Site Selection of Rain Water Harvesting Structures Using Remote Sensing and GIS Techniques for Diluting Fluoride Concentration in Groundwater

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Abstract— Water is a natural resource, basic ingredient of life, agriculture, industry and economic development of the country. Groundwater constitutes major source of drinking water and more in rural areas of our country. India is facing the major problem of drinking water due to quality mainly in the rural areas. Quality is major when compared to the quantity of water. Thus, provision of safe drinking water to the entire rural population assumes a primary and essential task. Among the groundwater quality parameters fluoride is the main constituent which affect the quality of groundwater which originates in subsurface aquifers in different rock types. Fluorite and apatite are the principal bearers of fluoride and are found in granite and granite gneiss. Fluoride had both advantages and disadvantages on the human body depending upon the limit of intake. Below the permissible limit is safe it is 1.5mg/l. Beyond this limit it causes dental and skeletal fluorosis. Dental fluorosis means the enamel part over the teeth get effected and depending on the intensity we can observe white patches on the teeth in starting stage then yellowish color marks appeared on the teeth then finally the teeth contains brown patches. Skeletal fluorosis means the bones get deformed and unable to walk properly. The present study aimed to identify the fluoride effected zones and areas to construct rain water harvesting structures like check dams, desilting of tank, percolation tanks, nala bands, recharge pit etc. for diluting the fluoride concentration in groundwater of Narketpally mandal, Nalgonda district, Telangana State, India. Fluoride analysis both from the surface and groundwater sources like open wells, bore wells, dug wells etc. was carried out to estimate fluoride levels and correlated with geology, geomorphology to identify the low and high fluoride groundwater zones. Various thematic maps such as Geology, Geomorphology, Soil, Slope, Land use and Land cover etc. were prepared using remote sensing data of high resolution. These layers along with geology, drainage and slope were integrated using GIS techniques to derive suitable water harvesting sites. The rain water harvesting structures are constructed on the upstream of the drinking water thus infiltration takes place more and also stores water these waters can be used for the agricultural purpose and also for other purposes depending up on the usage. These rain water harvesting structures not only dilute the fluoride level in groundwater but also increase the groundwater level. As the groundwater level increases the area under irrigation also increases.

Keywords: Ground Water Data, Fluoride Data

I. Introduction

Gathering of samples from 25 zones to cover total district. From 1990-1992 the water tests were gathered. The samples are examined for the fluoride and other water boundaries. Soil tests are also done. After determining all the tests, they confirmed that the high fluoride fixation is connected with all the factors like soil, topography, geology [1].

The intake of elevated fluoride has a significant impact on human health, especially immediate problems that are seen in children's teeth. The primary aim of the study was to identify the seasonal variation in fluoride concentration and associated health risks in the residents of the study region. To assess the fluoride contamination in groundwater, a total of 158 samples were analyzed in two seasons [2].

As drinking water is considered as a major pathway of exposure to fluoride in the human body, an endeavor has been made for the assessment of the non-carcinogenic health risk by using hazard quotient (HQ) of fluoride for males, females, and children separately in fluoride affected ground water areas. The study suggests that children groups are more prone to the non-carcinogenic risk of fluoride in the area as HQ for fluoride is more than unitary in 44% (Pre-monsoon) and 38% (Post-monsoon) samples respectively [3].

Groundwater is the biggest accessible wellspring of new water lying underneath the ground and comprises a significant hotspot for different purposes like household needs, flexibly for businesses and for horticulture and so on. Also, due to over abuse the accessibility of groundwater is decreasing steeply. Other than focusing on groundwater possible zones, it has now gotten pivotal to target revive zones for counterfeit energize so as to safe watchman the future [4].

The high availability of fluoride in surface and groundwater was documented during the colonial period. Since the early 1960s, many studies have been conducted to solve the fluorosis crisis in this region. At present, no cost-effective solution to mitigate fluoride contamination is available for the large majority of the population. This situation prompted a process analysis of commonly used technologies [5].

Availability of groundwater varies spatially and temporally depending upon the terrain. The scarcity of water affects the environmental and developmental activities of an area. Construction of small water harvesting structures across streams/watersheds is gaining momentum in recent years. In the present study, potential sites for construction of rainwater harvesting structures in India have been identified by using remote sensing and GIS techniques. Various thematic maps such as Land use/Land cover, geomorphology and lineaments, etc. were prepared using remote sensing. These layers along with geology and drainage were integrated using GIS techniques to derive suitable water harvesting sites [6].

