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Analysis of Hydro-Geochemical Characteristics of Groundwater Quality Parameters in Hard Rocks of Mahesh River Basin, Akola and Buldhana Districts, Maharashtra, India Using Geo-Informatics Techniques

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Abstract

Water is the main source for domestic, engineering, industrial, agricultural and multipurpose uses which affects surface as well as groundwater quantity. The study area falls within the semiarid region and frequently facing water scarcity and quality problems. The present study generates the primary data to map the spatial variation of groundwater quality in hard rock terrain of Mahesh river basin through Geo-informatics technique. The suitability of groundwater quality of 35 wells located in the study areas was assessed for drinking purpose based on the various water quality parameters and the present study area 35 well samples collected from different parts of the study area during pre-monsoon period (June-2013) to assess its parameters such as Carbonate (CO^{3-}), Chloride (Cl^{-}), Sulphate (SO_4^{2-}), Potassium (K^{+}), Sodium (Na^{+}), and Bicarbonate (HCO_3) Standard methods for physicochemical analysis of groundwater samples were employed. Most of the samples analysed were above the Guidelines set by both national (BIS) and international (WHO, 2011) bodies for drinking water. Geographical Information System (GIS) capabilities are used to classify zones with acceptable groundwater quality for drinking purpose. LISS-IV satellite data through Visual interpretation techniques to evaluate the possible pollution of groundwater quality by rock-water interfaces, agro-chemicals and storage & movement of water. This study highlights the potentiality of Geo-informatics technique in preparation of more consistent and accurate baseline information predicting the groundwater quality in hard rock terrain of the study area, Assessment of groundwater samples from various parameters indicates that groundwater in most part of the study area is chemically unsuitable for drinking purpose.

Keywords

Groundwater Quality, Drinking Water, IDW Interpolation, GIS, Major Icons, GIS and GPS

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1. Introduction

Groundwater quality is mainly affected by the geological formations that the water passes through its course and by anthropogenic activities (Kelepertsis, 2000; Siegel 2002; Stamatis, 2010; Sullivan et al. 2005, Khadri and Kanak Moharir (2014). The hydro-geochemical study with GIS reveals the zones where the quality of water is suitable for drinking, agricultural and industrial purposes. Groundwater pollution occurs when used water is returned to the hydrological cycle. Intensive application of fertilizers, agrochemicals, sewage/drain water and mining activities on major lineaments are observed to be a serious threat to groundwater quality. As a result, the naturally existing dynamic equilibrium among the environmental segments get affected leading to the state of polluted rivers.

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Hence monitoring of surface water quality has become indispensable. On the Surface water quality depends on various parameters such as pH, Electrical Conductivity (EC), Total Dissolved Solids, Ca, Mg, Nitrate etc. A similar approach was adopted by Khadri et. al. (2013) where GIS was used to prepare layers of maps to locate promising well sites based on water quality and availability. Assessment of the water quality for drinking purpose involves the determination of the chemical composition of groundwater and the remedial measures for the restoration of the quality of water in case of its deterioration demand the identification of possible sources for the contamination of groundwater. This paper presents findings on the chemical composition of the groundwater and investigates the possible geogenic and anthropogenic sources for chemical solutes. Many researchers across the globe (Babiker et. al., 2007; Vennila et. al., 2008; Shomar et. al., 2010, Khadri and Chaitanya Pande (2015), Khadri and Kanak Moharir (2015) have carried out studies with spatial technologies and interpreted the quality of groundwater.

The present study attempts to the map the spatial variation of surface water quality parameters for Mahesh River Basin using Spatial Interpolation. GIS is an effective tool for water quality mapping and essential for monitoring the environmental change detection. The water samples were collected from 35 observations well randomly distributed in the study area. Considering the above aspects of groundwater contamination and use of GIS in groundwater quality mapping, the present study was undertaken to map the groundwater quality in Mahesh River Basin in the Akola district of Maharashtra, India. Geostatistical interpolation techniques (e.g. kriging) utilize the statistical properties of the measured points. In the present study is based on the analysis of ground water samples collected from different source like open well, tube well, hand pump and water supplied by Agriculture land and drinking purpose.

