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Quality Assessment of Drinking Water in Vehari District of Punjab, Pakistan

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Abstract: The current study is performed to assess the physio-chemical characteristics and drinking water quality in three Tehsils (Mailsi, Burewala and Vehari) of District Vehari, Punjab (Pakistan). The water samples of investigated regions were subjected to physicochemical characterization (pH, EC, TDS, HCO_3^-, CO_3^{-2}, Cl^-, NO_3^-, PO_4^{-3}, SO_4^{-3}, Na^+, K^+, Ca^{+2}, Mg^{+2}, Fe^{+2}, Cu^{+2}, Zn^{+2} and Mn^{+2}). It was demonstrated that certain parameters were exceeding WHO standard limits. The water of Lalazar colony, college town, Y-Block and Sharqi colony was found unfit for drinking purposes so it may cause serious health concerns in the citizens of the investigated areas.

Keywords: Water quality, chlorination, physio-chemical parameters, industrialization, WHO.

Introduction

Clean and safe water is highly important for the healthy life and proper functioning of the human body (Khalid et al., 2011). Water is the most abundant compound in the universe. However, about 97% water of the earth planet exists as seawater that is not fit even for washing purposes while the remaining 3% of water, is freshwater (Nishigaki et al., 2004). From this 3% freshwater, 2% is present in glaciers and polar ice caps, whereas only 1% water is available for drinking purposes. But nowadays, this 1% water is not even safe for drinking due to its contamination with several impurities and waste byproducts. The contaminated water generally contains a higher concentration of bicarbonates, carbonates, chlorides, phosphates, and sulfates of magnesium and calcium (Organization, 2004). These contaminations are mixed in drinking water (DW) and make it unfit for human consumption.

The waste products and industrial byproducts are directly disposed off on the earth surface or dumped into the soil by reverse boring, or they are discarded into streams (Kodarkar, 1992). The waste by-products may contain hazardous chemicals and damage the quality of water (Farah et al., 2002). Another factor is the storage of waste byproducts in the pits and mines where the leakage of water-soluble materials causes contamination of underground water and makes it useless for human consumption (Jaini, 2003).

Due to industrial development and heavy usage of agricultural fertilizers *etc*, substantial pollution is being created in natural water sources, marine environment and water biota (Estefan et al., 2013). It is hence essential that the quality of water should be monitored periodically because consumption of polluted water may produce several diseases in the human population (Pandey and Siddiqi, 1993). The quality of water has been seriously disturbed especially in Pakistan due to industrial and other waste materials (Malik and Khan, 2016). Insufficiently treated industrial, residential, mechanical and horticultural wastewater may also contain higher concentrations of metals, which are frequently released into nature (Singh et al., 2014). Keeping the significance of water quality in view, a large number of investigations are reported on the evaluation and treatment procedures of the drinking water quality (Farhat et al., 2021, Hussain, 2020, Iqbal et al., 2019, Rehman et al., 2019). The present study is performed to assess the quality of drinking water in the Vehari (Vehari, Burewala and Mailsi) District of Punjab, Pakistan.

Materials and Methods

Study Area

The drinking water of three different Tehsils (Mailsi, Burewala and Vehari) of District Vehari, Punjab (Pakistan) was subjected to its Physico-chemical characterization and quality. Vehari District is positioned between 29.36º and 30.22º North and 71.44º' and 72.53º' East (Fig.1), it is positi oned on the right bank of river Satluj. In selected areas, electric pumps and hand pumps are used to pull out the groundwater for domestic uses.

Sample Collection

Fifteen samples (W1-W 15) of drinking water (DW) were collected from areas under investigation of District Vehari (Table 1). The collected water samples were stored in pre-washed polyethene bottles. They were analyzed for colour, pH, electrical conductivity (EC, mS/cm), total dissolved solids (TDS, mg per L) and determination of HCO_3^-, CO_3^{-2}, Cl^-, NO_3^-, PO_4^{-3}, SO_4^{-3} anions as well as Na^+, K^+, Ca^{+2}, Mg^{+2}, Fe^{+2}, Cu^{+2}, Zn^{+2}, Mn^{+2} cations (unit = mg per L); the obtained results were compared with established WHO standards.

