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# IMPACT OF MINING ON WATER AVAILABILITY IN MINING AREAS OF JHARKHAND, INDIA. A STATISTICAL APPROACH

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**Streszczenie:** Kurczenie się zasobów wody wskutek działalności górniczej jest ogólnie znane. Analizując przyczyny takiego stanu rzeczy, stwierdzono, że zjawisko to występuje wyraźniej na terenach powstałych na podłożu skał osadowych niż skał zwięzłych, gdzie woda występuje głównie w spękaniach i strefach wietrzenia.

Zjawisko to dokładnie bano na obszarze działalności górniczej (około 15 000 km$^2$) na terenach zbudowanych ze skał zwięzłych we wschodnich Indiach. Badania dotyczyły okresu około 70 lat (1923–1994). Stwierdzono, że od 1923 do 1926 r. i od 1984 do 1986 r. obszar ten tracił naturalne powierzchniowe linie odwadniające w tempie 0.0027 km/km$^2$/rok. Okazało się, że poważnie uszkadza to ekosystem, jeśli brać pod uwagę jego zasięg w przestrzeni i w czasie.

Następnie analizowano poziom wody na podstawie danych dotyczących blisko 150 studni kopanych na tym obszarze w ciągu dwudziestu lat (1974–1994), aby dowiedzieć się, jak obniża się on w okresie przed- i pomonsunowym. Stwierdzono, że poziom wody obniżał się o średnio 0,516 m/rok w okresie przedmonsunowym i o 0,297 m/rok w okresie pomonsunowym. Istotność tego stwierdzenia sprawdzano, korzystając z testu *t* przeciwstawionego hipotezie zerowej, która zakładała, że brak efektywnego obniżenia się poziomu wody. Hipotezę zerową odrzucono, a więc obniżenie się poziomu wody jest istotne dla poziomu ufności powyżej 0,01.

**Abstract:** Water resource depletion due to mining is a common feature. An analysis of the cause behind this reveals that the effect is more prominent in sedimentary terrains than in hard-rock bearing regions, where water occurs mainly in cracks and weathered zones.

The situation was thoroughly analysed in a mining area (about 15,000 km$^2$) in hard rock terrain in eastern India over a period of about 70 years, from 1923 to 1994. It was observed that in the period from 1923–1926 to 1984–1986 the region has lost natural surface drainage lines at a rate of 0.0027 km/km$^2$/year. It appears to be a serious damage to ecosystem if its coverage in space and time is considered.

Then water level (WL) data from about 150 dug wells in the same area were analysed during the twenty-year span from 1974 to 1994 to know lowering of WL in pre-monsoon and post-monsoon time separately. It was observed that the WL has gone down on an average by 0.516 m/y and 0.297 m/y in pre- and post-monsoon days, respectively. Significance of this was tested by *t*-test against the null hypothesis that there is no effective lowering of WL. The hypothesis was rejected for both the seasons so that the lowering of WL was noted to be significant above 0.01 level of confidence.

**Резюме:** Значительное понижение ресурсов воды вследствие горной деятельности общеизвестно. Анализируя причины такого состояния, было установлено, что это явление выступает более четко в областях, расположенных на основаниях из осадочных, чем из твердых пород.

Это явление было точно исследовано в области горной деятельности (около 15 000 км$^2$) на территориях, образованных из твердых пород в восточной Индии. Исследования касались времени ок. 70 лет (1923–1994). Было установлено, что в годы с 1923 по 1926 и с 1984 по 1986 эта территория утрачивала натуральные поверхностные водоотводные канавы со скоростью 0,0027 км/км$^2$/год. Оказалось, что это значительно повреждает экосистеме, если принять во внимание дальность на протяжении времени.

