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Conservation of Drinking Water in Public Sector Rural Supply

P. Lakshmi Ganapati[1], V. Ranga Rao[1], P. V. S. Machiraju[2], and Mannam Krishna Murthy[3]*

1. Department of Chemistry, Government College (A), Rajahmundry, **INDIA**
2. Department of Chemistry, Pragati Engineering College (A), Surampalem-533437, **INDIA**
3. Acharya Nagarjuna University Research Centre, SVRM College, Nagaram-522 268, **INDIA**

Email: mannamkm@gmail.com

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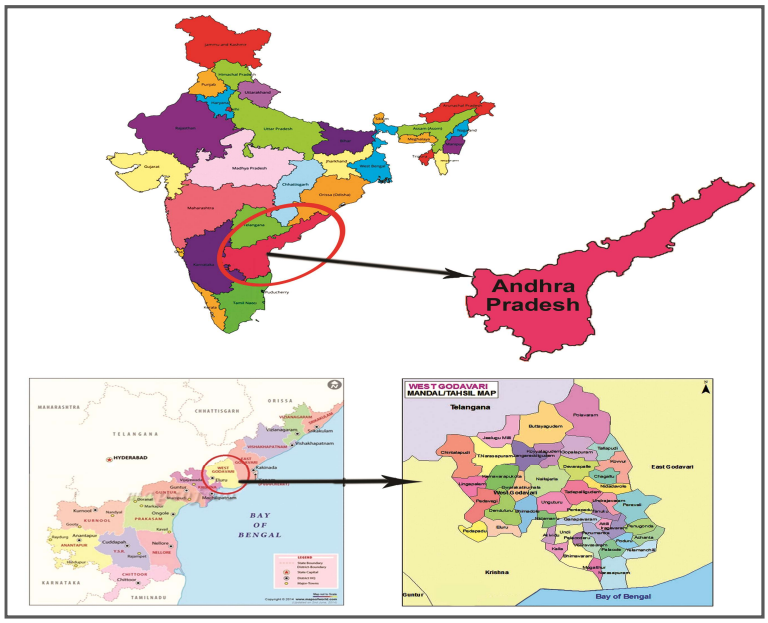
ABSTRACT

Water conservation is now an important global task. Potable water supply of public sectors in the rural area of West Godavari district of India was selected. Physicochemical characterization of water samples was carried and analyzed. The results were consolidated and useful conclusions were drawn.

Graphical Abstract



Andhra Pradesh **West Godavari Region**

Selected study areas and their satellite pictures

Keywords: Water conservation, Chemical analysis, Human heath, Public sector, Rural water.

INTRODUCTION

Water sustains agriculture, industry, energy and life. It is the key compound in our daily life. Good quality potable water may be consumed in any desired amount without adverse effect on health. Over large parts of the world, humans have inadequate access to potable water and use sources contaminated with pathogens, disease vectors, unacceptable levels of toxins and suspended solids. Reduction of waterborne diseases is a major public health goal in developing countries. Rural India has more than 700 million people residing in about 1.42 million habitations spread over 15 diverse ecological regions. Meeting the drinking water needs of such a large population can be a daunting task. The problems of chemical contamination are thus prevalent in India with 1, 95,813 habitations in the country are affected by poor water quality [1].

The health burden of poor water quality is enormous. It is estimated that around 37.7 million Indians are affected by waterborne diseases annually 1.5 million children are estimated to die of diarrhea alone and 73 million working days are lost due to waterborne disease each year [2]. India has 16 per cent of the world's population and four per cent of its fresh water resources. It is expected that by around 2020, India will be a *'water stressed'* state with per capita availability declining to 1600 cu.M person^{-1} year^{-1} [3]. A country is said to be water stressed when the per capita availability of water drops below 1700 cu.M person^{-1} year^{-1}. The provision of clean drinking water has been given priority in the Constitution of India. Rural Water Supply (RWS) programme in India can be divided into several distinct phases [4]. The present proposed research study can generate a baseline on the physicochemical parametric levels, metal ion concentrations and the type of bacterial species present in drinking waters in the study area. Protection of drinking water sources from contamination and their elimination have become important and improvements in water supplies are believed to reduce the transmission of pathogens and thus improve children's growth rate and concomitantly reduce mortality rates [5]. Considering the multiple causes of disease and death, it is therefore essential to look at all these problems in an integrated water management fashion [6].

