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Original Research

Bacteriological and Physico-Chemical Quality of Main Drinking Water Sources

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Abstract

Drinking water quality assessment in Mahabubnagar has been always been crucial with reference to public health. A study was conducted to evaluate the bacteriological and physico-chemical analysis of drinking water supply of the Mahabubnagar district in India. Four samples were collected from Ramanpadu and Koilsagar water (both natural reservoir and filtered), and for each sample bacteriological parameters and chemical parameters were evaluated. The bacteriological results indicated that the bacterial count was highest in Ramanpadu water (RP-736 CFU/ml) and the least count was found in Koilsagar water (KS-06 CFU/ml). The total plate count revealed the highest count in Koilsagar filter (KSF) water and the least in Koilsagar (KS) water. The most probable number method was used to detect and count the total coliform and *E. coli*. Results revealed that the one indicator bacteria were present in two samples (RP and RPF). The samples were monitored for the various physicochemical parameters comprising pH, EC, color, turbidity, phenolpthalene alkalinity, methyl orange alkalinity, total alkalinity, total hardness, phenolic compounds, anionic detergents, residual chlorine, mineral oil, polynuclear aromatic hydrocarbons as PAH, cyanide, Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, HCO_3^-, SO_4^{2-}, NO_3^-, Cl^-, F^-, and trace metals such as Fe, Cu, Mn, Zn, Cd, Pb, Hg, Se, Ag, and Cr. The pH of water samples was alkaline and varied from 7.21 to 7.96, and the mean value was 7.52. In this study, all 4 samples did not exceed the reference values for chemical parameters. The results showed that physiochemical parameters are within permissible limits.

Keywords: drinking water, public health, coliform, CFU, physico-chemical parameters

Introduction

The microbiological quality of water is measured by the analysis and enumeration of indicator microorganisms [1]. It is estimated that around 37.7 million Indians are affected by waterborne diseases annually, including about 1.5 million children who are estimated to die of diarrhea each year. The resulting economic burden is estimated at $600 million a year [2].

Chemical pollutants can cause a different type of intoxication. The effects of inorganic chemicals are better known than those of trace levels of organic chemicals detected in groundwater. The list of groundwater contaminants includes hydrocarbons, metals, cyanide, arsenic, various synthetic substances, plus soluble forms of nitrogen, phosphorous, and organic matter [3-5]. Growing demand for energy during the last few decades has affected the physico-chemical parameters and biological attributes of the ground and surface water [6]. Depending on the source, raw water may contain a wide variety of harmless heterotrophic microorganisms such as *Flavobacterium* spp., *Pseudomonas* spp., *Acinetobacter* spp., *Moraxella* spp., *Chromobacterium*, *Achromobacter* spp., and *Alcaligenes* spp., as well as numerous unidentified or unidentifiable bacteria [7-9], but

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there also are a wide variety of pathogenic bacteria that cause severe diseases like diarrhea, gastric enterititis, and food poisoning The quality of water for drinking has deteriorated because of the inadequacy of treatment plants, direct discharge of untreated sewage into rivers, and inefficient management of piped water distribution systems [10]. Groundwater represents an important source of drinking water, and its quality is currently threatened by a combination of over-abstraction and microbiological and chemical contamination [11].

It recent years more and more hydro biological studies have been focusing on the studies of chemical and bacteriological parameters that are characteristic of surface and subsurface layers of the estuarine water [12].

In Indian context, studies on the physicochemical and biological parameters of water resources are utilized to predict the pollution level and framing of suitable strategies for restoration and remediation measures. The results on the study will provide the preliminary information on the chemical and microbial load that may be useful in projecting the strategies required for the appropriate measures for remediation of the water. The findings may be considered as a basis for water health policy decisions at different administrative levels in the study area.

The objective of this research was to determine the bacteriological and physico-chemical quality of the Ramanpadu Balancing Reservoir and Koilsagar Reservoir (both natural reservoirs and filtered water).

Material and Methods

Study Area

Mahabubnagar is one of the drought districts in Andhra Pradesh. The geographical area of the district is 18,432 km^2, consisting of 64 mandals with 1,549 villages. Mahabubnagar is the district headquarters town of Mahabubnagar district, which lies between north latitudes 15º55'00" and 17º20'00" and east longitudes 77º15'00" and 79º15'00". The main sources of potable water in the township of Mahabubnagar are the Ramanpadu Balancing Reservoir and Koilsagar Reservoir.