Chemicals used

Water samples, EDTA, Eriochrome Black-T (EBT), sulfuric acid (H_2SO_4), phenolphthalein, methyl orange, potassium chromate (K_2CrO_4).

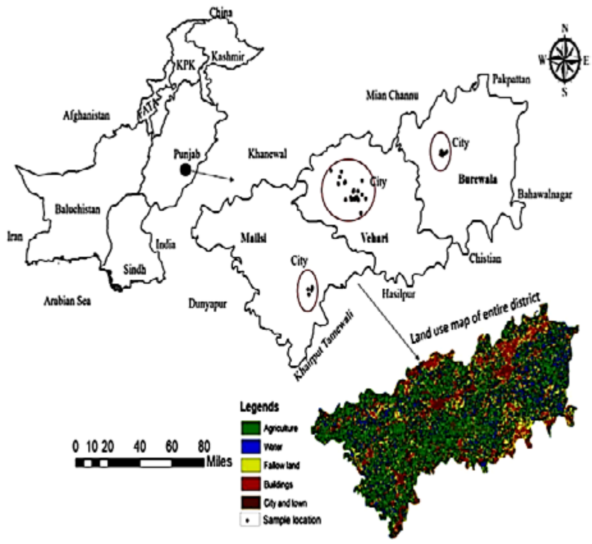

Fig. 1 Selected areas of 3Tehsils (Burewala, Mailsi and Vehari) for study.

Physical Analysis

The physical analysis of freshwater was carried out at the sample collection site. Colour of all samples was analyzed by their first appearance visually at the point of collection. The pH values were determined by a pH meter which was calibrated before each experiment. TDS measurement was done by a TDS meter of Barry Century while EC was measured by a conductometer (Hanna, HI2300).

Chemical Analysis

A flame spectrophotometer (JENWAY PFP7) was used to evaluate the concentration of K^+ and Na^+ ions (Estefan et al., 2013, Khalid et al., 2018). While the concentration of other salts of Ca^{+2}, Mg^{+2}, carbonate ions, bicarbonate ions, chloride ions and sulfates ions were determined by Mohr Method (an Argentometric Titration). In the Mohr titration method, samples were allowed to titrate with 0.01 N ethylene diamine tetra-acetic acid (EDTA) solution by using the monochrome black T (EBT) indicator until a blue-coloured endpoint was obtained.

To analyze the concentration of soluble carbonate salts, water samples were titrated with 0.01 N H_2SO_4 solution by using the phenolphthalein indicator to a colourless endpoint. Titration of the samples with 0.01 N H_2SO_4 solution in the presence of methyl orange indicator (endpoint = pinkish-yellow) was used for the determination of bicarbonate ions. After both tests, a third test was performed to find the concentration of chloride ions using Mohr method by treating the samples with 0.01 N $AgNO_3$ in the presence of potassium chromate (K_2CrO_4) indicator till a brick red colour (endpoint) was attained.

The amount of sulfate ions were determined by finding the difference between the total dissolved solids (TDS) and total anions as represented by the following formula:

$$SO_4^{-2} = \text{TDS-anions*}$$

$$\text{anions*} = (CO_3^{-2} + HCO_3^{-} + Cl^{-})$$

Amounts of nitrate ions and phosphate ions were analyzed by applying the spectrophotometer method. For the determination of nitrate ions, 1 ml of chronotropic acid (0.1%) was mixed with each sample (10 mL) drop by drop in glass tubes, glass tubes were in turn placed in chilled water for some minutes to be cooled. Then concentrated sulfuric acid (6mL) was mixed and the mixture was left to attain a normal temperature. Yellowish colour appeared within the duration of 45 minute time. The same procedure was performed with the standard solutions. For blank reading, the baseline was set to autozero, then absorbance of standard solutions and water samples were recorded on a spectrophotometer at λ_{max} = 430 nm while the number of nitrate ions was calculated by a relation which was given by standard calibration curve.

To find the amount of phosphorous in samples, 1ml sulfuric acid (11 N), 4ml ammonium molybdate-antimony tartrate, and 2ml ascorbic acid were mixed in 25 ml of standard solution and sample solutions. The extent of absorbance was determined after five minutes with a spectrophotometer at λ_{max} = 650 nm while the concentration of phosphorus was determined with the help of a standard calibration curve. The amounts of trace metals in tested water samples were found by atomic absorption spectrophotometer.

