Chemical Quality of Water in Northern Nigeria, 1965-1968

by

Raymond T. Kiser

U.S. Geological Survey

Open-File Report

December 1968

Contents

Illustrations

Tables

Abstract

This report presents results of more than 300 complete chemical analyses of water samples collected during the period July 1965 to August 1968 from widespread sources in Northern Nigeria. Most of the samples were obtained from ground-water sources, but some samples were taken from lakes, ponds, and streams. The samples were obtained from sources in the Chad, West Chad, and Sokoto Basins, Kerri Kerri area, Kaduna-Zaria area, and other scattered localities. The waters vary widely in dissolved solids concentration and chemical type, but most sources are suitable for livestock and drinking by man with the exception of dug wells containing water with high nitrate. Nearly half the water samples, however, from dug wells in West Chad Basin and Kerri Kerri area have high nitrate, and many water sources from boreholes (drilled wells) in Chad and Sokoto Basins have undesirable amounts of iron or manganese. Some ground-water sources, particularly in the Chad Basin, are limited in their suitability for irrigation use because of salinity, sodium, or bicarbonate hazards. The boron hazard, however, in the analyzed samples is almost nonexistent.

Introduction

During the period July 1965 to August 1968 more than 400 water samples were analyzed in the laboratories of the Geological Survey of Nigeria, (GSN), Kaduna South. These analyses were made under the direction and guidance of the writer, a chemist with the U. S. Geological Survey (USGS), while on assignment as a technical advisor to the GSN under the auspices of the U. S. Agency for International Development (US AID). Of these analyses, 324 are given in tables 1-6, representing complete analyses of water samples from widespread sources in northern Nigeria. The areas for which analyses are listed in the table are shown in figure 1. About a third of the analyses had been previously reported by Kiser and Akingbehin (1966).

Most of the water samples were collected by personnel of the GSN or the USGS in support of ground-water studies in Chad, West Chad, and Sokoto Basins, the Kerri Kerri area and the Kaduna-Zaria area. Some surface-water sources, however, were also sampled to compare the quality of the surface water with that of the ground water in areas of study. Field determinations of pH and Eh in water samples from the Chad Basin were made by G. C. Tibbitts, Jr., USGS.

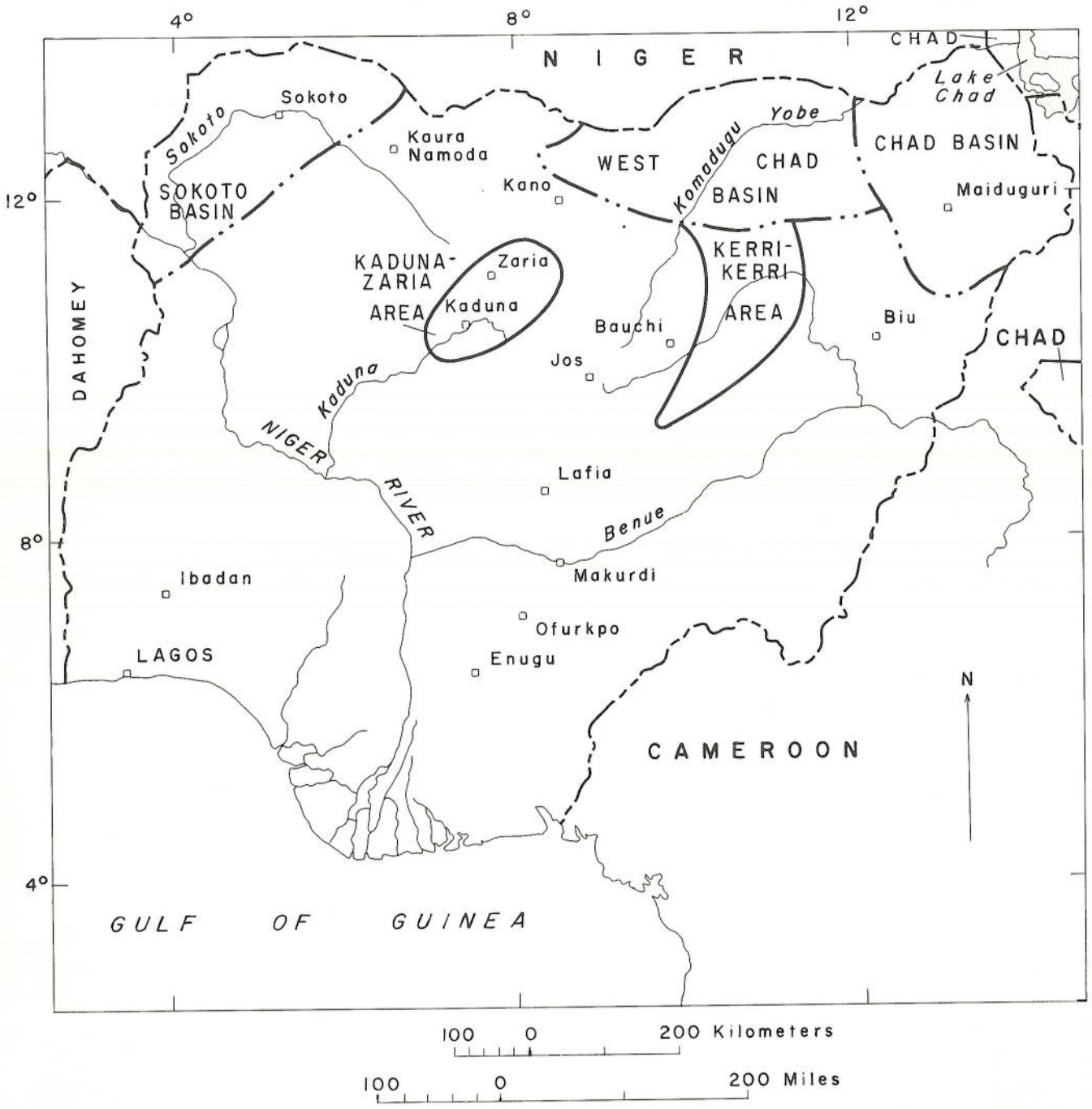


Figure 1.--Index Map of Nigeria showing Areas in which Water Samples were collected for Chemical Analysis, 1965-68.

The author wishes to acknowledge the help and cooperation of personnel of the GSN, especially those in the laboratories in Kaduna South. Financial and logistic support to the Chad and Sokoto Basin projects as well as to the writer's work in the water analysis laboratory of the GSN was provided by US AID.

Explanation to Accompany Tables 1-6

Location.--Under this heading is usually given the name of a village or town, at or near which the water sample was collected. Other designations include mileages on highways or in the case of Lake Chad, the approximate latitude and longitude of the sampling point.

Borehole or other source.--In Nigeria "borehole" is synonymous with "drilled well" insofar as ground-water studies are concerned. Each borehole is assigned a serial number by the Geological Survey of Nigeria. "Well" refers to an open dug well. Other sources include springs, rivers or streams, lakes, and ponds (or water holes).

Temperature.--This value, reported to the nearest degree F., was measured at the time of sample collection. It is not necessarily the same as aquifer temperature in the borehole unless a considerable flow of water occurred just prior to the collection of the sample.

Iron.--Because of the tendency for iron to precipitate in samples from boreholes, only total or precipitated iron is reported. These determinations were obtained from separate acidulated samples in which any precipitated iron was redissolved.

Manganese.--Most determinations were made on separate acidulated samples, but when such samples were not available, the values given represent manganese in solution rather than total manganese. It is believed that for these samples, manganese in solution is not greatly different from total manganese.

Residual sodium carbonate.--This value is the excess of carbonate and bicarbonate over calcium plus magnesium, all expressed in equivalents per million. Negative values are not reported, but are shown as zero (0). Residual sodium carbonate (RSC) is a measure of bicarbonate hazard in water for irrigation use, where values from 0 to 1.25 are considered safe, from 1.25 to 2.50 marginal, and values greater than 2.50 unsuitable (Wilcox, 1955).

Sodium adsorption ratio.--This is a calculated value, where

$$SAR = \frac{Na}{\sqrt{\frac{Ca + Mg}{2}}}$$

and the concentrations of sodium, calcium, and magnesium are in equivalents per million. The value indicates low, medium, high, or very high sodium hazard in using a water source for irrigation. The hazard varies with specific conductance of the water as follows:

Sodium hazard	Lower limit for specific conductance (approximate)				
	100	250	750	2,250	5,000
Low	0	0	0	0	0
Medium	10	8	6	4	2.5
High	18	15.5	12	8.5	6.5
Very High	26	22	18	13.5	11

(From U. S. Salinity Laboratory Staff, 1954)

Thus, a sodium adsorption ratio (SAR) of 7.0 would indicate low hazard for a specific conductance of 250, medium hazard for a specific conductance of 750, and high hazard for a specific conductance of 5,000.

Field or other determinations.--At a number of boreholes field determinations of pH and Eh were made at the borehole site. Such pH values are usually less than those subsequently determined in the laboratory because carbon dioxide initially present in the water tends to be lost upon standing. Eh represents the oxidation-reduction (redox) potential of the water and is measured in millivolts. Increasing positive values represent increasing oxidizing capability of the water, and increasing negative values represent the reduction capability. Both Eh and pH values determined from waters from Nigerian boreholes commonly indicate corrosive characteristics. Other determinations such as phosphate and nitrite were made in the laboratory. Many such determinations were made, but zero values are not reported in the tables. Thus, when no value is given for phosphate or nitrite, the value is zero or the determination was not made on that sample.

Chad Basin

Table 1 gives the chemical analyses for 116 water samples from the Chad Basin, including 60 from boreholes, 29 from wells, and 27 from surface-water sources.

Nearly all the borehole samples were obtained from the Middle Zone aquifer in the area of artesian flow lying between Lake Chad and a northwest--southeast line running through Maiduguri. The Middle Zone samples range in specific conductance from 307 to 1,690 micromhos cm at 25°C., which correspond to dissolved-solids contents ranging from 196 to 1,180 ppm. However, the highest specific conductances, from 921 to 1,690 micromhos, are from water in the northern part of the artesian flow area. Just south of the area of high specific conductance is a subarea of minimum specific conductance, with values ranging from 307 to 593 micromhos; and in a third subarea, approximately the southern half of the artesian area, the specific conductance values range from 454 to 1,020 micromhos. The water of highest specific conductance and dissolved-solids content is the sodium sulfate-bicarbonate or sodium sulfate type, however, the water of low and intermediate specific conductance and dissolved-solids content is nearly all of the sodium bicarbonate type. In a few samples of intermediate concentration, sulfate and chloride are relatively important, that is, the water is of the sodium bicarbonate-sulfate type and sodium bicarbonate-chloride type.

Most water samples from boreholes in the Chad Basin have iron or manganese, or both, in amounts that will cause staining of surfaces which come in contact with the water. Iron in excess of 0.3 ppm and manganese in excess of 0.1 ppm will usually produce such stains in sinks, on concrete surfaces, or on fabrics washed in water containing these elements.

Two borehole samples, one from the Upper Zone and the other from the Lower Zone aquifer of Maiduguri, have specific conductances of 222 and 308 micromhos, with dissolved-solids contents of 202 and 241, respectively. Both water sources are of sodium bicarbonate type.

Water samples from wells in the Chad Basin are more variable in chemical quality than those from boreholes. Specific conductance ranges from 120 to 7,600, with corresponding dissolved solids ranging from 129 to 6,240 ppm. Up to a specific conductance of about 2,800 micromhos, all samples are of bicarbonate type with sodium, or calcium, or both, as the predominant cations. Near the southern end of Lake Chad are seven wells for which water analysis was made. These samples have specific conductance greater than 2,800 micromhos, and all but one are of sodium-sulfate type. The exception is a sodium-calcium sulfate type. These wells of high specific conductance are all within about 15 miles of Lake Chad, and it seems likely that evapotranspiration has played some part in increasing the concentration of the water in these wells. The observation well runs begin at Maiduguri, and the analyses are listed in the order of increasing distances toward or beyond Bama, Dumboa, Geidam, Kauwa, and Ngala (table 1).

Most of the surface-water samples listed in table 1 are Lake Chad itself, but five analyses are given for inflowing streams. The latter show low dissolved solids, from 61 to 107 ppm, with corresponding specific conductance ranging from 82 to 140 micromhos. The stream water has bicarbonate as the predominant anion, with sodium and calcium as the predominant cations.