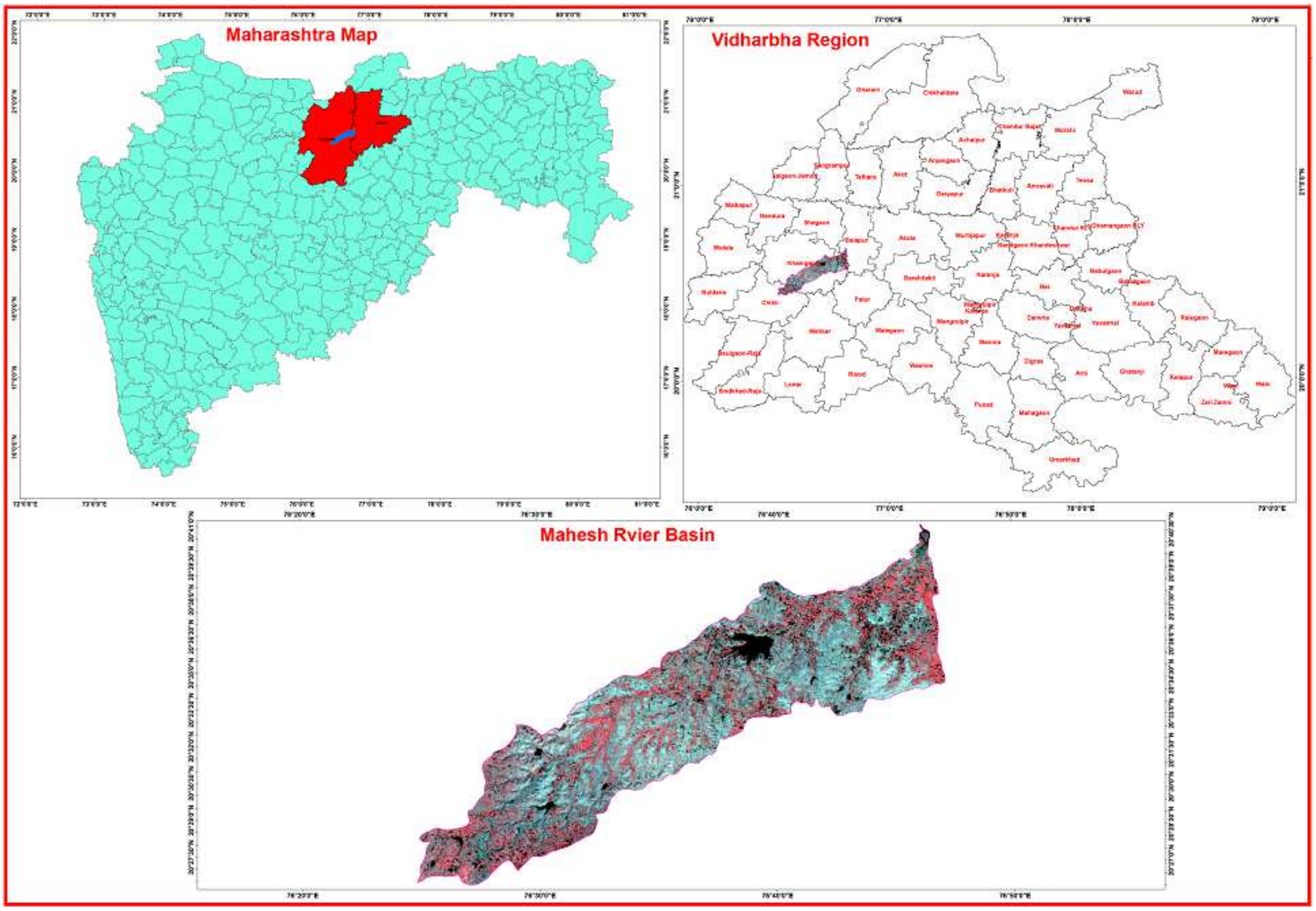

Fig. 1. Location Map of Mahesh River Basin.

2. Study Area

The Mahesh River basin is situated in Akola and Buldhana Districts of Maharashtra which is located between 76° 46'11"E and longitude 20°40′ 36" N latitude covered by survey of India toposheets no. 55 D/9, 55 D/7, 55D/11,55D/13,55D/14 and 55 D/15on 1:50,000 scale. It can be approached from Amravati by road transport which is about 120 Km. The Mahesh River basin which is a major tributary of Mun River lies towards the western and southern part of Akola and Buldhana district. The total area covered by Mahesh River Basin is 328.25 Sq. Kms. the study area is occupied by alluvium and Deccan basalts which are horizontally disposed and is traversed by well-developed sets of joints. The Ajanta hill ranges are bordering the district in the Southern with their slope towards Western. The starting part of Akola district is plain whereas the Western part is again elevated with its general slope towards Sothern. The Mahesh River Basin flows in the Southern to Western direction having western slope and meets the Mun River near Balapur village in Akola district. Purna is the major river of the Akola and Buldhana district. The important tributaries of Purna River are Katepurna, Morna, Man, Vidrupa, Shahanur, Van and Nirguna. Most of the watershed area was covered by unconsolidated sediments, black cotton soil, Red soils and basaltic rocks of Deccan Traps. The study area was drained by Mahesh River flowing south to western with almost dendritic to sub-dendritic drainage pattern.

3. Geology

Despite widespread acceptance of the impact hypothesis, the lack of a high-resolution eruption timeline for the Deccan basalts has prevented full assessment of their relationship to the mass extinction. However, recent research carried out by Blair Schoene et al. (2015) through Uranium - Lead (U-Pb) Zircon geochronology to Deccan rocks has showed that the main phase of Deccan eruptions initiated ~250,000 years before the Cretaceous-Paleogene boundary and that >1.1 million cubic kilometres of basalt erupted in ~750,000 years and their results are consistent with the hypothesis that the Deccan Traps contributed to the latest Cretaceous environmental change and biologic turnover that culminated in the marine and terrestrial mass extinctions. Chenet et al., (2009) have proposed that Deccan volcanism occurred in three rather short, discrete phases or mega pulses, an early one at _67.5 ± 1 Ma near the C30r/C30n transition and the two largest around 65 ± 1 Ma, one entirely within C29r just before the K-T boundary, the other shortly afterward spanning the C29r/C29n reversal. They also estimated sulfur dioxide (likely a major agent of environmental stress) amounts and fluxes released by SEEs: they would have ranged from 5 to 100 Gt and 0.1 to 1 Gt/a, respectively, over durations possibly as short as 100 years for each SEE. The chemical input of the Chicxulub impact would have been on the same order as that of a very large single pulse. The impact, therefore, appears as important but incremental, neither the sole nor main cause of the Cretaceous-Tertiary mass extinctions.

The northern part of the Mahesh River basin is characterized by presence of alluvial deposit and southern part is covered by Deccan trap, the alluvium deposit belongs to quaternary age and can be broadly divided into older and younger alluvium and it shows graded pattern, the older clay silt and coarse sand grading upward into fine sand silt and clay and unconformably overlies the basaltic lava flows, whereas the younger alluvium consists of fine sand silt and clay deposits with few lenses of pebble beds in between. The study area is characterized by the presence of nearly 200 to 250 m. thick horizontal basaltic lava flows showing Cretaceous to Eocene age with a mantle of recently formed soil. The lava flows can be grouped into massive basalt showing limited water resources. The vesicular and amygdaloidal basalt containing weathered and jointed horizon indicating potential aquifers. The thickness of flows varies from few feet to more than 30 meters, showing both simple and compound nature. Therefore 11 flows identified of the Mahesh River Basin. The vesicles are normally filled with secondary minerals like Zeolite, Quartz and Calcite. In general the lava flows do not extend laterally for long distances whereas vertically it shows wavy boundaries indicating pinching and swelling nature with an amygdaloidal horizon often merging into massive basalt. The water table decline in the sub-basin is ranges from 7m to 13m bgl.