Затем был алализирован уровень воды на основе данных, касающихся около 150 колодцев, выполненных на этой территории в течение двадцати лет (1974–1994), чтобы узнать, как он понижается в до- и послемуссонный срок. Было установлено, что уровень воды понижался в среднем на 0,516 м/год в домуссонный срок и на 0,297 м/год в послемуссонный. Сущность этого была проверена с использованием теста $t$, противопоставленного нулевой гипотезе, которая предпосылает, что не существует эффективное понижение уровня воды. Нулевая гипотеза была отброшена, а затем понижение уровня воды существенно для уровня доверчивости выше 0.01.

## 1. PROLOGUE

Water is life. Had there been no water on the planet Earth it would be as barren as any other lifeless planet. Water is one of the basic natural resources that protect life, environment and ecosystem. Water plays a pivotal role in protecting all aspects of environment (GHOSH and GHOSH [5]). This very important natural resource can be disturbed by some of the developmental activities of men, if conducted without any special care for water resource protection. One among these is mining.

Damage to water resource (availability) by mining is an almost known fact nowadays. In the present paper, the matter has been studied over a hard rock terrain in some mining areas of Jharkhand, a new state in eastern India. Further, whether the damage is significant or not has been tested statistically. Application of such statistics in the field of environmental impact assessment is comparatively new.

## 2. BACKGROUND

Water scarcity is a regular problem in many parts of the country, specially in some regions adjoining the mining areas. Some UNEP studies (MOHANTY [8]) report that India is heading towards desertification. Mining damages water resource of the region in many ways, some of which are as listed next.

- Whenever excavation is conducted below water table, a part of the aquifer gets excavated out. Water from the remaining parts flows into the excavation site and forms a sump. This water needs to be pumped out to facilitate mining. This becomes a continuous process. It forms a cone of depression in ground water level in the region due to draw-down. The cone spreads in the surrounding regions. The wells get the water level lowered, and shallow ones get dry. Some effluent streams become influent and some even dry-up.
- Excavation on hills and overburden dumps created by excavation on land supply rollings and washings to surface water bodies (ponds, lakes, reservoirs and rivers) situated downslope. These get silted, get their water holding capacity decreased, as a result the shallower ones even may get dry.
- This invites flood potentiality in the region, which creates more erosion by the flood runoff, more siltation and filling up of the surface water bodies more effectively.

• Mining damages greenery both directly and indirectly, while greeneries play some active role in keeping the hydrologic cycle running. Thus water resource in the region gets damaged.

• The cumulative effect of all the above effects pushes the region towards desertification as explained by the "cycle of land deterioration" (GHOSH [2]).

