cations(C) | | .843 | | 1.952 | | 1.719 | | 2.081 | | 1.775 | | 2.169 | | 2.282 | | 2.252 | | 2.436 | | 2.228 |
| $SiO_2$ | 66.8 | | 61.5 | | 52.2 | | 47.8 | | 58.2 | | 60.0 | | 53.6 | | 59.4 | | 56.2 | | 61.0 | |
| (A)/(C) | | 1.02 | | 1.015 | | 1.02 | | 1.01 | | 0.995 | | 1.00 | | 1.02 | | 1.01 | | 1.02 | | 1.01 |
| Ca/Na | | 1.43 | | 1.66 | | 1.54 | | 1.80 | | 1.15 | | 1.37 | | 1.28 | | 1.425 | | 1.37 | | 1.38 |
| K/Na | | 0.21 | | 0.22 | | 0.18 | | 0.18 | | 0.18 | | 0.17 | | 0.14 | | 0.14 | | 0.12 | | 0.14 |
| Mg/Ca | | 0.91 | | 0.95 | | 0.88 | | 0.79 | | 1.12 | | 1.005 | | 0.985 | | 0.83 | | 0.865 | | 0.835 |
| Analyst | M.Tsurumaki | | M.T. | | M.T. | | M.T. | | M.T. | | M.T. | | M.T. | | M.T. | | M.T. | | M.T. | |

Table 2－2. Chemical analyses of groundwaters from Hokusetsu area (2)

| Group | A | | A | | A | | A | | A | | A | | A | | A | | A | | A | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Well No. | Se－1 | | Se－2 | | Se－3 | | Se－4 | | Se－8 | | Se－9 | | Se－10 | | Se－11 | | Se－12 | | Se －13 | |
| Depth of Perforation(m) | 57～143 | | 44～134 | | 56.5～118.5 | | 78～208.5 | | 21～130 | | 22.5～130.5 | | 34～101 | | 49.5～142 | | 38.5～123.5 | | 53～167 | |
| Total Depth(m) | 150 | | 150 | | 120 | | 230 | | 140 | | 135 | | 106 | | 150 | | 130 | | 180 | |
| Date of Collection | Mar. 1, '68 | | Mar. 1, '68 | | Mar. 1, '68 | | Mar. 1, '68 | | Apr. 3, '68 | | Apr. 3, '68 | | Apr. 3, '68 | | Apr. 3, '68 | | Apr. 3, '68 | | Apr. 3, '68 | |
| Temp. (℃) | 16.9 | | 16.4 | | 16.9 | | 18.0 | | 18.3 | | 18.5 | | 18.3 | | 17.3 | | 17.0 | | 17.6 | |
| EC. ($\mu$℧ .18℃) | 335 | | 690 | | 222 | | 187 | | 365 | | 275 | | 355 | | 460 | | 290 | | 315 | |
| pH | 6.8 | | 7.1 | | 6.7 | | 6.7 | | 7.0 | | 7.0 | | 7.2 | | 6.8 | | 7.2 | | 7.2 | |
| | ppm | epm | ppm | epm | ppm | epm | ppm | eom | ppm | epm | ppm | epm | ppm | epm | ppm | epm | ppm | epm | ppm | epm |
| $HCO_3$ | 125.1 | 2.050 | 141.3 | 2.317 | 137.3 | 2.251 | 136.8 | 2.243 | 123.0 | 2.016 | 124.9 | 2.047 | 152.6 | 2.501 | 128.2 | 2.102 | 144.3 | 2.366 | 133.1 | 2.182 |
| Cl | 27.42 | 0.772 | 174 | 4.91 | 14.37 | 0.406 | 3.30 | 0.093 | 67.95 | 1.915 | 35.59 | 1.004 | 51.61 | 1.456 | 97.73 | 2.756 | 32.26 | 0.908 | 45.59 | 1.286 |
| $SO_4$ | 2.46 | 0.051 | 10.5 | 0.218 | 5.5 | 0.115 | 2.14 | 0.045 | 3.96 | 0.083 | 3.04 | 0.063 | 0.72 | 0.015 | 1.38 | 0.029 | 2.18 | 0.045 | 2.28 | 0.048 |
| $NO_3$－N | 0 | 0 | 0.01 | 0.001 | 0 | 0 | 0 | 0 | 0.076 | 0.005 | 0.032 | 0.002 | 0.097 | 0.007 | 0.059 | 0.004 | 0.033 | 0.002 | 0.092 | 0.006 |
| $PO_4$－P | 0.265 | 0.026 | 0.258 | 0.025 | 0.082 | 0.008 | 0.013 | 0.001 | 0.21 | 0.020 | 0.24 | 0.023 | 0.78 | 0.075 | 0.26 | 0.025 | 0.67 | 0.065 | 0.31 | 0.030 |
| Total Anions(A) | | 2.899 | | 7.471 | | 2.780 | | 2.382 | | 4.039 | | 3.139 | | 4.054 | | 4.916 | | 3.386 | | 3.552 |
| $NH_4$－N | 0.95 | 0.069 | 0.84 | 0.060 | 0.45 | 0.032 | 0.31 | 0.022 | 2.13 | 0.152 | 1.65 | 0.118 | 1.09 | 0.078 | 2.22 | 0.159 | 0.93 | 0.067 | 1.87 | 0.133 |
| Na | 25.3 | 1.100 | 127 | 5.52 | 16.8 | 0.731 | 10.8 | 0.470 | 33.2 | 1.443 | 27.8 | 1.209 | 56.0 | 2.435 | 40.6 | 1.765 | 41.0 | 1.783 | 33.5 | 1.457 |
| K | 6.05 | 0.155 | 7.3 | 0.19 | 4.8 | 0.12 | 4.7 | 0.12 | 10.2 | 0.261 | 8.7 | 0.222 | 5.8 | 0.148 | 10.8 | 0.276 | 6.6 | 0.169 | 9.2 | 0.235 |
| Ca | 12.85 | 0.642 | 15.93 | 0.796 | 16.27 | 0.843 | 14.48 | 0.724 | 18.65 | 0.932 | 13.80 | 0.690 | 11.64 | 0.582 | 24.26 | 1.213 | 10.53 | 0.527 | 16.52 | 0.826 |
| Mg | 8.85 | 0.728 | 9.90 | 0.814 | 10.21 | 0.840 | 9.06 | 0.745 | 14.28 | 1.074 | 9.55 | 0.786 | 7.24 | 0.596 | 16.22 | 1.335 | 7.87 | 0.657 | 10.13 | 0.836 |
| FeⅡ | 2.96 | 0.106 | 3.20 | 0.115 | 4.86 | 0.174 | 7.65 | 0.274 | 2.76 | 0.099 | 2.20 | 0.079 | 6.00 | 0.215 | 4.24 | 0.152 | 3.18 | 0.114 | 2.67 | 0.096 |
| Mn | 0.41 | 0.015 | 0.48 | 0.017 | 0.845 | 0.031 | 1.15 | 0.042 | 0.745 | 0.027 | 0.60 | 0.022 | 0.525 | 0.019 | 0.79 | 0.029 | 0.395 | 0.014 | 0.39 | 0.014 |
| Total Cations(C) | | 2.814 | | 7.512 | | 2.771 | | 2.397 | | 3.988 | | 3.126 | | 4.073 | | 4.929 | | 3.321 | | 3.597 |
| $SiO_2$ | 45.2 | | 40 | | 51.6 | | 62.4 | | 54 | | 44.3 | | 34.5 | | 42.5 | | 46.5 | | 53 | |
| (A)/(C) | | 1.03 | | 0.995 | | 1.00 | | 0.99 | | 1.01 | | 1.00 | | 0.995 | | 1.00 | | 1.02 | | 0.99 |
| Ca/Na | | 0.58 | | 0.14 | | 1.15 | | 1.54 | | 0.65 | | 0.57 | | 0.24 | | 0.69 | | 0.30 | | 0.57 |
| K/Na | | 0.14 | | 0.034 | | 0.17 | | 0.26 | | 0.18 | | 0.18 | | 0.06 | | 0.16 | | 0.095 | | 0.16 |
| Mg/Ca | | 1.13 | | 1.02 | | 0.995 | | 1.03 | | 1.15 | | 1.14 | | 1.02 | | 1.10 | | 1.23 | | 1.01 |
| Analyst | M.T. | | M.T. | | M.T. | | M.T. | | M.T. | | M.T. | | M.T. | | M.T. | | M.T. | | M.T. | |