4. Methods and Materials

Survey of India topographic maps, geology map published by GSI groundwater quality data and World Health Organization (WHO-2011) water quality standards were utilized in the present study. The ArcGIS 10.1 software is used for data generation and spatial integration. Sampling was carried out during pre-monsoon season for the year 2013. The GARMIN GPS was used to locate the exact coordinates of the sample collection to continuous monitoring purposes. A total of thirty five water samples were collected from the observation wells throughout the study area (Fig.1).

Inverse distance weighted (IDW) raster interpolation technique of spatial analyst module in ArcGIS software has been used for the present study to delineate the locational distribution of various water samples. The different locations of the sampling stations were imported into GIS software through point layer. Each sample point was assigned by a unique code and stored in the point attribute table. The data base file contains values of all chemical parameters in separate columns along with a sample code for each sampling station. The geodatabase was used to generate the spatial distribution maps of selected water quality parameters Na, K, HCO_3, Cl and SO_4, were analyzed for WQI. The statistical analysis of various quality parameters are given in Table 1.

Table 1. Physical and Chemical Parameters of Groundwater Samples show in Mahesh River Basin.

Sample No.	Cl mg/I	CO_3 mg/I	HCO_3 mg/I	SO_4 mg/I	Na mg/I	k mg/I
1	1.58	0.31	2.49	1.08	1.04	0.31
2	2.82	0.05	4.25	1.33	2.44	0.31
3	10.04	0.08	2.61	0.5	1	0.13
4	6.91	0.31	1.03	1	0.65	0.56
5	23.84	0.08	7.38	1.73	2.13	2.25
6	2.12	0	5.26	0.67	1.52	1.15
7	1.27	0.31	2.11	1.56	3.35	1.07
8	4.29	0.82	4.95	0.54	2.09	1.15
9	12.81	0.13	2.03	0.94	0.65	0.36
10	19.78	0.56	2.61	0.5	1.78	1.15
11	12.92	0	7.52	2.94	3.39	0.36
12	13.71	0.69	8.39	4.37	2.96	0.31
13	13.48	0	1.54	1.73	0.91	1.23
14	7.56	0.26	1.8	2.31	3.09	0.31
15	12.95	0.13	7.52	4.16	1.78	0.36
16	1.27	0.31	1.8	4.37	3.39	1.23
17	16.05	0	5.26	4.16	1.96	0.77
18	15.12	0.43	1.8	4.64	1.22	1.15
19	21.33	0.31	1.8	2.75	1.04	1.48
20	12.92	0	1.8	4.16	1.96	2.15
21	16.02	0.28	1.1	4.16	1.35	1.15
22	12.55	0	1.8	1.08	0.65	0.64
23	3.53	0.05	10.78	1.48	1.31	0.36
24	9.93	0	2.49	2.73	3.09	0.31
25	5.98	0.2	1.8	4.16	1.44	0.43
26	12.92	0.31	5.16	1.56	0.65	0.31
27	18.2	0	2.03	4.64	1.78	0.38
28	12.78	0.28	1.8	2.69	3.52	0.31
29	5.28	0.38	8.39	0.5	0.91	0.43
30	12.16	0	2.61	1.48	3.39	0.31
31	3.55	0.28	4.95	1.33	1.96	0.72
32	12.72	0.26	5.16	1.08	3.39	0.31
33	5.95	0.28	4.25	2.73	0.91	0.31
	9.82	0.33	1.54	2.77	1.22	0.31
	10.13	0	2.05	1.56	1.04	0.64

5. Chemical Parameters

In natural water dissolved solids consist mainly of inorganic salts such as carbonates, bicarbonate, chlorides, sulphates, phosphate, and nitrates of calcium, magnesium, sodium, potassium, iron etc. and small amount of organic matter and dissolved gases constituent measured by chemical analysis of water.

6. Spatial Distribution Pattern

The spatial distribution pattern of Calcium, Chloride**,** Magnesium, Sodium, Potassium and Sulphate during the study period is shown in Fig. 2 to 8.

7. Calcium (Ca)

It is one of the alkaline earth metals and widely distributed in earth crust and all way abundant present as a cation in ground water. In the presence of CO_2, Calcium bicarbonates can normally be dissolved up to 20 ppm at atmospheric pressure and up to 100 ppm at higher pressure. The concentration may higher in water coming from limestone zone. This spatial pattern clearly indicates that large values of calcium were observed in the Central region of Kherdi and Palsi Bk. Villages and Lower value were observed in the east and west region of Balapur and Undri Villages. The values of calcium in water sample of study area are equalized by chemical analysis. The observation pre 2013 of the Ca value in Mahesh river basin ranges between 1.9 to 6.24 Pre-monsoon 2013.

8. Chloride (Cl)

Chloride also occurs in bedrock cementing material, connate fluid inclusions and as crystals deposited during or after deposition of sediment. Chlorides in groundwater are originated from various sources including the dissolution of halite & related minerals, marine water entrapped in sediments and anthropogenic sources. Although chloride is often an important dissolved constituent in groundwater contamination from sewage and various types of industrial wastes by Hem (1985). Chloride is a widely distributed element in all types of rocks in one or the other form and its affinity towards sodium is high. In case of high temperature and reduced rainfall conditions the chloride concentration is found to be high. Soil porosity and permeability also shows their key role in building up chlorides concentration. Chloride is the member of halogen group of element and present in all natural water at greatly varying concentration depend on the geochemical condition. Chloride containing natural water can be attributed to leaching of chloride consisting roach and soil, discharge of effluents from chemical industries these surface may result in local contamination of both surface and ground water when chlorides concentration of 250 mg/lit is present along with sodium ions, a salty taste can be observed. In this present study higher chloride were observed Atali, Ambikapur, Wairagad and Vihigaon villages, while lower values were observed Umra Lasura, Nirod and Pimpri villages. The salty taste may be absent in water in absence of sodium ion even concentration of chlorides is high as 1000 mg/lit. The observation of the Cl value in study area ranges between 1.27 to 23.84 for 2013 pre monsoon in Fig.2. Chloride in drinking water originates from natural sources, sewage, industrial effluents, and urban runoff containing saline intrusion by WHO (2004).