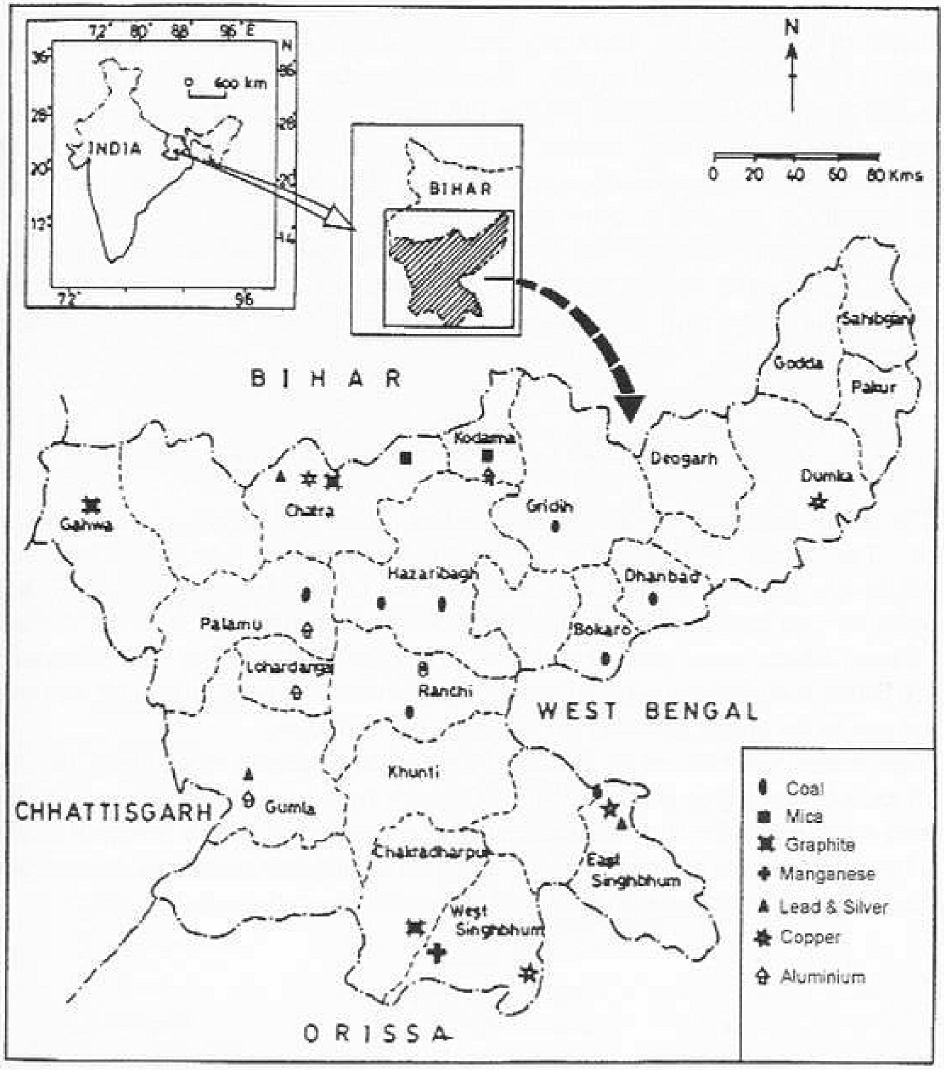


Fig. 1. Location and minerals (main) of Jharkhand

That such effects are really discernible in mining areas of India have been proved by studies from a part of Damodar river basin, Jharia coalfield (GHOSH [3]), some parts of Raniganj coalfield, a part of Subarna Rekha river basin in erstwhile Moasboni and Rakha mines areas (GHOSH and DAS [4]) and many others.

## 3. THE STUDY AREA

The study deals with a relatively young state in eastern India "Jharkhand", the southeastern part of which (the study area) (figure 1) is the store-house of mineral wealths in the country. Originally, about 100 years ago it was a forest-cum-agricultural land (RUTHERMOND [9]), as the name "JHARKHAND" signifies "Jhar" means "plants" and "Khand" means "land". Really it was a land full of plants. This natural lush green vegetation documents the fact that the region was not having any water scarcity in those days. Now many parts of it has changed into barren mining areas. Observations indicated that total alteration of the region has been geared by mining (GHOSH et al. [6]). Thus it has been assumed that in the mining areas of Jharkhand (the study area), the change in water availability, if any, is the effect (direct or indirect) of mining.

## 4. GEOLOGY AND HYDROGEOLOGY

The study area represents a part of Indian Peninsular shield, a stable cratonic block. The rocks are basically Archaean Precambrian granites. The district Singhbhum is the most mineral-rich district in the region (figure 2). It is a rift basin bounded by two basement dislocations coinciding with Sukhinda thrust at the south and Tamar Khatra shear zone at the north. Thus the total area has been sheared severely which has allowed entry of mineralising fluids along the planes of weakness, giving rise to the highly mineral rich Singhbhum Shear Zone.

Here ground water occurs in weathered zone of the Archaean rocks, along the cracks and fractures. The region is so sheared that though there is no continuous aquifer, there remains every possibility that the fractures are inter-connected. Hence lowering of water level (WL) in one may result in lowering of WL in the adjoining fractures. Natural drainage lines occur along topographic/erosional depressions or cracks sealed at depth.

## 5. OBJECTIVES

Against the above background, the research was planned to study the following features:

- Change in natural drainage (rivers and all their tributaries starting from the 1st order) length (DL) in the region, if any, over a period as long as possible, i.e., for which information source could be made available.

