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Water Quality Appraisal of Hasdeo River at Korba in Chhattisgarh, India

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Abstract: ***Continuous discharge of the organic pollutants from different industry into the environment has resulted in building up their high levels in various aquatic systems. River Hasdeo is largest tributary of Mahanadi, serves as the major source of municipal water supplies for domestic, irrigation and industrial purposes for korba town. Samples of water at four locations from the river were collected and analyzed for 20 physicochemical parameters and 8 heavy metals concentration. Throughout the study manganese and lead were quite higher in all samples and iron was 13 to 19 fold higher. Present investigation demonstrated that most of the physical and chemical parameters were exceeded from their prescribed limits which suggests all the samples are suitable for irrigation purpose but not for drinking use. If necessary actions should not be taken in future, the water quality will be seriously affected and ultimately it will cause environmental deterioration.***

Keywords: Hasdeo river, physico-chemical quality assessment, heavy metals.

Abbreviations: American Public Health Association (APHA), BALCO (Bharat Aluminium Company Limited), BDL (Bellow Detection Limit), BIS (Bureau of Indian Standard), BOD (Biological Oxygen Demand), Cd (Cadmium), Cl (Chloride), Cr (Chromium), COD (Chemical Oxygen Demand), CoPt (Cobalt Platinum Color Unit), CPCB (Central Pollution Control Board),Cu (Copper), DO (Dissolve Oxygen Demand), EC (Electrical Conductivity), F (Fluoride), Fe (Iron), HFD (NTPC Fly Ash Area Downstream), HFU (NTPC Fly Ash Area Upstream), HCD (Manikpur Coal Mine Area Downstream), HCU (Manikpur Coal Mine Area Upstream), K^+ (Potassium), Mn (Manganese), Na (Sodium), Ni (Nickel), NTPC (National Thermal Power Corporation), Pb (Lead), TDS (Total dissolve solid), TS (Total Solid), TSS (Total suspended solid), WHO (World Health Organization) Zn (Zinc).

1. Introduction

According to the world commission on water, more than half of the world‟s major rivers are so depleted and polluted that they endanger human health and surrounding ecosystems [1]. The increasing shortage of water in the universe caused by the steady increase of the population and the industrial development raises serious worries about the demand for appropriate water management practices [2]-[4]. Nowadays, great quantities of wastewater are produced from different industrial activities and reached to next door rivers. The organic loads along with heavy metals at low concentrations are essential for the growth and development of living organisms. But, above permissible limits, they may become very toxic [5], [6]. Moreover, Continuous discharge of persistent organic and inorganic contamination containing wastewater from different industries into the environment has resulted in building up their highest level in river systems. Some authors investigated that the organic and inorganic pollution above certain levels cause serious threat to living beings due to its mutagenic, cytotoxic, and carcinogenic potentials. [7], [8].

Hasdeo, a tributary of Mahanadi River Pathar in the valley of chota Nagpur from hill region of a Deogarh, district Koria, Chattishgarh and passes through Korba, Janjgir- Champa district and joined in Mahanadi river. River water is extensively used for domestic, recreational, industrial and irrigation purposes in the Korba region. It has been identified fifth rank among polluted cities in India according to Central Pollution Control Board [9]. Captive power plant of BALCO (Bharat Aluminium Company Limited), coal mines, Gopal explosive factory, and number of thermal power plant are situated along the side of river. Due to continuous discharge of industrial effluent along with city sewage in river, water quality is deteroirated. Therefore there is need for continuous monitoring of the pollutants load in this river water. Some studies on Hasdeo river water quality assessment have been done by different investigators [10]-[12] but the data was conflicting in nature. Till date, no or less scientific research regarding the complete physico-chemical parameters along with heavy metal issues in the study area has been conducted. For that reason, the present study is carried out to evaluate the current status in terms of pollution load on the Hasdeo River at Korba region.