Ramanpadu is a balancing reservoir under the left-hand canal of the Jurala project. A 64 km Ramanpadu drinking water pipeline project started in 1999 for the town of Mahabubnagar to reduce its drinking water problem. More than 2 lacks population of the town requires 13 million litres of water every day, whereas the Ramanpadu water scheme was designed to lift 18 million litres of Krishna water every day.

Koilsagar Dam is located at Koilsagar Village of Deverakadra Mandal in Mahabubnagar District. Koilsagar Dam is built on a minor tributary of the Krishna River. The proposal to construct a dam was put forward by the British rulers to collect and store the excess water in a catchment area of the Krishna River for irrigation purposes.

Water Sample Collection

The samples were collected in autoclaved bottles (1 liter capacity) under aseptic conditions from different sources in a manner to avoid contamination of water with other atmospheric bacteria. The water from the reservoir was collected in sterile bottles by opening at a depth of about 30 cm with its mouth facing the current and ensuring that the water entering the bottle has not contacted the hand or the water treatment plant. The sample bottles were capped and labeled with details of the source of water, time, and date of collection. The samples were assessed within 6 h of collection for their physio-chemical and bacteriological quality using most the probable number (MPN) test and further studies.

Water Quality Analysis

Various physico-chemical parameters pH, EC, color, turbidity, phenolpthalene alkalinity, methyl orange alkalinity, total alkalinity, total hardness, phenolic compounds, anionic detergents, residual chlorine, mineral oil, polynuclear aromatic hydrocarbons such as PAH, Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, HCO_3^-, SO_4^{2-}, NO_3^-, Cl^-, F^- and heavy metals such as Fe, Cu, Mn, Zn, Cd, Pb, Hg, Se, CN, Ag, Cr were determined.

Bacteriological Analyses

The bacteriological quality of water samples was assessed by the MPN test and Total Plate Count Method. Numbers of bacteria are also important, as well as their survival and possibilities to adapt and migrate deep into water-bearing underground reservoirs. Some of the bacteria, such as *Pseudomonas* or *Aeromonas*, may be a threat to human health due to their ability to multiply in drinking waters. Others, especially those which constitute natural micro flora of human and animal food tracts, can induce acute or chronic gastric diseases [14].

Prevalence of Total Coliform and *E. coli*

Total plate count can indicate the total count of bacteria in water, purification treatment efficiency, and the polluted degree of pipes. Too high total bacterial count means that the water is perfectly disinfected and the water has already been polluted by microbes [15]. Therefore, total plate count is an important parameter indicating whether the drinking water has been polluted by microbes, and can be used essentially to assess the disinfection effect. Drinking water with a total plate count of 100-500 CFU/ml will harm the health of human beings [16]. The present standard issued by BIS is 100 CFU/ml.

The MPN test revealing total coliforms per 100 ml water samples indicated that the quality of water samples was poor. MPN values in the samples of Ramanpadu Reservoir clearly indicate that the drinking water is contaminated with coliform bacteria.

Table 1. CFU and colony morphology of colonies on different microbial media.

S. No.	Sample	CFU				Unique colonies/colony morphology/pigmented colonies and colonies streaked on plates			
		NA	LBA	SBA	ZMA	NA	LBA	SBA	ZMA
1.	RP	380	736	346	17	1. small round cream 2. cluster large 3. cream round large	1. yellow round large 2. small round cream	1. small round cream 2. cluster large 3. white powdery 4. yellow small round	1. cream large round 2. cluster white small 3. small round yellow
2.	RPF	71	87	27	25	1. transparent round large 2. yellow round large 3. cream round large 4. cream round small	1. yellow round large 2. transparent round small 3. cream round large 4. orange round small	1. orange round large 2. transparent large 3. cream round 4. transparent round small	1. yellow round 2. cream round 3. transparent round small
3.	KS	28	49	42	6	1. cream round small 2.transparent round 3. cream large round	1. orange round large 2. cream small round 3. cream round large	1. cluster large 2. orange round large 3. cream round large 4. small round yellow	1. yellow round small 2. orange round large 3. cream round small 4. transparent round small
4.	KSF	381	723	560	1	1. cream round small 2. yellow round small	1. cream round small 2. yellow round small	1. cream round small 2. yellow round small	1. cream round small

