Hydrogeology of Mayurbhanj District, Odisha

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Abstract- *The present study illuminates the hydrogeological status of Mayurbhanj district of Odisha. Major rock types are Granite Gneiss, Quartzite, Ortho-Quarzite, Arkose, Shale , Phyllite,Gabbro, Granophyre and Pyroxene granite. The geology of the district is constituted by the Similipal complex at its central part belonging to Achaean age, unconformably lying over the Singbhum granite and Banded iron ore formation of Mayurbhanj. The soil mantle in the erosion plain varies from 0.5 to 3.0 meter. This is followed by weathered rock of 5.0 to 13.0 meter thickness. The basement rock occurs at a depth of 22.0 to 30.0 meter bgl. A thick clayey zone of about 10 to 40 meter serves as the top soil cover in the tertiary tract. This is followed by occurrence of alternate layers of sand , clay and sandy clay of varied thickness. The study of bore hole lihtology reveals that a sequence of alternate clayey and granular zone with occasional presence of some semi-consolidated layers are mostly encountered in the tertiary tract. In general it is observed that the ground water quality available in entire district may be used safely for irrigation purposes. The total annual recharge to the ground water body from all sources has been estimated to 1,68,961 HM. Out of this ,the annually utilizable component of the ground water resources for irrigation purpose works out to be 1,52,064 HM. At present the stage of ground water development of the district is 17.99 %. The overall ground water development of the district can be termed as Safe Category.*

Keywords- Hydrogeomorphology, Draft, Aquifer, Sustainable, Hydrogeology

I. INTRODUCTION

Mayurbhanj district located in the North-Eastern part of Orissa.The district of Mayurbhanj lying between the parallels Latitude $21^{0}17'$ to $22^{0}34'$ North and Longitudes $84^{0}47'$ and $87^{0}11'$ East has a gross geographical area of 10,412 sq.kms. The district is largely represented by crystalline formations and is featured in Survey of India Topo sheet No.73 / K, J, F, G and O. The district is bounded by the state of Jharkhand in the North and the state of West Bengal in the East. About 93 % of the population lives in rural areas and economy of the district is predominantly agrarian. Total cultivable area of the district is around 3,530.00 sq km, out of which nearly 26.90 % and 09.50% of this area receives irrigation from different sources. Due to paucity of irrigation facilities in the district, the agriculture is mostly dependant of South-West monsoon. At present the stage of ground water development of the district is merely 17.99 %, hence there is vast scope for ground water exploitation through installation of different ground water extraction structures to augment the irrigation potential. As per 1991 census, the total population of the district comes to 18,84,580, out of which SC/ST population is 12,22,391 (64.86. The Rural population of the district is 17,68,331 (93.80%) and Urban population is 1,16,249(06.20%). Around 93 % population of the district live in rural areas and this population depends on agriculture directly or indirectly. Since the rainfall in the district is erratic, ground water development is essential to provide assured irrigation. The district is well endowed with groundwater resources. Investigations pertaining to study of surface and sub-surface geology, demarcation of groundwater worthy area, study of aquifer characteristics, feasibility of irrigation wells and their cost effectiveness and above all the assessment of groundwater potential on scientific lines as per ground water estimation committee norms have been carried out.

The literature available on ground water evaluation, development and management was reviewed in detail. Sikdar et al. (2007), Sankar and Venkatram (2002), Chauhan (2000) Rokade et al. (2007), Mahapatra et al. (2000), Patnaik(2003), Reddy et al.(2003), Sahu and Sahoo (2006) and Sahu (2008) in their study relating to ground water exploration and targeting potential ground water zone, have emphasized that integrated geological, geophysical, remote sensing and GIS techniques should be adopted for targeting potential ground water zones in hard rock areas. Reddy (1999) has emphasized the need to adopt modern know-how i.e. Remote sensing and GIS to evaluate the ground water potential in hard rock provinces.Josrotia and Singh (2007), Singh et al. (2007), Prasad (2007) and Pandian (2007) and Sahu (2003) studied on the hydrochemistry and ground water quality in different parts of the country and emphasized the need of qualitative evaluation for sustainable development of ground water resources. Chadha (2000), Patnaik (2003), Jha (2000), Viswanathan (2002), Umrikar (2002), Nayak et al. (2003), Pradhan (2003), Sahu (2003) and Das (2006) in their studies on ground water development and management has remarked that artificial recharge structures / rain water harvesting structures play a key role in sustainable development of ground water resources.

