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Hydrogeochemistry of the Purana formations of eastern Madhya Pradesh in India

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ABSTRACT

The Raipur and Indravati series comprising the Purana formations of Chhattisgarh consist of conglomerates, orthoquartzites, sub-arkoses, shales, limestones and dolomites. The lithofacies in these have considerable lateral variations. Both Mahanadi and Indravati basins are saucer-shaped with centripetal dips; the arenaceous rocks along the fringes have dips up to 15°, while the younger rocks in the centre are almost horizontal. In carbonate rocks, karst is developed on a regional scale with sinkholes of higher topographic areas linked with resurgences of low relief areas.

Groundwater in the above formations occurs generally under water table condition, but in karstic limestone also under confined condition.

The chemical relationship of groundwater circulating in the various lithofacies are plotted in the trilinear diagrams after Piper. Groundwater within depths of 92 m has carbonate hardness (Secondary alkalinity) exceeding 50 per cent with the chemical properties dominated by alkaline earths and weak acids. The cations and anions in water from similar lithofacies of Mahanadi and Indravati basins are distributed in the same field of the trilinear diagram with almost similar scatter of ions suggesting thereby a similar geochemical environment.

The quality of groundwater is within permissible limits for irrigation and domestic purposes, while softening of water from temporary bicarbonate hardness may be necessary for certain specific industries.

Expansion of groundwater recharge by increasing the 'area of spreading' of flood water of the Mahanadi basin and application of the technique in the Indravati basin will enrich the soils. Prevention of disposal of industrial wastes underground, especially in karstic regions will be a primary step in pollution control.

INTRODUCTION

THE Raipur and Indravati formations of the Purana system occur in the Chhattisgarh region between the N lat. 18° 45′ and 22° 30′ and the E. long

81°00′ and 84°00′ with their major parts lying in eastern Madhya Pradesh. During the period 1968–71, systematic hydrogeological studies were undertaken in parts of Raipur and Bastar Districts covering parts of toposheet Nos. 64–G, H and K and 65–E and I, to explore the possibility of groundwater followed by the study of chemical quality for growing needs of agriculture and industries. The areas of the present study are all within 300 km of Raipur, the principal township of the region, and are well connected by the road and rail.

Physiography

The area covering parts of Raipur, Bilaspur, Durg and Raigarh Districts, is in general a flat country surrounded by arcuate ridges. The average altitude of the hills is about 340 m, while that of the flat terrain is 290 m above M.S.L. The basin has a gentle easterly slope with a local gradient towards the Mahanadi. The river Mahanadi has initially a northerly course, but beyond the borders of Raipur District it has an easterly course. The gradient is gentle, being about a metre per kilometre.

The terrain covered by the rocks of the Indravati series is similar with a maximum altitude of 862 m in the hilly region, while the average elevation of the central flat country is 610 m above M.S.L. Major part of the area is drained by the Indravati and its tributaries and only a small part in the south by the Sabari, both being the tributaries of the Godavari. The Indravati has a gentle westerly course up to Chitrakut (19° 13′ : 81° 42′; 65–E/12), where it descends with a fall of about 30 m and thereafter it continues to have slightly steeper westerly course. The Sabari has a southerly course in the area. One of the tributaries of the Sabari, the Mungabar *nadi* descends with a fall of about 45 m at Tirathgarh (18° 54′ : 81° 50′; 65–F/13).

Climate

The Chhattisgarh region has a tropical climate with an average minimum temperature of 25° C, while the maximum recorded is 47·5° C. Major part of the area receives an average annual rainfall of about 125 cm. The Bastar District has relatively a milder climate with an average annual rainfall of about 150 cm.

Geology

The generalised geological succession in the area is given in table 1.