Water samples from Lake Chad indicate considerable variation in quality from place to place and from time to time. Observed specific conductances ranged from 87 to 1,130 micromhos and the corresponding dissolved solids from 84 to 801 ppm. The dissolved-solids content of the lake waters generally increases from south to north, principally because the bulk of the fresh-water inflow from streams enters the lake at its south end. Other surface inflow causes a decrease in dissolved solids locally. The maximum observed concentration of dissolved solids, 801 ppm, was determined on a sample obtained near the shore of the lake at its north end. A sample from a nearby pond, not connected with the lake, with dissolved solids of 5,860 ppm, illustrates extreme concentration by evaporation. The lake water is of the same type, sodium calcium bicarbonate, as the inflowing stream water, but is generally several-fold more concentrated than is the stream water.

West Chad Basin

Of 76 water sources sampled in the West Chad Basin, 74 were from wells, one was from a lake, and one was from a water hole. (See table 2). The well water varies greatly in quality, ranging in specific conductance from 39 to 3,700 micromhos and corresponding dissolved-solids content from 37 to 2,710 ppm. Most water sources have calcium or sodium, or both, as the predominant cations, with bicarbonate or nitrate, or both, as the predominant anions. There is an apparent correlation between nitrate and calcium. Also for several of the highest nitrates, potassium is also unusually high. The analyses for Abalago, Burdodo, Dakayawa, Dambam, Dandi, Garin Gudinia, Garki, Karasuwa, Kuilanu, Likori, Machina, and Shiro Kusko illustrate the high potassium accompanying some of the high nitrate values(table 2).

Only about 20 of the well sources have nitrate less than 5 ppm; others have as much as 1,660 ppm, with values commonly exceeding 100 ppm. As no borehole water in Nigeria is known to have nitrate concentrations of this magnitude, it is believed that the nitrate is introduced from the top of the well, and not from the aquifer. It seems likely that organic nitrogen, later oxidized to nitrate, originates in the guano of bats, which are known to roost in the cribbing of many wells. The water of highest nitrate, from the well at Dandi, appears to have had sufficient acidity, possible as nitric acid, to neutralize the natural bicarbonate of the water. At other localities, as at Burdodo, the acid may have reduced the amount of bicarbonate in the water.

Water from the water hole has dissolved solids of only 130 ppm and is of the calcium bicarbonate type. Water from the lake at Tapki Kaska illustrates extreme concentration by evaporation; calcium and magnesium have precipitated from solution, yielding a sodium bicarbonate water with dissolved solids of 8,780 ppm.

Sokoto Basin

Table 3 gives chemical analyses from 55 water sources sampled in the Sokoto Basin of northwestern Nigeria, including 30 from boreholes, 18 from wells, one from a spring, 5 from streams and one from a lake.

Basement Complex.--Four water samples were taken from boreholes in Basement Complex rocks adjacent to the Sokoto Basin (table 3). Three of these are of calcium bicarbonate type, whereas the fourth is of the sodium-magnesium bicarbonate type. Specific conductance ranges from 211 to 500 micromhos and dissolved solids from 142 to 328 ppm. The high iron content of 12 ppm in the borehole sample from Mile 52 on the Gusau-Sokoto Road will cause characteristic rust-colored stains or deposits within a short time after contact with oxygen from the atmosphere.

Gundumi Formation.--Sixteen water samples were collected from boreholes screened in the Gundumi Formation (table 3) of the Sokoto Basin. Except at Isa and Kaloye the water is low in dissolved solids, ranging from 28 to 243 ppm. Most water samples are predominantly of sodium or calcium and bicarbonate or sulfate type, but sodium chloride water occurs at Isa and Kaloye.

East and south of Sokoto along the Gusau-Sokoto Road is found an area of acid water. At Dange and Mile 105 the pH is 5.1, at Mile 110 it is 3.7. These waters are low in dissolved solids, ranging from 28 to 79 ppm. The predominant anion is sulfate, which may be produced by oxidation of pyrites. This process would also account for the acidity of the water. The water at Mile 110 contained 32 ppm of iron and 1.8 ppm of manganese, the highest values for these ions determined for borehole samples in Sokoto Basin. In the outcrop area of the Gundumi Formation east of Sokoto; at Sabon Birni, Isa, and Mile 73 on the Gusau-Sokoto

Road; are the most alkaline water sources in Sokoto Basin, all having pH of 8.7.

Rima Group.--Representing the Rima Group in the Sokoto Basin are analyses of water samples from nine boreholes and five wells (table 3). Most of the samples from boreholes are low in dissolved solids, ranging from 44 to 170 ppm. Water from a borehole 700 feet deep at Kaloye has a moderate dissolved solids content of about 500 ppm. Most water from boreholes tapping water in the Rima Group is predominantly a calcium bicarbonate or sulfate type. Magnesium is occasionally present in significant quantities, but sodium is the predominant cation only at Kaloye.

Of considerable interest is the highly mineralized water from two wells at Goronyo, near Taloka. A sample from a private well collected in September 1967 was nearly identical to one from the village well collected in March 1968. The water was of a magnesium-aluminum sulfate type, with also considerable amounts of calcium, nitrate, manganese, and sodium. The acidity and sulfate were possibly derived through oxidation of pyrites, with subsequent solution of relatively large quantities of aluminum and manganese in the acid water. The high nitrate, however, was probably introduced at the top of the wells, possibly as bat guano. A later sample, collected in April 1968, from the village well, then nearly dry, was no longer acid. Manganese was absent, aluminum was nearly so, and other cations except sodium were greatly reduced in amount. Among the anions, there were substantial increases in nitrate, chloride, and bicarbonate, but a lower concentration of sulfate. The water type was sodium sulfate. It is possible that the village well taps water from two

water-bearing horizons, and that the acidity was generated only in the upper horizon. Thus when a dry period resulted in dewatering of the upper horizon, a marked change in the water quality occurred because only the alkaline water from the lower horizon was then supplied to the well.

Kalambaina Formation.--From this aquifer in the north-central part of the Sokoto Basin there are analyses for water samples from eight wells and one spring (table 3). As might be expected from a limestone aquifer, the water is basically a calcium bicarbonate type. Because all sources are from a shallow aquifer, they are subject to pollution, which generally results in high nitrate, and sometimes high potassium and chloride. Except at Chimola the water has a moderate dissolved solids content, ranging from 130 to 400 ppm. The water from the well at Chimola contains extremely high nitrate and potassium, and high calcium and chloride, with a dissolved solids content of 2,340 ppm.

Gwandu Formation.--Table 3 includes analyses for five wells and one borehole tapping aquifers in the Gwandu Formation, but Ogilbee and Anderson (1965) have reported earlier chemical analyses for 14 boreholes screened in this formation. The waters are typically of calcium-magnesium bicarbonate type, but sodium or sulfate predominate in a few sources. Nitrate is high in some well waters, as at Kurdula and Balle. Dissolved solids values are generally low, to a maximum of about 160 ppm.

Surface Water.--Chemical analyses of surface-water sources in the Sokoto Basin include five from rivers and one from a lake (table 3). Dissolved solids contents are low, ranging from 33 to 157 ppm. The river water has bicarbonate as the dominant anion, with calcium and sodium as the predominate cations. The water sample from Kalmalo Lake is significantly higher in magnesium, potassium, and fluoride than the river water samples.

Kerri Kerri Area

Table 4 includes 46 water analyses, 43 for wells, one for a borehole, and two for springs in the Kerri Kerri area.

The well water varies greatly in dissolved solids, ranging from 34 to 1,500 ppm, although most values are less than 500 ppm. The water type is also highly variable, but most of the water has calcium or sodium, or both, as the predominant cations, and bicarbonate or nitrate, or both, as the predominant anions. Potassium is a predominant cation in a few sources where nitrate is also predominant. Nitrate exceeds 5 ppm in all but six of the wells, a fact that suggests pollution of the water. Further, the highest nitrates are found at centers of highest population, as at Lago. Conversely, the lowest nitrates tend to occur in places away from concentrated centers of human and animal population, as at Muncika,

Two well sources indicate acid water, with pH of 3.85 and 4.35 at Buri Buri and Pali, respectively; in each water nitrate is about half the dissolved-solids content.

The water from Wuro Bundu is highly alkaline, with pH of 10.7 and hydroxide of 17 ppm. However, this unusual analysis may have resulted from the introduction of lime or cement into the well. Relatively high concentrations of nitrite in well No. 1 at Lago and the market well at Potiskum are probably intermediate decomposition products of organic matter, a condition likely resulting from pollution of the water.

Kaduna-Zaria Area

Table 5 includes chemical analyses of water samples from 16 wells and one borehole, all ending in Basement Complex rocks in the general area of Kaduna and Zaria. Dissolved solids range from 24 to 511 ppm, but the only values exceeding about 200 ppm accompany high nitrate concentrations. The predominant cations are calcium and sodium, but a few analyses have significant magnesium or potassium. Bicarbonate is the usual predominant anion, but chloride or nitrate may be predominant, especially when they accompany the higher dissolved-solids content, as for the well at a mosque in Kujama. About two-thirds of the well sources have nitrate in excess of 5 ppm, indicating the strong possibility of pollution of the water.

Miscellaneous Chemical Analyses

Table 6 includes analyses of 14 water sources scattered over a large area from Kaduna on the north and west to Oturkpo on the south, and Biu on the east. (See fig. 1). The sources include six springs, two boreholes, one well, four rivers (including treated tap water at the city of Kaduna from the Kaduna River), and one lake. The largest group of samples, five salt springs near Lafia, is highly mineralized, having dissolved solids ranging from 7,550 to 20,000 ppm, of which more than 90 percent is sodium-chloride type. The river samples, from Makurdi area and Kaduna, are typically low in dissolved solids, ranging from 71 to 159 ppm; the Kaduna River water is of the calcium bicarbonate type, while the Makurdi waters are mixed cation bicarbonate types, with approximate equal reacting values of calcium, magnesium, and sodium.

Lake Tilla, near Biu, lies in an inactive volcanic crater without apparent outlet. The lake is fed by ground water, represented by the analysis of the well at Lake Tilla. The results of the chemical analyses suggest that the ground water entering the lake has been concentrated several-fold by evaporation. The loss of calcium and magnesium is probably caused by their precipitation, as carbonates. The large loss of silica may be explained by action of algae, but the considerable increase in potassium would be caused by factors other than evaporation.

The water from a test hole at the Teacher Training College near Bauchi is low in dissolved solids, 65 ppm, of calcium-bicarbonate type, but has an objectionable amount of iron.

Waters from Okokolu Springs at Oturkpo and from the General Hospital No. 1 borehole at Lafia are among the lowest in dissolved solids of those waters from all sources analyzed in northern Nigeria. The former is a sodium bicarbonate-chloride type and has dissolved solids of 23 ppm. The latter is a calcium-sodium bicarbonate type, but with nearly the equivalent of sulfate and bicarbonate, and a dissolved-solids content of 20 ppm.

Use of Water

Although various standards have been proposed to indicate suitability of a water source for drinking or other domestic use, it must be recognized that adherence to such standards is not likely where there is little choice in the selection of the water. In other words, if there is only one available source of drinking water, even though it be of poor quality chemically or bacteriologically, it will be used.

The following are concentrations of selected constituents that should not be exceeded in drinking water, unless water of better quality is unavailable, according to the U. S. Public Health Service (1962):

Constituent	Concentration, in mg/l (ppm)
Dissolved solids	500
Sulfate	250
Chloride	250
Nitrate	45
Fluoride	approx. 0.7 (for average annual maximum air temperature above 90°F.)
Iron	0.3
Manganese	0.05

An examination of the analyses given in tables 1-6 shows that most water sources have dissolved solids less than 500 ppm except in Chad and West Chad Basins. Even in these areas relatively few samples have dissolved solids exceeding 1,000 ppm. Other chemical quality shortcomings include nitrate exceeding 45 ppm in nearly half the wells in West Chad and Kerri Kerri areas, and objectionable amounts of iron, manganese, or both, in many borehole water sources in Chad and Sokoto Basins. The following table lists the number of water analyses with certain drinking water limitations:

Area	Total number of samples	Dissolved Solids between 500 and 1,000 ppm	Dissolved Solids over 1,000 ppm	NO_3 over 45 ppm	Fe over .3 or Mn over .05 ppm
Chad	116	38	14	3	57
West Chad	76	21	13	36	0
Sokoto	55	2	5	6	19
Kerri Kerri	46	5	2	21	0
Kaduna-Zaria	17	1	0	3	0
Misc.	14	1	6	0	1
Totals	324	68	40	69	77

Sulfate or chloride rarely exceeds 250 ppm except where dissolved-solids content is high. Some of the latter, such as the salt springs near Lafia (table 6), are not used for drinking. A few sources contain fluoride in excess of 0.7 ppm, to a maximum of 3.5 ppm in a well at Gagarawa in West Chad Basin. Such water would probably cause mottling of the teeth, particularly in children, of those drinking the water over an extended period of time.