9. Magnesium (Mg)

Magnesium and calcium are the two elements mainly responsible for hardness water. Olivine, biotite, hornblende, serpentine is the some major magnesium bearing minerals. The presence of carbon dioxide influences the solubility of magnesium. The desirable limit of magnesium in natural water is 30 mg/Lit (ISI.1983). The observation of the Mg value in study area ranges between 2.93 to 8.06 for Pre-monsoon Magnesium distribution map (Fig. 4) indicates the high Magnesium distribution towards the North-central part and lower value observed towards southern, north and west part of the study area.

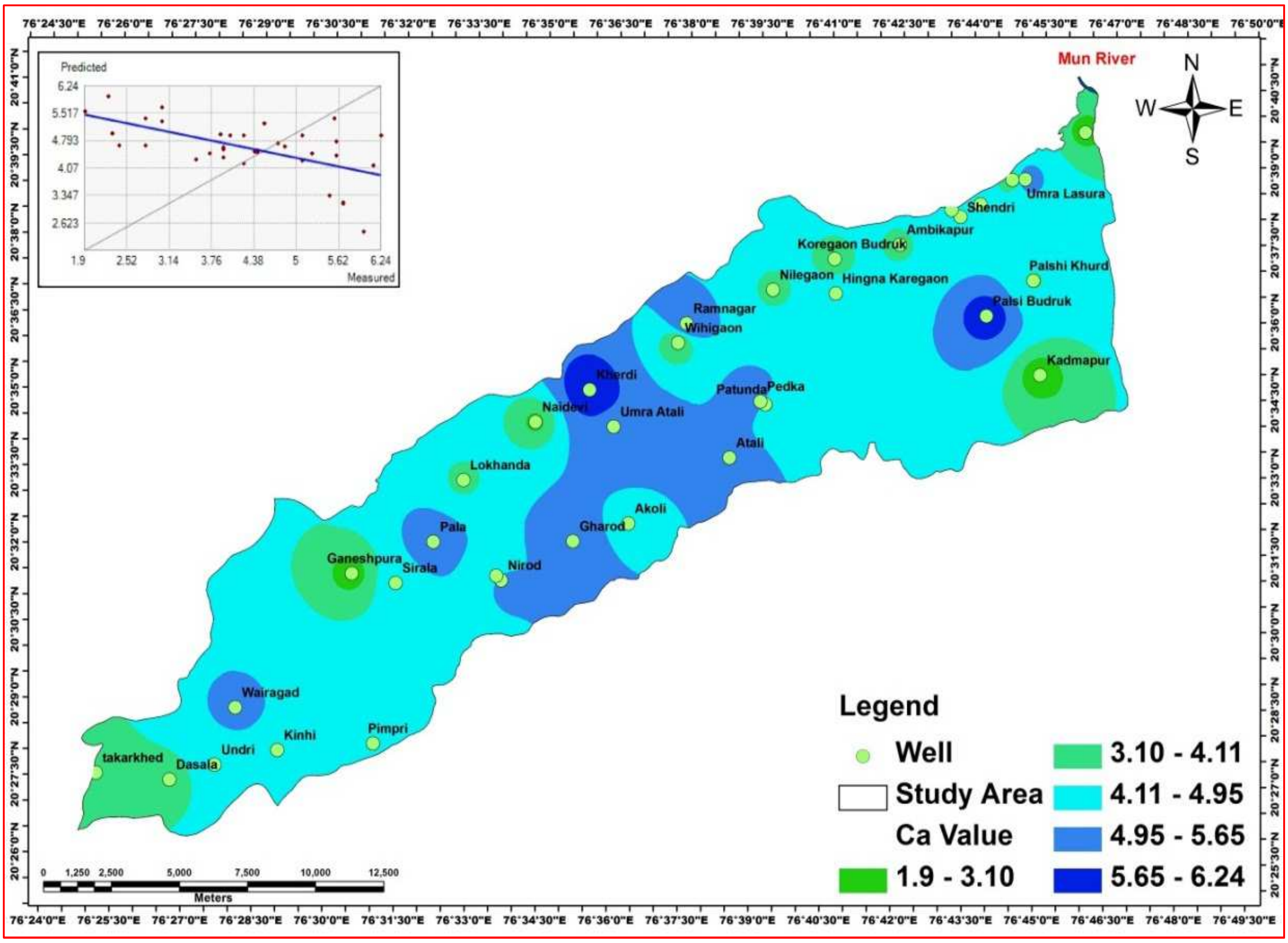

Fig. 2. Spatial Distribution Map of Ca Pre-Monsoon 2013.