The strata in general have centripetal dips. The arenaceous rocks along the fringes of the basins have dips up to 15°, while the younger

Table 1. Purana formation of Chhattisgarh in Madhya Pradesh

Raipur, Durg, Raigarh and Bilaspur Districts (Raipur Series)		Bastar District (Indravati Series)	Lithology
Raipur (450 m)	..	Jagdalpur (150 m)	Dolomites, magnesian limestones and shales with stromatolites;
Khairagarh (35 m)	..		
Gunderdehi (180 m)	..		
Charmuria (300 m)	..	Kanger (140 m)	Limestones, shales, sandstones and conglomerates;
Chandarpur (300 m)	..	Tirathgarh (270 m)	Shaly sandstones, sub-arkoses, orthoquartzites and conglomerates.

argillaceous and calcareous rocks have lower dips, and are almost horizontal in the central parts of the respective basins.

HYDROGEOLOGY

In hard rocks groundwater occurs in the weathered mantle and the fracture zone. In case of carbonate rocks solution cavities and channels are the repositories of groundwater. Karstic features like the etched, pitted and uneven surfaces, grikes, clints, solution cavities and sinkholes of various shapes and dimensions and caverns are recognisable in the carbonate rocks. Some of the sinkholes end in caves as observed in the Kanger limestones, about 1·5 km south of Kotomsar (18° 52′ : 81° 56′; 65–F/13) and in Jagdalpur limestones at Gupteshwar (18° 54′ : 82° 14′; 65–J/1). Thus karst is intricately developed on a regional scale with the sinkholes of high relief areas in line with the resurgences of low topographic areas.

Groundwater in the Purana formations generally occurs under water table conditions. The water levels range between 0·3 and 15 m b.g.l. during winter and 2 to 16 m b.g.l. in summer. Open wells range in depth up to 17 m and are yielding between 20 and 70 klpd of water for drawdowns up to six metres; the higher yields being from carbonate rocks.

Occurrence of groundwater under confined conditions in karstic limestones has been noted. Borewells in these limestones range in depth up to 90 m with a diameter of 15 cm. The static water levels range between 1 and 14 m b.g.l. These wells are yielding up to 300 klpd for a drawdown of 4 to 17 m. Perennial springs occur with yields of 0·3 to 6·6 lps and five multi-orifice springs from limestones record discharges from 70 to 800 lps rendering the major rivers perennial.

GEOCHEMISTRY OF GROUNDWATER

The chemical analysis of water from wells, resurgences and rivers are summarised in table 2.

Distribution of Constituents

Groundwater from the sandstones within depths of 15 m contain 0·8 to 11 ppm of sodium, 0·3 to 4·4 ppm of potassium, 2·4 to 59 ppm of calcium, up to 11·5 ppm of magnesium, 2·7 to 188 ppm of bicarbonates, traces of sulphates, 1 to 23 ppm of chlorides, 3 to 35 ppm of silica and less than 0·1 ppm of fluorides and boron. The total dissolved solids range between 15 and 200 ppm with hardness as $CaCO_3$ from 12 to 193 ppm and pH values from 7·7 to 8. The water is in general weakly alkaline, and soft to moderately hard. But in case of Tirathgarh sandstones the groundwater records pH values of 4·2 to 5·7, suggesting thereby strong acidic tendency. It is thus excellent for irrigation of sensitive crops and for domestic purposes and also within permissible limits for industries.

In the terrain of carbonate rocks within depths of 92 m, groundwater analyses 1 to 28 ppm of sodium, 1 to 2·2 ppm of potassium, 18 to 122 ppm of calcium, 4·5 to 42 ppm of magnesium, 111 to 344 ppm of bicarbonates, traces of sulphates, traces to 39 ppm of chlorides, 5 to 15 ppm of silica, 0·1 to 0·4 ppm of fluorides and less than 0·1 ppm of boron. The total dissolved solids range between 120 and 490 ppm with 119 to 470 ppm of hardness as $CaCO_3$. The specific conductance in micromhos at 25° C varies from 245 to 700 and the pH values from 6·3 to 8. The waters from the magnesian limestones and dolomites contain higher ranges of magnesium along with hardness and total dissolved solids. The water is in general weakly alkaline and moderately hard. The quality is good for sensitive crops and within permissible limits for domestic purposes as well. For industrial uses like boiler feed, breweries, paper, steel, rubber and tanning, softening may be necessary.