Considering water for livestock use, Hem (1959) reports that most animals can tolerate water of much poorer quality than is generally accepted as suitable for human beings; he indicates an upper limit of dissolved solids to at least 5,000 ppm. On this basis very few of the water sources given in tables 1-6 would be unsuitable for livestock watering.

Water for irrigation use is evaluated largely on the basis of four criteria: salinity hazard, sodium hazard, bicarbonate hazard, and boron hazard. Salinity hazard of water has been classified by the U. S. Salinity Laboratory Staff (1954) as low, medium, high, or very high according to conductivity (specific conductance). The dividing points between the classes are 250, 750, and 2,250 micromhos/cm at 25°C. This classification places most ground waters in Northern Nigeria in the medium or high category, indicating that use for agriculture should be satisfactory on permeable soils with good drainage, provided other hazards are low. Surface waters usually have low salinity hazard and are generally satisfactory on most soils.

Sodium hazard was previously defined in the section on "Explanation to Accompany the Tables 1-6." Medium or greater hazard is indicated for a number of the ground-water sources in Chad Basin and for a few sources in Sokoto and West Chad Basins. Such water should not be applied, except perhaps on very sandy, highly permeable soils, or in conjunction with chemical soil amendments such as gypsum. Surface waters usually have low sodium hazard and can be used successfully on most soils.

Bicarbonate hazard is indicated by residual sodium carbonate (RSC), according to the limits given in the section on "Explanation to Accompany the Tables 1-6." This hazard is marginal or unacceptable in many of the ground-water samples from Chad and some samples from West Chad and Sokoto Basins. Also some of the surface samples from Lake Chad have marginal bicarbonate hazard. It would be advisable to avoid use of such waters for irrigation, unless gypsum or other chemical amendment is applied to the soil.

This group of analyses is the first in Nigeria known to have included determinations for boron, so prior to 1965 the extent of the boron hazard in water was unknown in northern Nigeria. The relative boron tolerance by various crops has been determined by Eaton (1935), who gives 0.3 to 1 ppm, 1 to 2 ppm, and 2 to 4 ppm as the ranges in boron concentration that will be tolerated in irrigation water by sensitive, semi-tolerant, and tolerant crops, respectively. Since the maximum boron determined (tables 1-6) is 1.0 ppm, only the sensitive crops need be considered. Among these sensitive crops only citrus fruits are commonly grown in Nigeria.

Boron values from 0.5 to 1.0 ppm are given for several sources in Sokoto Basin (table 3) and for Azara Spring (table 6), but all these present hazards other than boron that limit their use for irrigation. In Chad Basin about 20 ground-water sources have boron from 0.4 to 0.6 (table 1); most of these have other characteristics that would also limit their usefulness for irrigation. Only citrus plants, however, might be adversely affected by the level of boron in the irrigation water. As a very small amount of boron is essential for plant growth, the 0.0 ppm of boron determined in many of the analyses would indicate that boron deficiency may be much more prevalent than boron toxicity.

References

Eaton, I. M., 1935, Boron in Soils and Irrigation Waters and its Effect on Plants, with Particular Reference to the San Joaquin Valley of California: U. S. Dept. of Agriculture Tech. Bull. 448, 131 p.

Hem, J. D., 1959, Study and Interpretation of the Chemical Characteristics of Natural Water: U. S. Geol. Survey Water-Supply Paper 1473, p. 241.

Kiser, R. T., and Akingbehin, J. A., 1966, Chemical Quality of Waters in Nigeria, 1965-66: Geol. Survey of Nigeria Open-File Report No. 1441, 51 p., 1 fig.

Ogilbee, W., and Anderson, H. R., 1965, Exploratory Drilling for Ground Water in Western Sokoto Province, Nigeria with particular reference to artesian aquifers in the Gwandu Formation: U. S. Geol. Survey Open-File Report, p. 54.

U. S. Public Health Service, 1962, Drinking Water Standards, 1962: U. S. Public Health Service Pub. 956, 61 p.

U. S. Salinity Laboratory Staff, 1954, Diagnosis and Improvement of Saline and Alkali Soils: U. S. Dept. of Agriculture Handbook No. 60, p. 80.

Wilcox, L. V., 1955, Classification and Use of Irrigation Waters: U. S. Dept. of Agriculture Circ. No. 969, 19 p.

Table 1.--Chemical Analyses of Water Samples from the Chad Basin

(Constituents in Parts per Million)

Analysis by R. T. Kiser and J. A. Akingbehin

Location	Borehole (with GSN number) or other source	Date of Collection	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids (calculated)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25°C.)	pH	Residual sodium carbonate	Sodium adsorption ratio	Field or other determinations
											A. Ground Water													
Abadan Model Village	3303	11-67	97	69	.08	1.5	28	14	147	15	196	205	66	0.5	0.0	0.3	642	126	0	941	7.1	0.69	5.7	pH 6.5, Eh 24
Achim, Chad	Well	3-68	86	53	--	--	62	19	97	36	529	29	14	.6	.0	.0	573	232	0	856	7.4	3.03	2.8	PO_4 1.1
Adjadja	Well	4-68	86	94	--	--	81	19	833	27	786	1,370	26	.9	.0	.1	2,840	280	0	3,750	7.8	7.28	22	PO_4 2.0
Al Greg, Chad	Well	3-68	88	42	--	--	119	40	518	17	678	887	89	1.3	.0	.0	2,050	462	0	2,870	7.7	1.87	11	
Ariourou, Chad	Well	3-68	86	45	--	--	34	18	300	37	856	141	22	1.9	.0	.1	1,020	160	0	1,580	7.8	10.83	10	PO_4 3.2
Baboshe	2693	3-68	93	66	.55	.54	14	7.5	101	10	170	56	79	.4	.1	.0	418	66	0	648	7.0	1.47	5.4	pH 6.1, Eh 147
Badu	2280	6-68	114	22	3.0	32	5.8	1.6	65	9.6	159	26	16	1.2	.0	.2	225	21	0	357	7.2	2.19	6.2	pH 6.6, Eh 105
Baga	2451	6-68	107	72	1.7	1.7	66	28	257	19	322	495	82	.2	.0	.4	1,180	278	14	1,690	7.3	0	6.7	pH 6.3, Eh 20 PO_4 .10
Baga Road, mile 26	3610	11-67	100	68	6.9	.99	12	6.6	107	9.5	234	46	46	.5	.0	.1	411	57	0	612	6.9	2.70	6.2	pH 6.5, Eh -77 PO_4 .05
Baga Road, mile 36	3613	11-67	105	71	2.3	.68	11	5.0	111	9.1	237	60	38	.4	.0	.1	424	48	0	615	7.0	2.92	7.0	pH 6.6, Eh -75 PO_4 1.2
Baga Road, mile 40	3614	1-67	--	74	.96	.66	12	5.4	101	9.4	221	63	32	.3	5.1	.3	412	52	0	630	6.8	2.58	6.1	PO_4 .30
Baga Road, mile 45	3615	11-67	101	71	4.3	.85	14	5.6	107	10	240	70	30	.4	.1	.2	426	58	0	617	6.9	2.77	6.1	pH 6.6, Eh -76 PO_4 .05
Baga Road, mile 60	3621	11-67	102	69	6.1	.73	8.4	3.6	82	7.2	200	37	20	.6	--	.1	327	36	0	458	7.0	2.56	6.0	pH 6.6, Eh -84 PO_4 .10
Baga Road, mile 76	3624	3-68	105	69	10	.44	7.2	2.2	80	7.8	196	33	20	.9	.5	.2	318	27	0	430	7.5	2.67	6.7	pH 6.8, Eh -69
Baga Road, mile 115	3637	3-68	108	71	3.9	.83	20	9.7	137	13	246	163	39	.2	.2	.4	574	90	0	851	7.6	2.23	6.3	pH 6.6, Eh -73
Beni Sheik Road, mile 27½	3642	10-66	98	69	--	1.5	23	10	80	11	134[a]	165	18	--	.0	.1	444	99	0	645	8.6	.22	3.5	
Bout El Fil, Chad	Well	3-68	86	63	--	--	51	12	33	15	306	7.4	4.0	.2	.0	.0	337	178	0	492	7.2	1.45	1.0	
Bulongowa	2105	3-68	99	68	12	1.2	23	11	126	12	306	29	103	.4	.0	.0	523	103	0	856	7.3	2.96	5.4	pH 6.4, Eh -3
Busama	2082	11-67	96	68	2.3	2.3	58	24	160	17	218	327	97	.3	.0	.3	859	245	66	1,280	6.7	0	4.4	pH 6.2, Eh -36 NO_2 .20
Dagile	2095	5-68	97	68	.3	.48	7.8	4.7	134	6.9	301	62	28	.3	.0	.4	461	39	0	674	7.0	4.15	9.3	pH 6.2, Eh 211 PO_4 1.0
Daiya	2992	11-67	103	72	.01	1.9	36	16	150	16	216	230	72	.5	.0	.4	699	154	0	1,030	6.9	.46	5.3	pH 6.5, Eh 9
Dalori	2274	8-65	92	68	10	1.3	14	6.6	79	11	255[a]	28	10	.3	.6	.2	343	62	0	440	8.6	2.93	4.4	
Dalori	3019	11-67	97	72	3.1	2.0	17	7.7	82	12	274	26	11	.1	.0	.1	367	74	0	513	6.8	3.01	4.1	pH 6.6, Eh -16 PO_4 4.5

a/ Includes carbonate

Table 1.--Chemical Analyses of Water Samples from the Chad Basin (cont'd)

(Constituents in Parts per Million) Analysis by R. T. Kiser and J. A. Akingbehin

Location	Borehole (with GSN number) or other source	Date of Collection	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids (calculated)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25°C.)	pH	Residual sodium carbonate	Sodium adsorption ratio	Field or other determinations
A. Ground Water (cont'd)																								
Dalori	3032	8-68	97	10	0.16	0.00	8.8	5.8	78	13	274[a/]	1.0	11	0.2	0.0	0.1	263	46	0	454	8.7	3.58	5.4	pH 7.2, Eh -2 PO_4 .35
Dikwa	1839	3-68	105	78	1.8	.63	19	9.8	129	12	318	16	97	.7	.2	.4	519	88	0	825	7.4	3.45	6.0	pH 6.2, Eh -8
Dokora, Chad	Well	3-68	84	94	--	--	85	36	94	40	580	115	16	.4	.0	.1	767	362	0	1,100	7.6	2.27	2.2	PO_4 .85
Fairam	Well	4-68	84	91	--	--	364	105	983	39	612	1,770	305	1.1	835	.0	4,790	1,340	838	6,080	7.7	0	12	
Frigisilim	2297	6-68	105	73	.27	1.7	36	15	147	15	193	221	83	.5	.0	.4	686	152	0	1,040	7.0	.12	5.2	pH 6.2, Eh 116
Gajibo	3027	3-67	98	72	1.5	.98	26	12	171	12	358	90	86	.2	.0	.3	646	115	0	1,020	6.8	3.57	6.9	pH 6.4, Eh -5
Gajiran	1982	6-68	108	74	.78	.78	12	6.3	102	8.7	230	68	26	.5	.0	.2	411	56	0	574	7.2	2.65	5.9	pH 6.4, Eh -1 PO_4 .40
Gashagar	2532	11-67	89	67	9.0	1.9	30	14	128	16	180	181	87	.3	.0	.3	613	132	0	927	6.9	.31	4.8	pH 6.5, Eh -60
Gazabure	2519	6-68	102	75	.72	2.7	56	23	200	16	238	319	128	.4	.0	.3	935	236	41	1,400	7.1	0	5.7	pH 6.3, Eh 154
Gubio	2512	6-68	102	22	2.0	.27	4.2	1.8	58	6.4	152	13	13	2.0	.0	.2	196	18	0	307	7.3	2.13	5.9	pH 6.8, Eh 149 PO_4 .50
Gudumbali	2087	6-68	110	50	1.5	2.2	42	19	188	16	231	295	99	.8	.0	.3	824	185	0	1,260	7.1	.09	6.0	pH 6.3, Eh 74
Hererime, Cameroon	Well	4-68	88	65	--	--	292	124	500	34	554	1,760	60	.5	.0	.0	3,110	1,240	786	3,670	7.6	0	6.2	
Isaka	2998	6-68	104	74	.07	2.7	42	19	162	15	213	291	76	.5	.0	.3	785	185	10	1,160	7.1	0	5.2	pH 6.4, Eh 129
Jilbe	2097	5-68	100	68	.50	.74	8.8	5.1	115	6.5	274	46	28	.4	.0	.5	415	43	0	611	7.0	3.63	7.6	pH 6.3, Eh 221 PO_4 1.3
Juwa Kumon	2252	6-68	107	73	.65	.58	12	7.1	118	9.0	272	72	35	.3	.0	.2	461	59	0	675	7.2	3.28	6.7	pH 6.6, Eh 40 PO_4 .65
Kahar	3008	6-68	103	75	.73	4.3	66	31	214	18	212	425	128	.6	.0	.3	1,060	292	118	1,560	7.0	0	5.4	pH 6.2, Eh 132
Kaigaman	Well	8-65	--	51	--	--	188	56	581	135	2,260	83	90	.0	1.4	.2	2,300	700	0	2,800	7.8	23.04	9.6	
Kanema	2418	6-68	101	75	.68	1.8	47	20	191	15	204	337	75	.4	.4	.4	861	201	34	1,250	6.8	0	5.9	pH 6.4, Eh 72
Kauwa	3021	8-68	104	71	5.6	1.5	49	21	210	18	291	362	68	.3	.0	.4	943	207	0	1,400	6.6	.63	6.4	pH 6.6, Eh 24
Kawia	3013	11-67	97	68	.53	2.1	45	20	147	17	183	254	107	.4	.1	.3	755	196	46	1,140	6.7	0	4.6	pH 6.3, Eh 7 NO_2 6.0
Kingoa	1986	6-68	107	74	1.2	.95	14	6.6	87	11	108	165	16	.6	.0	.2	427	62	0	593	6.9	.53	4.8	pH 6.4, Eh 145
Loe, Niger	New borehole	6-68	96	75	.57	.29	8.8	4.6	96	9.5	123	52	76	.7	.0	.2	385	41	0	547	6.9	1.20	6.5	pH 6.6, Eh 287 PO_4 .75
Madkous, Chad	Well	3-68	86	73	--	--	21	6.2	160	20	523	17	5.0	.4	.0	.0	561	78	0	819	7.4	7.01	7.9	PO_4 .45