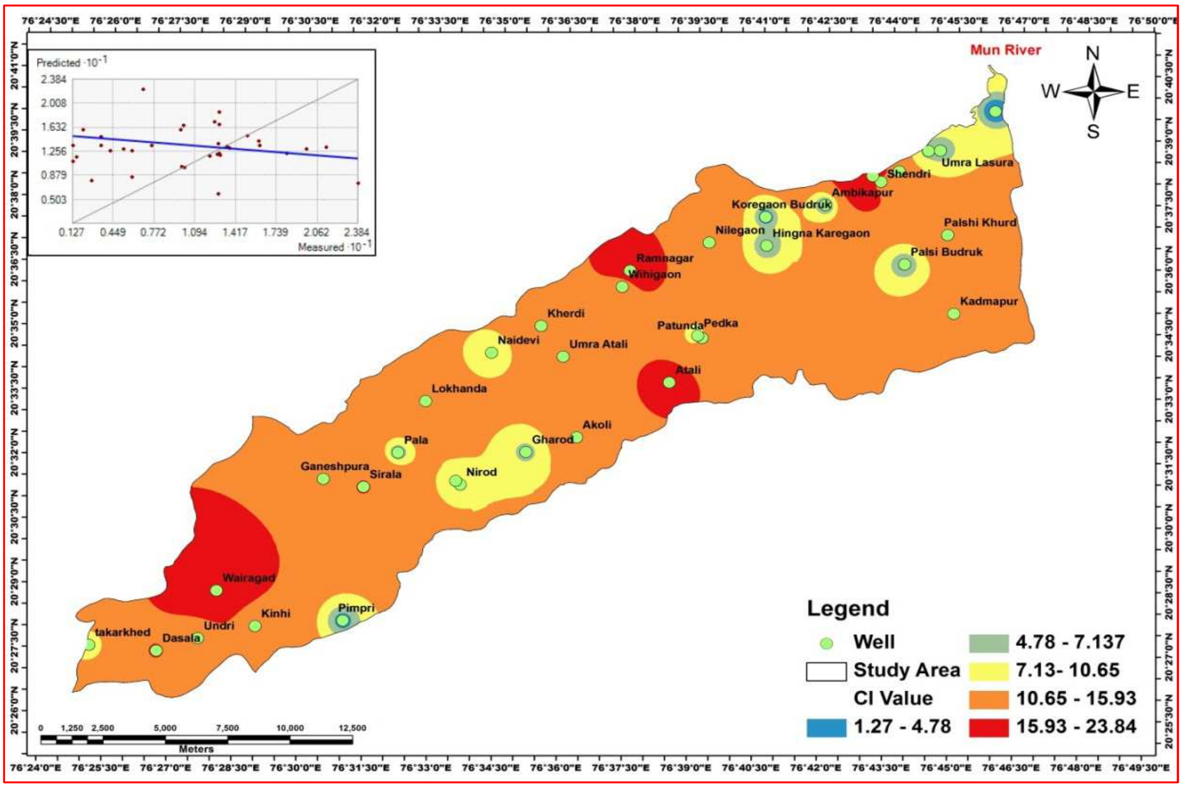

Fig. 3. Spatial Distribution Map of Cl Pre-Monsoon 2013.

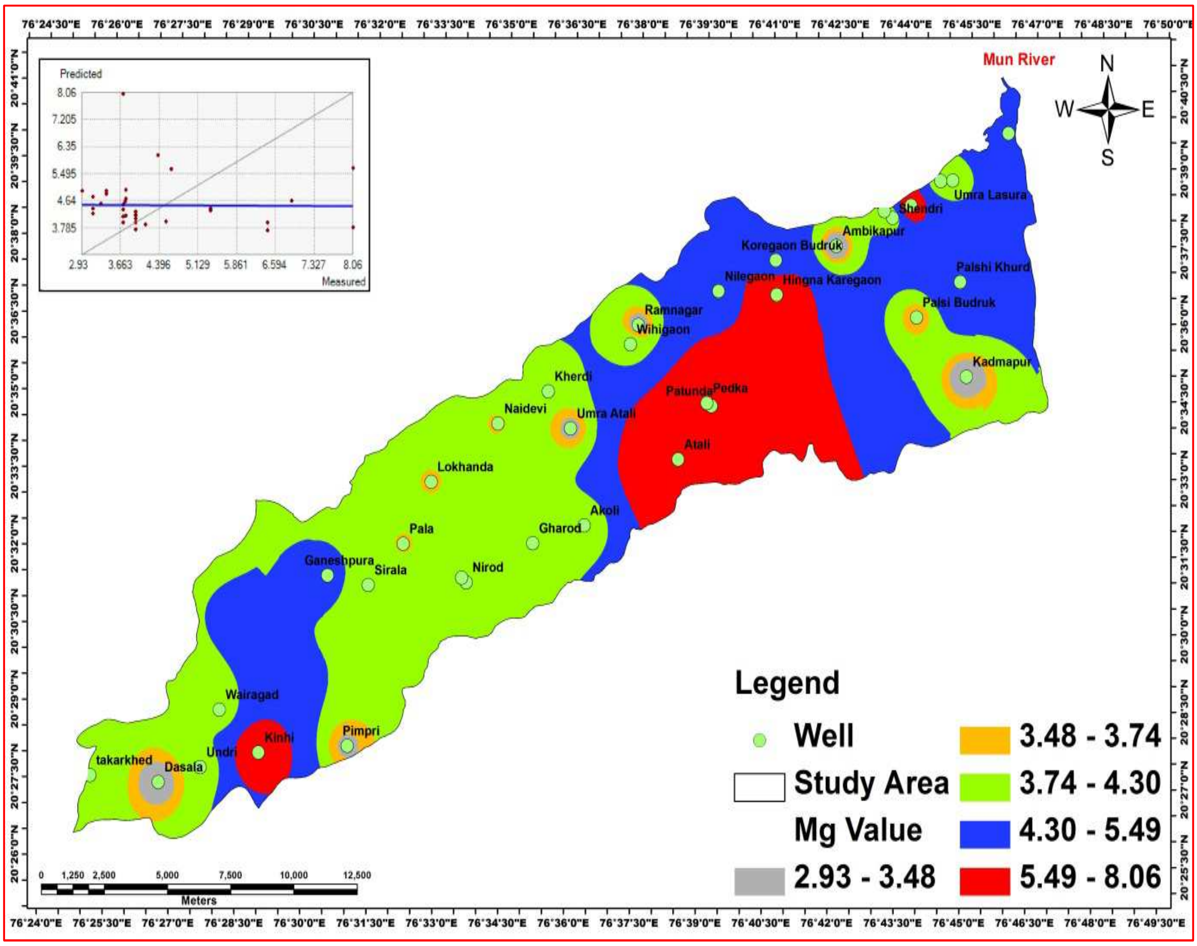

Fig. 4. Spatial Distribution Map of Mg Pre-Monsoon 2013.