RP – Ramanpadu Water, RPF – Ramanpadu Filter Water, KS – Koil Sagar Water, KSF – Koil Sagar Filter Water

Results and Discussion

In this research, the color values varied from 0 (clear) to 11 hazens. The suspended sediments in the water give a muddy or turbid appearance. Odor and taste in the water samples were acceptable. Temperature varied between 27ºC to 30ºC. Temperature can directly affect the growth and survival of microorganisms.

It is suggested that turbidity of more than 1 nephelometric turbidity unit (NTU) will influence disinfection efficiency; turbidity more than 5 NTU can be identified by the naked eye. In this research, the turbidity of all water samples has met the drinking water standards.

In the study area, the pH value of water samples is 7.21-7.96, which indicated that the pH value has met the drinking water standards. The electrical conductivity with 400 µ mhos/cm at 25ºC is considered suitable for human consumption and greater than 1,500 µ mhos/cm at 25ºC may cause corrosion of iron structures. In the study area, an electrical conductivity value ranges from 498-797. TDS (total dissolved solids) is an important parameter of drinking water quality testing that denotes the presence (or absence) of various kinds of minerals, like chlorides, sulphates, and phosphates, and ions like calcium, magnesium, potassium and iron, etc., in water. Its value varied from 290-491 mg/L. High amounts of dissolved solids (above 500 mg/L) impart a particular taste to water and reduce its palatability.

Alkalinity in natural waters is a result of dissolution of CO_2 in water. Carbonates and bicarbonates thus formed are dissociated to yield hydroxyl ions. In the samples analyzed, total alkalinity ranged from 123-151 mg/L, drinking water having alkalinity less than 200 mg/L is desirable for domestic purposes. The alkalinity value is essential to evaluate the dose of disinfection in water treatment practices and defluoridation processes.

The total hardness of water was caused mainly by dissolved calcium salt and magnesium salt from the surrounding ores. The hardness will influence the taste of water, but the taste threshold differs from person to person. If the total hardness is too low, the water may accelerate pipe erosion; when the total hardness is too high (higher than 200 mg/L), boiler scale and water scale will form in the heating process. From the angle of favorable taste, the total hardness is standardized at 10-100 mg/L as $CaCO_3$. It is suggested in this research that water treatment plant sources supply water of higher total hardness at about 158 mg/L, which is still lower than the standard value.

The application of chlorine is essential to insure the safety of drinking water. When the concentration of chlorine in water is about 2-3 mg/L, people can smell an irritant odor. In consideration of the feeling of most people and the disinfection efficiency of residual dosage, WHO recommends that the residual chlorine in drinking water takes 0.6-1.0 mg/L as standard [16]. In the test for free available residual chlorine, almost no residual chlorine can be detected in all samples. The cyanide concentration in all the water samples is <0.01 mg/L and is in desirable limit of BIS standards. The anionic detergents were absent in all the water samples. In this research the Mineral oil in the water samples is <0.01 mg/L. Among the cations, Ca^{2+}, Mg^{2+}, Na^{+}, and K^{+} ions range from 24 to 36, 11.06 to 17.01, 76 to 103, and 2.1 to 3.8 mg/L (Table 2), with a mean of 28.25, 14.80, 82.25, and 3.11 mg/L, respectively. Dissolved anions, Cl^{-}, SO_4^{2-}, NO_3^{-}, and F^{-}, lie between 70 and 104, 12 and 80, 8.0 and 14, and 0.82 and 0.96 mg/L, with a mean of 89.5, 49, 11.5, and 0.89 mg/L, respectively.

The principal polycyclic aromatic hydrocarbons (PAHs) include phenanthrene, fluoranthene, pyrene, anthracene, benzo (a) pyrene (BaP), benzofluoranthene, chrysene, anthanthrene, and naphthalene. PAHs are wide-

Table 2. Comparison of physico-chemical parameters with the IS Norms for drinking water.