II. METHODOLOGY

1. Collection of secondary data like population, rainfall, ground water abstraction structures and irrigation potential. Collection of Toposheets, references etc.

2. Reconnaissance survey with special reference to lithology, structure, topography and weathering characteristics.

3. Systematic collection of hydro geological data for both pre and post monsoon period during well inventory studies and interpretation of data

4. Estimation of ground water resources using "water table fluctuation method" recommended by the Ground water Estimation Committee (GEC-1997) constituted by Govt. of India.

5. Remote sensing technique has been adopted

6. Vertical Electrical Sounding (VES) survey has been carried out in selected locations and interpretation has been done to understand the gross aquifer condition.

7. Systematic collection of ground water samples from shallow and deeper aquifers during pre and post monsoon period and chemical analysis for ions like Ca, Mg, Na, K, CO_3, HCO_3, Cl, SO_4, NO_3 and other parameters like Ph, Temp., TDS, EC etc. are measured in the field.

8. Based on the hydro-geological set up, a map showing suitable site-specific artificial recharge structures has been prepared.

III. RESULTS AND DISCUSSION

Physiographically the study area can broadly be divided into three categories. The first physiographical unit of the district is high mountain ranges Similipal comlex being at its central part. The mountain ranges comprises mainly of high land plateau and valleys with intrusive running through them. The second physiographical unit is Tertiary plain occurring in the Eastern part of the district. The third physiographical unit is Alluvial plain which lies partly in Rasgovindapur, Morada, Samakhunta, Betanati,Baripada,Badasahi ans Suliapada Blocks of the district. Geomorphologically the district is divided into the following three units.

1.The denudational hills with moderate to high slope occurring in the Western parts of the district.
2.Dissected pediments having gentle slope.
3.Pediplain having slope between 0^0 to 5^0.

The district is drained by a network of rivers and nallas having flow in different directions. Budhabalanga,Baitarani,Subarnarekha and Kharkhei are the principal rivers flowing through the district. Rivers Deo and Khairibandhan also drains the area significantly both during monsoon and non-monsoon period. The north eastern part of the district is mostly drained by river Subarnarekha and Jambhira. River Budhabalanga and Gangahar drain the southeast part of the district. The southwest and north west part of the district are mostly drained by the rivers Baitarani and Kharkhei respectively. The drainage density is observed to be fairly moderate and drainage pattern is observed to be dendritic in nature.The district comprises chiefly of lateritic, sandy loam and clayey loam type of soil. Lateritic soil is mostly marked in the area occupied by crystalline rocks. The low lying valley fields are covered with clayey loam type of soil. The thickness of the soil cover varies from 0.5 to 3.00 mts, depending upon the topographical situation of the region. In high lands, lateritic and sandy loam soils are mostly encountered. In sloping land situations, clayey loam and sandy loam soils form the top soil mantle, whereas in low lands,clayey loam and little pockets of sandy loam are encountered.