To identify the low fluoride zones the thematic maps were used. Geography and geomorphology maps are prepared. Samples are gathered and tested in labs. Low fluoride zones are connected with geomorphology and topography. The observation is done in some places that low fluoride zones are created as the surface water infiltrates into the high fluoride water. Water gathering structures as percolation tank, check dams are proposed to construct on the upstream of the fluoride zone, it increases the groundwater and also decreases the fluoride in groundwater both ways it can be use [7].

High levels of fluoride (beyond 1.5 ppm) in ground water as source of drinking water are common in many parts of India. The study carried has indicated that the fluoride-rich ground water present in the wells located downstream and close to the surface water bodies is getting diluted by the low-fluoride surface water. Encouraged by this result, check dams were constructed upstream of the identified marginally high fluoride bearing ground water zones to reduce fluoride levels as an alternate solution for safe drinking water. An attempt is made to study the utility and effect of these check dams in dilution of fluoride concentration in drinking water and its resultant impact on the health aspects of certain villagers of Anantapur District through the analysis of their blood serum and urine [8].

In many regions around the globe, including India, degradation in the quality of groundwater is of great concern. The objective of this investigation is to determine the effect of recharge from a check dam on quality of groundwater, in India. For this study, water samples from 15 wells were periodically obtained and analysed for major ions and fluoride concentrations. The number of major ions present in groundwater was compared with the drinking water guideline values of the Bureau of Indian Standards. With respect to the sodium and fluoride concentrations, 38% of groundwater samples collected was not suitable for direct use as drinking water [9].

An attempt has been made to delineate different hydro geomorphological units in and around the immediate environs of an area with a view to attempt a correlation between the well yields and hydrogeomorphic units using satellite remote sensing technique. In general, a positive correlation is observed between the geomorphic units and the borewell yields with overlapping yields at the margin [10].

Remote sensing provides much of the information that is input to a GIS from global scale vegetation and climatic data to the ground water exploration. The two technologies provide complementary capabilities. Remote sensing analyses are improved by the verification data retrieved from the GIS, and application of GIS can greatly benefit from the information that remote sensing data contain. Often the image data are the most current spatial information available for an area. The use of digital image data offers the additional advantage of a computer compatible format that can be input directly to a GIS. The present study demonstrates that the integrated use of remote sensing and GIS methods in ground water exploration not only improves the quality of geographic information but also enable information previously unavailable to be economically produced. [11].

Excess intake of fluoride through drinking water causes fluorosis on human beings in many States of the country (India), including Andhra Pradesh. Groundwater quality has been studied, with reference to fluoride content, for its possible sources for implementing appropriate management measures, according to the controlling mechanism of fluoride concentration in the groundwater. The area occupied by the river basin is underlain, over which the Recent sediments occur. Results of the chemical data of the groundwater suggest that the considerable number of groundwater samples show fluoride content greater than that of the safe limit prescribed for drinking purpose. [12]

II. STUDY AREA

Narketpally Mandal is located in the GPS coordinates of latitude: 17°20'33.8"N to 17°19'23.7"N and longitude: 79°41'35.2"E to79°42'06.6"E.

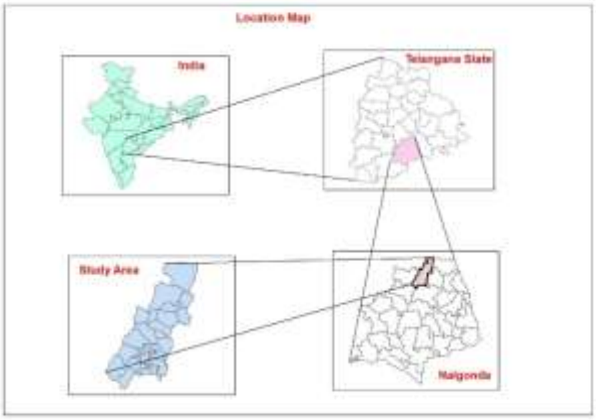


Fig. 1: Study Area

III. METHODOLOGY

The groundwater quality data collected for pre monsoon and post monsoon from different sources of Narketpally mandal and analyzed for water quality parameters. Village wise analysis of fluoride content in both surface water and groundwater sources were carried out. Thematic maps such as Geology, Geomorphology, Land use and Land cover, Slope and Soil were prepared. Fluoride values were correlated with Geology and Geomorphology. Based on the overlay of all the thematic layers, the feasibility areas are selected for the construction of check dams and other groundwater harvesting structures not only for diluting the fluoride concentration in groundwater and also increase the groundwater levels.