A systematic review showed that water contamination occurs between source and point-of-use [7]. This pattern has been confirmed by subsequent studies of water contamination [8]. Access to safe drinking water and sanitation is a global concern, especially in recent years, it has been increasingly addressed as one of the basic human rights of nations. However, in most rural areas of the developing world, safe drinking water from an improved source and sanitation services remain unacceptably lacking. Despite the importance of these issues in the political agenda, water policies in many countries do not promote the creation of appropriate institutions to manage water needs and enhance supply and maintenance capabilities [9].

MATERIALS AND METHODS

It is proposed to select two Mandal Head Quarters in Jangareddygudem Revenue Division of West Godavari Region of Andhra Pradesh (India) for the present research study. The selected two Mandal Head Quarters are Buttayagudem, Gopalapurm. Sample Number, Area of Sampling, Status, Source type, Date of samples collected (in both pre and post monsoon seasons) and coordinates are presented in table 1. Selected study areas and their satellite pictures are presented in figure 1.

Characterization for physicochemical parameters: RWS Drinking water samples collected before and after treatment were labeled with code numbers W-1 (Before Treatment), W-2, W-3, W-4 and W-5 (After Treatment) from the above identified Mandal Head Quarters during Pre and Post Monsoon seasons were characterized for physicochemical parameters viz., pH by pH meter, Electrical conductivity (EC) by Conductivity meter, Total Dissolved solids (TDS) using the relation ECx0.64, Total Hardness (TH), Total Alkalinity (TA) and chloride (Cl^-) by Titrimetry. Calcium (Ca^{2+}), magnesium (Mg^{2+}) estimated from hardness. Sodium (Na^+), potassium (K^+) by flame photometry.

Fluoride (F^-), sulphate (SO_4^{2-}) nitrate (NO_3^-) and phosphate (PO_4^{3-}) by spectrophotometry followed the standard analytical procedures.

Table 1. Sample code, Area of Sampling, Status, Source type and parameters

Jangareddygudem Revenue Division					
MHQ Code-2A: Buttayagudem Mandal Head Quarter					
Sample No.	**Area of Sampling**	**Status**	**Source**	**Longitude**	**Latitude**
W-1	Inflow of RWS tank	BT	GW	$81^0.31^1$ E	$16^0.85^1$ N
W-2	Near RWS station	AT	TW		
W-3	Devudi manyyam				
W-4	BSNL Exchange				
MHQ Code-2B: Gopalapuram Mandal Head Quarter					
W-1	Bore at main road	BT	GW	$80^0.25^1$ E	$13^0.05^1$ N
W-2	Near Panchayathi	AT	TW		
W-3	Near high school				
W-4	Near Sivalayam				

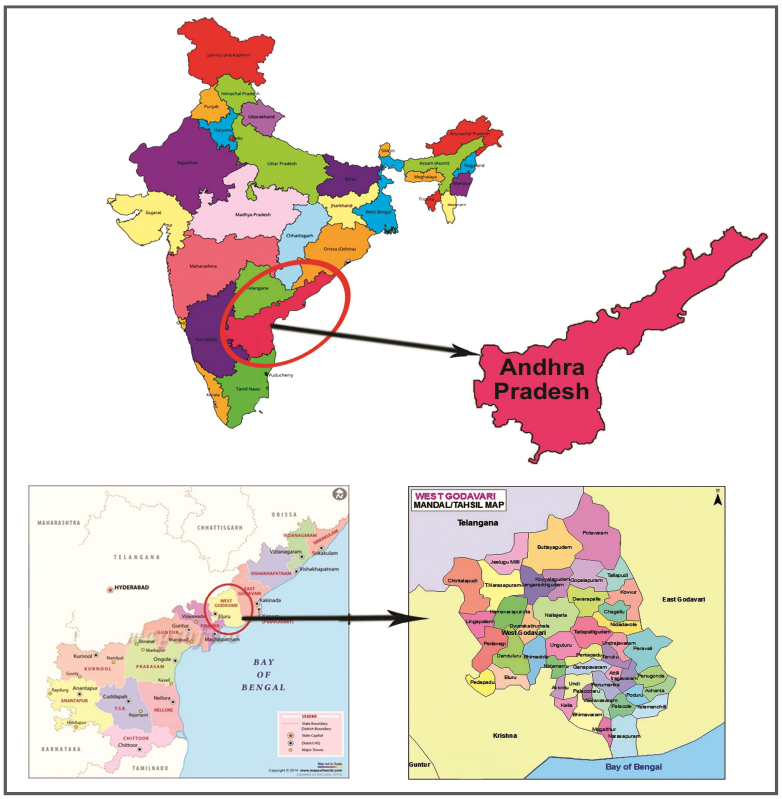


Figure 1. Selected study areas and their satellite pictures.