The Major rock types foundin the district are Granite Gneiss, Quartzite, Ortho-Quarzite, Arkose, Shale , Phyllite,Gabbro, Granophyre and Pyroxene granite. The geology of the district is constituted by the Similipal complex at its central part belonging to Achaean age, unconformably lying over the Singbhum granite and Banded iron ore formation of Mayurbhanj. It constitutes three alternate bands of volcanic sedimentary units uniquely disposed in a ring like circular pattern formed under sub-marine condition. The sedimentary of Similipal mostly comprise of orthoquartzites arkose and minor band of ferruginous shales and phyllites. The quartzites are devoid of any volcanic materials within it and exhibit well preserved cross beddings and paleo current structures indicating shallow water sub-marine origin. The dip of quartzites are towards the center of the Similipal basin. The three consecutive bands of volcanics denotes three period of quiescence. At the center of Similipal lies the Amjori sill which covers an area of about 130 sq.kms. The parental Magma of Similipal is saturated and a close plateau type.Following the volcanic phase Gabbro, Granophyre, Pyroxene granite were intruded along fractures in the periphery at Similipal complex. Baripada bed of Miocene age occurs to east of Similipal built up by marine deposits in the form of continental shells. The laterite of Eocene age are found overlying the others. Some parts are covered by insitu and alluvial soil of recent age.

Geophysical investigation was under taken during preliminary as well as detailed phase of ground water survey to ascertain the occurrence of different aquifers, fractured zone, and basement along with the position of water level below ground level in different parts of the district. The soil mantle in the erosion plain varies from 0.5 to 3.0 meter. This is followed by weathered rock of 5.0 to 13.0 meter thickness. The basement rock occurs at a depth of 22.0 to 30.0 meter bgl. A thick clayey zone of about 10 to 40 meter serves as the top soil cover in the tertiary tract. This is followed by occurrence of alternate layers of sand , clay and sandy clay of varied thickness. The occurrence of basement has not been marked in course of exploratory drillings undertaken in the tertiary tract of the district. The thickness of topsoil cover (clayey zone) in alluvial tract is found to be varying from 10 to 30 meter. This is followed by occurrence of granular zones (sand and sandy clay) charged with fresh water. The occurrence of basement has not been marked in course of exploratory drillings undertaken in this tract.

The study of bore hole lihtology reveals that a sequence of alternate clayey and granular zone with occasional presence of some semi-consolidated layers are mostly encountered in the tertiary tract. The clayey bands occurring at different depths vary significantly in colors viz.. light grey , deep grey ,light brown , deep brown ,black ,yellow etc .In some cases black sticky clay mixed with kankar are also found . Granular zones of varied thickness occurring in the area mostly consist of sand and gravel (fine to very coarse). Fine to coarse sand with little proportion of gravel form the most potential aquifers in Rasgovindapur, Suliapada, Morada, Baripada, Betanati, Kuliana, Badasahi and part of G.B. Nagar Blocks .The sequence of sedimentary rocks occurring in the district exhibit a wide range in the geological age ranging from Miocene to Holocene. The aquifer material found in the Blocks of Badasahi,Kuliana,Part of G.B.Nagar and part of Suliapada adjoining to Kuliana Block is mostly medium sand. The average discharge of medium deep tube well of 80 mtr. depth comes around 1250 - 1350 LPM. In Rasgovindapur, Morada, Betanati, Baripada and other part of Suliapada, fine sand form the potential aquifer. The discharge range of tubewells of 80 mtr. depth in these area comes around 500-1000 LPM.

The ground water available in the district occurs both in unconfined and confined aquifers depending on the hydro-geological setup of the district. In consolidated hard rock formation which covers nearly 78.31% of the total geographical area, the weathered rock lying subsurface as well as laterite capping at ground level or subsurface serve as the main aquifer. These aquifers are mostly encountered under unconfined conditions. In tertiary tract, which covers nearly 17.00% of the geographical area, adequate thickness of granular aquifer (fine sand) occurs in both confined and unconfined conditions. The ground water occurring in granular aquifer is mostly found in semi-confined condition and ground water occurring in deep-seated aquifer is mostly found in confined condition. In alluvial formation which lies partly in Samakhunta, Rasgovindapur, Morada, Betanati, Baripada, Badasahi and Suliapada blocks of the district, ground water occurs in the saturated pore spaces of the granular aquifers encounters at shallow depth under unconfined condition(Table 1)