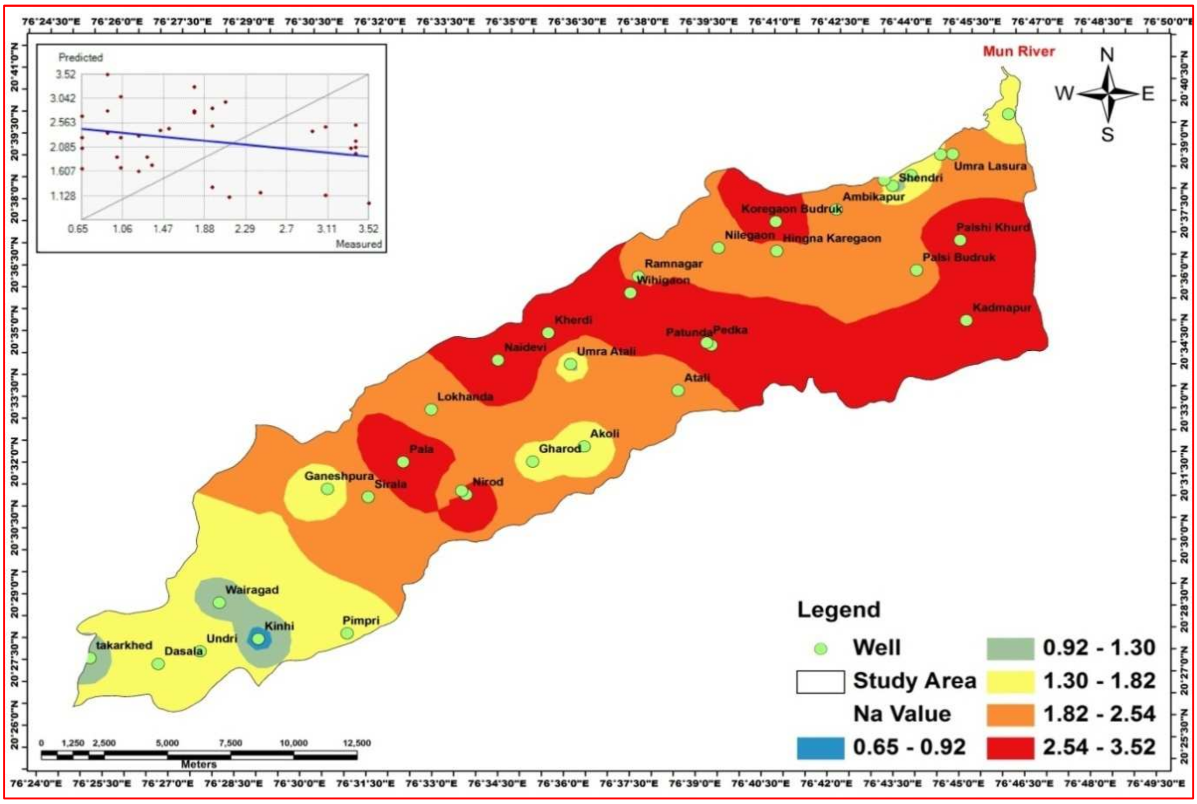

Fig. 5. Spatial Distribution Map of Na Pre-Monsoon 2013.

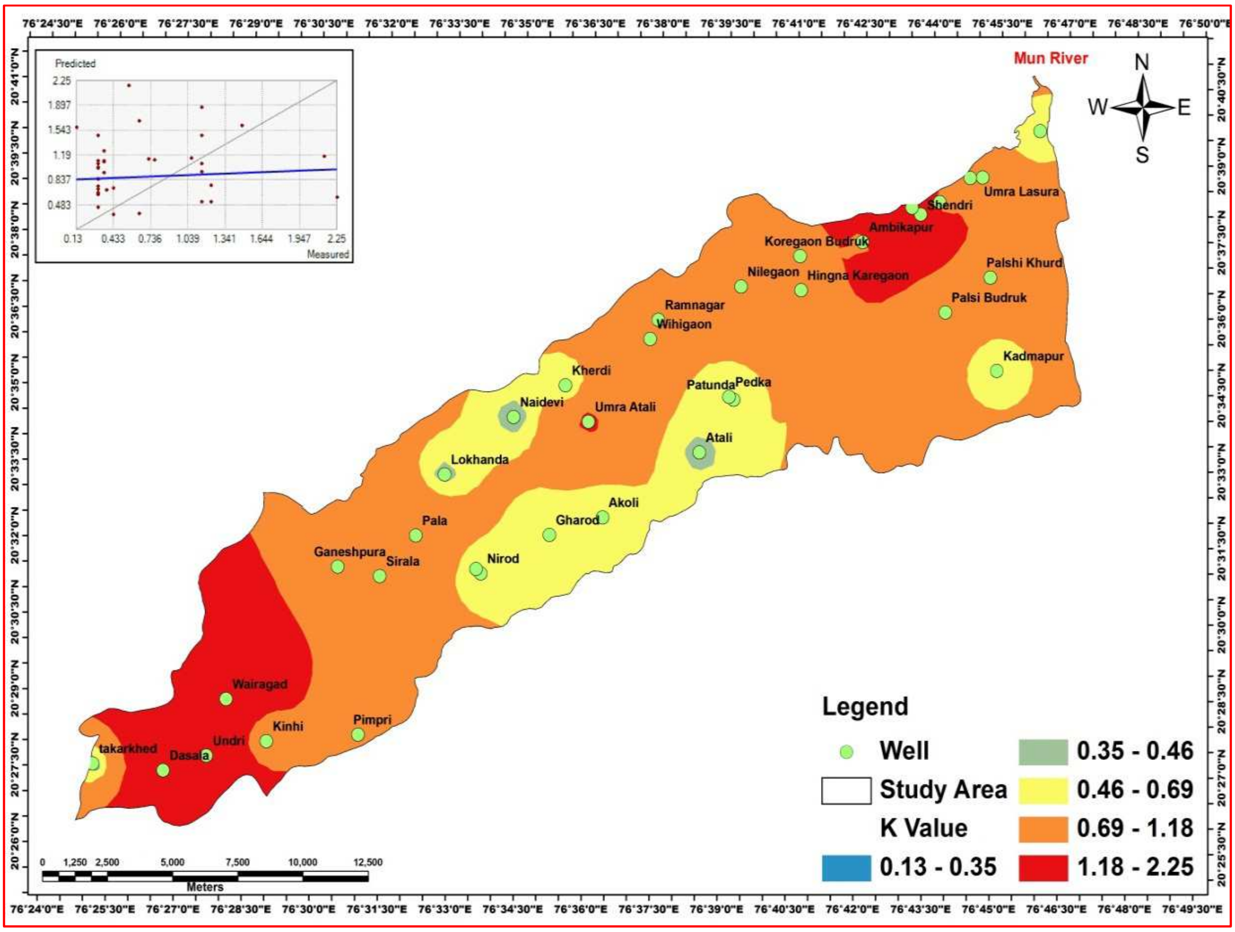

Fig. 6. Spatial Distribution Map of K Pre-Monsoon 2013.