S. No.	Parameters	RP	RPF	KS	KSF	Desirable Limits (as per IS:10500-1991)	Permissible Limits (as per IS:10500-1991)
1	Color	2.0	Clear	8.0	11	5 max	25 max
2	Odour	Unobjection-able	Unobjection-able	Unobjection-able	Unobjection-able	Unobjectionable	-
3	pH	7.52	7.96	7.21	7.40	6.50-8.50	-
4	E.C (microomhos/cm)	759	797	498	533	-	-
5	Total dissolved solids	460	491	290	316	500 max	2000 max
6	Phenolpthalene alkalinity	Nil	Nil	Nil	Nil	-	-
7	Methyl orange alkalinity	144	151	131	123	-	-
8	Total alkalinity	144	151	131	123	200 max	600 max
9	Total hardness	150	158	120	98	300 max	600 max
10	Calcium	32	36	24	21	75 max	200 max
11	Magnesium	17.01	16.53	14.58	11.06	30 max	100 max
12	Sodium	103	108	42	76	-	-
13	Potassium	3.60	3.80	2.95	2.10	-	-
14	Copper	0.05	0.04	0.04	0.02	0.05	1.50
15	Iron	0.16	0.15	0.13	0.11	0.3 max	1.0max
16	Manganese	<0.01	<0.01	<0.01	<0.01	-	-
17	Chlorides	104	109	70	75	250 max	1000 max
18	Sulphates	76	80	12	28	200 max	400 max
19	Nitrates	13	14	8.0	11.0	45 max	100 max
20	Fluorides	0.85	0.82	0.96	0.94	1.0 max	1.5 max
21	Phenolic compounds	<0.001	<0.001	<0.001	<0.001	0.001	0.002
22	Mercury	<0.001	<0.001	<0.001	<0.001	0.001	No relaxation
23	Cadmium	<0.004	<0.004	<0.004	<0.004	0.01	No relaxation
24	Selenium	<0.01	<0.01	<0.01	<0.01	0.01	No relaxation
25	Cyanide	<0.01	<0.01	<0.01	<0.01	0.05	No relaxation
26	Lead	<0.04	<0.04	<0.04	<0.04	0.05	No relaxation
27	Zinc	0.01	0.008	0.03	0.015	5.0	15
28	Anionic detergents	Absent	Absent	Absent	Absent	0.2	1.0
29	Residual chlorine	<0.04	<0.04	<0.04	<0.04	0.2	-
30	Pesticides	Absent	Absent	Absent	Absent	Absent	0.001
31	Silver	<0.01	<0.01	<0.01	<0.01	-	-
32	Mineral oil	<0.01	<0.01	<0.01	<0.01	0.01	0.03
33	Hexavalent chromium	<0.01	<0.01	<0.01	<0.01	0.05	No relaxation
34	Polynuclear aromatic hydrocarbons	Absent	Absent	Absent	Absent	-	-

All the values are expressed in mg except pH and E.C

spread throughout the environment. Contamination of drinking water can occur by direct atmospheric deposition and by leaching from bituminous liners in water distribution systems. PAHs were absent in all samples.

Water bodies get polluted with trace metals from a variety of sources, such as chemical weathering of rocks and soils, dead and decomposing vegetation and animal matter, and humanity's activities, including the discharge of various domestic and industrial effluents [17, 18]. The natural water analysis for physical and chemical properties, including trace element contents, are very important for public health studies. These studies also are a main part of pollution studies in the environment [19].Though trace metals, such as zinc, chromium, manganese, cadmium, cobalt, etc., play a biochemical role in aquatic life, their excess presence is toxic and non-biodegradable. The quality of water with regard to the concentration of trace metals Fe, Cu, Mn, Zn, Cd, Pb, Hg, Se, Ag, and Cr is assessed, and to get an idea about the distribution pattern of the metal contents in water, data are represented below (Table 2).