Results and Discussion

Physical Analysis

The investigated water samples were found colourless at the time of their collection. The pH of the samples (Table 2) was lying in the range of 7.31-7.71; the observed values were completely lying within the standard limits of WHO (6.5-8.5). The EC values of the samples (Table. 2) were ranging from 0.41 to 2.21mS/cm; these values were found far beyond the WHO limits; it indicates that these samples have contamination of numerous salts which are present in the ionic form in water. The samples with higher EC values were possibly polluted with salts dissolved from rocks. TDS values of samples (Table 2) were lying in

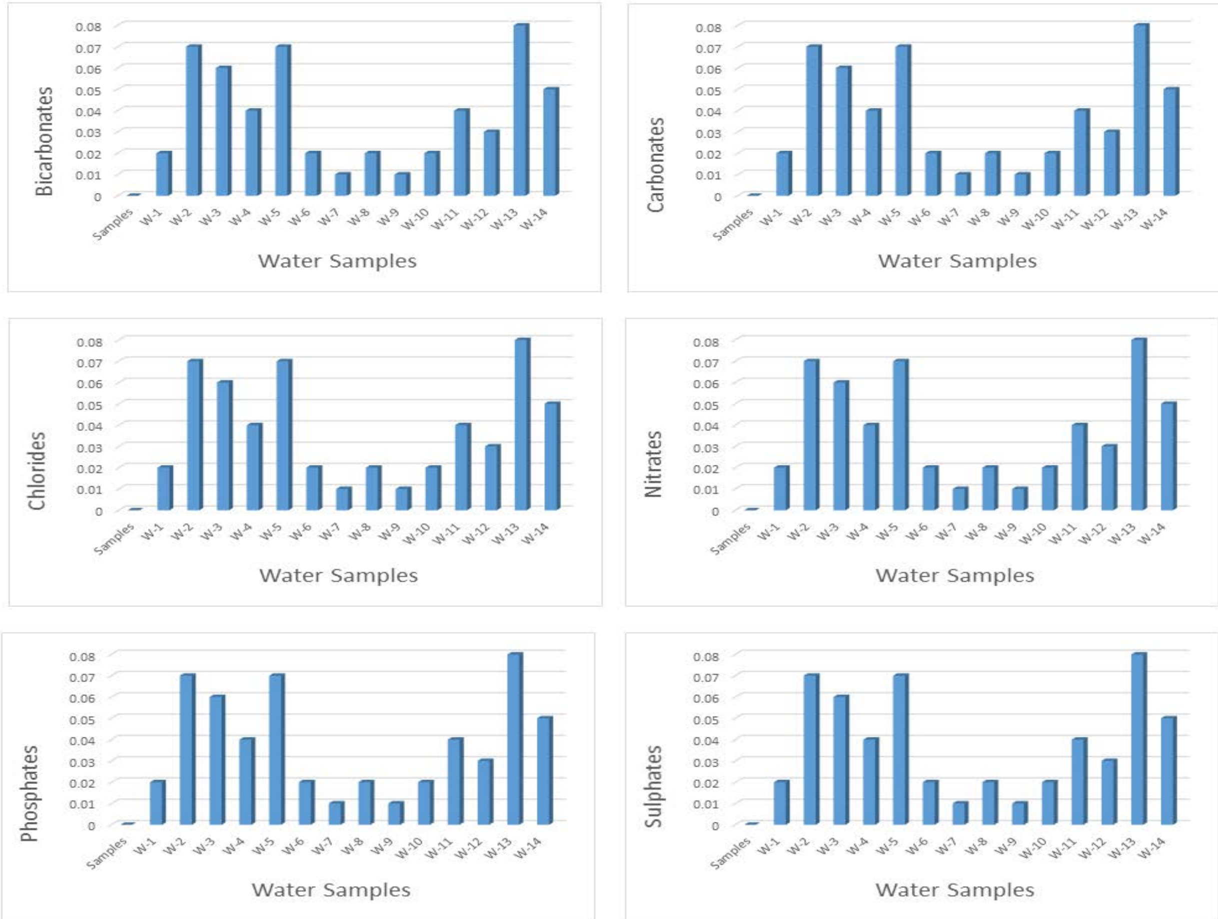

Fig. 2 Graphical representation of HCO_3^-, CO_3^{-2}, Cl^-, NO_3^-, PO_4^{-3} and SO_4^{-2} ions in tested water samples.