Andhra Pradesh **West Godavari Region**

Characterization for Metal ions: Representative sample of treated drinking waters were collected from Buttayagudem, Gopalapuram Mandal Head Quarters of Jangareddygudem Revenue Division during pre and post monsoon periods and were characterized for Metal ions by employing ICP-MS technique and the analytical data is presented in ppm in table 2.

Table 2. Characterization of metals in water samples

Metal ion Concentration (ppm)	Representative sample location			
	Buttayagudem		Gopalapuram	
	Pre-monsoon	Post -monsoon	Pre-monsoon	Post-monsoon
Li	0.0020	0.0018	0.0011	0.0010
Be	ND	ND	ND	ND
Al	0.0239	0.0165	0.0055	0.0091
V	0.0007	0.0010	0.0007	0.0011
Cr	0.0006	0.0010	0.0007	0.0016
Mn	0.0017	0.0009	0.0006	0.0024
Fe	0.0228	0.0146	0.0029	0.0130
Co	ND	ND	ND	0.0003
Ni	0.0008	0.0011	0.0010	0.0021
Cu	0.0029	0.0021	0.0010	0.0016
Zn	0.0547	0.0171	0.0043	0.0071
As	ND	ND	0.0001	0.0001
Rb	0.0021	0.0017	0.0030	0.0029
Sr	0.3218	0.4232	0.2123	0.2464
Ag	ND	ND	ND	0.0001
Cd	0.0001	ND	ND	ND
Cs	ND	ND	0.0001	0.0001
Ba	0.0571	0.0616	0.0799	0.0939
Tl	ND	ND	0.0002	0.0002
Pb	0.0026	0.0006	0.0005	0.0009
U	0.0015	0.0018	0.0065	0.0076

RESULTS AND DISCUSSION

pH: pH of water before treatment in Buttayagudem, Gopalapuram is 8.3, 7.9 respectively, while the average pH of water after treatment is 7.7, 7.5 respectively (Pre- monsoon). pH of water before treatment of the two Mandals is 7.9, 7.9 respectively, while the average pH of water after treatment is 7.85, 7.7 respectively. The pH levels of water during both seasons are within the permissible limit of drinking water standards [2] (Post monsoon). The pH level of water indicates the slight alkaline nature of water.

Electrical Conductivity (EC): EC of untreated waters of Buttayagudem, Gopalapuram is 819, 621µmhos cm^{-1} respectively, while the average EC of treated waters is 787, 616 µmhos cm^{-1} respectively. Higher levels of EC in waters of Buttayagudem indicate slightly saline nature (Pre-monsoon). EC of untreated waters of the above two Mandals is 682, 643 µmhos cm^{-1} respectively; while the average EC of treated waters is 634, 547µmhos cm^{-1} respectively (Post monsoon).

Total Dissolved Solids (TDS): TDS of waters before treatment of Buttayagudem, Gopalapuram is 524, 279.7 mg L^{-1} respectively. The average TDS is 496.3, 402.4 mg L^{-1}respectively in waters after treatment (Pre- monsoon). TDS of waters before treatment of the above two Mandal is 436.4, 293.8 mg L^{-1} respectively. The average TDS is 403.8, 353.6 mg L^{-1} respectively in waters after treatment (Post monsoon).

Total Hardness (TH): TH of waters before treatment of Buttayagudem, Gopalapuram is 200, 300 mg L^{-1} respectively, while the average TH of waters after treatment is 275, 300 mg L^{-1} respectively. TH of waters from the two Mandals during pre- monsoon season is within the permissible limits. TH of waters before treatment of the above two Mandal is 600, 500 mg L^{-1} respectively, while the average TH of waters after treatment is 625, 625 mg L^{-1} respectively. TH of waters from the two Mandals during post monsoon season crossed the permissible limit of drinking water standards indicating the encrustation nature of waters (Pre- monsoon).