a/ Includes carbonate

Table 1.--Chemical Analyses of Water Samples from the Chad Basin (cont'd)

(Constituents in Parts per Million) Analysis by R. T. Kiser and J. A. Akingbehin

Location	Borehole (with GSN number) or other source	Date of Collection	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids (calculated)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25°C.)	pH	Residual sodium carbonate	Sodium adsorption ratio	Field or other determinations
A. Ground Water (cont'd)																								
Maiduguri (Lower Zone)	2728	11-67	115	22	0.37	0.00	1.6	0.2	75	3.8	177	0.3	8.5	2.8	0.1	0.2	202	5	0	308	7.5	2.80	15	pH 7.7, Eh 43 PO_4 .15
Maiduguri (Upper Zone)	3042	11-67	90	111	.01	.00	2.8	.7	50	2.6	130	4.8	3.0	.2	.0	.0	241	10	0	222	7.2	1.93	6.9	pH 6.8, Eh 236 PO_4 2.1
Majigeti	2098	3-68	100	69	1.8	1.2	22	12	120	12	258	23	107	.2	6.6	.1	499	103	0	807	7.1	2.17	5.1	pH 5.8, Eh 27 NO_2 .02, PO_4 .20
Majiri	2529	11-67	106	69	1.1	2.8	58	25	157	18	208	335	101	.4	.0	.3	866	249	80	1,290	6.7	0	4.3	pH 6.4, Eh 185
Mallam Fatori	3605	5-67	106	71	1.7	1.6	33	14	152	16	195	235	64	.4	.0	.5	682	142	0	1,000	6.8	.36	5.5	pH 6.6, Eh -29
Mallam Fatori	3612	11-67	108	69	1.5	1.5	34	15	153	16	199	244	67	.3	.0	.4	697	148	0	1,020	7.2	.30	5.5	pH 6.5, Eh 11
Masu	2259	6-68	107	74	.49	1.3	25	12	158	13	288	151	60	.4	.0	.2	636	110	0	970	7.4	2.52	6.6	pH 6.4, Eh 98 PO_4 .35
Mbutta	1648 and 3305	6-68	108	79	.76	.61	16	7.1	123	9.7	286	83	30	.3	.0	.2	490	69	0	702	7.1	3.31	6.4	pH 6.6, Eh 131 PO_4 .45
Meleri	2104	5-68	100	70	.22	.48	11	4.3	154	6.8	323	80	40	.3	.0	.6	527	45	0	796	7.0	4.39	10	pH 6.4, Eh -133 PO_4 .70
Mokono	Well	4-68	89	96	--	--	138	51	627	31	802	1,120	145	.5	.0	.1	2,610	554	0	3,510	7.7	2.06	12	PO_4 2.5
Mongonu	1980	3-68	--	70	.77	.44	5.2	3.4	89	5.9	193	36	18	.7	.1	.3	328	27	0	445	7.3	2.62	7.4	NO_2 4.1 PO_4 .30
Mongonu	2264	6-68	105	70	.66	.51	6.4	2.7	85	5.5	196	34	18	.7	3.1	.2	323	27	0	440	7.2	2.67	7.1	pH 6.6, Eh -22 PO_4 .15
Mudu	2090	5-68	100	68	.60	.96	16	8.8	147	10	315	71	74	.2	.0	.5	552	76	0	861	7.0	3.64	7.3	pH 6.2, Eh 237 PO_4 1.1
Muzuguli	2466	5-68	102	66	.99	.87	15	7.4	144	9.1	344	69	54	.3	.0	.5	539	68	0	833	7.2	4.28	7.6	pH 6.2, Eh 139 PO_4 1.0
Naala, Chad	Well	3-68	86	92	--	--	20	6.8	14	11	122	4.3	16	.2	.0	.0	224	78	0	241	6.8	.44	.6	
Ndiobdi, Chad	Well	3-68	86	72	--	--	39	17	36	13	312	2.7	4.0	.4	.0	.0	338	166	0	492	7.2	1.79	1.3	PO_4 .40
Ngaratuwa	2430	6-68	108	79	.35	2.1	50	23	211	16	252	379	87	.4	.0	.4	970	218	12	1,410	6.9	0	6.2	pH 6.3, Eh 85
Njine	2408	6-68	99	74	.76	.72	14	6.3	187	8.0	351	105	52	.3	.0	.5	620	61	0	912	7.1	4.53	10	pH 6.5, Eh 105 PO_4 .10
Nyau	2091	6-68	107	72	1.2	2.3	50	21	189	18	236	326	88	.4	.0	.4	881	212	18	1,300	7.2	0	5.6	pH 6.3, Eh 79
Observation borehole	2266	3-67	97	69	21	1.3	34	12	129	15	294	68	90	.5	.0	.1	563	134	0	895	6.9	2.14	4.8	pH 6.4, Eh -100

Table 1.--Chemical Analyses of Water Samples from the Chad Basin (cont'd)

(Constituents in Parts per Million) Analysis by R. T. Kiser and J. A. Akingbehin

Location	Borehole (with GSN number) or other source	Date of Collection	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids (calculated)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25°C.)	pH	Residual sodium carbonate	Sodium adsorption ratio	Field or other determinations
A. Ground Water (cont'd)																								
Observation wells:																								
Bama run:	MOW No.																							
Gauramari	736/54	3-68	86	55	--	--	3.6	1.0	23	2.4	60	2.8	2.5	0.3	8.6	0.0	129	13	0	120	6.8	0.72	2.8	NO_2 .03
Dala Gonebori	499/53	3-68	86	99	--	--	33	13	212	3.3	649	38	10	.7	27	.0	756	136	0	1,070	7.9	7.92	7.9	
Kofa	616/53	3-68	86	51	--	--	14	2.4	14	14	72	3.1	4.5	.0	30	.0	168	45	0	198	7.1	.28	.9	NO_2 .03
Dumboa run:																								
Delwa West	551/52	4-68	84	53	--	--	24	2.4	16	3.2	74	2.8	7.5	.1	39	.0	184	70	10	235	6.7	0	.8	
Delwa West	552/52 (GSN 1647)	4-68	86	57	--	--	6.0	2.4	54	8.1	131	20	18	--	1.1	.0	232	25	0	315	7.0	1.65	4.7	PO_4 .05
Mulgwe	Well	4-68	82	36	--	--	16	2.4	14	31	127	5.4	4.5	.2	1.3	.0	174	50	0	248	6.8	1.08	.9	PO_4 .05
Kafa	Well	4-68	84	73	--	--	24	4.9	31	2.2	172	1.8	3.0	.3	.4	.0	226	80	0	280	7.3	1.22	1.5	PO_4 .05
Geidam run:																								
Yanayaku	805/55	4-68	92	133	--	--	30	3.9	69	9.8	146	81	27	.4	1.0	.1	444	91	0	509	7.0	.57	3.1	PO_4 17
Yashu	Well	4-68	88	101	--	--	38	6.8	31	7.9	127	15	7.5	.2	83	.0	354	123	19	412	7.0	0	1.2	PO_4 .30
Belle	392/51	4-68	84	91	--	--	15	3.0	11	25	119	3.5	1.0	.1	1.0	.0	210	50	0	216	7.1	.95	.7	PO_4 .15
Kalalawa	534/53	4-68	88	85	--	--	20	1.5	9.5	7.0	96	2.5	2.0	.1	.0	.0	175	56	0	171	6.9	.45	.5	PO_4 .75
Kauwa run:																								
Checheno	Well	5-68	88	75	--	--	22	15	364	42	740	115	45	1.7	168	.1	1,210	118	0	1,780	7.9	9.77	15	PO_4 .45
Kauwa	Well	5-68	87	83	--	--	11	7.4	600	66	1,210	319	73	2.3	7.1	.2	1,770	58	0	2,630	8.0	18.67	34	PO_4 .55
Ngala run:																								
Kariari	Well	5-68	88	104	--	--	79	18	74	7.0	508	20	5.5	.4	1.1	.0	559	272	0	804	7.6	2.89	2.0	PO_4 .10
Ngala	1026/58	5-68	84	90	--	--	346	82	1,540	46	555	3,460	398	--	.0	.2	6,240	1,200	745	7,600	7.3	0	19	PO_4 .65
Qanramari, Cameroon	Well	4-68	88	62	--	--	224	89	800	61	706	1,960	67	.3	.0	.1	3,610	925	346	4,500	7.8	0	11	PO_4 .45
Rann	2476	5-68	102	71	.73	1.4	8.2	4.7	144	6.4	308	71	30	.3	.0	.4	489	40	0	717	7.1	4.25	9.9	pH 6.4, Eh 28c PO_4 1.3
Ridjil Haz, Chad	Well	3-68	86	45	--	--	39	5.2	9.0	20	176	9.1	16	.1	.0	.1	234	119	0	355	7.0	.50	.4	PO_4 3.1
Silala	2417	5-68	100	70	.11	.44	7.6	2.9	96	5.5	247	6.1	38	1.3	.0	.4	350	31	0	515	7.2	3.43	7.5	pH 6.5, Eh 239 PO_4 .15
Wulgo	2715	5-68	104	72	.10	.35	7.4	3.3	154	6.4	330	75	32	.3	.0	.4	515	32	0	756	7.2	4.77	12	pH 6.6, Eh 196 PO_4 1.4

Table 1.--Chemical Analyses of Water Samples from the Chad Basin (cont'd)

(Constituents in Parts per Million)

