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Appraisement of the Pernicious Status of Drinking Water Exposed to Precambrian Rocks of Chenab Nagar Area, Punjab, Pakistan

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Abstract: Natural and anthropogenic indulgence in the form of industrialization, urban sprawl, and population increase deplete the water resources that entails immediate consideration. So, contemplating this need for eco-rehabilitation, drinking water quality predicted in contemporary research for surface and groundwater in proximity of Precambrian rocks (Chenab Nagar, Punjab) revealed poor water quality status. Physical parameters (EC, TDS, and temperature), chemical (pH, carbonates, bicarbonates, chlorides, and heavy metals) and microbiological (total coliforms, fecal coliforms, and the absence or occurrence of *E. coli*) distinctiveness of water were determined in forty-two samples, collected from study area. The mean values of pH, EC, TDS, carbonates, bicarbonates, chlorides, and temperature for water samples fluctuated discretely in all months. Likewise, heavy metals depicted an increasing trend as the concentration of cadmium and lead was high among all analyzed metals. Microbiological study shows that large number of the samples had elevated concentration of fecal coliforms and *E. coli* bacteria thus making water harmful for human consumption.

Keywords: Groundwater, surface water, microbiological, WHO standard, drinking water.

Introduction

Overall, the current water supply coverage in Pakistan is 79%. About 7% of the rural population of Punjab depends upon rivers and dug wells for water supply. In this semi-arid region, water extracted from wells is used for domestic and agricultural purpose. Punjab might convert into a desert in the next 25 years owing to the overexploitation of groundwater resources (Aggarwal, 2019; Khan et al., 2020). Likewise, the toxicity echelon of water resources in Punjab is also grave, as high level of salinity is being experienced in this region. The Kirana hills of Precambrian age exposed in Chenab Nagar demonstrate an asymmetrical topography of a sequence of rock masses. These rocks critically affect the groundwater quality as the groundwater has high electrical conductivity and total dissolved solids in the vicinity of Kirana hills due to the chemical reaction of the water-rock interface. It is because of the chemistry of groundwater directly correlate to the chemical characteristics of aquifers and mineral composition of nearby hydrological basements (Khattak et al., 2012; Yoshida and Ahmad 2018). Present study was carried out to understand the quality (physical, chemical, and biological distinctiveness) of drinking water distributed in the area of the basement rocks exposure belonging to Kirana Hills in Chenab Nagar, and to understand anthropogenic influence on hydrochemistry of drinking water.

Materials and Methods

Total forty-two water samples (10 surface water and 32 groundwater) were collected in November 2015 and from January to May 2016 in sterilized airtight bottles. Electrical conductivity, pH, total dissolved solids (TDS), and temperature were determined as main physical parameters of water samples while carbonates (CO_3^{-2}), and bicarbonates (HCO_3^-) were analyzed by titration (Ryan et al., 2001). The pre-eminent step was the presumptive phase, in which the MPN (Most Probable Number) technique was used while the second step was perspicacious of total coliforms and fecal coliforms in plausible samples. Finally, the presence and absence of *E. coli* were checked sagaciously (Anwar et al., 2010). Generated data were statistically analyzed by comparing the values with the prescribed standards set by the World Health Organization and the National Standard of Drinking Water Quality.

Results and Discussion

The pH is one of the prime parameters that substantiate the water quality as increased pH decreases the effectivity of disinfectant in water (Adigun and Kayode, 2019). So, pH being a crucial parameter of water was collected from selected sites in November 2015 and from January to May 2016. The sequence of pH (groundwater) in November, January, February, March, April, and May came out to be 6.75-8.25, 6.54-8.01, 7.75-8.66, 6.32-8.57, 7.49-8.37, and 7.81-8.41, respectively. According to the World Health Organization (WHO) and National Standards of Drinking Water Quality (NSDWQ), the recommended limit of pH in drinking water is 6.5 to 8.5. According to a study, an increased value of pH may be due to effective equilibrium of carbon dioxide and carbonate-bicarbonate (Simpi et al., 2011).

The EC of drinking water from Chenab Nagar ranged between nil to 199 mS/cm. The values of EC ranged between 2.04-1996, 2.99-190, 2.13-1761, 0-180, 2.1-1907, 2.2-1912 during November, January, February, March, April, and May, respectively. According to WHO standard limit for electrical conductivity in drinking water is 400 µS/cm, while NSDWQ value of EC in drinking water should not exceed 1000 µS/cm (Rahmanian et al., 2015). Hence, the EC of some amount of the samples was within the acceptable limit of NSDWQ, while more water samples showed elevated EC values.