Table 2－3. Chemical analyses of groundwaters from Eastern Osaka (1)

| Group | B | | B | | B | | B | | B | | B | | B | | B | | B | | B | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Well No. | N－5 | | N－6(1) | | N－6(2) | | N－7(1) | | N－7(2) | | N－7(3) | | N－8(1) | | N－8(2) | | N－9 | | N－11 | |
| Depth of Perforation(m) | 37～62 | | 45～65 | | | | 25～49 | | | | | | 25～49 | | | | 21～86 | | 33～67 | |
| Total Depth(m) | 78.8 | | 75 | | | | 60 | | | | | | 60 | | | | 91 | | 91 | |
| Date of Collection | Apr. 5, '67 | | Sep. 5, '67 | | Nov. 25, '68 | | Dec. 10, '65 | | Dec. 30, '67 | | Dec. 27, '69 | | Feb. 23, '66 | | Nov. 25, '68 | | Oct. 6, '67 | | Oct. 6, '67 | |
| Temp. (℃) | 16.6 | | 17.1 | | 17.1 | | 16.6 | | 16.7 | | 17.5 | | 16.6 | | 17.2 | | 16.8 | | 16.9 | |
| EC. (μ℧.18℃) | 963 | | 600 | | 464 | | 598 | | 445 | | 485 | | 540 | | 479 | | 710 | | 1043 | |
| pH | 7.4 | | 6.9 | | 7.0 | | 7.0 | | 7.1 | | 7.2 | | 7.0 | | 7.0 | | 7.0 | | 7.0 | |
| | ppm | epm | ppm | epm | ppm | epm | ppm | epm | ppm | epm | ppm | epm | ppm | epm | ppm | epm | ppm | epm | ppm | ppm |
| $HCO_3$ | 138.4 | 2.269 | 132.6 | 2.174 | 134.1 | 2.198 | 134.4 | 2.203 | 137.1 | 2.248 | 126.7 | 2.077 | 138.3 | 2.268 | 134.1 | 2.198 | 168.7 | 2.766 | 151.7 | 2.487 |
| Cl | 283.7 | 8.00 | 147.8 | 4.168 | 97.0 | 2.736 | 133.2 | 3.757 | 94.1 | 2.654 | 82.76 | 2.334 | 131.0 | 3.695 | 103 | 2.905 | 148.3 | 4.183 | 272.8 | 7.694 |
| $SO_4$ | 9.4 | 0.196 | 5.4 | 0.113 | 6.6 | 0.138 | 5.5 | 0.115 | 1.18 | 0.046 | 32.8 | 0.683 | 4.5 | 0.094 | 3 | 0.063 | 4 | 0.083 | 8.8 | 0.183 |
| $NO_3-N$ | … | … | … | … | 0.38 | 0.027 | 0.24 | 0.017 | 0.077 | 0.005 | 0 | 0 | 0.24 | 0.017 | 0 | 0 | … | … | 0.09 | 0.006 |
| $PO_4-P$ | 0.26 | 0.025 | 0.363 | 0.035 | 0.46 | 0.044 | 0.35 | 0.034 | 0.255 | 0.025 | 0.59 | 0.058 | 0.31 | 0.030 | 0.48 | 0.047 | 0.84 | 0.080 | 0.32 | 0.030 |
| Total Anions(A) | | 10.49 | | 6.490 | | 5.143 | | 6.126 | | 4.978 | | 5.152 | | 6.104 | | 5.213 | | 7.112 | | 10.40 |
| $NH_4-N$ | 1.20 | 0.086 | 0.90 | 0.064 | 1.01 | 0.072 | 0.85 | 0.061 | 0.95 | 0.068 | 0.955 | 0.068 | 0.86 | 0.061 | 0.72 | 0.051 | 1.26 | 0.090 | 1.25 | 0.089 |
| Na | 158 | 6.87 | 105 | 4.565 | 82.2 | 3.574 | 109 | 4.739 | 77.5 | 3.370 | 74.1 | 3.222 | 107 | 4.652 | 82.1 | 4.004 | 115 | 5.00 | 180 | 7.826 |
| K | 9.4 | 0.240 | 7.3 | 0.187 | 6.48 | 0.166 | 7.6 | 0.194 | 6.6 | 0.169 | 6.5 | 0.166 | 7.8 | 0.199 | 6.65 | 0.170 | 9.2 | 0.236 | 11.5 | 0.294 |
| Ca | 25.22 | 1.261 | 14.20 | 0.710 | 8.88 | 0.444 | 11.38 | 0.568 | 9.68 | 0.484 | 11.56 | 0.578 | 10.74 | 0.536 | 6.26 | 0.313 | 13.70 | 0.685 | 17.80 | 0.890 |
| Mg | 20.64 | 1.700 | 11.70 | 0.963 | 8.84 | 0.727 | 7.39 | 0.608 | 9.32 | 0.766 | 11.05 | 0.909 | 8.71 | 0.716 | 7.49 | 0.616 | 13.06 | 1.073 | 16.49 | 1.356 |
| FeⅡ | 3.48 | 0.127 | 2.97 | 0.106 | 4.56 | 0.163 | 2.40 | 0.087 | 2.9 | 0.106 | 5.74 | 0.205 | 2.50 | 0.091 | 1.76 | 0.063 | 2.35 | 0.084 | 1.36 | 0.049 |
| Mn | 0.745 | 0.027 | 0.725 | 0.026 | 0.72 | 0.026 | 0.55 | 0.020 | | … | 1.225 | 0.045 | 0.50 | 0.018 | 0.59 | 0.021 | 0.655 | 0.023 | 0.73 | 0.026 |
| Total Cations(C) | | 10.31 | | 6.621 | | 5.172 | | 6.277 | | 4.963 | | 5.193 | | 6.273 | | 5.238 | | 7.191 | | 10.53 |
| $SiO_2$ | 27.6 | | 26.3 | | 30.8 | | 24.9 | | 23 | | 25.4 | | 28.6 | | 28.4 | | 25.6 | | 30.2 | |
| (A)/(C) | | 1.02 | | 0.98 | | 0.99 | | 0.975 | | 1.00 | | 0.99 | | 0.97 | | 0.99 | | 0.99 | | 0.99 |
| Ca/Na | | 0.18 | | 0.155 | | 0.12 | | 0.22 | | 0.14 | 25.4 | 0.18 | | 0.115 | | 0.078 | | 0.14 | | 0.11 |
| K/Na | | 0.035 | | 0.041 | | 0.046 | | 0.041 | | 0.050 | | 0.051 | | 0.043 | | 0.042 | | 0.047 | | 0.038 |
| Mg/Ca | | 1.35 | | 1.36 | | 1.64 | | 1.07 | | 1.58 | | 1.57 | | 1.33 | | 1.97 | | 1.57 | | 1.52 |
| Na/Cl | | 0.86 | | 1.095 | | 1.31 | | 1.26 | | 1.27 | | 1.38 | | 1.26 | | 1.38 | | 1.19 | | 1.02 |
| Mg/Cl | | 0.21 | | 0.23 | | 0.27 | | 0.16 | | 0.29 | | 0.39 | | 0.19 | | 0.21 | | 0.26 | | 0.18 |
| Analyst | M.T. | | M.T. | | M.T. | | M.T. | | M.T. | | M.T. | | M.T. | | M.T. | | M.T. | | M.T. | |