Groundwater in the shales at depths less than 55 m analyse 1·3 to 40 ppm of sodium, 0·3 to 16 ppm of potassium, traces to 141 ppm of calcium, 5 to 36 ppm of magnesium, 61 to 243 ppm of bicarbonates, traces of sulphates, up to 127 ppm of chlorides, 5 to 15 ppm of silica, 0·1 to 0·2 ppm of fluorides and less than 0·1 ppm of boron. The total dissolved solids range between 110 and 750 ppm with hardness as $CaCO_3$ up to 504 ppm and the specific conductance in micromhos at 25° C from 60 to 1,220. The pH value ranges between 5·5 and 7·7. The water is in general weakly acidic to weakly alkaline and moderately hard; but relatively more acidic in Kanger shales. The quality is thus within the permissible limits for

Table 2. Summary of chemical analysis of waters from wells resurgences and rivers in the purana formations of Chattisgarh, Madhya Pradesh

Constituents	Raipur series, Raipur District					Indravati series, Bastar District				
	Chandarpur sandstone	Charmuria limestone	Gunderdehi shale	Raipur magnesian limestone	Maha-nadi river	Tirathgarh sandstone	Kanger limestone (with shales)	Kanger shales	Jagdalpur magnesian limestone	Indravati river
					(In part per million)					
Sodium ..	2 – 11	1	7 – 40	23 – 28	14	0·8– 1·1	2 – 6·6	1·3– 4·4	1·2– 6	2·5
Potassium ..	3·4– 4·4	1	8·4– 1·8	1 – 1·4	3·2	0·3– 0·4	0·8– 2·2	0·3–16	0·2– 1·8	2·5
Calcium ..	25–3– 59	60– 65·30	32·7– 140·8	17·9– 69·8	39	2·4– 3·6	34·7–122	Trace–8·4	22·7– 66	8·4
Magnesium ..	5·1– 11·5	9– 14·7	10·6– 36·5	12·8– 19·5	9	Trace	4·5– 11·9	5 – 5·9	10·4– 42	6·7
Carbonates ..	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Bicarbonates	74·7–188	147 –206	193 – 243	138 –342	126	2·7–18·6	111 –344	61 – 90	111 –339	36
Sulphates ..	Trace	Trace	Trace	Trace	Trace	Trace	Trace	Trace	Trace	Trace
Chlorides ..	10·6– 22·7	31·9	11·6– 127·6	7·1– 23·5	8·9	Trace	Trace–39	Trace–68	Trace–8·9	8·9
Silica ..	7·6– 35	..	10 – 15	12·6– 15	15	3 – 4	6·5– 12	5 – 9	5 – 12	7·5
Fluorides ..	0·1	..	0·1	0·1– 0·2	0·1	0·1– 0·2	0·13–0·4	0·1– 0·2	0·1– 0·4	0·4
Boron ..	0·1	..	0·1	0·1	0·1	0·1	0·1	0·1	0·1	0·1
Total dissolved solids	180 –200	300 –360	300 – 750	200 –450	220	15 –20	120 –490	110	120 –470	48
Hardness as $CaCO_3$	86 –193	200 –210	131 – 504	97 –267	135	11·9–14·9	119 –275	..	119 –470	47·8
Specified conductance in micromhos/cm at 25° C.	220 –425	440 –520	420 –1220	280 –650	320	21– 34	250 –540	60 –200	245 –700	112
pH ..	7·9– 8·0	7·7–8	6·7– 7·7	6·9–8	7·4	4·2– 5·7	6·3– 7·4	5·5– 5·8	6·5– 7·7	8·2

irrigation of sensitive crops and also for domestic use. Softening may be necessary for boiler feed, breweries, paper, steel, rubber and tanning industries.