The elevated echelon of TDS in water, saltier, or bitter will be the taste of water (Colgrov, 2016). In accordance, the dominate effect of TDS during experimented months came out to be between 2.13 and 1982(g/L). The TDS should not exceed the WHO limit of 500 mg/L in drinking water, while National Standards, the recommended limit for TDS is less than 1000 mg/L. Accordingly, the TDS ranges of all sites from the studied months showed that values of TDS in samples exceed the limits by both WHO and NSDWQ (Ahmad et al., 2020). According to Akhtar et al., (2013) the increased concentration of TDS in groundwater can be allied to the overexploitation of groundwater resources while other factors contributing to the elevated concentration of TDS in the ground water samples may be due to occurrence of carbonates, bicarbonates, and chlorides.

The carbonate values in surface water for opted months that are November, January, February, March, April, and May came out to be 0.6-6, 5.1-44, 0.4-5.6, 3.6-14.4, 1.8-6.4, and 0.5-96.4 mg/L, respectively. According to WHO, no specific limit of carbonates has been given for drinking water, while according to NSDWQ, carbonates are considered as total hardness for which the recommended limit in drinking water is less than 500 mg/L (Ruma et al., 2014; Rahmanian et al., 2015). Likewise, the results of carbonates from the study area during different months illustrated that carbonates lie between the recommended limits.

The common form of alkalinity is bicarbonate, which occurs in the range of -0.2-26 mg/L. NASDAQ and WHO have not given any limit for the incidence of bicarbonates in drinking water however according to WHO carbonates and bi-carbonates come under the category of hardness. In the present study, bicarbonates were found subordinated to results obtained by Tank et al. (2010) in which bicarbonates was ranging from 109.8 to 549mg/L in drinking water. Chloride elevated content increases the EC of water which in turn increase the corrosion status. The increased concentration of chloride in metallic pipes reacts with metal ions and developed into soluble salts, subsequently increasing the metal concentration in drinking water (Meride and Ayenew, 2016). Chloride in selected water samples and results lingered between 0 and 27.6 mq/L. While according to WHO and NSDWQ, the limit of chlorides for drinking water is 250 mg/L; so, the chloride contents of all sites during different months lie between the recommended limits.

The temperature is the fundamental parameter for the analysis of water. Results revealed that the condition of water remained between 21.4 and 33.1ºC. The temperature of water samples increased during hotter months and the highest temperature was recorded as 33.1ºC in April. WHO specified limit of temperature for drinking water is 30ºC, but according to Guidelines for Canadian Drinking Water Quality, the water temperature must be around 15ºC. Temperature plays

Table 1: Physiochemical analysis of ground and surface water samples of Chenab Nagar with their average and range values from November 2015-May2016.