## Table 2 − 4. Chemical analyses of groundwaters from Eastern Osaka (2)

| Group | B | | B | | C | | C | | C | | C | | C | | C | | C | | C | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Well No. | KD−15 | | KD−16 | | N−1 | | N−2 | | N−16 | | N−23 | | N−24 | | N−37 | | KD−5 | | KD−6 | |
| Depth of Perforation(m) | 37~90 | | 31~99 | | 42~85 | | 75~124 | | 42~57 | | 50~71 | | 45~120 | | 35~120 | | 80~150 | | 81~150 | |
| Total Depth(m) | 96 | | 106 | | 100 | | 130 | | 60 | | 76 | | 135 | | 121 | | 180 | | 180 | |
| Date of Collection | Nov. 21, '67 | | Nov. 21, '67 | | Dec. 10, '65 | | Dec. 10, '22 | | Dec. 22, '65 | | Nov. 8, '66 | | Nov. 8, '66 | | Mar. 27, '67 | | Feb. 8, '66 | | Feb. 8, '66 | |
| Temp. (℃) | 16.5 | | 16.5 | | 16.9 | | 17.8 | | 16.5 | | 16.5 | | 16.5 | | 16.3 | | 19.3 | | 19.7 | |
| EC. (μ℧·18℃) | 800 | | 935 | | 256 | | 250 | | 270 | | 185 | | 240 | | 307 | | 212 | | 222 | |
| pH | 7.0 | | 6.8 | | 6.7 | | 6.7 | | 6.8 | | 6.6 | | 6.6 | | 6.7 | | 7.0 | | 7.0 | |
| | ppm | epm | ppm | epm | ppm | epm | ppm | epm | ppm | epm | ppm | epm | ppm | epm | ppm | epm | ppm | epm | ppm | epm |
| $HCO_3$ | 217.9 | 3.572 | 164.3 | 2.694 | 178.5 | 2.926 | 176.1 | 2.887 | 181.6 | 2.977 | 85.6 | 1.404 | 123.5 | 2.025 | 194.5 | 3.188 | 134.1 | 2.198 | 138.4 | 2.269 |
| Cl | 187.7 | 5.295 | 267.1 | 7.535 | 3.77 | 0.106 | 4.52 | 0.127 | 4.09 | 0.115 | 18.0 | 0.507 | 12.5 | 0.352 | 17.9 | 0.505 | 6.09 | 0.172 | 7.61 | 0.215 |
| $SO_4$ | 6.9 | 0.144 | 0.94 | 0.020 | 1.9 | 0.040 | 0.7 | 0.014 | 3.0 | 0.062 | 3.0 | 0.062 | 0 | 0 | 2.4 | 0.050 | 0.9 | 0.019 | 1.7 | 0.035 |
| $NO_3$—N | 0.045 | 0.003 | 0.054 | 0.004 | 0.31 | 0.022 | 0.39 | 0.028 | 0.16 | 0.011 | 0.01 | 0.001 | 0.01 | 0.001 | 0.05 | 0.004 | 0.35 | 0.025 | 0.50 | 0.036 |
| $PO_4$—P | 1.00 | 0.097 | 0.78 | 0.075 | 0.97 | 0.095 | 0.41 | 0.040 | 1.24 | 0.120 | 0.173 | 0.017 | 0.52 | 0.050 | 0.405 | 0.040 | 0.36 | 0.035 | 0.38 | 0.037 |
| Total Anions(A) | | 9.111 | | 10.23 | | 3.189 | | 3.096 | | 3.285 | | 1.991 | | 2.428 | | 3.787 | | 2.449 | | 2.592 |
| $NH_4$—N | 3.48 | 0.249 | 3.18 | 0.227 | 2.88 | 0.206 | 2.30 | 0.164 | 3.27 | 0.234 | 0.47 | 0.033 | 2.14 | 0.153 | 4.09 | 0.292 | 3.20 | 0.229 | 3.12 | 0.223 |
| Na | 160 | 6.957 | 176 | 7.652 | 15.0 | 0.652 | 16.0 | 0.695 | 17.0 | 0.739 | 14.5 | 0.630 | 14.2 | 0.618 | 19.0 | 0.826 | 21.0 | 0.913 | 23.0 | 1.000 |
| K | 9.8 | 0.251 | 9.7 | 0.248 | 6.4 | 0.164 | 7.1 | 0.182 | 5.9 | 0.151 | 1.8 | 0.046 | 4.5 | 0.115 | 10.0 | 0.256 | 10.5 | 0.269 | 10.8 | 0.276 |
| Ca | 15.50 | 0.775 | 20.64 | 1.032 | 22.68 | 1.134 | 20.36 | 1.018 | 22.24 | 1.112 | 14.81 | 0.740 | 14.30 | 0.715 | 25.39 | 1.269 | 8.78 | 0.438 | 9.72 | 0.485 |
| Mg | 10.41 | 0.857 | 14.26 | 1.174 | 8.97 | 0.738 | 8.61 | 0.708 | 8.99 | 0.740 | 3.92 | 0.322 | 6.33 | 0.522 | 9.73 | 0.802 | 6.02 | 0.495 | 6.97 | 0.573 |
| FeⅡ | 2.12 | 0.076 | 4.54 | 0.163 | 6.55 | 0.234 | 7.00 | 0.251 | 7.10 | 0.254 | 5.90 | 0.211 | 8.35 | 0.298 | 9.05 | 0.324 | 1.00 | 0.036 | 1.38 | 0.050 |
| Mn | 0.355 | 0.013 | 1.22 | 0.044 | 0.48 | 0.017 | 0.37 | 0.013 | 0.57 | 0.021 | 0.235 | 0.009 | 0.46 | 0.017 | 0.625 | 0.023 | 0.44 | 0.016 | 0.55 | 0.020 |
| Total Cations(C) | | 9.178 | | 10.54 | | 3.145 | | 3.031 | | 3.251 | | 1.991 | | 2.438 | | 3.792 | | 2.396 | | 2.627 |
| $SiO_2$ | 43.8 | | 39.2 | | 43.4 | | 53.0 | | 48.6 | | 51.8 | | 52.4 | | 57.5 | | 54.0 | | 58.6 | |
| (A)/(C) | | 0.99 | | 0.98 | | 1.01 | | 1.02 | | 1.01 | | 1.00 | | 1.00 | | 1.00 | | 1.02 | | 0.99 |
| Ca/Na | | 1.11 | | 1.35 | | 1.74 | | 1.47 | | 1.51 | | 1.17 | | 1.15 | | 1.54 | | 0.48 | | 0.485 |
| K/Na | | 0.036 | | 0.032 | | 0.25 | | 0.26 | | 0.20 | | 0.073 | | 0.19 | | 0.31 | | 0.29 | | 0.28 |
| Mg/Ca | | 1.11 | | 1.14 | | 0.65 | | 0.69 | | 0.67 | | 0.435 | | 0.73 | | 0.63 | | 1.13 | | 1.18 |
| Na/Cl | | 1.31 | | 1.02 | | | | | | | | | | | | | | | | |
| Mg/Cl | | 0.16 | | 0.16 | | | | | | | | | | | | | | | | |
| Analyst | M.T. | | M.T. | | M.T. | | M.T. | | M.T. | | M.T. | | M.T. | | M.T. | | M.T. | | M.T. | |