The water from the Mahanadi and the Indravati rivers contains up to 14 ppm of sodium, 3·2 ppm of potassium, 39 ppm of calcium, 9 ppm of magnesium, 126 ppm of bicarbonates, traces of sulphates, 9 ppm of chlorides, 15 ppm of silica, up to 0·4 ppm of fluorides and less than 0·1 ppm of boron. The total dissolved solids are less than 220 ppm with hardness as $CaCO_3$ up to 135 ppm. The specific conductance in micromhos at 25° C is 320 and the pH values up to 7·4. The water is thus weakly alkaline, and soft and excellent for irrigation of sensitive crops, and also for domestic purposes as well as industries.

The temperature of groundwater ranges between 26° and 36° C within a depth range of 92 m.

Chemical Relationship

Analytical data in respect of 27 water samples have been utilised here. The ppm values of cations and anions have been converted into epm (equivalent parts per million). The percentage reacting values of the concerned cations and anions have also been calculated and plotted in Piper's diagram. An attempt has been made in the present case to utilise Piper's diagram for plotting the chemical relationship of the waters circulating in different formations. In the diamond field, symbols pertaining to various lithofacies are maintained to comparatively study the waters of Raipur and Indravati series. The total dissolved solids are therefore, avoided in the present case in the diamond field as more than one lithofacies are already represented.

The chemical relationship of the samples of groundwater circulating in various lithofacies of Raipur and Indravati Series are plotted in the trilinear diagrams after Piper in figure I. The diagrams show that the cations and anions are closely grouped in the triangular fields. In the diamond shaped field the chemical values in general fall within an area in which the carbonate hardness (secondary alkalinity) exceeds 50 per cent, and that the chemical properties are dominated by the alkaline earths and weak acids. This is evidently due to the circulation of water in calcaerous sediments. The cations and anions in water from similar lithofacies of Mahanadi and Indravati basins are distributed in the same field of the trilinear diagram with almost similar pattern of scatter of ions, suggesting thereby a similar geochemical environment.