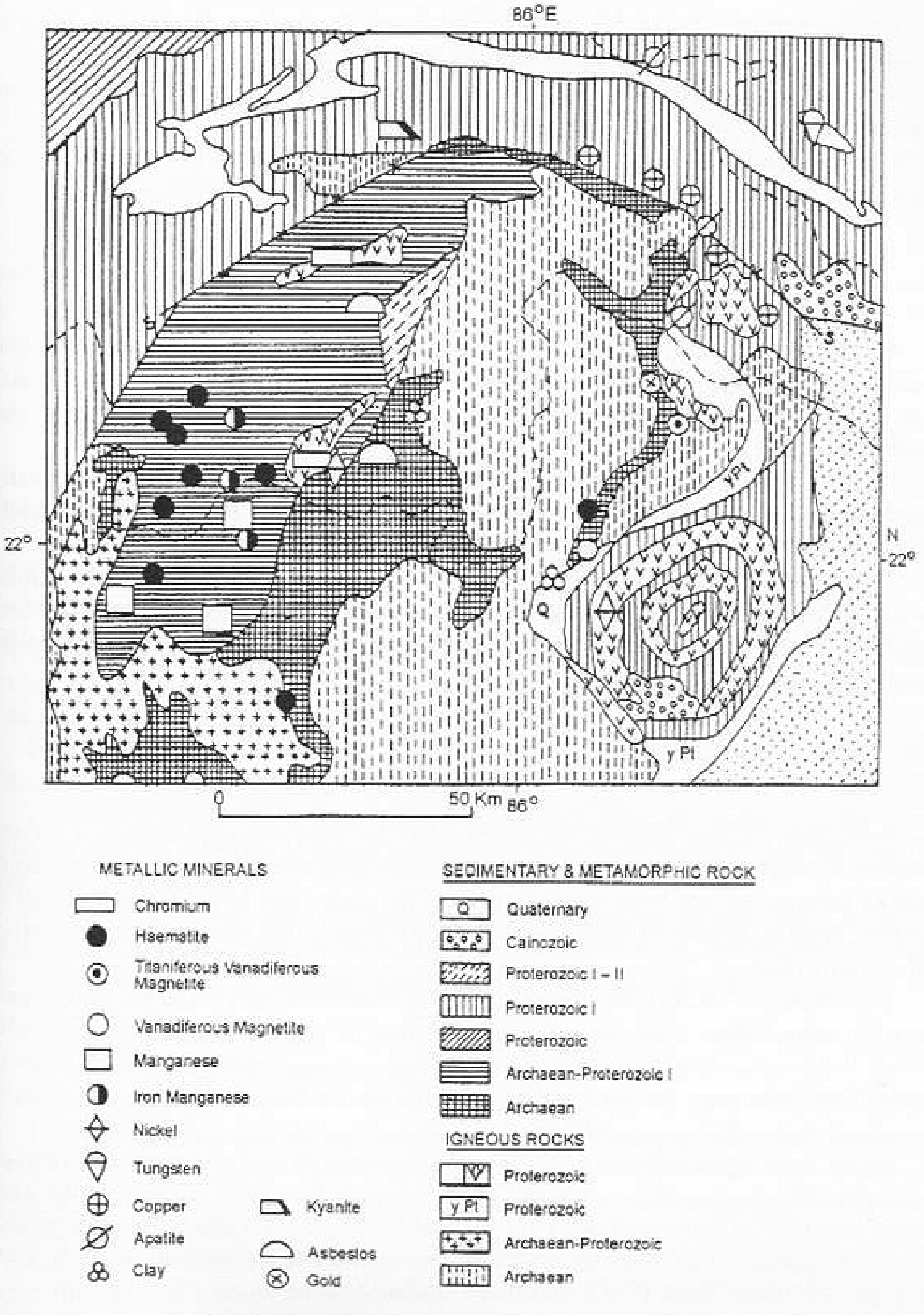


Fig. 2. Geological and detailed mineral (metallic) map of Jharkhand

• Change in the WL in dug wells in the region, if any, over a period as long as possible, i.e., for which information could be made available.