Table 1. Hydrogeological Formations

Sl. No.	Hydro-geological formations	Areal extension in Km.	Name of the Blocks covered fully or partly
1	2	3	4
1	River Alluvium	461.46	Rasgovindapur(P),Samakhunta(P),Morada(P), Betanati(P), Baripada(P), Badasahi(P) and Udala(P)
2	Tertiary tract	1,796.90	Kuliana(P), amakhunta(P),Baripada(P), Suliapada(P),Morada(P), Rasgovindapur(P), Betanati(P), Badasahi(P),Khunta(P), G.B.Nagar(P),Saraskana(P).
3	Consolidated hard rock formation	8,153.64	Badasahi(P), Kuliana(P),Jashipur(F), Khunta(P), Kaptipada(F), G.B.Nagar(P), Udala(P),Sukruli(F), Tiring(F),Rairangpur(F),Thakurmunda(F),Bahalda(F),Bangiriposi(F),Jamda(F),Bisoi(F),Raruan(F), Kusumi(F),Bijatola(F), Samakhunta(P), Saraskana(P).

The alluvial plain covering an area of 461.46 sq.kms. lies partly in Rasgovindapur, Samakhunta, Morada, Betanati, Baripada, Badasahi and Suliapada. This plain forms the fertile part of the district and is covered with moderate vegetation. This tract comprises of alluvial deposit of varied thickness contributed by a network of rivers traversing the tract. The general slope is towards North-South. The tertiary tract measuring about 1,797.00 sq.kms. covers roughly 17 % of the district and occurs in the eastern part of the district. The consolidated hard rock formation covers nearly 78.31 % of the total geographical area of the district.

The district of Mayurbhanja broadly comes under three distinct geological formations viz; consolidated sediments, un-consolidated sediments and the tertiary tracts. The consolidated hard rock occurring over an area of 8,153.64 sq.kms. constitute about 78.31 % of the total geographical area. The weathered rock along with jointed and fractured rocks serve as the ideal space for storage and movement of ground water. An area of 461.46 sq. km. covering nearly 4.40 % of the total geographical area of the district is occupied by un-consolidated sediments (alluvium).The un-consolidated sediments occurring in the district mostly consists of sand of varying grades, clay and kankar.In this tract the aquifers are mostly encountered at shallow depths. The tertiary tract occurring over an area of 1796.90 sq.kms. covers roughly

17.26 % of the total geographical area. This tract holds large quantity of ground water either in single aquifer or in the multiple granular zones having variable thickness. From the lithology of tube wells installed and A.P. test conducted in area , it is established that aquifers occur under both confined conditions and un-confined conditions.

The observation centers at Bahalda, Bijatola, Karanjia, Morada, Gundihudi in Samakhunta Block, Dhanghari & Nuagaon in Saraskana Block indicate high water table whereas Bagdiga in Bahalda Block ,Darkoli, Manchabandha in Baripada Block, Tangabila, Jashipur of Jashipur Block and Raruan indicate low water table. In tertiary tract, the average position of groundwater level during pre-monsoon & post-monsoon period which observed to be varying from 1.50 to 12.85 mtr. and 1.30 to 8.60 mtr bgl respectively.In alluvial tract, the average position of ground water level during pre-monsoon & post-monsoon period is observed to be varying from 2.10 to 10.80 mtr. and 1.60 to 8.40 mtr. bgl. Respectively
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In hard rock terrain, the average position of ground water level during pre-monsoon & post-monsoon period is observed to be varying from 3.50 to 14.65 mtr. and 1.85 to 8.50 mtr. bgl. respectively. Since the fluctuation of water table in different topographical situations of hard rock terrain varies significantly, the weighted average of the water table fluctuations has been worked out to represent the average situation.