2. Methodology

2.1 Study area and Sampling

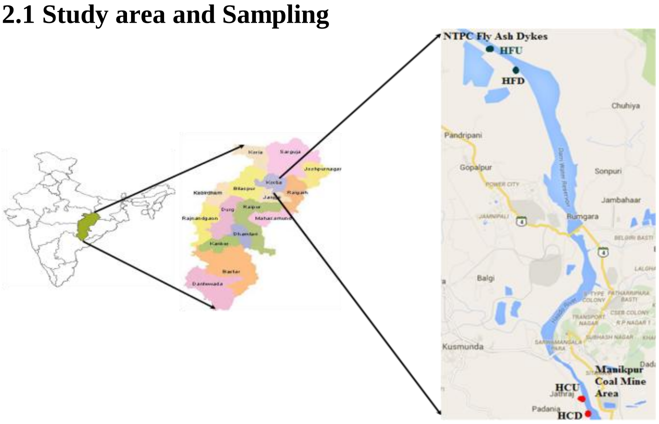

Figure 1: Study area: HCD - Manikpur Coal Mine Area Downstream, HCU - Manikpur Coal Mine Area Upstream,

HFD - NTPC Fly Ash Area Downstream, HFU - NTPC Fly Ash Area Upstream.

The research area and sampling site are schematically shown in Figure 1. Site HFD (NTPC Fly Ash Area Downstream) is downstream of the Hasdeo river and Site HFU (NTPC Fly Ash Area Upstream) is at 2 km upstream from HFD, where the very big National Thermal Power Corporation (NTPC) fly ash dykes are located and whose run off discharges flow into the Hasdeo River. Site HCD (Manikpur Coal Mine Area Downstream) is at 23 km downstream of site HFD which is situated after urban settlement, Korba city. Site HCD is downstream of Manikpur coal mine area and the Site HCU (Manikpur Coal Mine Area Upstream) is at 1.1 km upstream. The samples were collected in 10 liter clean, sterile cans. All the samples were immediately transported to the laboratory. The samples were stored in the laboratory at 4^{0}C until processed /analyzed. For collection, preservation and analysis of the samples, the standard methods: American Public Health Association (APHA) [13] were adopted.

2.2 Analytical procedures

The river water temperature was measured at the time of sampling using Mercury Thermometer. River water samples were analyzed for pH, electrical conductivity (EC), alkalinity (Alkalinity as $CaCo_3$), color, TS (Total Solid), TDS (Total Dissolve Solid), TSS (Total Suspended Solid), Total hardness (T- hard as $CaCO_3$), COD (Chemical Oxygen Demand), BOD (Biological Oxygen Demand), DO (Dissolve Oxygen), nitrite, nitrate (NO^-_3), Sulfate (SO_4^{--}), Phosphate (PO_4^{---}), Sodium (Na), Potassium (K^+), Chloride (Cl), Fluoride (F) [13]. EC, pH, chloride, fluoride, and nitrate were analyzed using multiple parameters ion meter model Thermo Orion 5 Star. Sulfate and phosphate were measured using a double beam UV–Vis spectrophotometer (Model Perkin Elmer Lambda 35) by turbidimetric and stannous chloride, respectively. Sodium and potassium was analyzed using flame photometer model CL-378 (Elico, India). Hardness (total) was determined by the EDTA titrimetric method. TS, TDS, TSS were measured gravimetrically. Total carbonate and bicarbonate alkalinities were measured by acid–base titration. Color, COD, and BOD were measured by visual comparison method, open reflux method, 5 day method, respectively. Chromium, cadmium, copper, iron, nickel, lead, zinc and magnesium were measured using Inductively coupled plasma spectrophotometer (Thermo Electron; Model IRIS Intrepid II XDL, USA) in the acid digested samples. The digestion was carried out with nitric/ perchloric acid mixture (5:1). The analytical data quality was controlled by standardization, procedural blank measurements and spiking the samples and necessary corrections were applied. All observations were recorded in triplicate and average values are reported.

3. Results and Discussion

According to the United Nation World Water Development Report, the Asian subcontinent which supports more than half of the world‟s population has only 36% of the world‟s fresh water resources. India‟s growing population enhances great pressure on river water. The main goal of the present study was to assess the impact of human and industrial activities on the water quality of river Hasdeo. The physicochemical parameters of river water were analyzed statistically and results are given in Table 1.