Analysis by R. T. Kiser and J. A. Akingbehin

Location	Borehole (with GSN number) or other source	Date of Collection	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids (calculated)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25°C.)	pH	Residual sodium carbonate	Sodium adsorption ratio	Field or other determinations
A. Ground Water (cont'd)																								
Wumbi	2719	5-68	101	70	0.06	0.56	8.8	5.1	147	6.4	324	74	32	0.3	4.0	0.4	509	43	0	741	7.0	4.45	9.7	pH 6.6, Eh 256 PO_4 1.3
Yedi	1978	6-68	104	75	.36	.72	15	6.9	169	8.0	358	94	47	.2	.0	.4	593	66	0	868	7.1	4.55	9.0	pH 6.6, Eh 111 PO_4 1.4
Yo	2982	11-67	99	70	.08	1.6	28	12	141	14	194	198	65	.5	.0	.3	625	121	0	921	7.1	.76	5.6	pH 6.4, Eh -6
B. Surface Water																								
Lake Chad:																								
13°14' N, 13°47' E		2-67	64	31			24	13	28	14	224[a/]	.3	.5	.4	.0	.1	222	114	0	365	8.4	1.39	1.1	PO_4 1.1
13°26' N, 13°28' E		2-67	68	29			21	9.6	25	12	188[a/]	.2	.0	.4	.0	.1	191	92	0	320	8.5	1.24	1.1	PO_4 .70
13°40' N, 13°33' E		2-67	68	29			26	12	30	15	233[a/]	.7	1.0	.4	.0	.1	230	113	0	380	8.5	1.56	1.2	PO_4 1.0
13°43' N, 13°40' E (Surface)		2-67	66	29			21	9.6	25	12	186[a/]	.5	.5	.3	.0	.1	191	92	0	310	8.4	1.21	1.1	PO_4 .70
13°43' N, 13°40' E (depth 5 m)		2-67	64	29			21	10	25	12	190[a/]	.2	.0	.4	.0	.1	192	94	0	325	8.4	1.25	1.1	PO_4 .75
13°51' N, 14°10' E		2-67	66	81			38	17	38	20	320[a/]	.7	2.5	.6	.0	.2	358	166	0	520	8.3	1.92	1.3	PO_4 2.1
13°52' N, 14°00' E		2-67	64	58			31	15	34	15	268	.3	1.5	.5	.0	.1	289	140	0	440	8.2	1.59	1.3	PO_4 1.5
13°59' N, 13°38' E		2-67	64	46			36	18	42	21	336[a/]	.7	2.5	.6	.0	.1	335	166	0	530	8.6	2.20	1.4	PO_4 1.7
14°22' N, 13°38' E		2-67	63	109			59	43	126	62	786[a/]	.8	10	1.4	.0	.3	801	324	0	1,130	8.7	6.39	3.0	PO_4 2.9
14°23' N, 13°38' E (Pond, north shore)		2-67	62	44			17	16	2,150	452	5,830[a/]	28	245	--	26	--	5,860	109	0	8,400	9.4	93.35	90	PO_4 10
13°09' N, 14°32' E		4-67	--	34			8.8	1.9	6.8	2.4	54[a/]	3.0	.0	--	.2	.1	84	30	0	87	8.6	.29	.5	PO_4 .25
13°27' N, 14°42' E		4-67	--	58			15	4.7	12	5.8	105	3.8	.0	--	1.4	.2	153	57	0	173	7.9	.58	.7	PO_4 .65
13°25' N, 14°10' E		5-67	86	36			16	5.8	16	7.7	123	2.0	.0	.3	.2	.0	145	64	0	202	7.8	.74	.9	PO_4 .55
13°28' N, 13°54' E		5-67	90	48			27	12	37	17	254	2.5	.5	.6	.3	.1	270	118	0	404	7.8	1.80	1.5	PO_4 2.2
13°28' N, 14°20' E		5-67	88	43			14	3.4	8.9	5.2	86	1.5	.0	.2	.5	.2	119	49	0	144	7.1	.43	.6	PO_4 .60
13°28' N, 14°27' E		5-67	86	40			9.6	4.4	7.5	4.4	71	1.3	.0	.1	.8	.0	103	42	0	125	7.1	.32	.5	PO_4 .50
13°39' N, 13°33' E		5-67	88	35			27	13	34	16	251[a/]	1.4	.5	.6	.1	.2	252	122	0	390	8.4	1.67	1.3	PO_4 1.4
13°36' N, 13°24' E		8-67	82	46			38	19	52	23	352	.8	3.5	.8	.2	.1	358	174	0	545	7.8	2.29	1.7	PO_4 1.8
13°36' N, 13°24' E		11-67	82	23			13	6.2	16	8.1	120	1.0	.5	.3	.7	.0	128	58	0	195	7.6	.81	.9	PO_4 .55
14°03' N, 13°38' E		12-67	82	68			51	25	72	31	488	3.1	5.5	1.0	.0	.2	499	228	0	733	8.2	3.44	2.1	PO_4 2.6

a/ Includes carbonate

Table 1.--Chemical Analyses of Water Samples from the Chad Basin (cont'd)

(Constituents in Parts per Million) Analysis by R. T. Kiser and J. A. Akingbehin

Location	Borehole (with GSN number) or other source	Date of Collection	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids (calculated)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25°C.)	pH	Residual sodium carbonate	Sodium adsorption ratio	Field or other determinations
B. Surface Water (cont'd)																								
Lake Chad: (cont'd)																								
14°12' N, 13°38' E		12-67	82	82			53	29	80	35	532[a/]	0.7	6.5	1.1	0.0	0.2	552	249	0	807	8.3	3.75	2.2	PO_4 2.4
14°18' N, 13°38' E		12-67	82	85			53	31	86	38	578[a/]	2.1	7.5	1.2	.0	.1	592	259	0	868	8.3	4.30	2.3	PO_4 2.7
Damasak	Komadugu Yobe	11-67	72	15			7.2	2.2	5.6	3.2	50	1.3	.5	.3	.3	.1	61	27	0	83	7.0	.28	.5	
Maiduguri	Ngadda River	11-67	81	19			8.4	1.9	7.6	2.6	53	.3	.0	.6	.1	.0	66	29	0	90	7.1	.29	.6	
Mutube	Yedseram River	11-67	--	27			6.0	1.9	8.6	1.8	47	1.6	1.0	.6	.0	.0	72	23	0	82	7.1	.31	.8	
Rille	Komadugu Yobe	2-67	70	13			11	3.8	7.7	5.2	77	.8	.0	.3	.0	.1	80	43	0	140	7.1	.40	.5	PO_4 .05
Tokombere	Stream	11-67	--	32			11	3.0	15	1.2	86	1.2	.5	.5	.0	.0	107	40	0	140	7.4	.61	1.0	PO_4 .15

a/ Includes carbonate

Table 2.--Chemical Analyses of Water Samples from the West Chad Basin of Northern Nigeria

(Constituents in Parts per Million)

Analysis by J. A. Akingbehin, John Adesuyi, and R. T. Kiser

Location	Borehole (with GSN number) or other source	Date of Collection	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids (calculated)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25°C.)	pH	Residual sodium carbonate	Sodium adsorption ratio	Field or other determinations
Abalago	Well	5-66	84	12			128	60	107	674	262	190	208	0.6	1,210	0.0	2,720	565	350	3,550	7.4	0	2.0	
Biriri	Well	12-65	88	56			21	2.8	28	7.2	145	7.8	3.5	.9	.4	.0	199	64	0	268	7.1	1.10	1.5	
Birniwa	Well	3-66	86	46			104	20	19	13	44	4.3	43	.0	366	.0	637	342	306	915	7.6	0	.5	
Bogwa	Well	3-66	86	61			6.0	1.5	55	12	135	10	6.0	--	28	--	246	21	0	310	7.2	1.79	5.2	
Budua	Well	11-65	86	66			90	22	31	13	94	16	32	.4	310	.0	646	314	237	813	7.2	0	.8	
Bulabori	Well	3-66	87	48			50	9.5	114	16	293	50	40	1.5	107	.0	580	164	0	875	8.2	1.52	3.9	
Bulangu	Well	5-66	86	52			66	15	42	17	26	3.5	39	.0	320	.0	564	228	206	800	6.0	0	1.2	
Burdodo	Well	4-66	86	46			192	53	84	154	27	122	132	.0	941	.0	1,740	695	673	2,330	6.8	0	1.4	PO_4 .10
Bursari	Well	2-66	84	112			266	39	87	27	282	6.1	102	.0	870	.0	1,650	825	594	2,100	7.6	0	1.3	
Cementi	Well	12-65	88	115			12	2.4	27	7.4	83	29	8.0	--	.0	.0	242	40	0	245	6.9	.56	1.8	
Dagashi	Well	5-66	86	88			43	8.1	31	8.2	194	2.5	13	.1	40	.0	330	141	0	440	6.9	.36	1.1	PO_4 .40
Dakayawa	Well	3-66	80	37			163	35	91	185	274	110	123	.4	558	.0	1,440	550	326	1,990	8.0	0	1.7	
Dakidaka	Well	4-66	88	108			156	16	19	13	106	6.8	51	.0	416	.0	838	456	369	1,160	6.6	0	.4	PO_4 .70
Dambam	Well	11-65	81	13			23	7.9	20	154	144[a/]	26	33	.0	153	.0	501	90	0	719	8.4	.56	.9	
Dan Banki	Well	3-66	88	87			32	7.3	16	6.2	75	9.9	7.0	.3	94	.0	294	110	48	350	6.7	0	.7	
Dandi	Well	4-66	83	45			306	121	138	151	0	21	265	.5	1,660	.0	2,710	1,260	1,260	3,700	4.30	0	1.7	
Dangiato	Well	5-66	82	74			19	7.4	191	12	448	72	19	--	48	--	663	78	0	990	7.5	5.78	9.4	
Dan Kumbo	Well	3-66	88	59			74	20	25	10	62	7.2	35	.1	269	.0	530	266	215	780	6.7	0	.7	
Dara	Well	2-66	80	39			79	11	82	16	294	164	13	.2	13	.3	562	244	3	813	7.5	0	2.3	
Dilala	Well	2-66	87	88			10	1.2	18	4.4	59	13	8.5	.0	3.0	.0	175	30	0	159	8.0	.37	1.4	
Dummadumi Kyaure	Well	5-66	84	35			232	55	122	28	68	54	161	.0	941	.0	1,660	805	750	2,330	6.3	0	1.9	PO_4 .05
Fagan Kawo	Well	5-66	86	80			114	21	30	14	132	14	42	.1	342	.0	723	370	262	1,000	6.8	0	.7	PO_4 .65
Farimaram	Well	3-66	88	82			62	12	100	15	251	164	16	--	38	-	613	202	0	875	7.1	.07	3.1	
Gabai	Well	12-65	86	66			286	53	40	31	112	83	90	.1	989	.0	1,690	930	838	2,080	7.4	0	.6	
Gadau	Well	11-65	85	38			38	9.0	49	8.2	56	28	33	.0	157	.0	388	132	86	547	8.1	0	1.9	
Gadia	Well	11-65	85	38			22	4.4	7.9	4.4	106	3.3	2.0	.4	.2	.0	135	73	0	186	6.9	.28	.4	
Gagarawa	Well	3-66	86	77			18	4.6	273	14	628	33	32	3.5	102	.0	886	64	0	1,260	7.7	9.01	15	
Gamawa	Well	11-65	86	100			35	7.9	15	8.5	107	6.0	10	.2	55	.0	291	120	32	354	6.6	0	.6	

a/ Includes carbonate

Table 2.--Chemical Analyses of Water Samples from the West Chad Basin of Northern Nigeria (cont'd)

(Constituents in Parts per Million)