Table 2－5. Chemical analyses of groundwaters from Eastern Osaka

| Group | C | | C | | C | | C | | C | | C | | | | D | | D | | D | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Well No. | KD－10 | | KD－11 | | N－39(1) | | N－39(2) | | N－39(3) | | N－42 | | M－22 | | KD－13 | | KD－18 | | KD－19 | |
| Depth of Perforation(m) | 230～286 | | 90～159 | | 182～215 | | | | | | 181～235.5 | | 67～133 | | 62～166 | | ? | | ? | |
| Total Depth(m) | 300 | | 180 | | 223 | | | | | | 250 | | 137 | | 180 | | 200 | | 180 | |
| Date of Collection | Feb. 8, '66 | | Dec. 13, '65 | | Nov. 30, '67 | | Nov. 25, '68 | | Nov. 27, '69 | | Nov. 27, '69 | | Sep. 28, '66 | | Jan. 22, '68 | | Nov. 8, '66 | | Dec. 5, '67 | |
| Temp. (℃) | 21.7 | | 18.5 | | 20.5 | | 20.1 | | 20.2 | | 19.8 | | 17.5 | | 19.1 | | 20.0 | | 19.5 | |
| EC. (μ℧.18℃) | 192 | | 238 | | 218 | | 262 | | 304 | | 330 | | 870 | | 1020 | | 1450 | | 1164 | |
| pH | 7.4 | | 7.2 | | 7.2 | | 7.1 | | 7.2 | | 7.0 | | 7.2 | | 7.1 | | 7.0 | | 6.9 | |
| | ppm | epm | ppm | epm | ppm | epm | ppm | epm | ppm | epm | ppm | epm | ppm | epm | ppm | epm | ppm | epm | ppm | epm |
| $HCO_3$ | 122.2 | 2.003 | 152.9 | 2.506 | 131.9 | 2.163 | 132.2 | 2.173 | 132.1 | 2.166 | 134.3 | 2.202 | 261.4 | 4.285 | 247.2 | 4.053 | 237.7 | 3.896 | 245.7 | 4.028 |
| Cl | 3.59 | 0.101 | 4.42 | 0.125 | 8.34 | 0.234 | 28.3 | 0.798 | 38.48 | 1.085 | 49.38 | 0.393 | 167.6 | 4.727 | 328 | 9.255 | 483 | 13.625 | 386 | 10.89 |
| $SO_4$ | 0.7 | 0.015 | 3.1 | 0.065 | 0 | 0 | 0.4 | 0.008 | 2.0 | 0.042 | 1.6 | 0.033 | 3.8 | 0.079 | 2.3 | 0.049 | 3.4 | 0.071 | 6.4 | 0.134 |
| $NO_3$－N | 0.36 | 0.026 | 0.57 | 0.041 | 0.05 | 0.004 | ··· | ··· | 0.025 | 0.002 | 0.02 | 0.001 | ··· | ··· | 0.07 | 0.005 | 0.028 | 0.002 | 0.063 | 0.005 |
| $PO_4$－P | 0.44 | 0.043 | 0.51 | 0.049 | 0.20 | 0.020 | 0.21 | 0.020 | 0.23 | 0.022 | 0.23 | 0.022 | 0.58 | 0.057 | 0.85 | 0.082 | 1.56 | 0.150 | 1.50 | 0.145 |
| Total Anions(A) | | 2.188 | | 2.786 | | 2.421 | | 2.999 | | 3.315 | | 3.651 | | 9.148 | | 13.44 | | 17.74 | | 15.20 |
| $NH_4$－N | 2.67 | 0.191 | 4.37 | 0.312 | 2.14 | 0.156 | 2.72 | 0.194 | 2.63 | 0.188 | 3.375 | 2.241 | 7.83 | 0.559 | 13.1 | 0.936 | 16.7 | 1.195 | 18.7 | 1.336 |
| Na | 18.0 | 0.783 | 24.8 | 1.078 | 22.0 | 0.956 | 28.3 | 1.231 | 33.4 | 1.454 | 31.1 | 1.354 | 80.0 | 3.478 | 125 | 5.435 | 206 | 8.96 | 153 | 6.652 |
| K | 8.8 | 0.225 | 13.6 | 0.348 | 9.9 | 0.253 | 10.6 | 0.271 | 10.5 | 0.269 | 11.65 | 0.298 | 18.5 | 0.473 | 28.8 | 0.738 | 30.0 | 0.767 | 26.2 | 0.670 |
| Ca | 9.46 | 0.472 | 8.78 | 0.438 | 8.57 | 0.428 | 9.70 | 0.485 | 10.50 | 0.525 | 12.12 | 0.606 | 46.69 | 2.335 | 57.31 | 2.865 | 63.23 | 3.162 | 60.82 | 3.041 |
| Mg | 4.91 | 0.404 | 6.02 | 0.495 | 7.29 | 0.600 | 9.42 | 0.775 | 9.44 | 0.776 | 12.09 | 0.994 | 24.72 | 2.033 | 38.44 | 3.161 | 44.05 | 3.625 | 40.21 | 3.307 |
| FeⅡ | 0.79 | 0.029 | 0.83 | 0.030 | 1.78 | 0.064 | 2.10 | 0.075 | 2.17 | 0.078 | 2.00 | 0.072 | 1.12 | 0.041 | 2.00 | 0.072 | 2.40 | 0.086 | 2.52 | 0.090 |
| Mn | 0.45 | 2.016 | 0.32 | 0.011 | ··· | ··· | 0.56 | 0.020 | 0.50 | 0.018 | 0.58 | 0.021 | 0.41 | 0.015 | 0.845 | 0.031 | 0.93 | 0.033 | 0.82 | 0.030 |
| Total Cations(C) | | 2.120 | | 2.712 | | 2.457 | | 3.051 | | 3.308 | | 3.586 | | 8.934 | | 13.24 | | 17.883 | | 15.13 |
| $SiO_2$ | 58.4 | | 52.2 | | 55 | | 54 | | 55 | | 55 | | 49.2 | | 57.8 | | 65.3 | | 54 | |
| (A)/(C) | | 1.03 | | 1.03 | | 0.99 | | 0.99 | | 1.00 | | 1.02 | | 1.02 | | 1.015 | | 0.995 | | 1.005 |
| Ca/Na | | 0.60 | | 0.41 | | 0.45 | | 0.39 | | 0.36 | | 0.45 | | 0.67 | | 0.53 | | 0.35 | | 0.46 |
| K/Na | | 0.29 | | 0.32 | | 0.26 | | 0.22 | | 0.19 | | 0.22 | | 0.14 | | 0.14 | | 0.086 | | 0.11 |
| Mg/Ca | | 0.86 | | 1.13 | | 1.40 | | 1.60 | | 1.48 | | 1.64 | | 0.87 | | 1.10 | | 1.15 | | 1.09 |
| Na/Cl | | | | | | | | | | | | | | 0.74 | | 0.59 | | 0.66 | | 0.61 |
| Mg/Cl | | | | | | | | | | | | | | 0.43 | | 0.34 | | 0.27 | | 0.30 |
| Analyst | M.T. | | M.T. | | M.T. | | M.T. | | M.T. | | M.T. | | M.T. | | M.T. | | M.T. | | M.T. | |