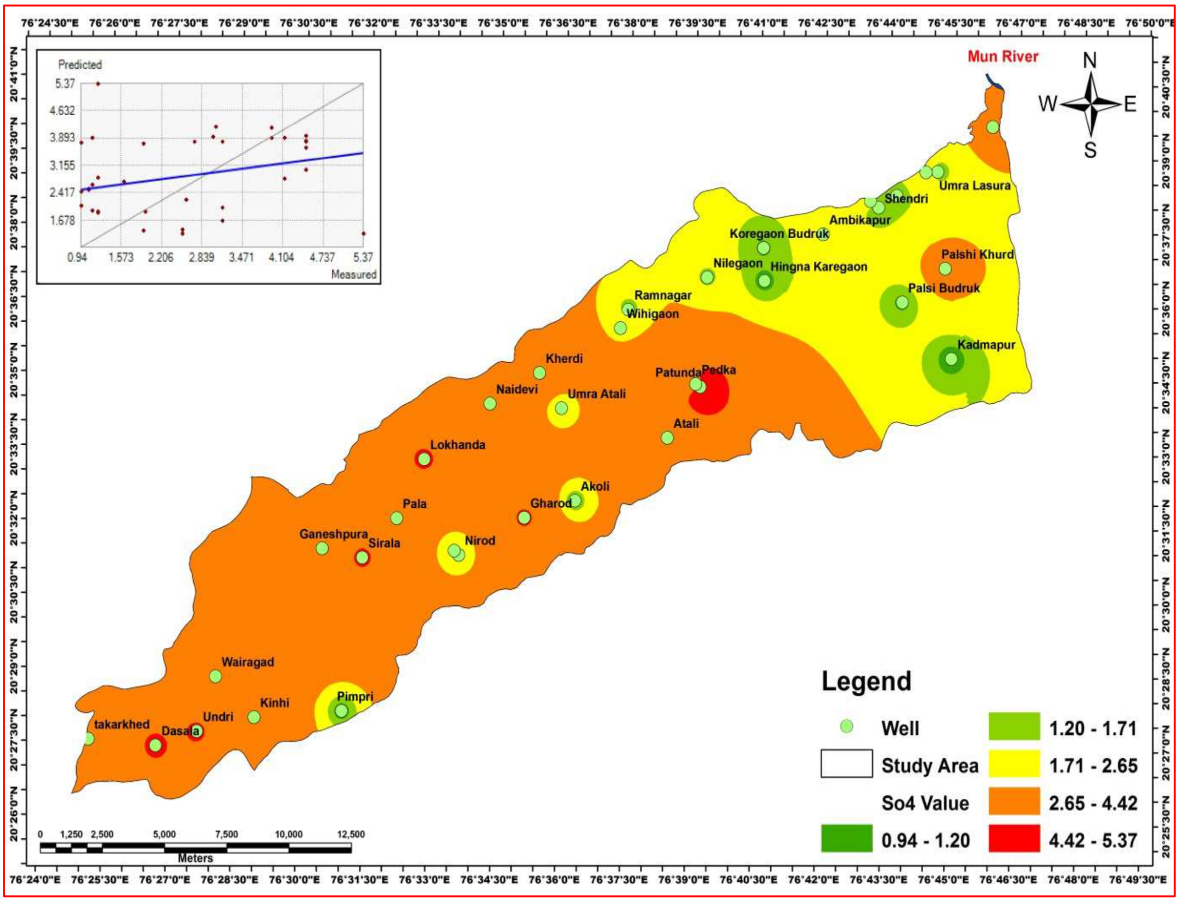

Fig. 7. Spatial Distribution Map of So4 Pre-Monsoon 2013.

