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SUITABILITY OF GROUNDWATER FOR AGRICULTURAL PURPOSES IN MAHENDERGARH DISTRICT, HARYANA, INDIA: A HYDRO- CHEMICAL ANALYSIS

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ABSTRACT:

In the recent years, the increasing threat to groundwater quality due to human activities has become a matter of concern. A vast majority of groundwater quality problems today are caused by contamination and overexploitation of groundwater for irrigation and other purposes. Groundwater problem worldwide necessitate developing innovative method and efficient strategies to protect this vital resource. The situation becomes more critical in arid semi-arid regions of the world. The present study is a comparative assessment of evaluation of water quality in Mahendergarh district Haryana using multi-site groundwater quality data. Based on physic chemical analysis, irrigation quality parameters such as sodium absorption ratio (SAR), sodium, Residual sodium carbonate (RSC), permeability index (PI) were also calculated. All these parameters reveals that groundwater of the study area is not suitable for irrigation purpose in all parts of district.

KEYWORDS: *groundwater quality , evaluation of water quality.*

INTRODUCTION:

Groundwater has emerged as a key resource input in India's agriculture and food security in recent years. Over the past three decades it has become the main factor of growth in irrigated areas. At present tubewells accounts for over 60 percent irrigated area in the country. It is estimated that over 70 per cent of India's foodgrain production now comes from irrigated agriculture in which groundwater plays a dominant role (Gandhi and Bhamoriya 2011). Excessive pressure on groundwater resources has resulted in its overexploitation and deterioration of groundwater quality in many regions of country. As it is evident from the discussion in chapter 2 groundwater emerged as a dominant source of irrigation in Haryana by early 1990s. With the intensification of cropping and expansion of rice-wheat crop combination not only the depletion of groundwater started, excessive mining of water led to deterioration of groundwater quality. The excessive draft of groundwater in many parts of state the quality of groundwater resulted in alteration in its hydro-geochemistry. In fact the suitability of groundwater for irrigation depend upon the chemical constituents of soil as well as water. Excessive amount of ions in soil and water negatively affect the yield of crops. Excessive salts in irrigation water also increase osmotic pressure in soils and high amount of ions negatively affect growth as well metabolism of plants. There is also negative impact of excessive salt on the soil properties in term of composition, structure, permeability and aeration. So it is very relevant to know the status of groundwater quality for irrigation usages in Mahendergarh district in the state which continues to be over dependent on groundwater irrigation.

Objective

The objective of present study is:-

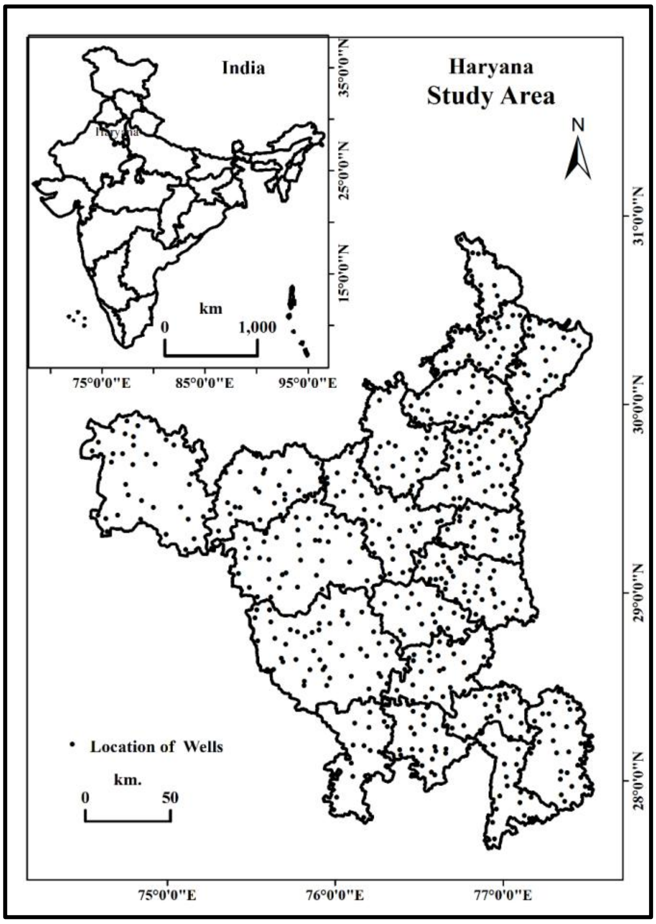
- To analyse the temporal changes in the groundwater quality for agricultural usage in the district.