## Table 2−6. Chemical analyses of groundwaters from Eastern Osaka (4)

| Group | D | | D | | D | | D | | D | | D | | D | | D | | D | | D | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Well No. | KD−22 | | D−15 | | D−16(1) | | D−16(2) | | D−16(3) | | D−17(1) | | D−17(2) | | D−17(3) | | D−18(1) | | D−18(2) | |
| Depth of Perforation(m) | 82~195 | | 86~169 | | 60~162 | | | | | | 64~187 | | | | | | 81~230 | | | |
| Total Depth(m) | 200 | | 182 | | 182 | | | | | | 200 | | | | | | 240 | | | |
| Date of Collection | Dec. 5, '67 | | Nov. 29, '66 | | Nov. 29, '66 | | Feb. 7, '69 | | Dec. 8, '69 | | Nov. 29, '66 | | Feb. 7, '69 | | Dec. 8, '69 | | Nov. 29, '66 | | Feb. 23. '68 | |
| Temp. (℃) | 19.5 | | 20.2 | | 19.3 | | 20.2 | | 20.0 | | 19.4 | | 20.0 | | 19.6 | | 21.1 | | 21.5 | |
| EC. (μ℧.18℃) | 1960 | | 314 | | 319 | | | | 878 | | 315 | | | | 618 | | 333 | | 606 | |
| pH | 7.0 | | 7.2 | | 7.0 | | 6.9 | | 6.8 | | 7.0 | | 7.0 | | 6.9 | | 7.0 | | 6.9 | |
| | ppm | epm | ppm | epm | ppm | epm | ppm | epm | ppm | epm | ppm | epm | ppm | epm | ppm | epm | ppm | epm | ppm | epm |
| $HCO_3$ | 244.1 | 4.002 | 271.5 | 4.450 | 312.8 | 5.128 | 314.5 | 5.155 | 305.7 | 5.011 | 286.0 | 4.688 | 288.5 | 4.73 | 283.5 | 4.647 | 281.1 | 4.608 | 247.1 | 4.050 |
| Cl | 814 | 22.96 | 6.3 | 0.177 | 5.12 | 0.144 | 62.4 | 1.76 | 139.8 | 3.944 | 6.58 | 0.186 | 158.6 | 4.473 | 69.5 | 1.961 | 8.13 | 0.230 | 419 | 11.82 |
| $SO_4$ | 30.1 | 0.627 | 0.7 | 0.015 | 1.56 | 0.032 | 4.08 | 0.085 | 1.1 | 0.023 | 1.43 | 0.030 | 4.34 | 0.090 | 1.2 | 0.025 | 0.88 | 0.019 | 3.04 | 0.063 |
| $NO_3-N$ | 0.034 | 0.002 | 0 | | 0 | | 0.024 | 0.002 | 0 | | 0 | | 0.070 | 0.005 | 0 | | 0 | | 0.09 | 0.006 |
| $PO_4-P$ | 1.60 | 0.155 | 0.64 | 0.062 | 0.81 | 0.079 | 1.08 | 0.105 | 1.82 | 0.176 | 1.20 | 0.116 | 1.24 | 0.120 | 1.355 | 0.131 | 0.53 | 0.051 | 1.27 | 0.123 |
| Total Anions(A) | | 27.75 | | 4.704 | | 5.383 | | 7.107 | | 9.154 | | 5.020 | | 9.418 | | 6.739 | | 4.908 | | 16.06 |
| $NH_4-N$ | 35.7 | 2.550 | 6.35 | 0.453 | 8.30 | 0.592 | 10.28 | 0.734 | 14.74 | 1.053 | 6.40 | 0.457 | 9.00 | 0.642 | 10.34 | 0.739 | 6.40 | 0.457 | 19.4 | 1.384 |
| Na | 298 | 12.96 | 22.4 | 0.974 | 26.3 | 1.144 | 37.0 | 1.610 | 54.5 | 2.372 | 25.0 | 1.087 | 60.0 | 2.610 | 39.1 | 1.700 | 25.3 | 1.198 | 108 | 4.696 |
| K | 30.8 | 0.787 | 18.9 | 0.483 | 18.9 | 0.483 | 16.0 | 0.409 | 19.9 | 0.509 | 14.2 | 0.363 | 17.0 | 0.435 | 15.8 | 0.404 | 15.9 | 0.407 | 22.3 | 0.571 |
| Ca | 104.50 | 5.225 | 28.74 | 1.434 | 32.44 | 1.618 | 43.14 | 2.154 | 59.56 | 2.878 | 33.10 | 1.651 | 57.55 | 2.870 | 40.88 | 2.044 | 31.57 | 1.575 | 90.60 | 4.520 |
| Mg | 77.60 | 6.382 | 15.07 | 1.239 | 17.40 | 1.431 | 20.06 | 1.652 | 26.75 | 2.200 | 16.30 | 1.340 | 27.62 | 2.270 | 20.84 | 1.714 | 15.86 | 1.304 | 56.60 | 4.655 |
| FeⅡ | 4.74 | 0.169 | 0.60 | 0.021 | 2.52 | 0.090 | 3.46 | 0.124 | 3.64 | 0.130 | 1.70 | 0.061 | 3.46 | 0.124 | 2.30 | 0.073 | 1.82 | 0.065 | 5.36 | 0.192 |
| Mn | 1.42 | 0.051 | ··· | ··· | ··· | ··· | 0.72 | 0.026 | 0.97 | 0.035 | ··· | ··· | 0.81 | 0.029 | 0.56 | 0.020 | ··· | ··· | 1.22 | 0.044 |
| Total Cations(C) | | 28.12 | | 4.604 | | 5.358 | | 6.709 | | 9.177 | | 4.959 | | 8.980 | | 6.694 | | 5.006 | | 16.07 |
| $SiO_2$ | 49.5 | | 54.5 | | 61.0 | | 69 | | 65 | | 58.3 | | 62.8 | | 55.5 | | 41.4 | | 68.3 | |
| (A)/(C) | | 0.99 | | 1.02 | | 1.00 | | 1.06 | | 1.00 | | 1.01 | | 1.05 | | 1.01 | | 0.97 | | 1.00 |
| Ca/Na | | 0.40 | | 1.47 | | 1.41 | | 1.34 | | 1.21 | | 1.52 | | 1.10 | | 1.20 | | 11.31 | | 0.96 |
| K/Na | | 0.061 | | 0.50 | | 0.42 | | 0.25 | | 0.22 | | 0.33 | | 0.17 | | 0.24 | | 0.34 | | 0.12 |
| Mg/Ca | | 1.22 | | 0.86 | | 0.88 | | 0.77 | | 0.76 | | 0.81 | | 0.79 | | 0.84 | | 0.83 | | 1.03 |
| Na/Cl | | 0.56 | | | | | | | | 0.60 | | | | 0.58 | | | | | | 0.40 |
| Mg/Cl | | 0.28 | | | | | | | | 0.56 | | | | 0.51 | | | | | | 0.39 |
| Analyst | M.T. | | M. Nagasawa | | M.N. | | M.N. | | M.T. | | M.N. | | M.N. | | M.T. | | M.N. | | M.N. | |