Total Alkalinity (TA): TA of untreated waters of Buttayagudem, Gopalapuram is 854, 488 mg L^{-1} respectively, while the average TA of treated waters is 762.5, 579.5 mg L^{-1} respectively. TA of untreated waters of the above Mandals is 732, 610 mg L^{-1} respectively, while the average TA of treated waters are 732, 579.5 mg L^{-1}respectively. TA of waters from the Mandals during both pre and post monsoon season crossed the permissible limit of drinking water standards and can cause unpleasant taste to waters (Post monsoon*)*.

Calcium (Ca^{2+}): Ca^{2+} of untreated waters of Buttayagudem, Gopalapuram is 40 and 80 mg L^{-1} respectively, while its average concentration of treated waters is 70, 80 mg L^{-1} respectively. Calcium ion concentration in waters of Gopalapuram Mandal during pre-monsoon season crossed the permissible limit of drinking water standards indicating the encrustation nature of waters. Calcium ion concentration of untreated waters of Buttayagudem, Gopalapuram is 120, 80 mg L^{-1} respectively, while its average concentration of treated waters is 120, 90 mg L^{-1} respectively. Calcium ion concentration in waters of two Mandals crossed the permissible limit of drinking water standards and can cause encrustation on water supply systems.

Magnesium (Mg^{2+}): Magnesium ion concentration of waters before treatment and its average concentration of waters after treatment of Buttayagudem, Gopalapuram is 24.4 mg L^{-1} each and within the permissible limit of drinking water standards (Pre-monsoon). Magnesium ion concentration of waters before treatment in of the above two Mandals is 73.2 each, while its average concentration of waters after treatment is 79.3, 97.6 mg L^{-1} in post monsoon season respectively. Magnesium concentration in waters of Buttayagudem Mandal during post monsoon season exceeded the permissible limit of drinking water standards and can cause laxative effect on water.

Sodium (Na^{+}): Sodium ion concentration of untreated waters of Buttayagudem, Gopalapuram is 9.7 and 6.1 mg L^{-1} respectively, while its average concentration is 9.6 and 7.1 mg L^{-1} respectively in treated water (Pre- monsoon). Sodium ion concentration of untreated waters of the two Mandal is 38.2 and 19.1 mg L^{-1} respectively. Its average concentration is 38.3 and 24.0 mg L^{-1} respectively in treated waters. Sodium ion concentrations in waters of pre and post monsoon season are within the permissible limit of WHO standards.

Potassium (K^{+}): Potassium ion concentration of untreated waters of Buttayagudem, Gopalapuram is 0.9, 2.4 mg L^{-1} respectively. Its average concentration is 0.8 and 1.9 mg L^{-1} respectively in treated water. Potassium ion concentration of untreated waters of the above two Mandals is 4.9 and 21.2 mg L^{-1} respectively. Its average concentration is 4.9 and 12.9 mg L^{-1} respectively in treated waters. In all areas K^{+} is within the permissible limit of WHO standards (Post monsoon).

Chloride (Cl^{-}): Chloride ion concentration of waters before treatment of Buttayagudem, Gopalapuram is 70.9 and 106.4 mg L^{-1} respectively, while its average concentration of waters after treatment is 53.2 and 62.1 mg L^{-1} respectively (Pre-monsoon). Chloride ion concentration of waters before treatment of the above two Mandals is 35.5and 35.5 mg L^{-1} respectively, while its average concentration of waters after treatment is 35.5 and 53.2 mg L^{-1} respectively (Post monsoon). Chloride ion concentrations of water of all Mandals during both seasons are within the permissible limit of drinking water standards.

Fluoride (F^{-}): Fluoride ion concentration of waters before treatment of Buttayagudem, Gopalapuram is 0.56 and 0.52 mg L^{-1} respectively, while its average concentration of water after treatment is 0.48 and 0.46 mg L^{-1} respectively (Pre- monsoon). Fluoride ion concentration of waters before treatment of the above two Mandals is 0.52 and 0.50 mg L^{-1} respectively, while its average concentration of waters after treatment is 0.45 and 0.43 mg L^{-1} respectively (Post monsoon). Fluoride ion concentrations of water during both seasons are within the permissible limit of drinking water standards after treatment less than required amount of 0.5. Hence waters cannot cause any fluorosis before treatment only.

Sulphate (SO_4^{2-}): Sulphate of untreated waters of Buttayagudem, Gopalapuram is 29 and 21 mg L^{-1} respectively, while its average concentration is 32 and 25.3 mg L^{-1} respectively in treated water (Pre-monsoon).