Temperature – The temperature of body of water influences its overall quality. Variation in water temperature is not recorded in present study, however, during day time the temperature recorded at all the sites were in the range of 24 ^{o}C -26^{o}C.

pH – In neutral water, the pH scales runs from 0 to 14. All sampling sites (HCD to HFU) were characterized by pH between 6.5 and 8.5 which is within appropriate limits of BIS (Bureau of Indian Standard), [14] for water supply and aquatic life. The pH value varies from 7.39 to 7.95 which is indication of slightly alkaline nature of river water of the region; arise due to the dissolved constituents into the river water.

Color - The color of river water were more in downstream sampling sites HCD and HFD in comparison with upstream sampling sites HCU and HFU, respectively which were 115.1±9.2 and 169.37±13.5CoPt (Cobalt Platinum Color Unit) for downstream and 65.11±3.8 and 65.11±4.5CoPt for upstream, respectively. This color variation in downstream and upstream sampling sites might be due to higher deposition of coal particles coming from Manikpur coal mines (HCD-HCU) and fly ash from NTPC fly ash dam (HFD-HFU) in downstream sites compared to upstream.

Electric conductance - EC values of site HCD and HCU were 1400±30 µS/cm and 1175±33 µS/cm, respectively. Whereas, sample collected from HFD and HFU were 557±21.3 µS/cm and 340±17.8 µS/cm, respectively. The values of EC exceeds the permissible limit (1,000 µS/cm) design by BIS [14] in sampling sites HCD and HCU might be due to mining activities of Manikpur coal mine, urban discharges and other major industries. According to Olsen‟s classification [15] water having conductivity between 250 and 1000 µS/cm are

Table 1: Chemical texture of collected river water from sampling sites.

Characteristics	HCD	HCU	HFD	HFU	Standard*
pH	7.39±0.2	7.49±0.1	7.88±0.22	7.95±0.2	6.5-8.5
Temperature (°C)	25.6	25.3	25.5	25.6	-
Conductivity (µS/cm)	1400±30	1175±33	557±21.3	340±17.8	1,000
Color (Copt.)	115.1±9.2	65.11±3.8	169.37±13.5	65.11±4.5	-
TS	1235±128	950±68	415±49	540±43	-
TDS	930±55.8	780±55	370±26	455±36	500
TSS	305±27	170±12	45±3.1	85±5.1	-
COD	68±4.7	60±4.8	22±1.5	17±1	-
BOD	37±3.3	32.6±2.6	13±1.1	8±0.6	2 to 3
Sulphate	66.34±4.6	70.26±4.9	17.84±1	46.08±3.2	200
Phosphate	0.18±0.01	0.12±0.009	0.27±0.02	0.25±0.02	-
DO	6.78±0.5	6.37±0.5	7.9±0.6	8.4±0.7	4 to 6
Total hardness	356±25	266±21	123±8.6	94±5.6	300
Alkalinity	108±7.5	98±5.8	67±4	37±2.5	200
Chloride	59±4.7	53±3.7	29±1.7	24±1.6	250
Fluoride	1.37±0.1	1.21±0.1	0.72±0.05	0.39±0.03	1.0
Nitrate	1.43±0.1	1.19±0.08	0.66±0.03	0.47±0.03	45
Nitrite	0.1±0.008	0.15±0.01	BDL	BDL	-
Na	122.35±11	127.87±11	67.66±5.4	67.88±4	20
K	6.78±0.4	5.51±0.2	2.77±0.1	2.08±0.1	-
Heavy Metal analysis (mg/L)					
Cd	BDL	BDL	BDL	BDL	0.01
Cr	0.055	0.194	0.024	0.039	0.05
Cu	0.021	0.28	0.015	0.014	0.05
Fe	4.247	3.997	5.974	5.956	0.3
Mn	0.567	0.399	0.670	0.649	0.1
Ni	0.015	0.041	0.026	0.020	0.02
Pb	0.025	0.041	0.047	0.030	0.01
Zn	0.366	0.327	0.111	0.334	5

All the parameters in mg/L except color, conductivity and pH; HCD: Manikpur Coal Mine Area Downstream; HCU: Manikpur Coal Mine Area Upstream; HFD: NTPC Fly Ash Area Downstream; HFU: NTPC Fly Ash Area Upstream. BDL: Bellow Detection Limit. Standard* BIS(2005), WHO(2003), and CPCB(2001) desirable limits of drinking water rich in electrolytes and are characterized as eutrophic. There is a strong relation between EC, TDS, BOD and COD values because conductivity mainly depends on ionic concentration or dissolved inorganic substance so EC can be used to estimate the TDS in river water (Table 2).