Samples	Months		Pb mg/L	Zn mg/L	Cd mg/L	Ni mg/L	pH	EC mS/cm	TDS g/L	CO_3 mEq/L	HCO_3 mEq/L	Cl^- mEq/L	Temp °C
Ground water	Nov 2015	A	0.27	0.18	0.24	0.44	7.25	748	766	6.41	2	3.5	22.7
		R	0.11-0.76	0.001-0.92	0.01-0.91	0.02-0.93	6.75-8.25	2.04-199	2.13-154	4.8-16		0-15	22.1-23.1
Surface water		A	0.36	0.23	0.36	0.79	6.99	803	500	3.62	2	3.94	22.32
		R	0.13-0.78	0.02-0.47	0.09-0.83	0.03-1.38	6.81-7.17	6.67-149	252-940	0.6-6		0-9	22.1-22.6
Ground water	Jan 2016	A	0.92	0.11	0.13	0.70	7.14	682	765	10.8	2	7.917	22.3
		R	0.18-0.39	0.01-0.57	0.07-0.25	0.08-1.25	6.54-8.01	2.99-190	2.75-170	4-32		0-14.8	21.9-22.9
Surface water		A	0.23	0.59	0.21	0.80	7.12	824	500	19.5	2	5.5	22.4
		R	0.19-0.28	0.02-0.45	0.07-0.99	0.41-1.15	6.01-8.5	7-123	298-901	5.1-44	--	4.9-10	22.3-22.6
Ground water	Feb 2016	A	0.14	0.11	0.01	0.007	8.19	294	568	4.35	5.07	15.43	22.42
		R	0.009-0.77	0-0.19	0.001-0.09	0-0.04	7.75-8.66	2.13-1761	2.32-186	0.4-10.4	-2.1-20	0-44.6	21.9-22.6
Surface water		A	0.16	0.12	0.01	0.004	8.06	633	399	3.33	17.64	3.95	22.29
		R	0.02-0.6	0.05-0.25	0.002-0.03	0.002-0.007	7.02-8.36	2.98-147	2.34-936	0.4-5.6	-2.8-10.4	0.4-11	21.4-22.6
Ground water	Mar 2016	A	0.017	0.083	0.064	0.016	7.42	481.4	600	6.04	1.12	8.24	24.05
		R	0-0.28	0.01-0.38	0.001-0.27	0-0.317	6.32-8.57	0-180	2.15-179	0.8-55	-3.2-26	0-27.6	23.1-25.8
Surface water		A	0.009	0.042	0.048	0.002	7.56	730.4	472.4	6.8	5.1	4.06	24.14
		R	0.004-0.02	0.005-0.09	0.001-0.09	0.0009-0.0054	6.37-8.44	0-174	61.4-110	3.6-14.4	-0.4-26	1-13.8	23.7-24.6
Ground water	Apr 2016	A	0.009	0.031	0.325	0.532	7.93	453.6	593.1	3.98	0.8	6.02	32.1
		R	0.001-0.01	0.0179-0.098	0.25-0.40	0.12-0.96	7.49-8.37	2.1-1907	2.4-1982	0.8-11.6	-3.1-11.6	0.2-20.8	30.4-33.1
Surface water		A	0.013	0.035	0.298	0.455	7.93	543.5	575.2	4.73	0.84	2.94	32.4
		R	0.001-0.009	0.02-0.09	0.13-0.34	0.03-0.98	7.7-8.2	2.8-1249	3.6-1103	1.8-6.4	0-7.2	1.2-10.1	31.5-32.8
Ground water	May 2016	A	0.17	0.004	0.28	0.03	7.922	397	596	4.462	1.9	12.20	28.04
		R	0.01-0.5	0-0.02	0.1-0.40	0-0.42	7.81-8.41	2.2-1912	2.3-1916	-0.8-40.8	-2.5-10.6	2-28.6	27.9-29.6
Surface water		A	0.15	0.003	0.29	0.002	8.261	909	572.66	11.056	0.36	8.23	28.88
		R	0.02-0.28	0.001-0.006	0.21-0.33	0.0008-0.008	8.1-8.4	5.7-1505	3.6-948	0.5-96.4	-2.2-2.6	1.8-15.6	28.5-29.4
Permissible limits	WHO		0.01	3	0.003	0.07	7.5-8.5	-	500-1000 mg/L	-	-	250mg/L	30
	NSDWQ		≥0.05	5	0.001	≥0.02	7.5-8.5	1000 µS/cm	>1000 mg/L	>500 mg/L	-	250mg/L	-

an important role in controlling biological and chemical characteristics, as with the decrease in water temperature, the bacterial activity radically decreases and vice versa. Side by side, an increase in water temperature results in an awful odor. So, the temperature of the water is the best indicator to determine that the quality of water body is suitable for human utilization and consumption (Water CD, 2021). Subsequently, the analyzed water temperature is within the tolerable limit prescribed by WHO except for water samples in April.

Heavy Metal Toxicity

Drinking water having heavy metals elevated concentration is harmful to human well-being and health. This study also involved heavy metals (Zn^{+2}, Pb^{+4}, Cd^{+2}, Ni^{+1}) investigation and results were matched with WHO and NSDWQ set limits. Heavy metals content in the drinking water samples of Chenab Nagar with their average values during selected months is displayed in Table 1. Lead (Pb), a deleterious heavy metal may enter into the hydrosphere environment by various routes; mainly by piping used within the delivery system or domestic plumbing and lead paints industry. Following WHO, the permissible limit for Pb in drinking water is 0.01 mg/L. According to NSDWQ, the suggested limit of lead in drinking water is less than or equal to 0.05 mg/L. The Pb contamination level in collected drinking water samples remained at 0 to 0.78 (mg/L) and the highest concentration might be due to the piping system used in the water distribution channel. While comparing obtained values with guidelines of WHO and NSDWQ, it was found that the concentration of Pb was exceeding the permissible limits in all investigated months. This shows that water is not secure for consumption. Increased lead concentration in drinking water may be due to the composition of boreholes and open-dug wells containing this metal which is in line with various previous studies (Adekunle, 2007; Quagraine, 2010; Rossiter, 2010; Rahman, 2011; Sorlini et al., 2013).