Study Area

The state of Haryana in India is located between 27º39' to 30º56'N latitude and 74º 27' to 77°36'E longitudes, covering an area of 44,212 sq. km. It occupies about 1.40 percent of the total area of the country. At present, the state is divided into four commissionaires and 22 districts. The state has natural geographical boundaries of the Shiwalik hills in the north, the Yamuna River in the east and the Ghaggar River in the north. In the south Aravalli hills define the natural boundary which runs through southern Delhi and Gurgaon district. In the west of the state lies the Thar Desert of Rajasthan. The state is bounded by Uttar Pradesh and Delhi in the east, Punjab in the north, Himachal Pradesh in the northeast and Rajasthan in the south and west.

Mahendergarh district has been selected for present study. The district lies between 27° 50' to 28° 29' north latitude and 75° 57' to 76° 21' east longitude Fig. 1. It is bounded on the north by Bhiwani district, on the east by Rewari district and on the south-east, south, south-west and west by the state of Rajasthan.

Fig.1



DATA BASE AND METHODOLOGY

The present study is based on secondary sources of data collected for the years 1992, and 2015. The data about salts and chemicals dissolved in groundwater of observations wells have been collected from the Annual Reports of Central Groundwater Board, North-western Region, Chandigarh. Details are given below:

Source	Parameters	Data unit	Year
Groundwater Annual Year Book, Haryana, Central Groundwater Board, Northwestern Region, Chandigarh.	Ph, EC, TDS Cation, Anions etc.	Groundwater Observation Wells	1992 2015

The suitability of groundwater for irrigation purposes have been analyzed. Following indices have been utilized to assess the suitability of groundwater for irrigation purpose.

Electrical Conductivity (us/cm) (Salinity Hazards)

Sodium Absorption Ratio (Alkalinity Hazards) values were calculated for each observation wells across different regimes by the following equation suggested by Richard (1954):

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

Concentrations is expressed in meq/l.

Percent Sodium (Sodium Hazard) has been calculated using following formula suggested by Todd and Mays 2005:

$$\%Na= \frac{(Na+K)\times 100}{\sqrt{(Ca+Mg+Na+K)}}$$

All ionic concentration are expressed in meq/l.

Residual of Sodium Carbonate (Bicarbonate Hazards) has been calculated by following equation (Ragunath 1987)

$$[CO3^{2-} + HCO^{3-} - (Ca^{2+} + Mg^{2+})]$$

The concentration is expressed in meq/l.

Permeability Index (PI), as defined by Donean (1964) and Ragunath (1987), has been calculated by using equation:

$$PI= \frac{(NA+\sqrt{HCO3}}{\sqrt{(CA+Mg}+Na} \times 100$$

All ions are expressed in meq/l

Salinity and alkalinity hazards of groundwater have been depicted with the help of US Salinity Hazards Diagram. Wilcox diagram has been prepared to see the suitability of groundwater for irrigation purposes.

SUITABILITY OF GROUNDWATER FOR IRRIGATION

The suitability of groundwater for irrigation usages is a product of interaction of different ions of water. Some important parameters which is used to determine groundwater suitability for irrigation are:

1) Electrical Conductivity us/cm (Salinity Hazards)
2) Chloride Concentration
3) Residual of Sodium Carbonate (Bicarbonate Hazards)
4) Percent Sodium (Sodium Hazard)
5) Sodium Absorption Ratio
6) Permeability Index

ELECTRICAL CONDUCTIVITY (EC)

Electrical conductivity is a measure of capacity of water to pass electric current. Higher values of EC indicate the enrichment of groundwater with salt concentration. It is valuable measure of salinity hazards to crops as it reflects the total dissolved solids in water. Higher EC in groundwater negatively it affects the yield of crops. Literature also revealed that due to higher salt in water plants became incapable to fetch water from soils (Tank and Chandel 2009). It is apparent from Table 1 that in 1992, on an average 50 percent observation wells had permissible groundwater quality in terms of EC. Only 6 percent observation wells fell in the category of unsuitable groundwater for irrigation.