TS, TSS and TDS - In water, dissolved solids mainly consists of various inorganic salts such as carbonates, bicarbonates, chlorides, sulfates, phosphates, nitrates, calcium, magnesium, sodium, potassium, iron etc., a small amount of organic matter and dissolved materials. The TDS of river water was maximum 930±55.8mg/L and minimum 370±26 mg/L in sample HCD and HFD, respectively. These results indicated that water from HCD was containing approximately 2 times higher TDS than HFD that may be due to the mixing of pollutants through industrial activities, sewerage and garbage dumping. TDS from HFD and HFU were within a range of desirable limit of BIS [14] that is 500 mg/L and HCD and HCU were exceeded through this range if this water will be used for drinking purposes it may induce an unfavorable physiological reaction in the transient consumer and gastrointestinal infections [16]. The TSS and TS was ranged between (45±3.1 mg/L to 305±27 mg/L) and (415±49 mg/L to 1235±128 mg/L) respectively.

Dissolved oxygen- DO is indicative of the health of an aquatic system, the vital metabolism of aerobic organisms and respiration depends purely on the amount of oxygen dissolved in the water [17, 18]. Pattern of DO level at different sampling sites was HFU>HFD>HCD>HCU. At HFU, which was having minimum BOD, river water was least polluted because of presence of maximum amount of DO. A similar pattern was recorded for the river Suswa [19]. A level of DO were exceeding CPCB, [20] criteria of class A,B,C,D water ranged from 4 to 6 mg/L at all the sampling sites indicated that river was high re-aeration rate and rapid aerobic oxidation of biological substances that is an indicator of good water quality.

BOD and COD– BOD is used as the index of organic pollution of waste water that can be decomposed by bacteria under anaerobic conditions. In this study, BOD ranged from 8±0.6 mg/L (minimum at HFU) to 37±3.3 mg/L (maximum at HCD). Moreover, increased BOD value also indicates high organic pollution in the aquatic systems, which adversely affect the river water quality and biodiversity. The BOD levels at all sampling sites were exceeding the CPCB criteria (i.e., 2 to 3 mg/l for Class A, B, and C) [20]. A pattern of decreasing BOD was HCD> HCU> HFD> HFU this clearly indicated that Hasdeo river water from upstream of NTPC fly ash area was least polluted than downstream and when river flowed towards downstream of Manikpur coal mine area its pollution load increased due to addition of sewage discharges, agricultural runoff, discharges through industries, domestic and mining activities and maximum pollution load was recorded in terms of BOD at downstream area of Manikpur coal mine.

The sulphate, alkalinity, chloride, nitrate were found within the desirable limit of drinking water prescribed by BIS, [14] (Table 1). The phosphate was highest at sampling site HFD (0.27±0.02 mg/L) and lowest at HCU (0.12±0.009 mg/L). At all the sampling sites except HCD total hardness was within a desirable limit of BIS, 2005 (300 mg/L). HCD was slightly exceeded might be due to anthropogenic activities. The maximum concentration of fluoride was 1.37±0.1 mg/L at HCD and minimum 0.39±0.03 mg/L at HFU. The sampling sites HCD and HCU were exceeded from BIS, [14] desirable limit (1.0mg/L) due to geological and anthropogenic activities like mining which are the main sources of Fluoride. Our findings were supported by [21, 22]. Nitrite at HCD and HCU was ranged from 0.1±0.008 mg/L and 0.15±0.01 mg/L respectively and at HFD and HFU it was below detectable limit. Na is the main constituents of table salt. In our study Na ranged from 67.66±5.4 mg/L at HFD and 127.87±11 mg/L at HCU which were exceeded World Health Organization WHO, [23] standard of portable water. K was recorded maximum at HCD (6.78±0.4 mg/L) and minimum at HFU (2.08±0.1 mg/L).