Analysis by J. A. Akingbehin, John Adesuyi, and R. T. Kiser

Location	Borehole (with GSN number) or other source	Date of Collection	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids (calculated)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25°C.)	pH	Residual sodium carbonate	Sodium adsorption ratio	Field or other determinations
Garin Alkali	Well	12-65	84	72			15	2.8	--	70	196	11	11	--	23	--	299	49	0	381	7.7	2.13	4.3	
Garin Gudinia	Well	4-66	84	34			42	22	29	171	281	42	45	.6	152	.0	676	196	0	1,040	7.1	.69	.9	
Garki	Well	4-66	87	23			74	24	29	62	44	17	54	.0	344	.0	640	282	246	990	6.3	0	.8	PO_4 .45
Gashua	Well	12-65	76	112			29	2.3	33	6.1	160	26	8.0	.0	.5	.0	296	82	0	342	7.2	.98	1.6	
Geidam	Well	2-66	80	24			12	2.7	7.3	7.2	74	4.6	3.0	.1	.0	.0	97	41	0	137	7.1	.39	.5	
Girgir	Well	2-66	85	114			59	14	20	8.4	96	8.2	28	.0	160	.0	459	204	126	575	7.0	0	.6	
Gujba	Well	12-65	87	81			10	2.9	4.8	5.4	61	1.8	2.2	.2	.0	.0	138	37	0	106	6.5	.26	.3	
Gununu	Well	12-65	84	35			5.0	.6	4.7	4.4	29	.5	2.2	.1	1.4	.0	68	15	0	61	6.1	.18	.5	
Guzaram	Well	11-65	87	86			15	1.8	15	3.9	80	4.5	1.5	.2	.2	.0	167	45	0	158	7.1	.41	1.0	
Ingweljabi	Well	12-65	88	118			6.0	3.9	16	8.1	60	9.7	5.5	--	.8	.0	198	31	0	154	7.7	.36	1.3	
Jajere	Well	12-65	87	38			12	1.2	24	6.8	113	2.8	3.5	.2	.2	.1	145	35	0	196	7.1	1.15	1.8	
Jajeri	Well	3-66	88	104			17	4.7	10	4.8	70	4.1	6.0	.3	25	.0	209	62	4	200	7.0	0	.6	
Jibbirti	Well	2-66	86	28			40	12	27	14	30	42	21	.0	158	.0	357	149	124	531	7.1	0	1.0	
Kaffin Romi	Well	11-65	84	95			168	31	72	26	88	71	75	.0	594	.0	1,080	548	476	1,440	7.2	0	1.3	
Kailu	Well	12-65	88	103			28	1.7	55	11	203	24	10	2.8	2.4	.2	338	77	0	420	7.1	1.79	2.7	
Karasuwa	Well	3-66	81	33			71	31	61	188	36	103	70	.1	551	.2	1,130	304	274	1,510	7.6	0	1.5	
Kaska	Well	3-66	71	22			7.6	3.2	3.4	6.2	45	5.3	2.5	.1	6.4	.1	79	32	0	102	7.4	.10	.3	
Kayairi	Well	11-65	84	34			26	1.9	9.5	2.6	102	2.3	2.0	.2	.4	.0	129	73	0	185	6.7	.21	.5	
Kirboa	Well	2-66	84	86			57	9.3	194	15	195	209	148	.1	39	.0	853	180	20	1,280	7.1	0	6.3	
Kuilanu	Well	12-65	83	44			178	60	112	355	249	143	168	--	954	.1	2,140	690	486	2,830	7.2	0	1.9	
Kumagunnam	Well	3-66	83	20			11	5.7	7.9	22	22	26	10	.1	51	.0	165	51	33	243	6.9	0	.5	
Kwubsa	Well	3-66	85	83			60	13	213	18	561	136	57	--	.6	--	857	202	0	1,290	7.5	5.15	6.5	
Likori	Well	3-66	79	58			87	36	98	198	604	39	76	1.2	182	.1	1,070	366	0	1,620	8.2	2.58	2.2	
Machina	Well	2-66	84	31			23	10	12	138	205	8.8	8.5	2.4	97	.1	432	100	0	597	7.3	1.36	.5	
Maidashi	Well	3-66	88	96			11	2.8	48	10	157	23	9.0	--	.9	.1	278	39	0	317	8.0	1.79	3.3	
Maigamarka	Well	3-66	88	87			41	12	20	9.0	46	5.3	10	.3	186	.0	394	151	114	495	6.8	0	.7	
Maisamiya	Well	4-66	82	29			40	11	52	74	201	31	36	.5	123	.0	496	146	0	785	7.3	.37	1.9	
Mallamti	Well	2-66	86	112			15	2.6	33	6.2	85	20	9.5	.1	27	.0	267	48	0	275	6.8	.43	2.1	

Table 2.--Chemical Analyses of Water Samples from the West Chad Basin of Northern Nigeria (cont'd)

(Constituents in Parts per Million)

Analysis by J. A. Akingbehin, John Adesuyi, and R. T. Kiser

Location	Borehole (with GSN number) or other source	Date of Collection	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids (calculated)	Hardness as $CaCO_3$		Specific conductance (micromhos at 25°C.)	pH	Residual sodium carbonate	Sodium adsorption ratio	Field or other determinations
																		Calcium, magnesium	Noncarbonate					
Masho	Well	12-65	86	47			112	17	48	30	326	163	8.0	0.4	0.6	0.0	587	348	81	907	7.7	0	1.1	
Nangere	Well	11-65	84	91			38	8.0	21	5.4	162	8.0	8.5	.2	19	.0	279	128	0	356	7.0	.10	.8	
Nasari	Well	2-66	88	103			4.4	1.7	14	7.6	58	8.2	2.5	--	.1	.0	170	18	0	125	7.1	.59	1.4	
Ngel Hoa	Well	2-66	87	112			12	1.5	20	5.8	85	12	5.0	.3	.7	.0	211	36	0	182	8.2	.67	1.5	
Ngelzarma	Well	12-65	82	57			44	22	102	39	250	34	47	.8	191	.0	660	200	0	907	7.9	.10	3.1	
Sabon Gari Guba	Well	12-65	86	100			16	2.9	18	4.9	96	7.1	4.0	.2	1.6	.0	202	52	0	199	7.6	.53	1.1	
Saiyori	Well	4-66	88	61			25	4.5	11	7.6	101	4.0	4.5	.2	23	.0	191	81	0	245	6.7	.04	.5	PO_4 .30
Sankara	Well	4-66	85	49			384	83	95	46	144	207	208	.1	1,190	.1	2,330	1,300	1,180	3,080	6.8	0	1.4	
Shekau	Well	12-65	86	114			12	3.6	41	8.1	152[a/]	10	8.5	1.7	27	.0	301	60	0	352	8.4	1.29	2.3	
Shiro Kusko	Well	12-65	82	70			65	13	45	179	104	62	75	.3	334	.0	894	216	131	1,170	7.2	0	1.3	
Tapki Kaska	Lake	3-66	69	220			0	0	3,450	115	7,050[a/]	1,310	199	--	10	--	8,780	0	0	11,000	9.6	115.63	--	
Tapki N. Kaska	Water hole	3-66	70	19			26	5.4	4.7	5.6	125	1.5	3.5	.8	1.2	.0	130	87	0	210	8.0	.31	.2	
Taura Station	Well	4-66	85	45			6.8	2.2	50	11	152	4.8	7.0	--	5.6	--	207	26	0	285	7.0	1.97	4.3	
Tshamo	Well	5-66	84	33			44	8.3	8.5	20	140	15	15	.2	44	.0	257	144	30	415	6.8	0	.3	PO_4 .15
Tumpidwa	Well	3-66	83	66			63	9.2	80	13	391	12	27	.4	8.4	.0	472	195	0	730	7.4	2.51	2.5	
Udubo	Well	11-65	84	21			9.2	1.9	12	7.6	40	2.1	6.0	.2	26	.0	105	31	0	142	6.3	.04	.9	
Uhi	Well	4-66	87	53			69	17	29	8.8	66	14	46	.2	212	.0	482	242	188	715	6.5	0	.8	
Ungwan Magaji	Well	4-66	86	16			2.4	.2	3.3	2.8	15	2.6	2.5	.0	.6	.0	37	7	0	39	6.1	.11	.5	
Yadiara	Well	12-65	88	110			55	5.6	50	36	704	43	13	--	3.3	.2	782	160	0	1,240	7.6	--	1.7	NH_4 (calc.) 119
Yan Molo	Well	4-66	84	28			65	19	138	16	619	17	7.0	.2	30	.0	625	240	0	1,060	7.6	5.35	3.9	

a/ Includes carbonate

Table 3.--Chemical Analyses of Water Samples from the Sokoto Basin of Northern Nigeria (cont'd)

(Constituents in Parts per Million) Analysis by J. A. Akinghehin, John Adesuyi and R. T. Kiser

Location	Borehole (with GSN number) or other source	Date of Collection	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids (calculated)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25°C.)	pH	Residual sodium carbonate	Sodium adsorption ratio	Field or other determinations
											D. Kalambaina Formation (cont'd)													
Sokoto	Well, commercial area	11-67	--	12	--	--	26	5.8	6.1	2.6	76	37	3.0	0.3	0.1	0.0	130	89	26	215	7.0	0	0.3	
Tombawal	Well	9-66	86	13	--	.08	18	5.4	8.8	28	20	7.2	16	.0	97	.0	203	67	50	315	7.2	0	.5	
											E. Gwandu Formation													
Balle	Well	7-66	89	13	--	.00	5.6	1.2	5.5	2.2	9	.5	2.5	.0	29	.0	64	19	12	80	6.9	0	.6	
Gwandu	Well	6-66	88	11	--	.00	9.6	.7	2.6	2.9	34	.3	.5	.0	11	.0	56	27	0	79	7.5	.02	.2	
Kurdula	Well	7-66	87	25	--	.00	14	7.5	30	26	52	16	16	.1	111	.0	272	66	24	405	7.7	0	1.6	
Kwakwara	Well	5-66	--	18	--	--	6.4	1.7	3.9	10	31	1.3	4.5	.0	10	.0	71	23	0	90	7.4	.05	.4	
Yeldu	3063	2-68	91	14	.86	.03	13	10	21	6.2	114	28	4.5	.8	.0	.0	154	75	0	252	7.3	.37	1.1	pH 7.1 Eh -27
Yeldu	Well	6-66	89	13	--	.00	2.2	.6	2.3	2.7	13	.2	.5	.0	5.3	.0	33	8	0	35	7.3	.05	.4	
											F. Surface Water													
Dolle	Niger River	5-66		18			6.4	1.9	8.0	4.4	40	9.4	4.0	.2	.3	.0	73	24	0	100	7.8	.18	.7	
Jega	Zamfara River	9-66	85	6.6	--	--	4.4	1.0	2.4	3.6	23	2.3	.5	--	.9	--	33	15	0	44	7.4	.08	.3	
Kalgo	Shella River	9-66	84	24	--	.00	20	4.9	16	4.4	111	15	3.5	.2	.2	.0	143	70	0	220	7.2	.42	.8	
Kalmalo	Lake	4-66		5.1			24	10	7.1	23	152[a/]	2.8	6.5	1.6	2.2	--	157	103	0	300	8.3	.40	.3	
Sokoto	Rima River	9-66	86	7.3	--	--	8.0	1.9	3.9	3.2	46	2.1	.5	--	.6	--	50	28	0	78	7.7	.19	.3	
Sokoto	Sokoto River	9-66	86	7.3	--	--	5.2	.5	3.3	3.6	27	3.0	.0	--	.0	--	36	15	0	49	7.5	.14	.4	

a/ Includes carbonate

Table 3.--Chemical Analyses of Water Samples from the Sokoto Basin of Northern Nigeria

(Constituents in Parts per Million)