Total plate count can indicate the total count of bacteria in water. Too high total bacterial count means that the water is perfectly disinfected and the water has already been polluted by microbes [11]. Therefore, total plate count is an important parameter indicating whether the drinking water has been polluted by microbes, and can be used essentially to assess the disinfection effect. Drinking water with a total plate count of 100-500 CFU/ml will harm the health of human beings [12]. The present standard issued by BIS is 100 CFU/ml. The TPC of all water samples were above the standards. The MPN test revealing total coliforms per 100 ml water samples indicated that the quality of Water samples was very poor. MPN values in the samples of Ramanpadu Balancing Reservoir clearly indicate that the drinking water is contaminated with coliform bacteria. The Bureau of Indian Standards (BIS) prescribed the total plate count limit as 100 CFU/ml at 22ºC in 72 h on nutrient agar. In this study, TPC, total coliforms and *E. coli* have crossed the permissible levels of BIS guidelines. The CFU and the colony morphologies on different bacteriological media are listed in Table 1.

Different bacteriological media were used for the culturing of bacteria from water samples to ensure maximum bacterial diversity. Zobell's Marine Agar (HIMEDIA, India) medium was used for isolation of heterotrophic bacteria present in seawater as well as sediment. The medium was supplemented with 500 JM phosphate, using KH_2PO_4 (BDH) in addition to the phosphate already available in the ready-made medium. Final concentration of phosphate in the medium, after the addition of 50000M of (KH_2PO_4), was 1800 M (after autoclaving). Marine agar is prepared according to Zobell's, containing almost double the mineral content of sea water. The high salt content helps to simulate sea water. Bacteriological peptone provides nitrogen, vitamins, minerals, and amino acids essential for growth. Yeast extract is a source of vitamins, particularly of the B group.

Soybean Agar medium contains enzymatic digests of casein and soybean meal, which provides amino acids and other nitrogenous substances, making it a nutritious medium for a variety of organisms. Glucose is the energy source. Sodium chloride maintains the osmotic equilibrium, while dipotassium phosphate acts as buffer to maintain pH.

The CFU was found to be highest on LB agar plates (736) than all others used. A wide variety of colonies were found before and after filtration (Fig. 1).

Conclusion

The current major obstacles to human health in developing regions are well understood and a large component relates to unsafe water, poor sanitation, and inappropriate hygiene. Coliform concentrations were higher than the maximum permissible limit and the physicochemical parameters fully meet the sanitary requirements; therefore the waters from both reservoirs, Ramanpadu and Koilsagar, are not suitable for public supply. The bacteria may become the source of various diseases, the intensity of which would largely depend on microorganism pathogenecity and disease potential. The results from this study further insist on the molecular diversity and bacterial population dynamics of potable water bacterial communities. Moreover, the development of molecular analysis is further needed to target the pathogenic bacteria in potable water. In conclusion, despite our efforts, pathogens and chemical quality of drinking water always will be a major issue for human health, and particularly in developing regions.

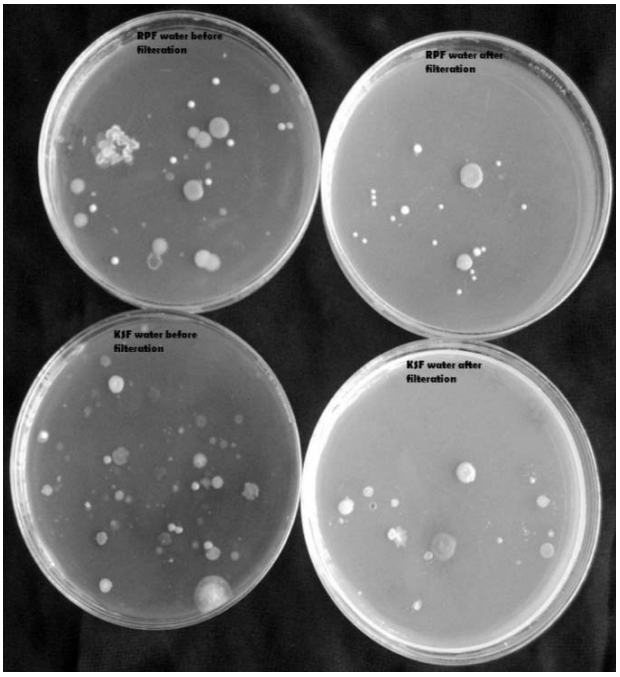

Fig. 1. Bacterial diversity in Ramanpadu and Koil Sagar drinking water source before and after filtration.

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