Heavy metals– Heavy metals contamination in river water has received great attention during recent years due to their toxicity and accumulative behavior in the system. These elements, in comparison to other pollutants, are not biodegradable and undergo a global eco-logical cycle in which natural waters are the main pathways [20]. Cadmium was recorded below detectable level at all the sites. Non-biodegradability of these elements leads to enter in the food chain through a number of pathways causing progressive toxicity due to accumulation in human and animal‟s organs during their life span on long term exposure to contaminated environment [24]. The metal analysis of different sites was shown in (Table 1). Chromium and iron concentration in this study was 0.05 to 0.194 mg/L and 4.24 to 3.99 mg/L on site HCD and HCU and 0.024 to 0.039 mg/L and 5.97 to 5.95 mg/L on site HFD and HFU, respectively. Results revealed that chromium concentration was within the desirable limit (0.05mg/L). Cr sources in river Hasdeo could be attributed to surface runoffs, discarded chromium batteries and leachates from solid waste dumps. Iron was quite higher in all the samples compare to its desirable limit (0.3 mg/L) approved by BIS, [14]. Sources of Fe in river water might be from weathering processes of soil formation, municipal drain water, leachate from refuse dump sites like fly ash dams which are discharged into river water bodies.

The concentrations of the lead in the study area were found to be 2 to 4 times higher comparing to its desirable limit (0.01mg/L). Beyond this limit, the water becomes toxic. One of the major sources of lead in river water is industrial effluents, which are regularly discharged in river water without any prior treatment or improper treatment [25]. The high concentration of lead in river water causes a number of diseases. In babies and children, exposure to lead in drinking water above the desirable limit can result in delays in physical and mental development, along with slight deficits in attention span and learning abilities [26]. The concentration of Mn is highest at HFD (0.670 mg/L) and lowest at HCU (0.399 mg/L). Water body containing excessive level of Mn may impair objectionable staining properties on cloth washing operations. In this study, upper sites of sampling area that is HFD and HFU were found maximum polluted with Fe, Mn, Pb. Whereas, lower sampling sites HCD and HCU were mainly contaminated with Cr, Cu, Ni and Zn. This pattern was found mainly due to fly ash deposition and coal mine activity, respectively. Fly ash particles consists of silica with Al, Fe and Ca oxides, Mg, Na, K, Ti, S, C and trace elements like Hg; Cd, Ga, Sb, Se, V, As, Cr, La, Mo, Ni, Pb, Th, U, Zn, B, Ba, Cu, Mn, Sr [27-31] and mining effluent consists Cu, Cd, Cr, Zn, Fe and Ni [32].

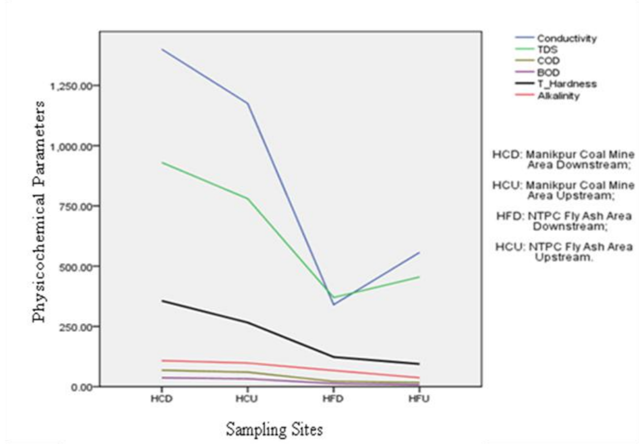

Figure 2: Correlation between Conductivity, TDS, COD, BOD, Total Hardness and Alkalinity.

Correlation coefficient (r) is a statistical measure of the interdependence of two or more random variables. Correlation analysis measures the closeness and degree of linear association between independent and dependent variables [33]. The correlation coefficient (r) is a measure of how well the points fit to a straight. „r‟ values close to +1 indicates a close fit to a straight line or in other words "strong correlation". „r‟ close to zero indicates a very poor fit to a straight line or little or „r‟ values close to -1 no correlation. The correlation coefficient „r‟ among 20 water quality parameters from different sites of Hasdeo River was calculated for correlation analysis. The correlation coefficients for various water quality parameters for different sites were given in Table 2 and 3. An attempt has been made to ascertain the relationship during all sites of EC with the TDS. However, EC also exhibit good significant