the range of 282-1412 mg/L. TDS values of some samples *viz* W-3, W-4, W-5, W-6, W-7, W-9, W-12, W-13 & W-15 were lying beyond the WHO limits (500 mg/L). The values of EC, as well as TDS, symbolize the aggregate quantity of salt anions and metal cations present in water (Shahid et al., 2015). They also affect the taste and quality of DW; thus, such a kind of water may be a risk for the health of the local citizens.

Table 1 Samples from the selected Tehsils of district Vehari.

Sr. No.	*Tehsil	Selected Area	Sample
1	*Vehari	E-Block	W1
2		F-Block	W2
3		Lalazar Colony	W3
4		College Town	W4
5		Danewal	W5
6	*Burewala	Satellite Town	W6
7		Y-Block	W7
8		TMA 9-11 Cistern	W8
9		Sharqi Colony	W9
10		22-24 Turbine Pull	W10
11	*Mailsi	Mailsi Cantt	W11
12		Hari Pura	W12
13		Kacha Kot	W13
14		Model Town	W14
15		Medina Town	W15

Chemical Analysis

The investigated water samples were subjected to analysis for the presence and quantity of HCO_3^-, CO_3^{-2}, Cl^-, NO_3^-, PO_4^{-3}, SO_4^{-3}, Na^+, K^+, Ca^{+2}, Mg^{+2}, Fe, Cu, Zn, and Mn. The results have been displayed in Tables 3-5.

The observed values of bicarbonates, carbonates, chlorides, nitrates, phosphates and sulphates are shown in Table 3 while Figure 2 displays the graphical representation of the said data. In most of the samples, these values (except chlorides of W-3, W-4, W-7, and W-9) were lying within the WHO limits (Table 3).

Table 2 Physical parameters of selected samples.

Sr. No.	Sample	Color	pH	EC (ms/cm)	TDS (mg/L)
1	W-1	Colorless	7.66	0.66	419.4
2	W-2	-	7.65	0.61	381.2
3	W-3	-	7.61	2.21	1412
4	W-4	-	7.42	1.82	1151.82
5	W-5	-	7.51	1.06	671.9
6	W-6	-	7.59	0.88	557.1
7	W-7	-	7.68	1.70	1061.9
8	W-8	-	7.49	0.90	570.1
9	W-9	-	7.42	1.66	1050.1
10	W-10	-	7.69	0.45	282
11	W-11	-	7.59	0.68	429
12	W-12	-	7.62	1.27	801
13	W-13	-	7.39	1.04	639.6
14	W-14	-	7.71	0.61	359.1
15	W-15	-	7.31	0.86	543.86
WHO		-	6.5-8.5	0.4	500
USEPA		-	6.5-8.5	-	-
Canada Limit		-	6.5-8.5	-	-
EU Standard		-	6.5-8.5	0.4	500
Pak EPA		-	6.5-8.5	-	-

There is no definite recommended value of bicarbonates by WHO, however, it is supposed to be less than 500 mg/L. The availability of bicarbonates of calcium and magnesium makes the DW hard, unfit for human consumption and causes gastrointestinal diseases (Pranavam et al., 2011). The chloride values of W-3, W-4, W-7 and W-9 were found to be 460.12 mg/L, 384.10 mg/L, 337.30 mg/L and 398 mg/L, respectively which were beyond the WHO limits (Gupta and Ayoob, 2016).

Table 3 HCO_3^-, CO_3^{-2}, Cl^-, NO_3^-, PO_4^{-3} and SO_4^{-2} in samples of DW.