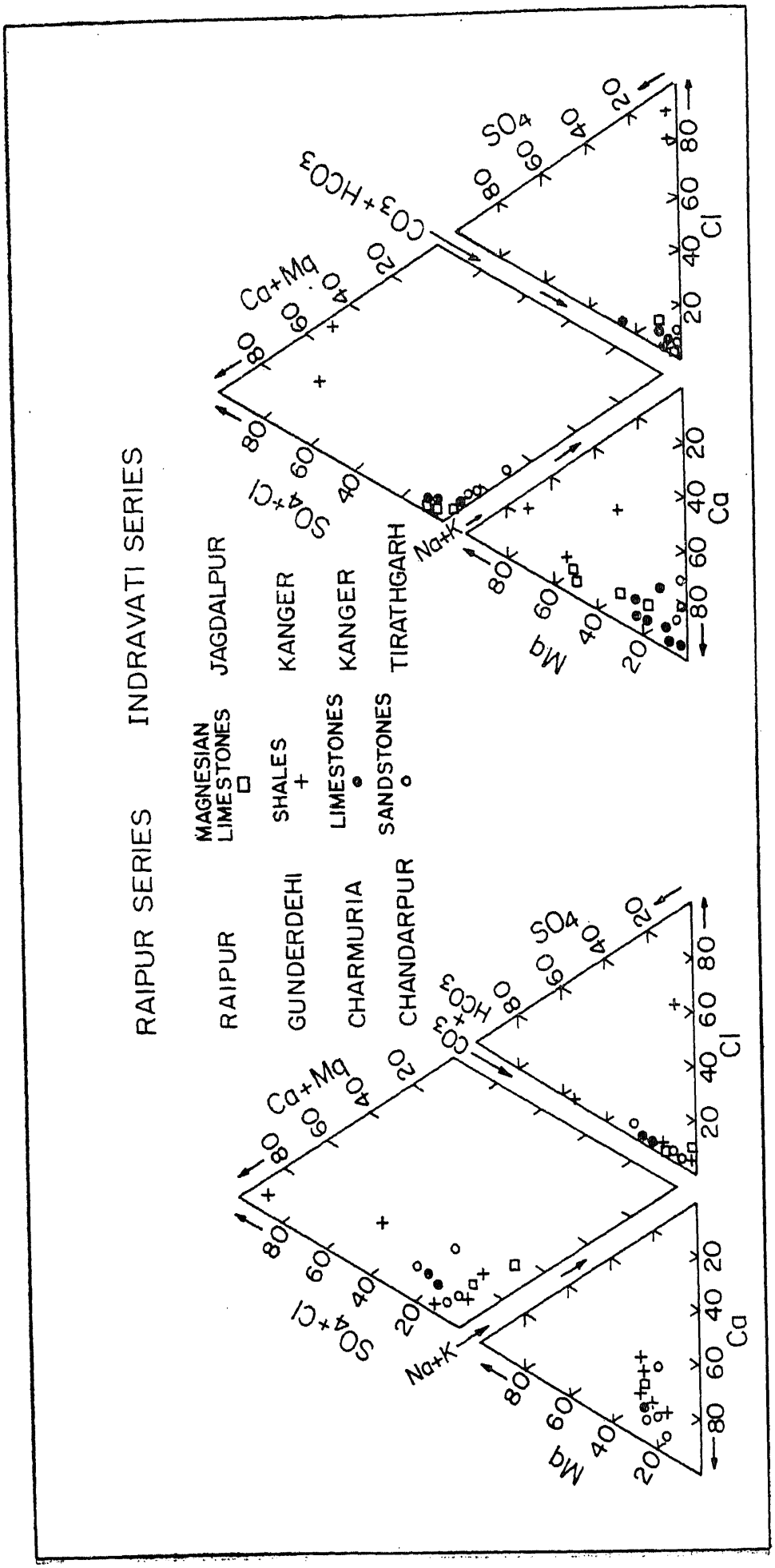

Figure 1. Chemical analyses represented by trilinear diagram.