IV. ANALYSIS OF RAIN WATER HARVESTING STRUCTURES

A. General

The rain water harvesting structures are artificial recharge structures used to store and use the rain water. Check dams. Percolation tanks, Nala bunds, Recharge pit these are the some of the examples of the rain water harvesting structures depending up on the area different structures are used. Mainly these structures are constructed on the upstream of the drinking water source as the infiltration increases the fluoride level in the downstream decreases. Check dams are suggested in the first and second order streams. Desilting of tank are also used for the removal of the sediments from the tank or reservoirs the removed material consists of high nutrients if this material is used for agriculture a very good yield is obtained, due to presence of these sediments in the tank it causes problem to the infiltration thus removal of the sediments is the better process. Percolation tanks are suggested in first and third order streams. Nala bunds are suggested on the first and fourth order streams. Recharge pits are constructed around or near the habitations where streams are not available. If we decrease the run off flow of water and makes water to infiltrate into the soil it is very useful to increase the groundwater and also for diluting the fluoride concentration on groundwater.

B. Soil Distribution

Soil is a major component of land system which procures a medium for plant growth. The potentials and limitations of a soil for sustained use under agriculture, horticulture, Silvispaure and forestry as well as its response to irrigation and other management practices are controlled by its inherent qualities and characteristics. The quality of a soil is a function of its morphologic, morphometric, physical, and chemical characteristics. These characteristics are expressed in a taxonomic class as depicted on soil map with location reference. The soil map thus, helps to know the characteristics of the soils of the area and to understand their problems, potentialities and management needs for their optimal use within the scale limitations.

Narketpally mandal consists of (17) villages and soils of Narketpally have been divided into three types namely, Loamy to clayey skeletal deep reddish-brown soils, Moderately deep calcareous moist clayey soils and Deep black clayey soils. Every soil has its own attributes. Permeability and porosity are the two main aspects which are important for groundwater prospect. Clayey soils have less porosity, black soils have moderate porosity and red soils have very high porosity so infiltration is more. Loamy to clayey skeletal deep reddish-brown soil covers 70% of the area and Moderately deep calcareous moist clayey soil cover 23% of the area Deep black clayey soil covers 7% of the area. Most of the study area is covered by the red soil. The red soils have the larger capacity to absorb the water. The black soils have the less absorption capacity as they cannot absorb, they hold the water on the surface only. The spatial distribution of soils of the Narketpally mandal is depicted in figure3.

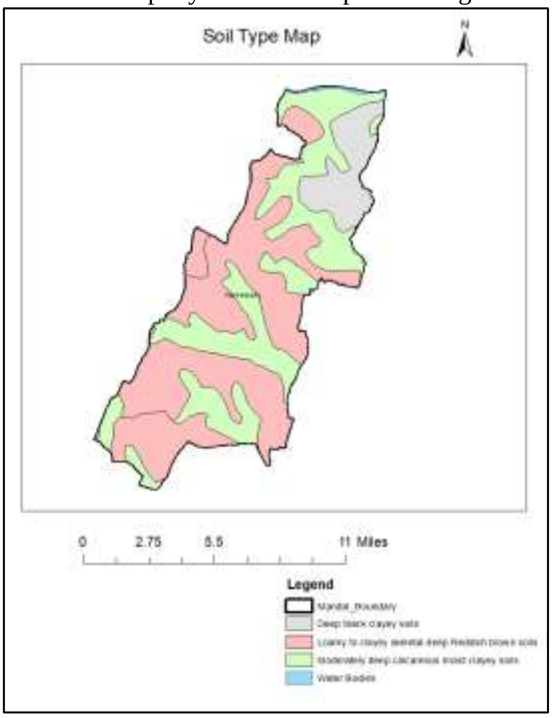


Fig. 3: Soil type map in Narketpally mandal

C. Land use / Land cover

The country's developmental activities are mainly based on the land utilization. The dependence of community/individuals on land for food, energy, shelter and many other needs for there, sustenance depends on the conservation and improvement of the utility of land. Land use information is critical for a variety of developmental activities especially for watershed development, wasteland development, urban planning, highway routing, village transportation network planning, tourism planning and management, facility planning and other developmental activities.