• To analyse the data thus made available, distributed in time and space to assess the trend and magnitude of change in WL and DL.

• To analyse statistically, whether the magnitude of variation (change), if any, is significant or not.

## 6. ASSUMPTIONS

As revealed in section 3, the study area was a forest-cum-agricultural land, 100 years ago. This documents that whatever water availability condition (natural drainage length and water level in dug wells) the region was having in those days, was ecofriendly.

Thus for statistical analysis, the hypothesis assumed was that in a hypothetically ideal ecofriendly condition, the change in natural drainage length (DL) and water level in dug wells (WL) of the region should be zero (i.e. no change).

It was not possible to get any data on DL or WL for 100 years ago, so it was considered that for each of the microdrainage systems and each of the dug wells the earliest available information on DL and WL will be assumed as relatively well defined initial condition.

## 7. DATA SOURCE

Nowadays "remote sensing" is considered as the most authentic document for any feature of land-surface, and hence for the drainage lines also. However, the science of remote sensing did not born even in the days for which the data were being tried to collect. Thus toposheets of those days were considered as the most authentic record of DL of early days.

Toposheets of 1923–1930 pertaining to the concerned area could be made available for consultation from the archives of Surrey of India (SOI). To compare with those, the latest available toposheets of the region were collected, which were of 1984–1986. However, for 2003, satellite imageries are being procured, the procurement activity is still in the pipeline.

It was much more difficult to get WL data for early days. The fact remains that no authentic WL data could be obtained for any year before 1974. However, WL data could be collected for years from 1974 to 1994 for some wells and for shorter periods for some more wells from a very authentic source, i.e., the regional office of the Central Ground Water Board (CGWB) Govt. of India (ANON [1]).

## 8. DATA

The basic data (source of information) were as follows:

1. SOI Toposheet nos 73F of 1923 in scale 1:253440 (1″ = 1 mile),
73J of 1930 in scale 1:253440 (1″ = 1 mile),
73F of 1984 in scale 1:250,000,
73J of 1986 in scale 1:250,000.

2. Data on depth to water level below ground level in meters (bgl in m) for about 150 dug wells distributed over an area of about 15,000 sq km, for a time span of 20 years from 1974 to 1994 (for some wells) and for shorter period (varying) for the others.

## 9. EXPERIMENTALS

### 9.1. DRAINAGE ANALYSIS

The toposheets were scanned, from which all the drainage lines (from order 1 to the highest) were searched out and drawn on tracing papers. The tracing papers were arranged together, in order, following the position as per latitudes and longitudes. Then a composite drainage map was prepared.

Two drainage maps were thus prepared, one for the time level of 1923–1930 and the other for the time level of 1984–1986.

The two drainage maps were studied thoroughly. Both the maps had the same drainage pattern, dendritic to sub-dendritic; however, the variation in drainage density was visually discernible.

Thus an attempt was made to measure (by length measurer) the total drainage length in two maps separately and also to measure the exact amount of area covered by these. Based on these results the drainage density (Dd) could be calculated for two periods.

### 9.2. ANALYSIS OF WATER LEVEL IN WELLS

The well data as could be obtained from CGWB were consulted. These were covering different time levels of intra-year and inter-year. As has already been reported, some were covering 20 years, some less. Further within each year, data on different months were available.

Attempt was made to generate a data set of controllable shape and size, at the same time as representative as possible. Thus attention was paid to pre-monsoon (May–June) and January data. Though theoretically November–December could better represent post-monsoon condition in India (specially in this part), January data was taken as the most representative one because of two reasons stated next.

• January is the time when the water level in cracks acquires a more or less steady state by recharge and discharge through cracks and saturating the cracks, over a considerable period after the rains stop.

• January was the month in which the available data was covering the maximum time span (in years).

The well data was processed and analysed step by step as listed next.

1. For each of the wells variation (difference) in WL bgl (in meters) was recorded against the time span (years) for which the data was available for the respective well, for a definite month, January.