Sr. No.	Sample	HCO_3^-	CO_3^{-2}	Cl^-	NO_3^-	PO_4^{-3}	SO_4^{-2}
1	W-1	219.70	23.9	53.40	2.55	0.91	31.25
2	W-2	116	8.98	106.4	1.18	0.87	35.94
3	W-3	235.2	15	460.12	11.02	0.76	228.10
4	W-4	238	29.89	384.10	8.90	0.30	163.40
5	W-5	97.70	45.10	190.10	3.64	0.93	97.9
6	W-6	214.10	0	181.06	2.78	0.74	4.81
7	W-7	213.57	0	337.30	2.48	0.73	173
8	W-8	232.10	0	170.61	9	0.7	14.39
9	W-9	244.05	0	398	8.99	0.56	57.7
10	W-10	92.04	0	88.81	10.04	0.40	19.30
11	W-11	116.1	18.1	135	6.81	0.30	19.34
12	W-12	152.55	29.90	247.98	6.71	0.38	96.10
13	W-13	152.54	14.98	185	9.14	0.75	87
14	W-14	122.04	0.5	121	6.79	0.18	9.61
15	W-15	128.16	2.98	213	8.15	0.27	14.7
WHO				250	50	-	500
USEPA				250	10	-	500
Canada Limit				≤250	45	-	≤500
EU Standard				250	50	-	250
Pak EPA				≤250	≤50	-	400

The nitrate concentration of all the samples was lying within the WHO limits. It means that the DW of selected areas contains a safe concentration of nitrate ions. An elevated concentration of nitrates is a probable health risk, especially it may result in the disease "Methemoglobinemia" a blood disorder, also known as a baby blue syndrome in human beings (Hassan and Nawaz, 2014).

The concentrations of sulphates (of calcium and magnesium) and phosphates were also found within the acceptable WHO ranges. The recommended concentration of phosphate ions in DW is 0.1-5mg/L (Raza et al., 2007).

Table 4. The concentration of Na^+, K^+, Ca^{+2}, Mg^{+2} in selected water samples

Sr. No.	Sample	Na^+	K^+	Ca^{+2}	Mg^{+2}
1	W-1	68.20	8.87	60.40	22.51
2	W-2	115	9.3	44.98	17.42
3	W-3	308.50	12.60	113	40
4	W-4	239	13.42	110	39.10
5	W-5	121	12.51	66	24.40
6	W-6	144	5.61	37.4	14.60
7	W-7	255	9.4	77	27.70
8	W-8	131	6.3	49.4	19.02
9	W-9	254.9	6.6	82.42	30.10
10	W-10	66	5.0	7.20	19.02
11	W-11	89.7	4.79	28.4	11.70
12	W-12	188.91	7.1	58.1	22
13	W-13	161	5.45	62	22.50
14	W-14	93	4.6	28.3	11.40
15	W-15	106.5	6.06	29.90	12.35
WHO		200	-	100	150
USEPA		-	-	-	50
Canada Limit		≤200	-	-	-
EU Standard		200	12	-	-
Pak EPA		-	-	200	-

The concentration of metal ions *viz* sodium, potassium, calcium and magnesium, in all samples were also determined; the results are summarized in Table 4. The concentration of magnesium ions in all samples was lying under the WHO limits. However, some water samples *viz* W-3 (308.50 mg/L), W-4 (239 mg/L), W-7 (255 mg/L) and W-9 (254.90 mg/L) have shown higher concentration of sodium ions as compared to the WHO limits. The high level of sodium in DW may cause several health problems *viz* blood pressure, vomiting, and weakness etc. The saline nature of groundwater may be owed to the elevated concentration of sodium ions in DW making it unfit for drinking and consumption.

The observed concentration of calcium in some samples *viz* Lalazar Colony (W-3, 113 mg/L), and college town (W-4, 110 mg/L) was exceeded from the WHO limits (100 mg/L). This elevated concentration of calcium may be rendered to the leakage of carbonates/bicarbonates from limestone into the groundwater. However, a balanced amount of calcium in DW is compulsory for better human health. The areas where the concentration of calcium is too much lower as compared to the WHO limits have greater chances of bone fracture and risk of rickets. Higher concentrations of calcium, sodium and magnesium may be due to diffusion of surface water, sewage mixtures and precipitation (having dissolved salts) into groundwater.

The concentration of potassium in some samples *viz* W-3 (12.60 mg/L) and W-4 (13.42 mg/L) were also found to exceed WHO limits (12 mg/L). Potassium is an important element for physiological actions and stimulations in living organisms and is also a part of their bone tissues and skeleton (Martineau et al., 2017). The total concentration of potassium in human beings may vary between 110 and 140 mg/L. Its deficiency may cause serious health issues like depression, muscle problems and heartbeat rates etc. While, higher level of potassium is also dangerous as it can cause homeostatic system disruption (Haq, 2005).