Analysis by J. A. Akingbehin, John Adesuyi and R. T. Kiser

Location	Borehole (with GSN number) or other source	Date of Collection	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids (calculated)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25°C.)	pH	Residual sodium carbonate	Sodium adsorption ratio	Field or other determinations
A. Basement Complex																								
Gusau-Sokoto Road, mile 52	Borehole	3-67	80	24	12	0.01	27	9.6	4.3	3.0	149	0.5	1.0	--	0.0	0.0	142	107	0	250	7.4	0.30	0.2	
Gusau-Sokoto Road, mile 54 ½ (Tunfafia)	3702	4-66	--	41	--	--	19	24	63	2.0	340	4.1	2.0	.1	5.7	.0	328	148	0	500	8.2	2.61	2.3	
Kwatarkwashi	School well no. 4	5-68	86	59	--	--	26	2.4	13	3.2	116[a]	3.7	3.0	.2	10	.0	178	75	0	211	8.3	.41	.6	PO_4 .15
Kwatarkwashi	School well no. 5	5-68	86	61	--	--	44	6.1	17	4.0	192	7.6	1.7	.2	3.0	.0	240	135	0	319	8.1	.45	.6	PO_4 .60
B. Gundumi Formation																								
Dange	3512	9-65	--	13	4.0	--	4.8	.5	3.3	1.1	3	21	1.0	.1	.4	.1	46	14	12	58	5.1	0	.4	
Girawsi	3704 (80')	7-66	90	19	6.4	.24	36	7.3	28	5.7	93	93	7.0	.8	.3	--	243	120	44	390	7.0	0	1.1	
Girawsi	3704 (905')	8-66	96	12	3.7	.15	18	4.6	20	8.0	100	32	5.5	.2	.1	.0	150	64	0	250	7.5	.36	1.1	
Girawsi	3704 (905')	2-68	91	14	.65	.03	18	4.9	20	5.8	94	31	5.5	.3	.1	.0	146	65	0	236	7.4	.24	1.1	pH 7.4 Eh -15
Gusau-Sokoto Road, mile 73	3526	5-66	91	21	14	.00	16	5.8	26	24	170[a]	7.7	2.5	--	.1	.0	187	64	0	299	8.7	1.51	1.4	
Gusau-Sokoto Road, mile 83	3524	5-66	91	14	--	.02	9.6	.5	2.1	2.4	36	.6	1.5	--	.3	.0	49	26	0	63	7.8	.07	.2	
Gusau-Sokoto Road, mile 93 ¾	3703	5-66	91	13	14	.10	3.2	.5	7.3	10	38	5.6	1.0	.1	.1	.1	60	10	0	86	7.6	.42	1.0	
Gusau-Sokoto Road, mile 95	3522	8-65	--	17	--	--	2.0	.2	5.8	8.5	19	12	2.0	.0	.3	.1	57	6	0	50	7.4	.19	1.0	
Gusau-Sokoto Road, mile 105	3520	4-66	--	14	--	--	1.0	.4	1.2	1.8	2	6.7	2.0	.1	.0	.0	28	4	2	24	5.1	0	.2	
Gusau-Sokoto Road, mile 110	3519	4-66	--	13	32	1.8	5.6	3.2	3.2	2.6	0	48	1.5	.3	.0	.0	79	27	27	160	3.70	0	.3	
Isa	3514	12-65	--	15	--	--	4.2	.6	265	8.0	189[a]	102	238	.6	.5	1.0	728	13	0	1,240	8.7	2.84	32	
Kyloye	3708 (1305')	3-67	94	13	--	--	292	21	800	27	134	116	1,640	.8	--	.9	2,980	815	705	4,900	7.7	0	12	
Mungadi	3707	10-66	86	13	--	.10	23	3.3	20	3.5	22	69	19	.2	.6	.0	163	71	53	280	6.6	0	1.0	
Rabah	2490	8-65	--	15	--	--	12	2.2	25	8.5	87[a]	29	2.0	.2	.3	.1	137	39	0	210	8.4	.65	1.7	
Sabon Birni	3513	12-65	--	15	--	--	2.2	.4	74	3.8	174[a]	14	8.5	.5	.5	.0	205	7	0	332	8.7	2.72	12	
Sainyinan Daji	3709	4-67	95	15	8.4	.19	17	3.3	20	4.8	66	43	3.0	.2	.0	.0	135	56	2	223	6.8	0	1.2	

a/ Includes carbonate

Table 3.--Chemical Analyses of Water Samples from the Sokoto Basin of Northern Nigeria (cont'd)

(Constituents in Parts per Million)

Analysis by J. A. Akingbehin, John Adesuyi and R. T. Kiser

Location	Borehole (with GSN number) or other source	Date of Collection	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids (calculated)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25°C.)	pH	Residual sodium carbonate	Sodium adsorption ratio	Field or other determinations
C. Rima Group																								
Bodinga	3508	7-65	--	18	--	--	15	1.6	9.5	1.6	20	23	1.5	0.0	29	0.0	109	44	28	158	7.4	0	0.6	
Dange	Well, 180'	8-66	88	12	--	.00	44	2.9	11	16	100	42	17	.4	23	.0	217	122	40	370	7.5	0	.4	
Dogwandaji	Well	6-66	89	15	--	.00	28	2.9	4.3	4.3	83	10	2.5	.1	17	.0	125	82	14	200	7.9	0	.2	
Girawsi	3705	9-66	85	14	3.7	.19	15	3.0	3.6	4.2	60	16	1.5	.4	.5	.0	88	50	1	145	8.1	0	.2	
Gusau-Sokoto Road, mile 120	3517	12-65	--	12	--	--	4.0	.5	1.7	4.7	16	11	2.2	.2	.1	.0	44	12	0	52	7.5	.02	.2	
Kaloye	3708 (700')	3-67	95	15	--	.00	18	4.4	157	5.5	291	102	48	1.4	2.2	.5	497	63	0	845	7.5	3.51	7.5	
Kaloye	3708 (700')	2-68	97	14	.38	.01	17	6.0	163	4.8	299	100	50	1.2	.2	.5	504	67	0	810	7.9	3.56	8.7	pH 7.7 Eh -118
Shuni	3511	8-65	--	17	--	--	23	2.8	3.4	7.1	18	67	3.0	.6	.3	.2	133	69	54	178	7.5	0	.2	
Sokoto, ECN	3706	8-66	90	16	14	.24	32	4.1	4.4	5.2	8	100	2.5	.2	1.4	.1	170	97	90	255	6.0	0	.2	
Sokoto, GRA	2859	6-66	90	17	6.1	.08	26	5.6	5.5	4.6	89	26	3.0	.3	1.1	.0	133	88	15	200	8.0	0	.3	
Sokoto, GRA	3505	6-66	91	3.6	4.4	.32	19	2.6	2.1	5.4	73	9.4	.0	.5	.0	.0	79	58	0	135	7.2	.04	.1	
Taloka (Goronyo)	Well, private	9-67	--	72	.6	270	581	572	210	200	0	5,590	245	--	1,030	.6	9,170	3,800	3,800	7,700	3.80	0	--	Al 390 NO_2 1.6 PO_4 3.7
Taloka (Goronyo)	Well, village	3-68	83	79	.5	260	571	675	206	211	0	5,670	303	--	1,260	.6	9,650	4,200	4,200	7,740	3.80	0	--	Al 410 NO_2 2.0 PO_4 2.1
Taloka (Goronyo)	Well, village	4-68	--	62	--	.00	481	467	2,660	120	582	4,660	702	3.0	3,540	.1	13,000	3,120	2,640	14,000	7.8	0	21	Al .6 NO_2 2.0 PO_4 1.3
D. Kalambaina Formation																								
Angwan Tudu	Spring	4-66	--	27	.44	.00	42	33	8.4	2.8	170[a/]	80	5.0	.7	35	.0	318	239	100	505	8.3	0	.2	
Bodinga	Well	7-66	89	15	--	.00	38	7.5	19	28	140	17	26	.7	40	.0	260	126	12	455	7.9	0	.7	
Chimola	Well	9-65	--	10	--	--	214	43	81	421	82	123	194	.2	1,210	.2	2,340	710	643	3,150	8.2	0	1.3	
Dange	Well, 25'	8-66	88	19	--	.00	78	5.2	19	34	160	36	45	.8	84	.0	400	216	85	660	8.1	0	.6	
Kware	Well	7-66	--	22	--	.00	50	5.4	2.9	4.3	155	2.5	3.0	.2	28	.0	194	147	20	320	7.5	0	.1	
Mungadi	Well	9-66	88	35	--	.00	26	11	19	74	104	44	34	.3	89	.0	385	109	24	580	8.2	0	.8	
Sokoto	Well	8-66	87	24	--	.00	59	4.6	3.0	2.6	180	4.9	3.5	.2	21	.0	212	166	18	335	7.7	0	.1	

a/ Includes carbonate

Table 4.--Chemical Analyses of Water Samples from the Kerri Kerri Area of Northern Nigeria

(Constituents in Parts per Million) Analysis by R. T. Kiser and J. A. Akingbehin

Location	Borehole (with GSN number) or other source	Date of Collection	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids (calculated)	Hardness as $CaCO_3$		Specific conductance (micromhos at 25°C.)	pH	Residual sodium carbonate	Sodium adsorption ratio	Field or other determinations
																		Calcium, magnesium	Noncarbonate					
Alkalere	Well	4-68	84	29			8.0	1.5	7.9	8.0	34[a/]	0.2	4.5	0.1	21	--	97	26	0	121	8.4	0.03	0.7	
Allaburum	Well	11-67	81	14			2.6	1.1	1.7	2.2	10	4.9	1.5	.0	1.9	.0	35	11	3	36	5.9	0	.2	
Bara	Well	4-68	81	27			22	6.1	7.4	7.2	24	.4	14	.2	76	--	172	80	60	253	6.6	0	.4	
Barka	Well	11-67	82	13			5.2	1.0	6.8	1.4	22	8.6	1.5	.0	6.7	.0	55	17	0	72	6.1	.02	.7	
Birniwa	Well	9-67	83	21			6.0	1.7	34	8.4	14	1.5	11	.0	99	.0	190	22	10	246	6.6	0	3.2	
Bojude	Well	6-68	84	14			16	6.1	5.2	19	112	2.1	11	.1	.3	--	129	65	0	229	7.2	.54	.3	
Buri Buri	Well	4-68	82	17			5.6	1.9	3.4	13	0	2.1	4.5	.1	59	--	107	22	22	202	3.85	0	.3	H .1
Cudi	Well	2-68	82	21			11	5.0	12	11	33	7.9	11	.0	48	.0	144	48	22	195	6.5	0	.8	PO_4 .90
Damagum	Rest house well	9-67	80	25			59	15	126	25	304	41	81	.4	98	.0	620	210	0	1,010	7.5		3.8	
Darazo	Well	9-67	83	22			67	24	27	104	189	40	45	.3	242	.0	664	267	112	990	6.9	0	.7	NO_2 .03
Darncuwa	Well	11-67	81	9.7			1.8	.1	5.6	2.2	2	4.9	2.5	.0	13	.0	40	5	4	51	5.6	0	1.1	
Daura	Well	1-68	78	16			7.2	3.2	6.7	3.7	10	3.6	4.5	.0	34	.0	84	31	23	109	6.5	0	.5	PO_4 .55
Daya	Well	9-67	85	14			27	4.3	12	14	26	1.2	6.5	.0	119	.0	211	85	64	297	6.2	0	.6	
Degubi	Well	9-67	85	17			126	26	25	108	251	53	41	.0	360	.0	880	423	218	1,290	8.0	0	.5	
Dogon Abere	Well	9-67	85	15			16	1.0	4.6	3.0	45	2.1	5.5	--	13	.0	82	44	7	123	6.8	0	.3	
Gabarin	Well	9-67	82	16			32	6.1	13	22	98	5.4	22	.2	50	.0	215	105	24	352	6.7	0	.6	
Gadaka	Well	2-68	82	32			22	2.2	8.4	9.4	92	4.0	4.5	.0	11	.0	139	64	0	188	7.0	.23	.5	PO_4 .35
Gamawa	Well	11-67	83	14			1.4	.4	6.6	.7	16	3.9	1.5	.0	1.9	.0	38	5	0	44	6.1	.16	1.3	
Garin Gambo	Well	11-67	82	20			2.0	.7	9.6	2.0	11	3.6	3.5	.0	18	.0	64	8	6	76	5.8	0	1.5	
Gujam	Well	11-67	82	.1			3.6	1.5	4.8	9.3	19	7.4	3.0	.0	13	.0	52	15	0	87	6.2	.01	.5	
Jalam	Well	9-67	84	13			5.6	.5	2.9	1.8	12	2.1	1.5	.1	15	.0	48	16	6	56	6.7	0	.3	
Jam	Well	6-68	82	103			20	2.2	9.3	2.4	103	2.7	3.5	.3	.0	--	194	59	0	176	7.0	.51	.5	
Jigawa	Well	5-68	88	17			10	1.7	12	4.1	13	1.2	5.5	.1	54	--	112	32	22	155	8.1	0	.9	
Jombo	Well	6-68	82	19			14	5.8	3.8	46	82	6.0	6.0	--	40	--	181	59	0	284	6.7	.16	.2	
Juma'a	Well	11-67	82	11			.8	.7	4.8	1.0	6	4.4	1.5	.0	7.0	.0	34	5	0	36	5.9	0	.9	
Kadi	Well	2-68	81	15			6.8	2.7	4.4	14	59	1.8	6.5	.2	5.5	.1	86	28	0	137	6.6	.41	.4	PO_4 .10
Lago	Well-1	9-67	83	25			136	49	46	324	479	122	85	.6	423	.0	1,500	540	148	2,250	8.1	0	.9	NO_2 58
Lago	Well-2	9-67	83	28			88	35	39	212	268	86	59	.5	394	.0	1,070	365	146	1,550	7.6	0	.9	
Lanzai	Borehole	9-67	--	11			4.4	1.2	4.3	11	1	.5	4.0	.0	44	.0	80	16	15	105	5.7	0	.5	

a/ Includes carbonate

Table 4.--Chemical Analyses of Water Samples from the Kerri Kerri Area of Northern Nigeria (cont'd)