2. Variation in WL bgl per year (in meters) was calculated (as $x$) from the variation through number of years, which represented fluctuation of WL bgl in each individual well.

3. This $x$ value was calculated separately for $n$ number of sample wells.

4. $\sum \bar{x}$ and then $\bar{x}$, i.e., the sample mean for the fluctuation of WL bgl in January, were calculated.

5. Standard deviation ($S$) of the mean was calculated using the formula

$$S = \sqrt{\frac{\Sigma(x-\bar{x})^2}{n}}.$$

6. Standard error of the mean was calculated using the formula $S/\sqrt{n}$.

7. Value of the critical ratio $t$ was calculated using the statistic $t$ (KREYSZIG [7])

$$t = \frac{\bar{x}-\mu}{S/\sqrt{n}},$$

where $\mu$ stands for population mean, which is assumed as desired to be equal to zero in the present study (population denotes the totality of a group from which the sample is drawn).

8. The same set of activity was repeated with May–June data, while the value of $n$ was 154 for January (post-monsoon) data and 144 for May–June (pre-monsoon) data.

## 10. RESULTS AND DISCUSSION

### PRE-MONSOON DATA

$\bar{x} = 0.5160.$

$$S = \sqrt{\frac{\Sigma(x-\bar{x})^2}{n}} = \sqrt{\frac{173.3517}{154}} = 1.06097.$$

Standard error of mean = $S/\sqrt{n}$ = 1.061/12.40967 = 0.08550.

$$t = \frac{0.5160}{0.08550} = 6.03509.$$

POST-MONSOON DATA

$\bar{x}$ = 0.2972.

$$S = \sqrt{\frac{\Sigma(x-\bar{x})^2}{n}} = \sqrt{\frac{105.1476}{144}} = \sqrt{0.73019} = 0.8545.$$

Standard error of mean = $S/\sqrt{n}$ = 0.8545/12 = 0.07121.

$$\therefore t = \frac{0.2972}{0.07121} = 4.17357.$$

In this study, *t*-test was applied to the hypothesis that in a theoretically ideal eco-friendly condition change in WL in wells over years (when observed for any definite season) should be zero. Thus, the null hypothesis in this case is "in a two-year period (in the same month) the difference between WL in wells is zero".

The values of calculated *t* for pre-monsoon and post-monsoon periods were compared with the tabulated value of *t*(3.373). For both the seasons, the calculated/observed value of *t* was noted to be much higher than the tabulated value. Thus the hypothesis was rejected for both the seasons. Hence it was concluded that the difference (i.e., the magnitude of lowering of WL bgl in this case) is significant at the 1 per cent level. In other words, one can be sure 99 per cent times that the observed difference in WL bgl (lowering of water level in wells in this case) is a real difference in population. Hence the water level in wells in the region has gone down significantly.

The length of natural drainage lines was measured and calculated from the drainage map of 1923–1930 to be 5780 km, while from 1983–1986 drainage map the same length was measured to be 3365 km. The area under consideration was measured as 14993.65 km$^2$. Thus drainage density in the area in 1923–1930 was 0.3855 km/km$^2$ and drainage density in the area in 1983–1986 was 0.2244 km/km$^2$. Thus the region has sufferd loss of 0.1611 km/km$^2$ of natural drainage length in 60 years, i.e., 0.0027 km/km$^2$/year. This is a serious loss to ecosystem because of two facts listed next.

- The period of observation is 60 years, and the area is about 15,000 km$^2$.
- Damage to surface water bodies pushes the region towards desertification. As indicated by the "land degradation cycle" (GHOSH [2]), such damages go-on multiplying themselves in cumulative manner.

## 11. CONCLUSIONS

Suitable statistical method could not be searched out to assess the significance of the data on loss of natural drainage length per year, but the damage appears to be serious. Further, the lowering of water level (bgl) per year in wells was observed to be strongly significant and it was concluded that the region has suffered serious depletion of water resource till 1994. The situation after that is being assessed.

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