In 2015 EC values of groundwater decline on an average,11.11 percent observation wells recorded unsuitable water for irrigation which were only 5.56 percent in 1992. The analysis reveals that due to scarcity of groundwater district has experienced deterioration of groundwater quality in last two decades.

Chloride Concentration

Water has been classified into eight categories by (Stuyfzand 1989) on the basis of chloride ion concentration (Table 2). It is observed that in 1992 only 33.32 percent observation wells observed in fresh and very fresh category.

In comparison to 1992 in 2015 there is expansion of brackish salt and brackish type water.It reveals that there is deterioration of groundwater quality.

Residual Sodium Carbonate (RSC) Concentration

The concentration of carbonate in natural water is a function of dissolved CO_2, temperature, pH, cation and other dissolved salts. The excess amount of carbonate and bicarbonate in groundwater over the sum of calcium and magnesium also affect the suitability of groundwater for irrigation. Because due to high concentration of bicarbonate and carbonate there is tendency for calcium and magnesium to precipitate as water in soil becomes more concentrated. Higher concentration of these ions may be harmful for physical properties of soil. It also causes dissolution of agriculture matter in soil, which in turn leaves a black stain on soil surface on drying (Ravikumar et.al. 2011). The classification of groundwater on the basis of RSC is presented in Table 3.

In 1992 on an average 55.55 percent observation wells lied in good category while in one third wells fell in unsuitable water. The analysis reveals that RSC based unsuitability of groundwater has increased sharply in 2015. A huge proportion of observation wells (89.47 percent) had unsuitable water in terms of RSC.

Table: 1
Mahendergarh: Classifications of Groundwater Based on Electrical Conductivity (Wilcox 1955)

Range EC (µS/cm)	Classification	1992 LGAR	2015 LGAR
<250	Excellent	00(0.00)	0(0.00)
250-750	Good	0(0.00)	1(5.55)
750-2250	Permissible	9(50.00)	11(61.11)
2250-5000	Doubtful	8(44.44)	4(22.22)
>5000	Unsuitable	1(5.56)	2(11.11)
Total Observation Wells		**18**	**18**

Source: Compiled and computed from 'Groundwater Year Book of Haryana (1992 and 2015)', Central Groundwater Board, North Western Region, Chandigarh.
(Figures in Parentheses are percentage of wells to total Observation Wells)

Table: 2

Mahendergarh: Classifications of Groundwater Based on Chloride (Stuyfzand 1989)

Range (meq/l)	Classification	1992 LGAR	2015 LGAR
<0.14	Extremely fresh	0(00)	0(00)
0.14-0.85	Very Fresh	1(5.55)	1(5.55)
0.85-4.23	Fresh	5(27.77)	5(27.77)
4.23-8.46	Fresh brackish	2(11.11)	4(22.22)
8.46-28.21	Brackish	9(50.00)	4(22.22)
28.21-282.06	Brackish-salt	1(5.55)	4(22.22)
282.06-564.13	Salt	0(00)	0(00)
>564.13	Hyper saline	0(00)	0(00)
Total Observation Wells		**18**	**18**

Source: Compiled and computed from 'Groundwater Year Book of Haryana (1992 and 2015)', Central Groundwater Board, North Western Region, Chandigarh.
(Figures in Parentheses are percentage of wells in total Observation Wells

Sodium Concentration

The suitability of groundwater for irrigation depends upon mineralization of water. It affect the plant growth as well as soil properties. In general sodium is dominant ion among cations and is found in most of natural water. When the concentration of $Na^{+}$is high in water, it tends to be absorbed by clay particles and it displace the Ca^{2+} and Mg^{2+} ions. Due to displacement of Ca^{2+} and Mg^{2+} ions the soil permeability is get reduced. Less soil permeability may obliterate vertical soil drainage. Soil becomes hard due to restriction in air and water circulation during wet conditions (Saleh et al. 1999).

Table 4 shows that in 1992 there were about 50 percent observation wells in doubtful category. About 11 percentwells hadin good to excellent water quality. Over the period 1992 to 2015 concentration of sodium has increased.

In 2015 the situation appear very critical in the study area where a huge proportion of observation wells (83.33 percent) recorded high concentration of sodium and fell in doubtful category for agricultural usages.