Information on the spatial spread and monitoring the dynamics of the land use /land cover is the basic prerequisite for planning and implementing various developmental activities. Apart from this national wide land use information becomes important from the point of view of addressing changing pattern in land use/land cover and also for overall reporting on the nation's land use/land cover scenario.

The Narketpally mandal contains the settlements, crop lands, waste lands, scrub, water bodies, mining, hills and it contains national highway 9 pasing through the study are and railway line is also present. The study area mostly consists of crop land, built up land, waste land. The present land use / land cover map of the Narketpally Mandal is depicted in Figure 4.

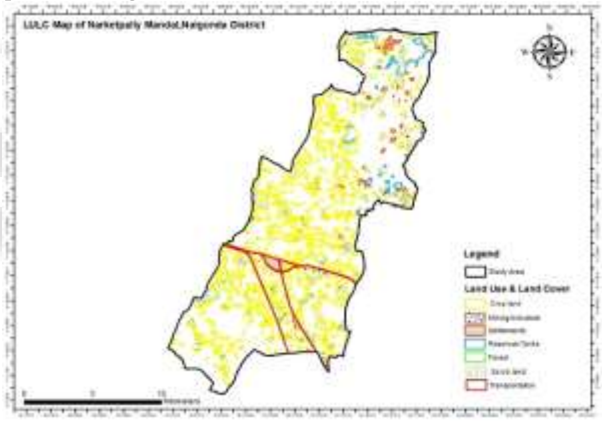


Fig. 4: Land Use/Land Cover map of Narketpally mandal

D. Drainage

Drainage map of the study area prepared from the SOI topo sheets and updated on the high-resolution satellite image of. The study area is consisting of dendritic pattern with the stream order ranging from 1st to 4th order.

The flow direction of streams and major streams from west to east because the western part in the study area occupies hills and elevated plains. The study area has steep slopes in the west and gradually the decrease slope towards east, gentle slopes in the east. So, the streams flow towards east direction. The drainage map shows the direction of the stream clearly.

Drainage network helps in delineation of watershed structures. The study area consists of Dendritic to sub dendritic and rectangular drainage, indicates homogenous rocks or soil. Drainage pattern reflects surface characteristics as well as subsurface formation & follows 4th order drainage pattern. The drainage map is given in Figure 5.

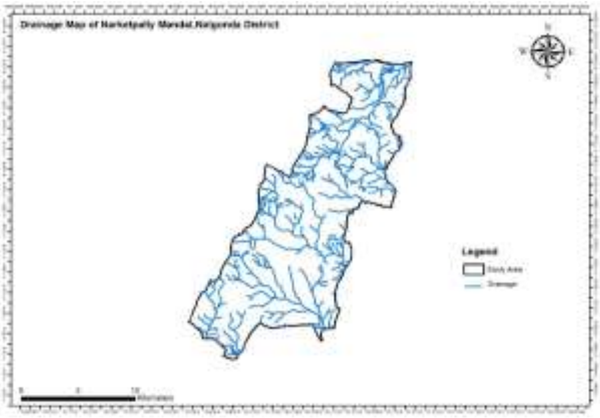


Fig. 5: Drainage map of Narketpally mandal

E. Slope Characteristics

Slope, aspect and altitude are important terrain parameters from land utilization point of view. Among the three, slope is very vital one for land irrigability and land capability assessment.

Slope is one of the most important terrain characteristics and plays vital role in groundwater potential, because it controls the runoff, soil erosion and land use planning. So, it is very important to know the spatial distribution of slopes for the development and planning of both land and water resources.

Fig. 6: contour map of Narketpally mandal

The closed contour lines indicate hills. Contour lines never intersects on another. For hills the middle value is very high and decreases at the bottom. For valleys the center value is low when compared to the bottom value. The study area mostly contains hills.