Table 2: Correlation matrix of physico-chemical analysis

	pH	Tem	Cond	Color	TS	TDS	TSS	COD	BOD	Sul	Phos	DO	TH	Alk	Cl	F	NO_3^-	NO_2^{-2}	Na	K
pH	1																			
Tem	-0.64	1																		
Cond	-0.9	0.41	1																	
Color	0.29	-0.02	-0.46	1																
TS	-0.83	0.46	0.96	-0.59	1															
TDS	-0.9	0.53	0.98	-0.53	0.98	1														
TSS	-0.85	0.34	0.88	-0.65	0.96	0.9	1													
COD	-0.68	0.3	0.96	-0.43	0.92	0.94	0.84	1												
BOD	-0.86	0.32	0.96	-0.4	0.93	0.94	0.85	1	1											
Sul	-0.67	0.2	0.77	-0.76	0.83	0.79	0.84	0.75	0.75	1										
Phos	0.53	-0.22	-0.6	0.33	-0.67	-0.64	-0.67	-0.72	-0.75	-0.69	1									
DO	0.83	-0.35	-0.89	0.21	-0.8	-0.86	-0.66	-0.91	-0.9	-0.51	0.51	1								
TH	-0.86	0.41	0.97	-0.45	0.98	0.97	0.92	0.98	0.98	0.78	-0.73	-0.86	1							
Alk	-0.85	0.38	0.95	-0.29	0.88	0.92	0.77	0.94	0.94	0.57	-0.54	-0.97	0.93	1						
Cl	-0.86	0.3	0.96	-0.4	0.92	0.94	0.84	1	1	0.74	-0.72	-0.91	0.98	0.95	1					
F	-0.83	0.33	0.96	-0.32	0.9	0.93	0.82	0.97	0.97	0.63	-0.65	-0.96	0.98	0.98	0.97	1				
NO_3^-	-0.82	0.35	0.97	-0.41	0.94	0.95	0.87	0.97	0.97	0.69	-0.65	-0.93	0.96	0.97	0.97	0.99	1			
O_2^{-2}	-0.83	0.35	0.89	-0.54	0.89	0.89	0.84	0.92	0.93	0.69	-0.85	-0.75	0.92	0.81	0.91	0.85	0.86	1		
Na	-0.68	0.33	0.89	-0.65	0.96	0.9	0.98	0.84	0.85	0.84	-0.69	-0.7	0.91	0.79	0.84	0.83	0.88	0.87	1	
K	-0.91	0.46	0.99	-0.5	0.97	0.98	0.9	0.94	0.94	0.79	-0.6	-0.84	0.97	0.92	0.94	0.93	0.94	0.89	0.8	1

Table 3: Correlation matrix of heavy metal analysis.

	Cd	Cr	Cu	Fe	Mn	Ni	Pb	Zn
Cd	1							
Cr	-0.010	1						
Cu	-0.051	0.4178	1					
Fe	-0.309	-0.554	0.141	1				
Mn	-0.394	-0.45	-0.1122	0.705	1			
Ni	0.534	0.619	0.011	-0.497	-0.5204	1		
Pb	0.252	0.068	-0.02	-0.549	-0.5501	-0.0946	1	
Zn	-0.484	-0.156	0.386	0.705	0.84571	-0.4524	0.4524	1

Tem: temperature; Cond: conductivity; TS: Total solid; TDS: total dissolve solid; TSS: total suspended solid; Sul: Sulphate; Phos: phosphate; DO: dissolve oxygen; TH: total hardness; Alk: alkalinity; Cl: chloride; F: Floride; Na: sodium; K: potassium positive correlation with COD, BOD, F, Cl, total hardness, alkalinity, nitrate and potassium (r^2>0.95). It is due to the fact that conductivity depends on TDS and TDS depends on the concentration of dissolved ions. TDS increases with increase in dissolved ions concentration. On other hand, pH and dissolve oxygen show negative correlation with most of the parameters.

4. Conclusion

This study provides significant information on water quality in the Hasdeo river, Chhattisgarh, India. High contents of various physico-chemical parameters viz. pH, TH, TDS, and heavy metals deteriorated the water quality of the study area, which are influenced by the effluents of different industries. High level of these parameters in river water may lead to unpleasant taste and adverse effects on domestic use. The quality of river water were compared with BIS standards and revealed that the all samples are suitable for irrigation purpose but not for drinking. If the situation is not control in future, it may assume alarming situation for inhabitants.

5. Acknowledgement

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