Rainfall is the major source of ground water recharge. The following two methods have been employed for computing the rainfall recharge of the district.(i) Rainfall infiltration factor method (ii) Water table fluctuation method. The normal rainfall obtained as the average rainfall over a sufficiently long no. of ground water years have been taken as a basis for computing rainfall recharge. Other sources of ground water recharge taken into consideration while computing the ground water recharge of the district are;

(i) Recharge from canals
(ii) Recharge from irrigation water applied by surface water irrigation
(iii) Recharge from irrigation water applied by ground water irrigation
(iv) Recharge from tanks & Ponds.

The total annual ground water recharge of the district from all sources computed as per GEC norms – 1997 is calculated to be 1,66,946 HM.

Ground Water Quality

In order to assess the quality of ground water occurring in the district, a large number of water samples have been collected from different sampling stations. There are total 81 sampling stations in the district out of which 16 are trend station and other 65 are base stations. Water samples have been collected from the aquifers occurring at different depths. The water samples have been analysed in the Hydro-chemical Laboratory. The range of occurrence of various constituents of water samples analysed chemically are enumerated below(table 2).

Table 2. Water quality range

Parameter	Value Range
PH	6.18 –9.35
E.C	67 –1800 mho/ cm
TDS	37 –1243 ppm
Ca^{++}	8.00- 64.0ppm
Mg^{++}	2.413- 55.503 ppm
Na^{+} K^{+}	1.4- 170.5 ppm 0.6- 151.7 ppm
Cl^{-}	7.1- 291.7 ppm
CO_3^{-}	0 – 60.00 ppm
HCO_3^{-}	18.30 –463 ppm
F^{-}	0 –1.32 ppm
SO_4^{--}	0.48- 45.43 ppm
NO_3^{-}	0 –8.124 mg, N/L
TH	30-350(Total)mg aco3/L

Analysis of water samples collected from different observation wells reveals the following PH of most samples are above 7.0.Kusalda in GB Nagar Block, Astia & Dhanghari in Samakhunta Block shows norma PH. Electrical conductivity (EC) is found to be varying from 42.0 to 1850 mhos/cm. Area showing high EC are Badasahi, Baripada, Jamda, Kusumi, Raruan Blocks etc. and area showing low EC are Bijatola, Bisoi, Jashipur, Khunta, Morada, Raruan, Rasgovindapur, Saraskana, Thakurmunda, Tiring etc. TDS is found to be varying from 27 to 1243 ppm.Bagdiga in Bahalda Block, Rangamatia in Baripada Block, Gohira in Jamda Block and Purunapani in Rairangpur Block show high TDS. In general it is observed that the ground water quality available in entire district may be used safely for irrigation purposes.

IV. ASSESSEMENT OF GROUND WATER RESOURCES POTENTIAL

Ground water being a dynamic and replenishable resource has to be estimated primarily basing on the component of annual recharge which could be subjected to development by means of suitable groundwater extraction structures and scientifically harnessed for various utilisation purposes. The annual ground water recharge of a region largely depends on the hydro-geological setup and climatic conditions, more so on the precipitation it enjoys. As per recommendations of the ground water estimation committee 1997, the annual recharge of the ground water reservoir is to be estimated based on water level fluctuation in areas where ground water level monitoring is being done regularly and adequate data on water level fluctuation are available. As such the Water Table fluctuation approach recommended by the ground water estimation committee has been followed to assess the exploitable ground water resources of the district. As earlier mentioned, the ground water available in the district occurs both in un-confined and confined aquifers depending upon the hydro-geological setup of the region. In this chapter, an attempt has been made to compute the ground water resources occurring in un-confined only. Detailed study of the confined aquifers occurring in the district is yet to be taken up in a systematic manner. The aquifers occurring at shallow depths both in hard rock terrain, alluvial and tertiary tract of the district are mostly un-confined in nature. The areal extension of such aquifers has been found to be 7,565.17 sq. km.