The study area contains nearly level slope, very gentle slope, gently sloping, moderately sloping, strongly sloping, moderately steep-to-steep sloping, very steep sloping. Mostly the study area occurs very gently sloping then nearly sloping followed by the gently sloping. These gently sloping observed at the hills very commonly. The following is the slope map of the study area Narketpally mandal.

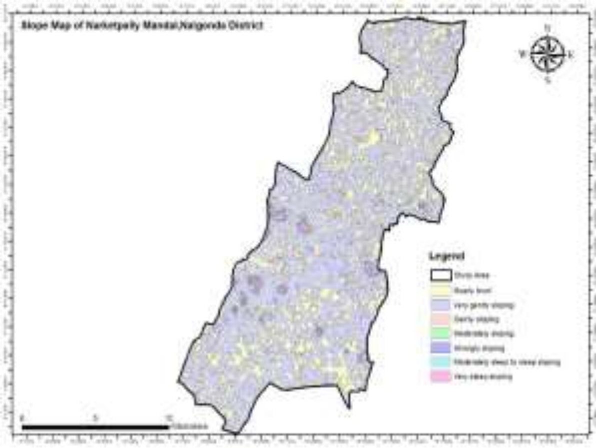


Fig. 7: Slope map of Narketpally mandal

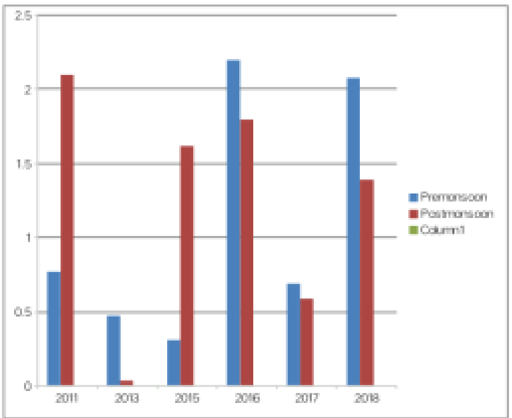
S.no	Slope Category	Slope (%)
1	Nearly level	0-1
2	Very gently sloping	1-3
3	Gently sloping	3-5
4	Moderately sloping	5-10
5	Strongly sloping	10-15
6	Moderately steep-to-steep sloping	15-35
7	Very steep sloping	>35

Table: 2 Slope gradient category

F. Fluoride data of Akkinepally Village from 2011 to 2018:

Akkinepally village is one of the village of the Narketpally mandal. The fluoride data is taken from the year 2011 to 2018. There is a change of fluoride level in both pre-monsoon and the post- monsoon it is shown in the below table.

-	Pre-monsoon	Post-monsoon
2011	0.77	2.1
2013	0.477	0.035
2015	0.31	1.62
2016	2.2	1.8
2017	0.689	0.59
2018	2.08	1.39



Graph 1: showing fluoride data of Akkinepally village from 2011 to 2018

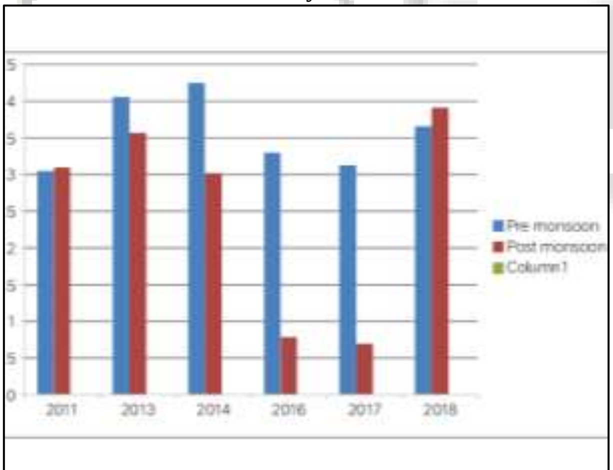
G. Fluoride data of Akkinepally Village from 2011 to 2018:

Akkinepally is one of the Village in Narketpally mandal. Fluoride data collected from the year between 2011 to 2018 i.e.,8 years. The graph shows that there is a fluctuation in the fluoride level. Some years have high fluoride value and some years have the low fluoride values. Blue color indicates the pre-monsoon data and the brown color indicate the post-monsoon. From the last three years data it is clearly observed that the fluoride level is high in pre-monsoon and decreased in the post-monsoon.