Table 5. The concentration of trace metals in water samples

Sr. No.	Sample	Fe	Cu	Zn	Mn
1	W-1	0.02	0	0.02	0.01
2	W-2	0.07	0.02	0.09	0.02
3	W-3	0.06	0.01	0.02	0.01
4	W-4	0.04	0.03	0.02	0.00
5	W-5	0.07	0.01	0.01	0.00
6	W-6	0.02	0.02	0.02	0.01
7	W-7	0.01	0.02	0.01	0.00
8	W-8	0.02	0.01	0.01	0.01
9	W-9	0.01	0.01	0.02	0.02
10	W-10	0.02	0.00	0.02	0.01
11	W-11	0.04	0.03	0.02	0.02
12	W-12	0.03	0.01	0.01	0.01
13	W-13	0.08	0.02	0.02	0.01
14	W-14	0.05	0.02	0.02	0.00
15	W-15	0.02	0.02	0.01	0.01
WHO		0.3	2	30	≤0.5
USEPA		0.3	1.3	5	0.05
Canada Limit		≤0.3	≤1	≤5	≤0.05
EU Standard		0.2	2	-	0.05
Pak EPA		-	2	5	≤0.5

In all water samples, the concentration of trace metals (Mn, Zn, Fe, Cu,) was found within the WHO limits (Simonis, 1990). The obtained data are summarized in Table 5 and graphically represented in Figure 3.

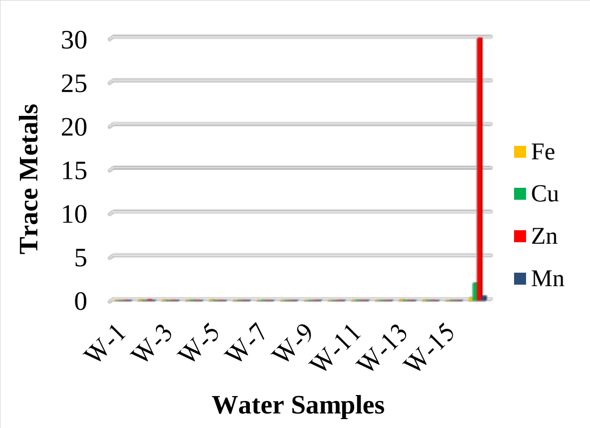

Fig. 3 Trace metals in water samples.

Conclusion

The investigated water samples in three Tehsils (Mailsi, Burewala and Vehari) of Vehari, Punjab (Pakistan) have shown the pH (7.31 to 7.71), EC (0.41 to 2.21mS/cm), TDS (282 to 1412 mg/L), HCO_3^- (92.04 to 244.05 mg/L), CO_3^{-2} (0.00 to 45.10 mg/L), Cl^- (53.40 to 460.12 mg/L), NO_3^- (1.18 to 11.02 mg/L), PO_4^{-3} (0.18 to 0.93 mg/L), SO_4^{-3}(4.81 to 228.10 mg/L), Na^+ (66 to 308.50 mg/L), K^+ (4.6 to13.42 mg/L), Ca^{+2} (7.20 to 113 mg/L), Mg^{+2} (11.40 to 40 mg/L), Fe (0.01 to 0.08 mg/L), Cu (0.00 to 0.03 mg/L), Zn (0.01 to 0.09 mg/L) and Mn (0.00 to 0.02 mg/L). However, certain physiochemical parameters were exceeding from WHO standard limits. The samples from Lalazar colony have shown higher values of Cl^- (460.12 mg/L), Na^+ (308.50 mg/L), Ca^{+2} (113 mg/L) and TDS (1412 mg/L) whereas higher TDS values were observed for the samples collected from Danewala (671 mg/L), Satellite town (557.10 mg/L), Y-Block (1061.90 mg/L), TMA 9-11 cistern (570.10 mg/L), Sharqi colony (1050.10 mg/L), Hari pura (801 mg/L), Kacha Kot (639.6 mg/L) and Madina town (543.86). The water of Lalazar Colony, College Town, Y-Block and Sharqi colony was found unfit for drinking purposes and may cause serious effect on the human health in the areas investigated.

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