(Constituents in Parts per Million) Analysis by R. T. Kiser and J. A. Akingbehin

Location	Borehole (with GSK number) or other source	Date of Collection	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids (calculated)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25°C.)	pH	Residual sodium carbonate	Sodium adsorption ratio	Field or other determinations
Lanzai	Well	9-67	85	15			40	10	15	117	102	42	22	0.3	202	0.0	513	142	58	743	7.5	0	0.5	
Muncika	Mission school well	9-67	85	19			3.2	.5	8.2	3.0	24	.8	6.5	.1	.0	.0	53	10	0	72	6.0	.19	1.1	
Pali	Well	5-68	84	12			8.0	2.9	5.0	20	0	.6	13	.4	59	--	121	32	32	205	4.35	0	.4	
Parinkassa Degubi	Well	9-67	85	14			36	6.6	7.3	4.8	26	1.9	6.5	.1	136	.0	226	117	96	325	6.1	0	.3	
Potiskum	Market well	5-66	--	14			2.4	.2	15	2.2	17	1.5	4.5	.0	15	.0	72	7	0	105	5.9	.14	2.5	NO_2 9.6
Potiskum	Well near D.O.'s office	5-66	--	13			9.6	1.9	23	5.2	5	1.6	5.5	.0	97	.0	159	32	28	232	5.6	0	1.8	NO_2 .21
Sakaraw	Well	11-67	82	16			5.4	1.8	9.8	4.6	40	9.7	3.5	.0	5.1	.0	76	21	0	104	6.1	.24	.9	PO_4 .10
Sirko	Well	9-67	82	27			50	13	21	74	180	32	37	.4	93	.0	436	179	32	690	7.1	0	.7	
Tarmasawa	Well	3-68	80	15			3.8	1.3	5.7	4.4	12	.5	5.0	.0	23	.0	65	15	5	76	6.6	0	.6	--
Tikau	Well	9-67	86	24			25	8.4	17	23	6	16	8.5	--	184	.0	309	97	92	555	6.0	0	.6	
Wahu	Well	3-68	82	18			55	21	24	218	250	89	41	.1	278	.0	867	223	18	1,200	7.0	0	.7	PO_4 .05
Watinani	Well	11-67	84	15			4.8	.5	4.0	1.0	21	3.8	1.0	.0	5.6	.0	46	14	0	51	6.3	.06	.5	--
Wawa	Well	6-68	83	45			22	6.1	5.2	50	114	13	9.0	.3	35	--	242	80	0	337	6.9	.27	.3	
Wuro Bundu	Well	4-68	84	15			8.0	.5	6.9	27	0	2.1	5.5	.0	.0	--	90	22	0	279	10.7	--	.6	CO_3 8 OH 17
Yankari Game Reserve	Dimil Warm Spring	5-66	--	13	.21	--	3.2	1.0	3.4	4.6	27	1.4	.5	.0	.0	.0	40	12	0	51	7.7	.20	.4	
Yankari Game Reserve	Wikki Warm Spring	5-66	--	15	--	--	2.0	.5	1.8	3.2	15	.7	.5	.0	1.3	.0	32	7	0	29	7.4	.11	.3	
Yuli	Well	5-68	84	64			39	9.8	33	5.4	134	17	23	.1	59	--	316	138	28	455	7.5	0	1.2	

Table 5.--Chemical Analyses of Water Samples from the Basement Complex in the Kaduna and Zaria Areas in Northern Nigeria

(Constituents in Parts per Million)

Analysis by R. T. Kiser

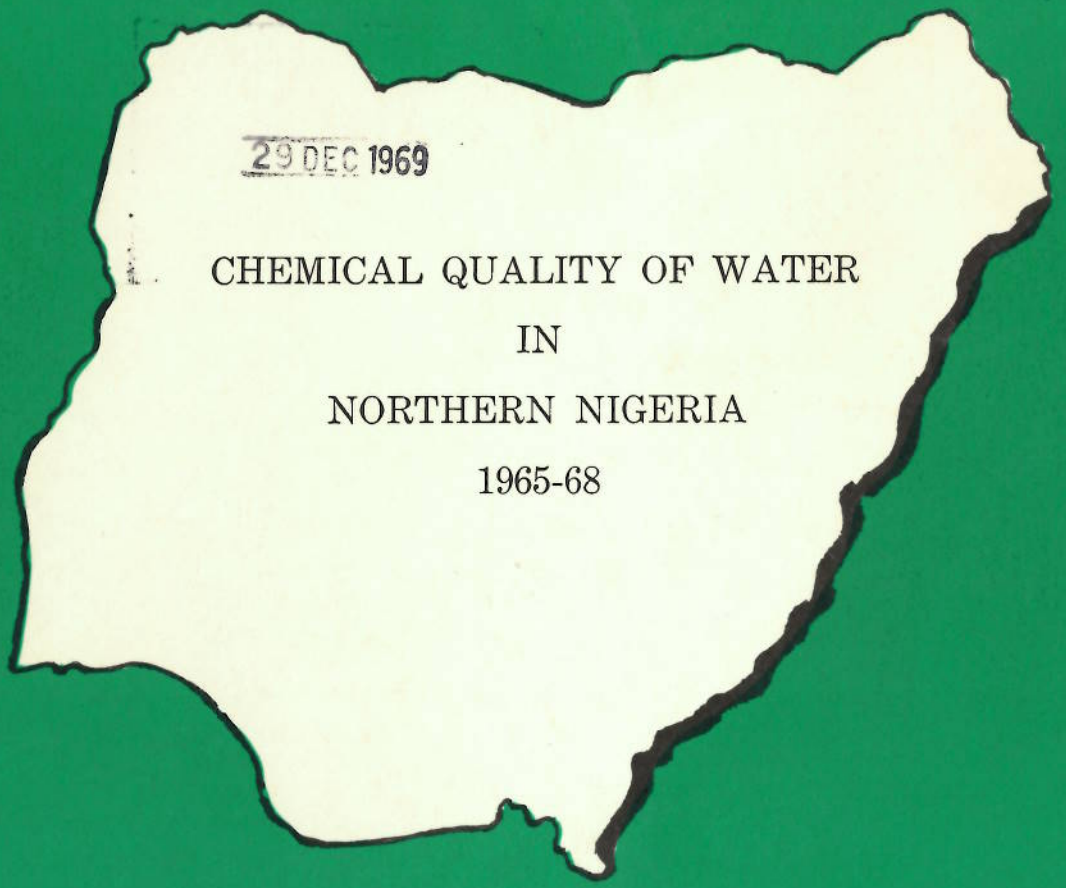
Location	Borehole (with GSN number) or other source	Date of Collection	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids (calculated)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25°C.)	pH	Residual sodium carbonate	Sodium adsorption ratio	Field or other determinations
Afaka	Well	9-67		14			33	10	5.9	29	176	9.9	9.0	0.4	9.5	0.0	208	125	0	349	7.1	0.38	0.2	
Amana	East well	9-67		25			12	.2	6.3	4.5	47	1.3	5.0	.1	1.9	.0	79	30	0	101	6.3	.17	.5	
Argaude	Well	9-67		18			3.2	.7	3.2	3.8	8	1.5	2.5	.1	14	.0	51	11	4	53	5.9	0	.4	
Gidan Gaya	East well	9-67		20			12	1.2	8.0	5.3	26	1.3	14	.1	16	.0	91	35	14	134	6.2	0	.6	
Gungu	Well	9-67		26			28	4.9	22	11	90	9.9	45	.2	5.1	.0	196	90	16	327	6.7	0	1.0	
Hange	Well	7-67		39			14	.5	9.0	4.6	58	3.0	4.0	.2	2.9	.1	106	37	0	127	6.5	.21	.6	
Kangimi	Well	9-67		13			2.4	.5	1.2	1.7	8	.7	.5	.1	.1	.0	24	8	2	27	5.6	0	.2	
Katabu	MOW east well	9-67		15			9.2	.7	2.7	1.4	30	.5	3.0	.0	6.4	.0	54	26	2	70	6.3	0	.2	
Katchia	MOW well No. 1	8-67		12			50	18	18	22	172	9.4	38	.2	67	.0	320	201	60	547	6.6	0	.6	
Katchia	MOW well No. 2	8-67		22			15	5.7	9.2	16	38	3.1	17	.1	47	.0	154	61	30	229	5.9	0	.5	
Kufena	Well	7-67		40			6.8	.7	8.1	3.1	29	1.0	4.5	.2	7.6	.0	86	20	0	88	6.5	.08	.8	
Kujama	MOW well east of camp	9-67		40			23	1.6	10	2.8	100	3.8	.5	.2	.5	.0	131	64	0	173	7.0	.36	.6	
Kujama	Well at mosque	9-67		13			72	14	34	45	104	14	72	.1	196	.0	511	239	154	819	6.5	0	1.0	
Rihogi	Well	9-67		15			14	1.9	10	5.3	39	1.2	14	.1	21	.0	102	43	11	159	6.4	0	.7	
Sabon Birni	Well	7-67		15			4.0	1.0	2.7	4.8	10	1.6	3.5	--	6.7	.0	44	14	6	54	6.0	0	.3	
Tsauni	Well	7-67		31			15	.9	4.5	2.5	60	.7	3.0	.2	.1	.0	88	41	0	108	7.2	.16	.3	
Zonkwa Hospital	MOW Borehole No. 1 at 112'	8-67		55			6.4	2.2	8.8	4.9	58	1.2	1.0	.1	.2	.0	109	25	0	94	6.9	.45	.8	

Table 6.--Chemical Analyses of Water Samples from Miscellaneous Sources in Northern Nigeria

(Constituents in Parts per Million) Analysis by J. A. Akingbehin and R. T. Kiser

Location	Borehole (with GSN number) or other source	Date of Collection	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids (calculated)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25°C.)	pH	Residual sodium carbonate	Sodium absorption ratio	Field or other determinations
Bauchi	Teacher Training College test hole	12-66	77	22	7.5	0.00	8.8	1.2	5.4	1.7	49	1.0	1.0	0.2	0.0	0.0	65	27	0	89	7.2	0.26	0.4	
Biu	Lake Tilla	1-68	-	12			6.4	106	737	210	2,800[a/]	1.2	81	-	.4	-	2,540	450	0	3,730	9.3	36.88	15	PO_4 3.1
Biu	Well at Lake Tilla	1-68	-	74			46	112	85	5.0	896	1.6	12	.4	.[illegible]	.0	779	576	0	1,230	8.1	3.17	1.5	PO_4 1.8
Kaduna	Tap	10-65	80	19			9.4	1.3	5.8	1.8	30	15	2.5	.0	1.1	.0	71	29	4	87	7.6	0	.5	
Lafia	Awe Spring-1	3-65	82	1.1			2.4	113	3,070	5.4	610	5.4	4,530	.5	1.8	.2	8,030	470	0	14,600	7.3	.60	62	
Lafia	Awe Spring-2	3-65	92	35			8.2	49	2,950	5.4	309	14	4,360	.7	12	.1	7,550	222	0	13,200	7.9	.62	87	
Lafia	Azara Spring	3-65	82	21			302	167	7,260	11	191	7.5	12,100	3.4	41	1.0	20,000	1,440	1,280	34,500	7.3	0	85	I .8
Lafia	General Hospital No. 1 borehole	9-66	90	12		.08	1.0	.1	.6	.9	4	2.2	.5	.[illegible]	.2	.1	20	3	0	12	6.0	.01	.2	
Lafia	Kanje Spring	3-65	82	4.8			121	114	3,500	9.9	183	6.6	5,540	1.7	15	.2	9,390	772	622	17,000	7.3	0	55	
Lafia	Keana Spring	3-65	82	30			90	139	3,460	14	350	4.1	5,660	.7	23	.3	9,560	794	507	17,500	7.3	0	58	
Makurdi	Guma River	3-65	82	26			14	7.8	20	5.4	90	4.9	27	.2	1.6	--	159	67	0	240	7.8	.14	1.1	
Makurdi	Mu River	3-65	80	25			9.2	5.4	9.0	3.5	68	2.1	9.6	.1	.2	--	104	45	0	125	7.6	.21	.6	
Makurdi	Ukeleke River	3-65	81	18			3.6	3.2	11	3.5	32	7.4	6.4	.1	3.1	--	77	22	0	81	8.2	.08	1.0	
Oturkpo	Okokolu Springs	8-65	--	4.4			1.0	.1	4.1	.8	8	1.2	3.2	.0	3.7	.0	23	3	0	23	5.9	.07	1.0	

a/ Includes carbonate



CHEMICAL QUALITY OF WATER IN NORTHERN NIGERIA 1965-68

Prepared cooperatively by
the United States Geological Survey and the Geological Survey of Nigeria
under the auspices of the
United States Agency for International Development