The total annual recharge to the ground water body from all sources has been estimated to 1,68,961 HM. Out of this ,the annually utilizable component of the ground water resources for irrigation purpose works out to be 1,52,064 HM. The annually utilizable ground water resources for irrigation purposes works out to be 1,52,064 HM. By now, nearly 2,73,62.00 HM of this key resources have been tapped through installation of 301 nos. of medium deep tube wells, 1680 nos. of shallow filter point tubewell,10,900 nos. of dug wells with pump sets and 9,075 no of dug wells with tenda. At present the stage of ground water development of the district is 17.99 %. The overall ground water development of the district can be termed as **Safe** category.

The entire district can be broadly divided into three distinct zones viz; crystalline formation, tertiary formation and river alluvium. The hydro-geological setup and ground water development potential of these formation varies significantly from each other. The weathered along with fractured and crumpled rocks occurring in crystalline tract can suitably be tapped through installation of dug well and limited bore wells. The area occupied with Lateritic formation is considered feasible of installation of standard dug well only. The granular zone occurring under un-confined and semi-confined condition in the tertiary tract of the district can suitably be tapped through installation shallow tube wells as well as medium deep tube wells. Besides the above, the limited thickness of alluvial tract occurring along the river Budhabalanga and Subarnarekha are found mostly suitable for installation of shallow tube wells and medium deep tube wells.

The number irrigation structures considered feasible in different blocks of the district have been worked out keeping in view the utilizable ground water potential available for irrigation purpose. Different types of irrigation wells considered feasible in the district have been worked out on the basis of available ground water balance proportionate to net area sown. The irrigation potential that can be created through installation of 87016 nos. of standard dug wells, 315 nos. of medium deep tube wells and 130 nos. of shallow tube wells has been worked out to be 58235 Hect.

V. CONCLUSION

Mayurbhanj district located in the north-east part of Orissa has a gross geographical area of 10412.00 sq.kms. Out of this an area of 3170.00 sq.kms. is covered under steep hills and reserve forest. The balance area of 7242.00 sq.kms. covered under three distinct geological formations viz; crystalline, tertiary and alluvium is considered suitable for ground water recharge. It largely comes under hard rock terrain and its economy is pre-dominantly agrarian. Detailed study on availability of ground water and its level of utilization in different blocks of the district have been carried out. The utilizable ground water potential available for irrigation has been estimated to be 1, 52,064 HM. By now nearly 27,632 HM of ground water have already been tapped through installation of 9,075 nos. of dug well with tenda, 10,900 nos. of dug wells with pump set, 1,680 nos. of filter point tube wells and 301 nos. of medium deep tube wells. The ground water balance available for future development works out to be 1, 22,550 HM. However, the ground water balance for future development works out to only 61,723 HM considering 60 % of net ground water resource for irrigation . Further, the ground water balance for future irrigation use can sustain installation of 87,016 nos. of standard dug wells, 130 nos. of shallow tube wells and 315 nos. of medium deep tube wells. The additional irrigation potential that can be created through installation of irrigation wells proposed has been estimated to be 58,235 Hect. and 38,421 Hect. During khariff and rabi seasons respectively. Keeping in view the need for careful and comprehensive planning for optimum development of ground water resources of the district, the following recommendations are made.

a. Typical design of different types of irrigation wells considered best suited to different hydro-geological setup of the district has to be finalized to ensure optimum yield.
b. Steps for revitalization of old and defunct wells needs be taken up in a large scale either through in-well drilling equipment or by means of suitable revitalization equipments.

c. The irrigation wells proposed to be installed in future need to be taken up in cluster to ensure economy and target bound progress.
d. The irrigation wells installed in cluster may be connected to a dedicated feeder line of the nearest electrical sub-station to minimize the cost involved in drawls of LT line and ensure better electrical services.
e. Suitable make pumps which would operate efficiently under low head conditions involved in pumping irrigation water from dug wells and filter point tube wells installed in private sectors need to be identified on priority basis.
f. An approved list of the available pumps considered suitable for different situations need to be prepared for use by the cultivators.
g. A leaflet in local language needs to be prepared describing the different components of the pump in relation to their functioning and maintenance. Farmers are expected to understand the process of routine and long-term maintenances.

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