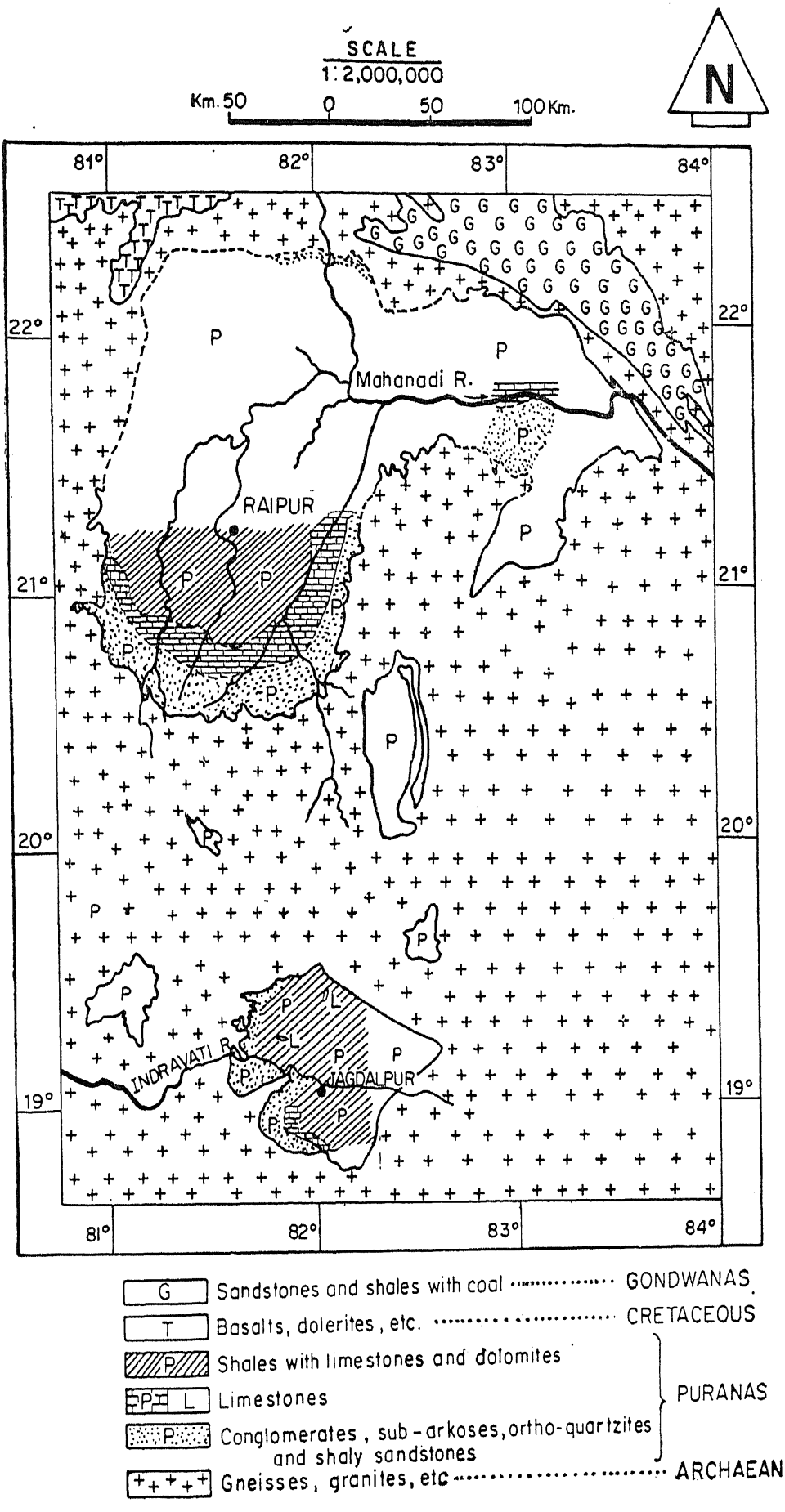

Figure 2. Map showing Geology in parts of Chhattisgarh, M.P.

Water Quality Management

The areas are predominantly covered by shales and carbonate rocks with a mantle of argillaceous silty soil. The groundwater in these areas contain negligible amounts of sodium and fair amounts of calcium and magnesium. Use of this water is not likely to cause sodium hazard; on the other hand it is advantageous for making the soil flocculated and more permeable. Recharge technique is in use in Raipur District by distributing the flood waters of Mahanadi through canals and fields. Expansion of the distributaries will bring more area under favourable geohydrological conditions. There is also scope for spreading of water in the Indravati basin which will increase the groundwater storage and fortify the soil. Disposal of any waste material underground needs deep meditation, as eradication of pollution, especially by inorganic matter, is an extremely difficult process.

CONCLUSIONS

In Mahanadi and Indravati basins of the Purana group, argillaceous and calcareous facies predominate in areal extent with arenaceous facies generally limited to the fringes. In carbonate rocks, karstic conditions are developed on a regional scale with resurgences in low topographic areas. Groundwater occurs generally under water table conditions, but also under hydraulic pressure in the karstic rocks.

The groundwater within a depth range of 92 m has the carbonate hardness (secondary alkalinity) exceeding 50 per cent, with the chemical properties dominated by the alkaline earths and the weak acids, which is possibly due to the circulation of water mostly in calcareous sediments.

The quality of groundwater and surface water is within permissible limits for irrigation and domestic purposes. Softening of water from carbonate rocks may be necessary for certain industries.

Though chemical analysis data are not available for the flood water of the Mahanadi, they are constantly under use by direct distribution through the network of canal system in Raipur and Bilaspur Districts of Madhya Pradesh. Further, there is no noted adverse effect so far on the crops or the ground-water of the region under consideration.

Thus, there is scope for expansion of groundwater recharge by increasing the 'area of spreading' of the flood water of the Mahanadi in Mahanadi basin and application of the technique to the Indravati basin as well, where it will incidentally enrich the soils. Prevention of disposal of industrial wastes underground, especially in karstic regions will be a primary step in pollution control.