The analysis reveals that sodium concentration is increase in the study area where tube well is only source of irrigation.

Wilcox (1948) has classified quality of groundwater by correlating percent sodium and electrical conductivity. A perusal of Wilcox diagram (Table 5) depicts that in 1992 maximum percentage of observation wells in unsuitable category 56 percent and about 22 percent observation wells had good to permissible water quality(Fig.2).

Table: 3

Mahendergarh: Groundwater Quality based on Residual of Sodium Carbonate (RSC) (Richard 1954)

Range (meq/l)	Classification	1992 LGAR	2015 LGAR
<1.25	Good	10(55.55)	1(5.26)
1.25-2.5	Doubtful	2(11.11)	1(5.26)
>2.5	Unsuitable	6(33.33)	16(89.47)
Total Observation Wells		**18**	**18**

Source: Compiled and computed from 'Groundwater Year Book of Haryana (1992 and 2015)', Central Groundwater Board, North Western Region, Chandigarh.
(Figures in Parentheses are percentage of wells in total Observation Wells)

Table: 4
Mahendergarh: Groundwater Quality based on percent Sodium (Wilcox 1955)

Range (Percent)	Classification	1992 LGAR	2015 LGAR
0-20	Excellent	1(5.56)	0(00)
20-40	Good	1(5.56)	1(5.56)
40-60	Permissible	7(38.89)	2(11.11)
60-80	Doubtful	9(50.00)	15(83.33)
Total Observation Wells		**18**	**18**

Source: Compiled and computed from 'Groundwater Year Book of Haryana (1992 and 2015)', Central Groundwater Board, North Western Region, Chandigarh.
(Figures in Parentheses are percentage of wells in total Observation Wells)
In 2015 on an average the proportion of unsuitable water is at same proportion what in 1992.

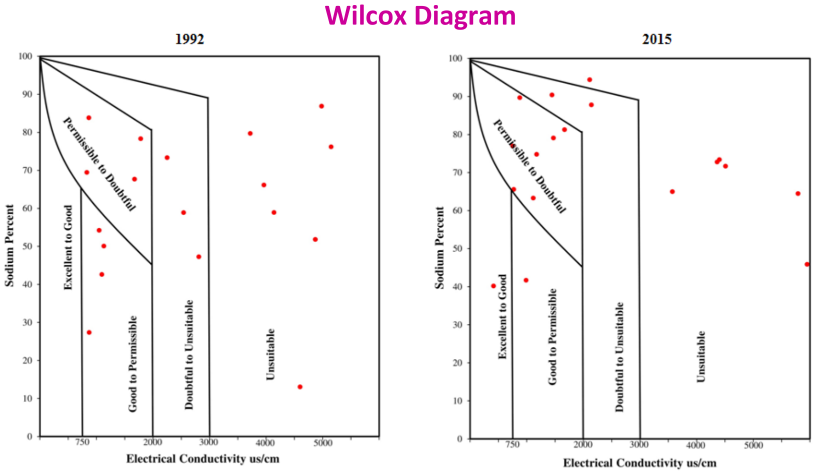
Sodium Absorption Ratio (SAR)

SAR is an important indicator for analyzing the suitability of groundwater for irrigation as it depicts sodium hazards to crops. $Na^{+}$is an ion which affects soil properties as well as permeability of soil. High concentration of this ion may be harmful for plants and soils (Kelly 1951 and Todd and Mays 2005). The concentration of this ion also determines cation exchange reaction in soils. Its property of replacing calcium and magnesium makes it a hazards for soil structure as well as permeability (Raju 2007).

Alkalinity of groundwater is measured on the basis of SAR value (Richard 1954) which is presented in table 6. It is observed that most of observation wells in 1992 and 2015 recorded excellent and good quality of water. However there is shift from excellent to good category in the study area over the period 1992 to 2015. In the study area some observation wells have recorded unsuitable water as well. It can be deduced from the preceding discussion that sodium concentration in groundwater is not a big hazard. However it may be a cause of concern in time to come in the study area with further over extraction of groundwater.