## Table 2－7. Chemical analyees of groundwaters from Eastern Osaka

| Group | D | | D | | D | | D | | D | | D | | E | | E | | E | | E | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Well No. | D−18(3) | | D−18(4) | | D−19(1) | | D−19(2) | | D−19(3) | | D−20(1) | | D−20(2) | | D−20(3) | | D−20(4) | | D−22 | |
| Depth of Perforotion(m) | | | | | 74～178 | | | | | | 178～290 | | | | | | | | 167～296 | |
| Total Depth(m) | | | | | 185 | | | | | | 300 | | | | | | | | 306 | |
| Date of Collection | Feb, 7, '69 | | Dec. 8, '69 | | Nov. 29, '66 | | Nov. 7, '67 | | Feb. 7, '69 | | Nov. 29, '66 | | Nov. 7, '67 | | Feb. 7, '69 | | Dec. 8, '69 | | Dec. 8, '69 | |
| Temp. (℃) | 20.5 | | 20.2 | | 20.2 | | 20.5 | | 20.8 | | 23.2 | | 24.7 | | 24.2 | | 24.2 | | 24.0 | |
| EC. (μ℧ . 18℃) | | | 830 | | | | | | | | 590 | | 470 | | | | 442 | | 520 | |
| pH | 6.9 | | 7.0 | | | | | | | | 7.1 | | 7.3 | | 7.2 | | 7.2 | | 7.1 | |
| | ppm | epm | ppm | epm | ppm | epm | ppm | epm | ppm | epm | ppm | epm | ppm | epm | ppm | epm | ppm | epm | ppm | epm |
| HCO$_3$ | 267.2 | 4.38 | 276.6 | 4.534 | 282.8 | 4.636 | 289.8 | 4.750 | 281.5 | 4.615 | 280.1 | 4.592 | 302.9 | 4.965 | 304.4 | 4.99 | 290.9 | 4.769 | 325.9 | 5.343 |
| Cl | 236.0 | 6.656 | 142.2 | 4.011 | 12.83 | 0.362 | 177.8 | 5.016 | 287.0 | 8.094 | 147.0 | 4.146 | 37.6 | 1.061 | 30.8 | 0.860 | 10.59 | 0.299 | 30.68 | 0.865 |
| SO$_4$ | 5.53 | 0.115 | 1.3 | 0.027 | 1.15 | 0.024 | 0.10 | 0.002 | 6.26 | 0.131 | 1.42 | 0.029 | 0.08 | 0.0 | 0 | 0 | 0.9 | 0.019 | 0.7 | 0.015 |
| NO$_3$—N | 0.037 | 0.003 | 0 | 0 | 0 | 0 | 0 | 0 | 0.019 | 0.001 | 0 | | 0 | | 0.03 | 0.002 | 0 | | 0 | |
| PO$_4$—P | 0.72 | 0.070 | 1.10 | 0.107 | 0.73 | 0.071 | 0.97 | 0.094 | 0.81 | 0.079 | 0.53 | 0.051 | 0.74 | 0.072 | 0.70 | 0.068 | 0.93 | 0.090 | 0.88 | 0.085 |
| Total Anions(A) | | 11.22 | | 8.679 | | 5.093 | | 9.862 | | 12.92 | | 8.818 | | 6.098 | | 5.920 | | 5.177 | | 6.308 |
| NH$_4$—N | 8.64 | 0.616 | 10.32 | 0.737 | 6.90 | 0.493 | 13.80 | 0.985 | 13.76 | 0.982 | 10.70 | 0.764 | 12.10 | 0.864 | 6.24 | 0.446 | 9.70 | 0.693 | 10.19 | 0.727 |
| Na | 78.8 | 3.428 | 58.1 | 2.526 | 22.6 | 0.983 | 57.8 | 2.513 | 90.0 | 3.915 | 73.2 | 3.084 | 57.7 | 2.505 | 69.0 | 3.002 | 58.8 | 2.557 | 65.95 | 2.867 |
| K | 16.6 | 0.424 | 16.1 | 0.412 | 17.0 | 0.435 | 22.2 | 0.581 | 20.8 | 0.532 | 28.0 | 0.716 | 22.2 | 0.667 | 16.6 | 0.424 | 16.0 | 0.409 | 18.1 | 0.463 |
| Ca | 65.80 | 3.284 | 50.36 | 2.518 | 31.76 | 1.584 | 58.25 | 2.907 | 77.10 | 3.850 | 41.86 | 2.086 | 17.86 | 0.891 | 19.17 | 0.957 | 14.38 | 0.719 | 22.00 | 1.100 |
| Mg | 37.00 | 3.042 | 30.00 | 2.467 | 17.50 | 1.439 | 32.28 | 2.655 | 39.21 | 3.224 | 24.86 | 2.044 | 13.52 | 1.112 | 12.14 | 0.998 | 9.61 | 0.790 | 13.39 | 1.101 |
| Fe II | 3.64 | 0.130 | 2.62 | 0.094 | 1.10 | 0.039 | 3.58 | 0.128 | 4.88 | 0.175 | 2.06 | 0.074 | 0.68 | 0.024 | 0.54 | 0.019 | 0.51 | 0.018 | 0.93 | 0.033 |
| Mn | 0.76 | 0.028 | 0.68 | 0.025 | … | … | 0.83 | 0.030 | 0.90 | 0.033 | … | … | 0.58 | 0.021 | 0.23 | 0.008 | 0.16 | 0.006 | 0.23 | 0.008 |
| Total Cations(C) | | 10.95 | | 8.779 | | 4.973 | | 9.799 | | 12.71 | | 8.768 | | 6.084 | | 5.854 | | 5.192 | | 6.299 |
| SiO$_2$ | 59.7 | | 55.5 | | 55.0 | | 60.7 | | 64.2 | | 69.1 | | 67.5 | | 67.2 | | 62 | | 66 | |
| (A)/(C) | | 1.025 | | 0.99 | | 1.02 | | 1.005 | | 1.02 | | 1.005 | | 1.00 | | 1.01 | | 1.00 | | 1.00 |
| Ca/Na | | 0.96 | | 0.99 | | 1.61 | | 1.16 | | 0.985 | | 0.675 | | 0.355 | | 0.32 | | 0.28 | | 0.38 |
| K/Na | | 0.12 | | 0.16 | | 0.44 | | 0.23 | | 0.14 | | 0.23 | | 0.27 | | 0.14 | | 0.16 | | 0.16 |
| Mg/Ca | | 0.93 | | 0.98 | | 0.91 | | 0.91 | | 0.84 | | 0.98 | | 1.25 | | 1.04 | | 1.10 | | 1.00 |
| Na/Cl | | 0.52 | | 0.63 | | | | 0.50 | | 0.48 | | 0.74 | | | | | | | | |
| Mg/Cl | | 0.46 | | 0.62 | | | | 0.53 | | 0.40 | | 0.49 | | | | | | | | |
| Analyst | M.N. | | M.T. | | M.N. | | M.N. | | M.N. | | M.N. | | MN | | MN | | MT | | M.T. | |

## Table 2−8. Chemical analyses of groundwaters from Eastern Osaka

| Group | E | | E | | E | | E | | E | | E | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Well No. | D−2 | | D−3 | | D−4 | | D−5 | | D−7 | | D−21 | | Hi−30 | | Hi−32 | | Hi−33 | | Hi−34 | |
| Depth of Perforation(m) | 57∼102 | | 23∼122 | | 21∼118 | | 92∼147 | | 52∼116 | | 69.5∼157 | | 83.5∼179.5 | | 66∼121 | | 60∼193 | | 56∼205 | |
| Total Depth(m) | 125 | | 127 | | 125 | | 147 | | 120 | | 175 | | 183 | | 150 | | 200 | | 210 | |
| Date of Collection | Jan. 28, '66 | | Jan. 28, '66 | | Nov. 11, '66 | | Jan. 28, '66 | | Nov. 11, '66 | | Apr. 9, '69 | | Apr. 11, '69 | | Nov. 20, '69 | | Nov. 20, '69 | | Nov. 20, '69 | |
| Temp. (℃) | 18.2 | | 18.0 | | 17.5 | | 19.5 | | 18.9 | | 19.2 | | 17.7 | | 18.8 | | 20.0 | | 19.1 | |
| EC. (μ℧.18℃) | 408 | | 450 | | 320 | | 345 | | 385 | | 404 | | 490 | | 306 | | 262 | | 324 | |
| pH | 6.9 | | 6.8 | | 7.4 | | 7.0 | | 6.9 | | 7.0 | | 7.1 | | 7.2 | | 7.4 | | 7.1 | |
| | ppm | epm | ppm | epm | ppm | epm | ppm | epm | ppm | epm | ppm | epm | ppm | epm | ppm | epm | ppm | epm | ppm | epm |
| $HCO_3$ | 322.1 | 5.280 | 370.9 | 6.080 | 332.1 | 5.444 | 263.2 | 4.315 | 377.9 | 6.195 | 276.7 | 4.536 | 368.0 | 6.032 | 229.2 | 3.757 | 190.7 | 3.126 | 220.3 | 3.612 |
| Cl | 5.99 | 0.169 | 6.63 | 0.187 | 7.60 | 0.214 | 4.49 | 0.127 | 7.02 | 0.198 | 6.16 | 0.174 | 6.32 | 0.178 | 4.74 | 0.134 | 5.18 | 0.146 | 5.18 | 0.146 |
| $SO_4$ | 3.58 | 0.075 | 7.42 | 0.155 | 1.88 | 0.039 | 0.56 | 0.012 | 1.81 | 0.038 | 1.44 | 0.030 | 2.34 | 0.049 | 0.8 | 0.017 | 0.8 | 0.017 | 0.8 | 0.017 |
| $NO_3$−N | 0.20 | 0.014 | 0.46 | 0.032 | 0 | | 0.14 | 0.010 | 0 | | 0.03 | 0.002 | 0.06 | 0.004 | 0.025 | 0.002 | 0.024 | 0.002 | 0.033 | 0.002 |
| $PO_4$−P | 0.62 | 0.060 | 0.58 | 0.056 | 0.27 | 0.026 | 0.895 | 0.087 | 1.34 | 0.130 | 1.76 | 0.170 | 2.31 | 0.224 | 0.49 | 0.047 | 0.275 | 0.027 | 1.40 | 0.136 |
| Total Anions(A) | | 5.598 | | 6.510 | | 5.723 | | 4.551 | | 6.561 | | 4.912 | | 6.487 | | 3.957 | | 3.318 | | 3.913 |
| $NH_4$−N | 6.86 | 0.489 | 12.28 | 0.877 | 13.30 | 0.949 | 3.85 | 0.274 | 15.10 | 1.078 | 6.85 | 0.489 | 9.8 | 0.700 | 1.53 | 0.109 | 1.24 | 0.089 | 3.05 | 0.218 |
| Na | 28.4 | 1.234 | 31.3 | 1.361 | 18.4 | 0.800 | 23.3 | 1.013 | 26.8 | 1.165 | 25.3 | 1.100 | 27.5 | 0.196 | 19.1 | 0.829 | 23.9 | 1.038 | 18.23 | 0.793 |
| K | 16.0 | 0.409 | 9.6 | 0.246 | 16.1 | 0.412 | 10.5 | 0.269 | 18.9 | 0.483 | 10.2 | 0.261 | 4.7 | 0.120 | 3.36 | 0.086 | 4.02 | 0.103 | 3.25 | 0.083 |
| Ca | 36.78 | 1.835 | 38.32 | 1.912 | 35.46 | 1.769 | 32.76 | 1.635 | 38.15 | 1.903 | 32.96 | 1.648 | 56.40 | 2.820 | 42.72 | 2.136 | 28.08 | 1.404 | 39.70 | 1.985 |
| Mg | 16.78 | 1.380 | 18.22 | 1.498 | 18.13 | 1.491 | 14.72 | 1.211 | 19.92 | 1.638 | 15.21 | 1.252 | 16.05 | 1.320 | 8.35 | 0.687 | 7.31 | 0.601 | 8.50 | 0.699 |
| FeⅡ | 5.32 | 0.191 | 9.64 | 0.345 | 8.12 | 0.291 | 0.76 | 0.027 | 6.74 | 0.241 | 0.90 | 0.033 | 4.28 | 0.153 | 0.35 | 0.012 | 0.30 | 0.011 | 1.60 | 0.056 |
| Mn | … | … | … | … | … | … | … | … | … | … | 0.48 | 0.018 | 0.95 | 0.035 | 0.24 | 0.009 | 0.16 | 0.006 | 0.47 | 0.017 |
| Total Cations(C) | | 5.538 | | 6.239 | | 5.712 | | 4.429 | | 6.508 | | 4.801 | | 6.344 | | 3.868 | | 3.252 | | 3.852 |
| $SiO_2$ | 67.6 | | 66.2 | | 41.3 | | 58.8 | | 66.1 | | 53.0 | | 52.5 | | 40 | | 39 | | 47.5 | |
| (A)/(C) | | 1.01 | | 1.04 | | 1.00 | | 1.03 | | 1.01 | | 1.02 | | 1.02 | | 1.02 | | 1.02 | | 1.02 |
| Ca/Na | | 1.49 | | 1.41 | | 2.21 | | 1.61 | | 1.63 | | 1.50 | | 2.36 | | 2.58 | | 1.35 | | 2.50 |
| K/Na | | 0.33 | | 0.18 | | 0.51 | | 0.27 | | 0.41 | | 0.24 | | 0.10 | | 0.10 | | 0.10 | | 0.105 |
| Mg/Ca | | 0.75 | | 0.78 | | 0.84 | | 0.74 | | 0.86 | | 0.76 | | 0.47 | | 0.32 | | 0.43 | | 0.35 |
| Analyst | M.N. | | M.N. | | M.N. | | M.N. | | M.N. | | M.T. | | M.T. | | M.T. | | M.T. | | M.T. | |