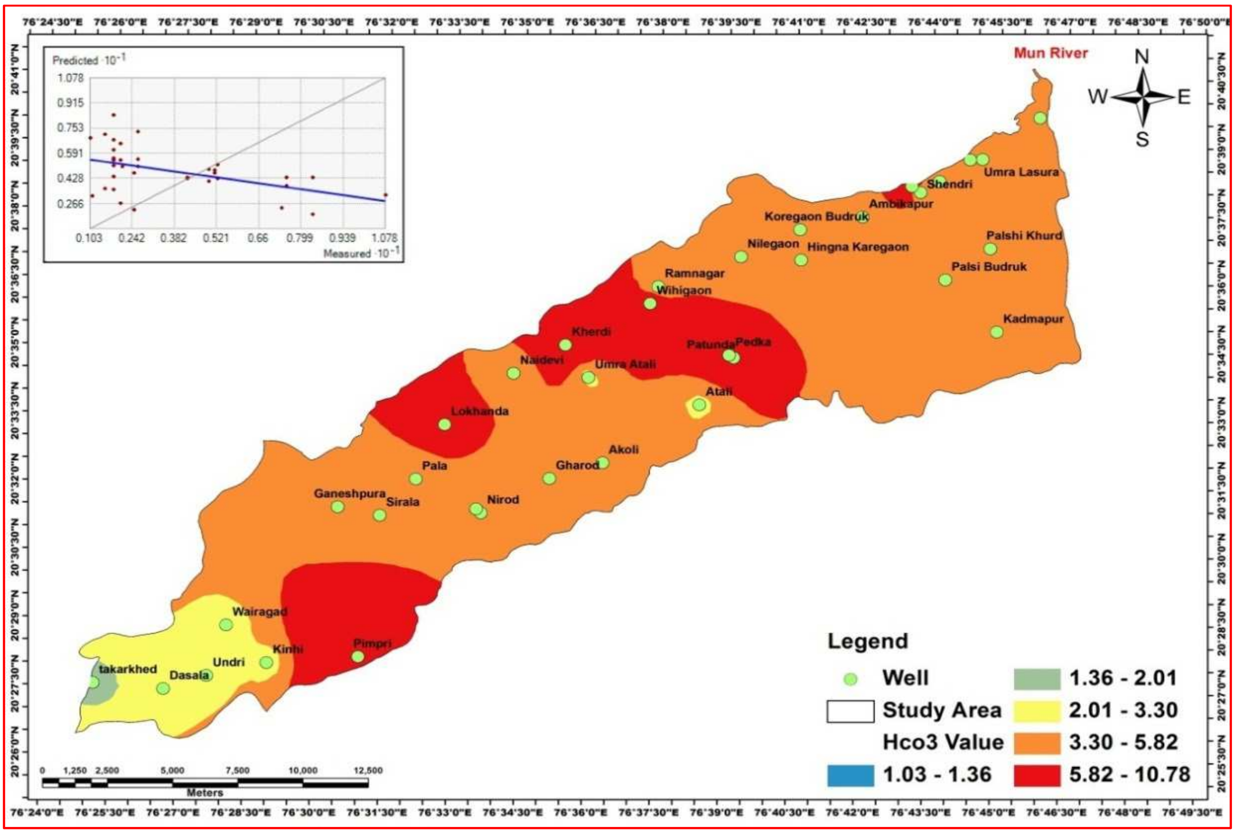

Fig. 8. Spatial Distribution Map of Hco3 Pre-Monsoon 2013.

10. Sodium (Na)

Groundwater for irrigational needs could be gauged by the salinity- Sodium hazards. A significant relationship has been identified between values of sodium in irrigation water and extent to which sodium is absorbed by the soils. High salt concentration in water leads to the formation of saline soil, while high sodium leads to development of an alkaline soil. If the proportion of sodium is high, then the alkali hazard will be high. Sodium is released in ground water due to weathering of plagioclase feldspar, clay mineral and amphiboles. The observation of the Na value in study area ranges between 0.65 to 3.52 for Pre-monsoon 2013. Sodium distribution map indicates the high Sodium distribution towards the South-Central part and lower value observed towards West-East part of the study area (Fig. 5).

11. Potassium (K)

Potassium in many respects is similar to sodium. In ground water, potassium is released due to weathering of igneous rocks rich in orthoclase, microcline and biotite etc. The observation of the Potassium value in study area ranges between 0.13 to 2.25 for Pre-monsoon 2013 respectively. Potassium distribution map (Fig. 6) indicates the high potassium K distribution towards the north and western part and lower value observed towards the central and southern part of the study area.

12. Sulphates (SO_4)

Sulphates occur in natural water at concentration up to 50 mg/l concentration. If 1000 mg/Lit can be found in water having contact with certain geological formation, Rain water has quite high concentration of sulphate particularly on area with high atmospheric, pollution in humid region, sulphate is ready leached from the zone of weathering by infiltrating water and surface run off. The observation of the SO_4 value in study area ranges between 0.94 to 5.37 for Pre-monsoon 2013. Sulphate distribution map (Fig. 7) indicates the high SO_4 distribution towards the eastern-central part and lower value observed towards north part of the study area. The semiarid and arid region, the sulphate are mostly accumulated in the top horizon of soil by physics-chemical reaction with soil colloids. The leaching of sulphate in to the shallow ground water is very high and often exceeds more than 500 mg/l.

13. Bicarbonate (HCO_3)

The minimum concentration of HCO_3 in the study area measured to be 1.03meq/1 so that the ground water of the study area in grouped as "Super carbonated water". The carbonate and bicarbonates are found to be higher in the central part as well as, north central part of the basin. While lower values of carbonate and bicarbonates are reported in lower central part of basin. In this present study area HCO_3 value ranges between 1.03-10.78. The distribution of sodium is high in northern part, moderate in north and some places of western part the lower sodium is observed in western part of Undri village in Fig.8.

14. Conclusion

In this research, physical and chemical analyses of the ground water samples collected from the Mahesh River Basin Akola and Buldhana district in Maharashtra have been studied to investigate to hydrochemistry of the basin in order to explain the impact of alluvial of incursion on the groundwater characteristics. Thus the use of ground in some areas which are very close to the Purna River Basin. Spatial distribution of ground water parameters were carried out through IWD interpolation methods shows that the quality of ground water based on Cl, $Co_{3,}$ $HCO_{3,}$ SO_4 etc. parameters. These methods have successfully identified in ground water quality mapping of Mahesh River Basin. There are several remedial measures including freshwater injection, soil and water conservation techniques used and extraction of saline water and Fresh water available for drinking and agriculture purpose, increase of the upland recharge areas. So it is essential to the planning and implementation of a long term program for the monitoring and improvement of groundwater quality. The spatial and time variant changes of groundwater quality are assessed through graphical representations. The predominance of chloride ion in certain areas reflects greater residence time of groundwater. The present study reveals that the influence of geological (geogenic) conditions is found to be more than the anthropogenic activities and supports the increasing concentration of physico-chemical characteristics in groundwater. The factors like slow circulation, longer period of contact between aquifer and water, dissolving of minerals at the time of weathering, residential time, drainage pattern and surface water link are the main factors are responsible for the vary in chemical concentrations of groundwater. Porosity of the soil and rock also alters the characteristics of the groundwater. Recharge process of rainfall water dilutes the constituents of the groundwater, but also raises the groundwater level that depletes due to large-scale exploitation. The toxic effluents from different sources are being contaminating the soil and leaching into the groundwater through seepage areas (lineaments). The chemistry of groundwater existing in hard rock terrain is mainly controlled by the rock-water interaction mechanisms. The total dissolved solids are expected to increase along the length of the flow path and also the time of residence. Groundwater is a major environmental parameter; its quality degradation is an issue of significant societal and environmental concern.

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