The concentration of Zinc (Zn) directly depends on higher contents of other metals mainly cadmium and lead while the anthropogenic sources of lead in water channels include coal-fired power stations, by-products of steel production, and smoldering of waste material. The premeditated range of zinc in the present study was from 0-0.92 (mg/L). Following WHO, the concentration of Zn should not be greater than 3 mg/L while according to NSDWQ, the recommended limit of Zn in drinking water is 5 mg/L. So, the concentration of Zn in all samples lies within the permissible limits prescribed by WHO and NSDWQ. The Zn is an indispensable element playing an imperative role in the physiological processes of organisms but increased concentrations may lead to toxicity (Kuma, 2004; Obiri, 2007; Paruchuri, 2010; Cobbina et al., 2015).

According to Rahmanian et al. (2015), there are diverse sources both anthropogenic and natural, through which Cadmium (Cd) enters into the water body. The foremost source of cadmium ingress into surface water and groundwater is from soil and rocks which naturally contain cadmium. While, the anthropogenic factors include mining and smelting operations, effluent by paints and pigments industry, discarding of sewage sludge, electroplating, and fossil fuel operations. The range of Cadmium was found to be between nil to 0.99 (mg/L). According to WHO, the recommended limit for Cd is 0.003 mg/L while according to the National Standards of Drinking Water Quality, the prescribed limit of Cd in drinking water is 0.01 mg/L. Cd exceeds the limits given by WHO and NSDWQ, during November and January while in February some samples showed a higher trend than set limits while others were within the permissible limits. The samples during March also showed increasing trend. However, in April, some samples are free from the cadmium, while others are slightly higher in Cd concentration; making water unsuitable for human consumption. Samples collected in May are within the required limit. Samples with a higher concentration of Cd may be due to the pre-Cambrian rocks present near water sources.

Table 2. Discrepancy in the microbiological parameters of the ground and surface water samples of Chenab Nagar from November 2015-May 2016.

Samples	Months	Presumptive phase			Coliforms and Fecal coliforms	E. coli	Sample		Presumptive phase			Coliforms and Fecal coliforms	E. coli
		10 (ml)	1 (ml)	0.1 (ml)					10 (ml)	1 (ml)	0.1 (ml)		
Ground water	Nov 2015	0	0	0	0	0	Surface water	Nov 2015	0	0	0	0	0
	Jan 2016	3	0	1	0	0		Jan 2016	1	0	1	0	0
	Feb 2016	20	15	5	0	0		Feb 2016	9	3	3	0	0
	Mar 2016	32	24	21	12	8		Mar 2016	10	10	9	10	2
	Apr 2016	22	12	13	9	7		Apr 2016	9	0	1	7	3
	May 2016	27	13	13	10	9		May 2016	10	3	3	5	3

The main source of Nickel (Ni) in drinking water is its dissolution from nickel ore-bearing rocks and leaching from pipes. Present study reveals increased nickel toxicity level in drinking water samples collected from different water sources present near Precambrian rocks. The recommended limit of Ni is 0.07 mg/L as prescribed by WHO while, NSDWQ, the recommended limit of Ni in drinking water is less than or equal to 0.02 mg/L. The concentration of Ni during November, January, April, and May were exceeding the permissible limit as for drinking water whilst it was within the standard limit during March and February.

Microbiological Parameter

The microbiological analysis of the drinking water of Chenab Nagar substantiates the prevalence of *E. coli* in water which leads to many waterborne diseases. The results show that the growth of E. coli has unswerving relation with temperature. As, in winter months the growth of *E. coli* was less; conversely, the growth of *E. coli* escalates with increase in temperature (Table 2). It is because of fact that *E. coli* requires high temperatures to thrive. Temperature affects both the biological and chemical characteristics of water since it directly impinges the DO (Dissolved Oxygen) level in the water and metabolic rates, growth and reproduction of aquatic beings as with warmer temperature the requirement of DO to accomplish 100% air saturation gets reduced so more number of bacteria and pathogens have chances to grow (Hannan et al., 2010; Kale, 2016). Likewise, the analysis of drinking water from selected sites in the present study confirmed the presence of *E. coli* and coliforms. Therefore these samples were all unsafe and unhealthy for human consumption. This is because they may have cross-contamination with sewerage pipelines.

Conclusion

It is concluded that pH of water samples was within internationally recommended limits whilst EC and TDS concentration exceeded the threshold values. Along with that, heavy metals and microbiological contaminations were at a disquieting state; as lead and cadmium were high in concentration owing to Precambrian rocks and some anthropogenic pursuits like throwing garbage in watercourses. In the case of microbial infectivity, it was verified that fecal coliforms particularly *E. coli* were present in the escalated amount due to mixing of untreated sewage water with drinking waterways. Likewise, the summer season shows a higher trend of microbial growth (*E. coli).* Present study shows that Chenab Nagar is facing serious problem of water perniciousness and people are consuming contaminated water that entails instantaneous steps.

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