More detailed analysis with respect to SAR can be done with the help of USSL Diagram. This diagram is based on integrated effects of EC and SAR. In this diagram EC is taken as salinity hazard and SAR is taken as alkalinity hazards. US Salinity Diagram (Richard 1954) clearly classified water on the basis of plotting SAR and EC values. The type of C_1, C_2, C_3 and C_4 are classified on the basis of salinity hazard (Electrical Conductivity) and S_1, S_2,S_3 and S_4 classes of water based on alkalinity hazard (Fig. 3).

Fig.2
Mahendergarh
Wilcox Diagram



Source: Compiled and computed from 'Groundwater Year Book of Haryana (1992 and 2015)', Central Groundwater Board, North Western Region, Chandigarh.

Table: 5
Mahendergarh: Groundwater Quality based on Wilcox Diagram

Water Quality	1992 LGAR	2015 LGAR
Excellent to Good	0(0.00)	1(5.56)
Good to Permissible	4(22.22)	1(5.56)
Permissible to Doubtful	4(22.22)	7(38.89)
Doubtful to unsuitable	3(16.67)	2(11.11)
Unsuitable	7(38.89)	7(38.89)
Total Observation Wells	**18**	**18**

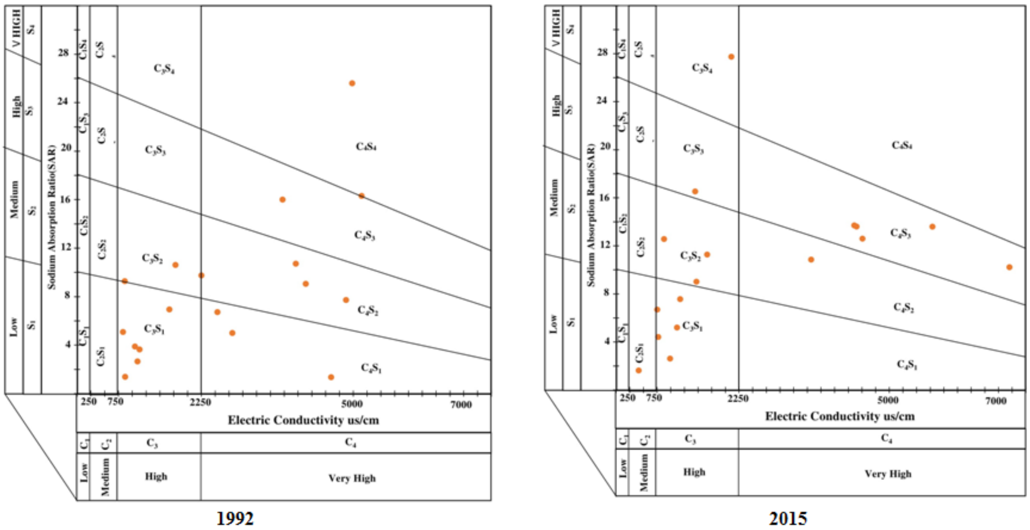
Source: Fig. 2 (Figures in Parentheses are percentage of wells to total Observation Wells)

Table 6
Mahendergarh: Groundwater Quality Based on Sodium Absorption Ratio (Richard 1954)

Range	Classification	1992 LGAR	2015 LGAR
<10	Low (excellent)	13(72.22)	1(5.55)
10-18	Medium(good)	4(22.22)	15(83.33)
18-26	High (doubtful/fair poor)	1(5.55)	0(00)
>26	Very High (Unsuitable)	0(00)	2(11.11)
Total Observation Wells		**18**	**18**

Source: Compiled and computed from 'Groundwater Year Book of Haryana (1992 and 2015)', Central Groundwater Board, North Western Region, Chandigarh.
(Figures in Parentheses are percentage of wells in total Observation Wells)

Fig. 3
Mahendergarh
US Salinity Diagram



Source: Compiled and computed from 'Groundwater Year Book of Haryana (1992 and 2015)', Central Groundwater Board, North Western Region, Chandigarh.