H. Fluoride data of Narketpally mandal from 2011 to 2018:

Year	Pre monsoon	Post monsoon
2011	3.05	3.1
2013	4.06	3.57
2014	4.25	3.02
2016	3.3	0.788
2017	3.13	0.699
2018	3.66	3.92

Narketpally mandal fluoride data collected from the year between 2011 to 2018 i.e.,8 years. The maximum fluoride value is observed in the pre-monsoon only. The fluoride value is decreased in the maximum years in post-monsoon season. It directly says that the fluoride value is decreased due to the rainfall effect. This shows that the infiltration of water is more, dilution of the fluoride takes plays. From 2013 to 2017 the decrease is observed clearly.



Graph 2: showing fluoride data of Narketpally mandal from 2011 to 2018

I. Ground water potential zones:

Ground water potential zones in Narketpally mandal are classified as very good, good, moderate, low and very low and 15.32% area is in very good condition, 28% area is in good condition, 30.71% area is moderate condition, 19.08% area is poor condition, 6.89% area is very poor condition for groundwater storage.

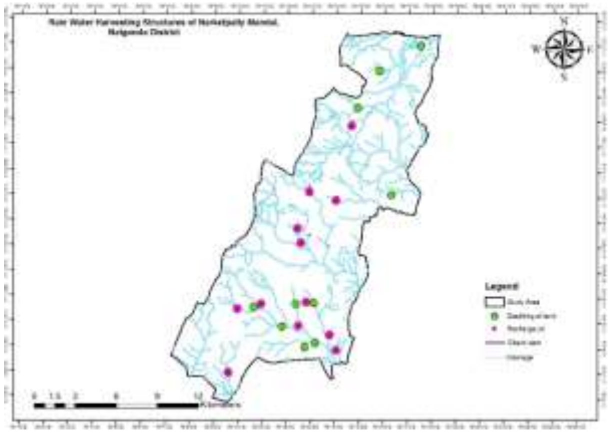


Fig. 8: shows the rain water harvesting structures of the study area.

The above figure shows the rain water harvesting structures of the Narketpally mandal Nalgonda district. Desilting of tank, recharge pits and check dams are present. Desilting of tanks are used to remove the sediments from the tanks. The removed sediments are used in agricultural lands for better yielding. As the sediments present in the tank, they cause problem to the water to infiltrate into the ground. Thus, removal plays major role in the infiltration and better dilution of fluoride is obtained. Recharge pits are constructed at near habitations where more surface area is not available. Check dams are constructed on the upstream of the drinking water at the first and second order streams the water not only used for dilution of fluoride but increases the groundwater level more irrigation area is obtained.

V. RESULTS & CONCLUSION

The study reveals that integration of five thematic maps such as drainage, slope, geology, soil and land use/land cover give first-hand information to local authorities and planners about the areas suitable for groundwater exploration. The given study area is classified in to excellent, good, moderate, poor and very poor groundwater potential zones. Area having slope 0º to 1º that means it is plain surface and cover with crop land is observed as excellent groundwater potential zone and covers area15.32Km2, the area having slope1ºto3º is observed as good ground water potential zone and covers an area of 28km2, the area having slope 3º to 5º observed as moderate ground water potential zone and covers area 30.71Km2, the area having slope 5º to 10º is observed as poor ground water potential zone and covers area 19.8Km2 and the area having slope 10º to 15º is observed as very poor groundwater potential zone and covers area 6.89Km2. This ground water potential information will be useful for effective identification of suitable locations for the construction of rain water harvesting structures to dilute the fluoride concentration and to increase the groundwater level.

In all the methods of artificial recharge structures the better and suitable process for Narketpally mandal is to construct check dams, recharge pits, desilting of tank and nala bands are suitable in the study area. Check dams are suitable to constructed on the first and second order streams along the foot hill zones and in the areas with 0 – 5% slope. Recharge pits are suitable where the surface area is not available and these are mostly constructed around the habitations, which is advantageous. Nala bands are suitable on the first and fourth order streams flowing through the plains and valleys having where acquisition of land for inundation of large areas is not possible. In this case, limited water will be stored in the river bed for some times which increases recharge.

Further, it is felt that the present methodology can be used as a guideline for further research.

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