## Table 2−9. Chemical analyses of groundwaters from Eastern Osaka

| Group | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Well No. | Ka−29 | | Ka−30 | | F−36 | | F−37 | | F−38 | | F−39 | | Y−14 | | Y−16 | | Y−44 | | Y−48 | |
| Depth of Perforation (m) | 47~198 | | 49~185 | | 106~162 | | 79~165 | | 40~115 | | 161~290 | | 23~58 | | 50~117 | | 52~142 | | 53~186 | |
| Total Depth(m) | 200 | | 200 | | 167 | | 205 | | 130 | | 290 | | 60 | | 118 | | 150 | | 200 | |
| Date of Collection | Nov. 20, '69 | | Nov. 20, '69 | | Nov. 13, '69 | | Nov. 13, '69 | | Nov. 13, '69 | | Nov. 13,'69 | | July. 21, '66 | | July. 21, '66 | | Aug. 17, '66 | | Aug. 17, '66 | |
| Temp. (℃) | 18.3 | | 18.4 | | 20.5 | | 19.6 | | 19.0 | | 24.2 | | 20.6 | | 18.0 | | 18.1 | | 17.5 | |
| EC. (μ℧.18℃) | 433 | | 450 | | 288 | | 302 | | 365 | | 289 | | 440 | | 410 | | 250 | | 253 | |
| pH | 6.8 | | 7.1 | | 6.9 | | 6.9 | | 6.9 | | 7.1 | | 6.6 | | 6.8 | | 6.8 | | 6.8 | |
| | ppm | epm | ppm | epm | ppm | epm | ppm | epm | ppm | epm | ppm | epm | ppm | epm | ppm | epm | ppm | epm | ppm | epm |
| $HCO_3$ | 289.6 | 4.748 | 292.1 | 4.789 | 196.3 | 3.218 | 213.6 | 3.502 | 252.6 | 4.141 | 201.1 | 3.296 | 139.6 | 2.289 | 142.7 | 2.340 | 145.4 | 2.384 | 147.0 | 2.410 |
| Cl | 20.17 | 0.569 | 25.40 | 0.716 | 9.54 | 0.269 | 6.00 | 0.169 | 11.18 | 0.315 | 4.36 | 0.123 | 48.56 | 1.370 | 60.01 | 1.692 | 14.78 | 0.417 | 15.67 | 0.442 |
| $SO_4$ | 0.8 | 0.017 | 0.8 | 0.017 | 〈1 | | 〈1 | .0 | 〈1 | | 〈1 | | 55.0 | 1.146 | 43.5 | 0.906 | 8.1 | 0.169 | 7.8 | 0.163 |
| $NO_3$−N | 0.041 | 0.003 | 0.043 | 0.003 | 0.032 | 0.002 | 0.04 | 0.003 | 0.043 | 0.003 | 0.04 | 0.003 | 1.50 | 0.107 | 0 | | 1.5 | 0.108 | 1.3 | 0.093 |
| $PO_4$−P | 2.54 | 0.247 | 2.67 | 0.259 | 0.895 | 0.087 | 1.415 | 0.137 | 1.69 | 0.164 | 1.81 | 0.176 | 0.065 | 0.006 | 0.13 | 0.013 | 0.855 | 0.083 | 0.9 | 0.087 |
| Total Anions(A) | | 5.584 | | 5.784 | | 3.576 | | 3.811 | | 4.623 | | 3.598 | | 4.918 | | 4.951 | | 3.161 | | 3.195 |
| $NH_4$−N | 7.02 | 0.501 | 7.43 | 0.530 | 2.46 | 0.247 | 4.17 | 0.297 | 4.75 | 0.339 | 5.25 | 0.375 | 0.054 | 0.004 | 0.115 | 0.008 | 1.69 | 0.121 | 2.04 | 0.146 |
| Na | 44.2 | 1.922 | 45.8 | 1.991 | 21.32 | 0.927 | 21.46 | 0.933 | 26.84 | 1.167 | 25.34 | 1.102 | 27.5 | 1.196 | 29.0 | 1.261 | 19.0 | 0.827 | 19.3 | 0.839 |
| K | 13.6 | 0.349 | 13.5 | 0.345 | 9.65 | 0.247 | 11.38 | 0.291 | 13.44 | 0.344 | 11.64 | 0.298 | 2.9 | 0.074 | 2.0 | 0.051 | 3.3 | 0.084 | 3.4 | 0.087 |
| Ca | 26.18 | 1.309 | 27.82 | 1.391 | 17.76 | 0.888 | 20.06 | 1.003 | 21.28 | 1.064 | 17.18 | 0.859 | 46.90 | 2.340 | 43.92 | 2.192 | 28.11 | 1.406 | 25.89 | 1.292 |
| Mg | 16.33 | 1.343 | 14.93 | 1.228 | 13.93 | 1.146 | 13.78 | 1.113 | 17.81 | 1.465 | 10.20 | 0.839 | 15.84 | 1.303 | 14.11 | 1.160 | 5.18 | 0.426 | 5.89 | 0.484 |
| FeⅡ | 4.46 | 0.160 | 4.40 | 0.157 | 2.26 | 0.081 | 2.02 | 0.072 | 4.08 | 0.146 | 1.02 | 0.036 | 0.92 | 0.033 | 3.05 | 0.109 | 5.06 | 0.181 | 6.18 | 0.222 |
| Mn | 0.69 | 0.025 | 0.695 | 0.025 | 0.60 | 0.022 | 0.51 | 0.018 | 0.675 | 0.025 | 0.395 | 0.014 | 4.65 | 0.169 | 2.70 | 0.098 | 0.86 | 0.031 | 0.97 | 0.035 |
| Total Cations(C) | | 5.609 | | 5.667 | | 3.558 | | 3.747 | | 4.550 | | 3.518 | | 5.119 | | 4.879 | | 3.076 | | 3.105 |
| $SiO_2$ | 62 | | 62 | | 55 | | 53.4 | | 54.6 | | 67.4 | | 27:2 | | 35.8 | | 50.8 | | 49.2 | |
| (A)/(C) | | 0.995 | | 1.02 | | 1.005 | | 1.02 | | 1.02 | | 1.02 | | 0.96 | | 1.015 | | 1.03 | | 1.03 |
| Ca/Na | | 0.68 | | 0.70 | | 0.96 | | 1.075 | | 0.91 | | 0.78 | | 1.96 | | 1.74 | | 1.70 | | 1.54 |
| K/Na | | 0.18 | | 0.17 | | 0.27 | | 0.31 | | 0.295 | | 0.27 | | 0.062 | | 0.040 | | 0.10 | | 0, 105 |
| Mg/Ca | | 1.03 | | 0.88 | | 1.29 | | 1.11 | | 1.38 | | 0.98 | | 0.56 | | 0.53 | | 0.30 | | 0.375 |
| Ma/Cl | | | | | | | | | | | | | | | | | | | | |
| Mg/Cl | | | | | | | | | | | | | | | | | | | | |
| Analyst | M.T. | | M.T. | | M.T. | | M.T. | | M.T. | | M.T. | | M.T. | | M.T. | | M.T. | | M.T. | |