Table: 7

Mahendergarh: Salinity and Alkalinity Hazards in Irrigation Water in US Salinity Hazard Diagram

Classification	Type of Water	1992 LGAR	2015 LGAR
Good water			
C_2S_1	Medium EC, Low SAR	0(0.00)	1(5.56)
C_3S_1	High EC, Low SAR	7(38.89)	5(27.78)
Total		**7(38.89)**	**6(33.33)**
Unsuitable Water			
C_3S_2	High EC, Medium SAR	2(11.11)	3(16.67)
C_3S_3	High EC, High SAR	0(0.00)	1(5.56)
Total		**2(11.11)**	**4(22.22)**
Highly Unsuitable Water			
C_3S_4	High EC, Very High SAR	0(0.00)	1(5.56)
C_4S_1	Very High EC, Low SAR	3(16.67)	0(0.00
C_4S_2	Very High EC, Medium SAR	3(16.67)	1(5.56)
C_4S_3	Very High EC, High SAR	2(11.11)	6(33.33)
C_4S_4	Very High EC and SAR	1(5.56)	0(0.00)
Total		**9(50.00)**	**8(44.44)**
Total Observation Wells		**18**	**18**

Source: Fig. 3 (Figures in Parentheses are percentage of wells to total Observation Wells)

Table: 8

Mahendergarh: Groundwater Quality based on permeability Index (Ragunath 1987)

Range (Percent)	Classification	1992 LGAR	2015 LGAR
<25	Unsafe (Class 3)	0(0.00)	0(0.00)
25-75	Moderate (Class 2)	9(50.00)	6(33.33)
>75	Safe (Class 1)	9(50.00)	12(66.66)
Total Observation Wells		**18**	**18**

Source: Compiled and computed from 'Groundwater Year Book of Haryana (1992 and 2015)', Central Groundwater Board, North Western Region, Chandigarh.

(Figures in Parentheses are percentage of wells in total Observation Wells)

Groundwater observation wells were classified into three categories on the basis of integrated value of both EC and SAR.

1. Good Groundwater Quality for Irrigation

C_2S_1 (Medium EC, Low SAR)

C_3S_1 (High EC, Low SAR)

2. Unsuitable Groundwater Quality for Irrigation

C_3S_2 (High EC, Medium SAR)

C_3S_3 (High EC, High SAR)

3. Highly Unsuitable Groundwater Quality for Irrigation

C3S4 (High EC, Very High SAR)

C4S1 (Very High EC, Low SAR)

C4S2 (Very High EC, Medium SAR)

C4S3 (Very High EC, High SAR)

C4S4 (Very High EC and SAR)

It is evident from Table 7 that in 1992 groundwater unsuitability for irrigation is prevalent. Mostly percentage of observation wells (61 percent) wells not having suitable water for irrigation.

In 2015 on an average the proportion of unsuitable water was again highest in the study area (67 percent). It has increased about 6 percent points over the period 1992 to 2015. It may be deduced from preceding discussion that groundwater quality in the study area has deteriorated during last two decades.

PERMEABILITY INDEX

Permeability is the property of soil to transmit water and air through its different horizons or in horizon itself. It is determined by various factors including composition of soil, water properties and agricultural activities. Excessive irrigation affect soil permeability due to accumulation as well as exchange of various ions concentration in water as well as soil. Doneen (1964) and Ragunath (1987) evolved a criterion for analysing the suitability of water on the basis of permeability index. According to the index water is classified in to three categories where Class 1 and class 2 are categories with good water for irrigation with more than 25 percent permeability and class (III) water is unsuitable having 25 and less permeability index value. The permeability index values are given in Table 8. It is evident that the groundwater of all observation wells falls in Class 1 and Class 2 categories during both time periods. It suggests that groundwater in the study area is by and large suitable for irrigation in this regard.

CONCLUSIONS

Groundwater depletion and deterioration of its quality are the major environmental issues in tubewell irrigated area of the state. The intensification of cropping and expansion of water intensive crops have led to excessive mining of groundwater and deterioration of groundwater quality. The excessive draft of groundwater in many parts of state has altered hydro-geochemistry. The study brings out that in the district groundwater quality due to scarcity of groundwaterhas experienced deterioration during last two decades. Chloride concentration has increased in the district. The unsuitability of groundwater in terms of RSC has increased in the district which means that RSC has increased in purely tubewell irrigated areas. Overall, the proportion of observation wells with unsuitable water was highest in the study area (67 percent). Overall in last two decades water quality for agricultural usages has beendeteriorated. It is evident that groundwater quality in the state has particularly deteriorated in groundwater scarcity district, in the Mahendergarh.

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