Table 2—10. Chemical analyses of groundwaters from test wells

| Group | Test Well, Niwakubo | | | | | | Test Well, Konoike | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Well No. | N—50m | | N—100m | | N—250m | | K—50m | | K—100m | | K—200m | |
| Depth of Perforation (m) | 31.5~45 | | 59~82 | | 208~238.5 | | 45~50 | | 92~97 | | 175~193 | |
| Total Depth (m) | 50 | | 100 | | 250 | | 51 | | 100 | | 200 | |
| Date of Collection | Mar. 11, '68 | | Mar. 15, '68 | | Mar. 20, '68 | | Dec. 22, '67 | | Jan. 24, '68 | | Dec. 7, '67 | |
| Temp. (℃) | 16.5 | | 17.4 | | 21.0 | | 18.3 | | 19.9 | | 23.3 | |
| EC. (μ℧ . 18℃) | 700 | | 810 | | 250 | | 575 | | 440 | | 909 | |
| pH | 7.1 | | 7.4 | | 7.4 | | 6.8 | | 7.4 | | 6.8 | |
| | ppm | epm | ppm | epm | ppm | epm | ppm | epm | ppm | epm | ppm | epm |
| $HCO_3$ | 163.7 | 2.684 | 153.8 | 2.521 | 151.3 | 2.480 | 380.0 | 6.229 | 293.6 | 4.813 | 251.5 | 4.123 |
| Cl | 160.0 | 4.513 | 184.6 | 5.206 | 3.30 | 0.093 | 40.86 | 1.152 | 5.73 | 0.162 | 212 | 5.979 |
| $SO_4$ | 2.94 | 0.051 | 2.34 | 0.049 | 1.17 | 0.024 | 1.35 | 0.028 | 3.64 | 0.076 | 1.19 | 0.025 |
| $NO_3$—N | 0 | | 0.04 | 0.003 | 0.04 | 0.003 | 0.057 | 0.004 | 0.066 | 0.005 | 0.025 | 0.002 |
| $PO_4$—P | 0.01 | 0.001 | 0.046 | 0.045 | 0.30 | 0.029 | 1.95 | 0.188 | 2.38 | 0.231 | 1.60 | 0.155 |
| Total Anions (A) | | 7.249 | | 7.824 | | 2.629 | | 7.601 | | 5.287 | | 10.28 |
| $NH_4$—N | 2.60 | 0.186 | 5.18 | 0.370 | 2.60 | 0.186 | 9.95 | 0.711 | 10.9 | 0.779 | 12.4 | 0.885 |
| Na | 94 | 4.087 | 92 | 4.000 | 17.2 | 0.748 | 46.0 | 2.000 | 28.0 | 1.217 | 57.0 | 2.478 |
| K | 10.4 | 0.266 | 19.7 | 0.504 | 9.0 | 0.230 | 19.9 | 0.509 | 21.1 | 0.537 | 20.0 | 0.512 |
| Ca | 24.44 | 1.222 | 24.86 | 1.243 | 14.76 | 0.738 | 41.28 | 2.064 | 24.75 | 1.237 | 67.26 | 3.363 |
| Mg | 17.90 | 1.472 | 19.06 | 1.567 | 7.30 | 0.600 | 26.06 | 2.142 | 17.24 | 1.420 | 33.80 | 2.775 |
| FeⅡ | 5.90 | 0.211 | 4.12 | 0.148 | 0.97 | 0.035 | 5.82 | 0.208 | 1.19 | 0.043 | 3.10 | 0.111 |
| Mn | 0.77 | 0.028 | 0.75 | 0.027 | 0.95 | 0.035 | 0.97 | 0.035 | … | … | 0.99 | 0.036 |
| Total Cations (C) | | 7.472 | | 7.849 | | 2.572 | | 7.669 | | 5.233 | | 19.16 |
| $SiO_2$ | 35.5 | | 56.7 | | 55 | | 49.8 | | 45 | | 62.5 | |
| Residue | 470 | | 533 | | 173 | | 407 | | 247 | | 655 | |
| $KMnO_4$ cons. | 5.60 | | 4.12 | | 3.35 | | 13.57 | | 8.50 | | 11.37 | |
| $CH_4$. mℓ/ℓ | 4.2 | | 9.7 | | 0.69 | | 41.0 | | 21.2 | | 24.6 | |
| Tritium T.U. | 7.3 | | 2.7 | | 1.2 | | 12.7 | | 3.9 | | 1.9 | |
| Analyst | M.T. | | M.T. | | M.T. | | M.T. | | M.T. | | M.T. | |

Table 2—11. Chemical analyses of surface waters

| Group | Surface Water | | | | |
|---|---|---|---|---|---|
| | Yodo R. | | Yamato R. | | Ishi R. |
| Local Description | Hirakata | Kema | Kashihara | Fujiidera | Fujiidera |
| Date of Collection | Feb. 1956 | Nov. 1956 | Feb. 14, 1968 | | |
| Temp. (℃) | 5.0 | 8.3 | 5.1 | 4.6 | 4.0 |
| pH | 7.1 | 7.0 | 7.2 | 7.2 | 7.1 |
| | ppm | ppm | ppm | ppm | ppm |
| $HCO_3$ | | | 141.3 | 131.9 | 82.2 |
| Cl | 7.8 | 37.8 | 37.55 | 47.35 | 77.31 |
| $SO_4$ | 5 | 8.6 | 28.3 | 43.0 | 19.9 |
| $NO_3$—N | | | 0.09 | 0.06 | 1.02 |
| $PO_4$—P | 0.10 | 0.01 | 0.71 | 0.55 | 0.10 |
| $NH_4$—N | 0 | 0.39 | 6.6 | 3.12 | 0.22 |
| Na | | | 32.0 | 44.0 | 45.6 |
| K | | | 9.4 | 7.0 | 2.65 |
| Ca | 8.0 | 10.2 | 29.12 | 28.61 | 28.95 |
| Mg | 1.6 | 4.1 | 5.88 | 6.15 | 6.45 |
| Fe (Total) | 0.03 | 2.55 | 1.66 | 1.14 | 0.98 |
| Mn | | | 0.45 | 0.34 | 0.06 |
| $SiO_2$ | 16.4 | 16.4 | 26.8 | 24.8 | 17.4 |
| Analyst | Geol. Surv. Japan | | M. Tsurumaki | | |