Sulphate of untreated water during post monsoon of the above two Mandals is 25 and 32 mg L^{-1} respectively, while its average concentration is 37.8 and 25.3 mg L^{-1} respectively in treated water. Sulphate ion concentrations of water during both seasons are within the permissible limit of drinking water standards. It indicates that no discharge of industrial effluents in to the water sources.

Nitrate (NO_3^-): Nitrate of untreated waters of Buttayagudem, Gopalapuram 14, 11 mg L^{-1} respectively, while its average concentration is 12.5 and 11.3 mg L^{-1} respectively in treated water ((Pre-monsoon). Nitrate of untreated water of the two Mandals is 12 mg L^{-1} each, while its average concentration is 10.8 and 9.5 mg L^{-1} respectively in treated water (Post monsoon). Nitrate concentrations of water during both seasons are within the permissible limit of drinking water standards. It indicates the absence of nitrate contamination from any domestic sources or agricultural activities.

Phosphate (PO_4^{3-}): During pre and post monsoons phosphate ion concentration is not detected (ND) level in untreated and treated water of two Mandal Head Quarters. It indicates that no discharge of agricultural runoff into the water sources.

Metal Ions: The concentration of Metal ions viz., Li, Be, Al, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Rb, Sr, Ag, Cd, Cs, Ba, Tl, Pb and U in treated drinking waters of pre and post monsoon season were found to be within in the permissible limits of drinking water standards.

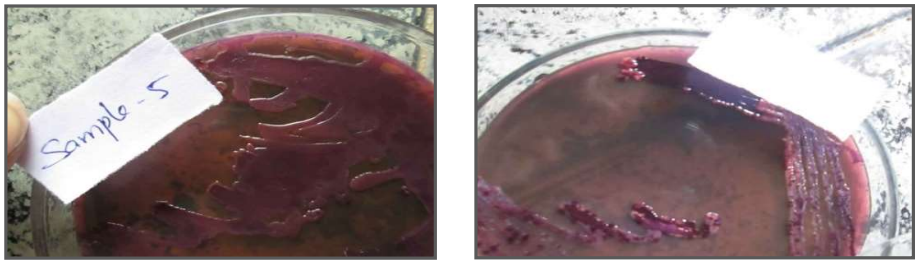
Microbial Analysis: The drinking water samples after treatment are collected in sterilized containers and immediately processed for analysis for determining the MPN count by the most probable number (MPN) technique.

The enumeration for the Coliform count involves the presumptive test using lactose broth and Nutrient agar confirmatory test using Eosin Methylene Blue (EBM) agar, pure colonies of the isolated were subjected to Grams stain, motility, Indole, Methyl red, Voges Proskauer Citrate utilization (IMViC) tests, Urease test, Catalase and Oxidase test. The cultural, Morphological characteristics and the details of Biochemical characterization for identification of bacteria are presented in table 3. The identified *bacterial spps* are represented in figure 2.

Table 3. The details of MPN count, cultural, Morphological characteristics and identified *bacterial spps* in treated drinking waters.

Mandal Name	MPN Count 100 mL^{-1}	No. of Bacterial Colonies	Morphology on EMB agar	Gram Stain	Motility	Biochemical Tests *(IMViC Tests)							*Bacterial spps* Identified
						I	MR	VP	C	CA	OX	UR	
Buttayagudem	76	Colony-1	Purple Centered	-ve	Motile	-	-	+	+	+	-	-	*Enterobacter*
Gopalapuram	210	Colony-1	Purple Centered	-ve	Motile	-	-	+	+	+	-	-	*Enterobacter*
		Colony-2	Pink mucoid	-ve	Non Motile	-	-	+	+	+	-	-	*Klebsiella*

*I = Indole, MR=Methyl red, VP=Voges Proskauer, C=Citarte, CA= Catalase, OX= Oxidase, UR= Urease



Enterobacter *Enterobacter and Klebsiella*

Figure 2. Photograph of identified bacteria.

pH of waters collected from the four mandals of Jangareddygudem indicates slight alkaline nature. Higher EC values of waters from two mandals indicate the saline nature of waters. TDS of waters of Polavaram mandal exceeded the permissible limit of drinking water standards [2] indicating the presence of dissolved solids in waters, while the TDS of waters from the remaining remaining mandal is within the permissible limit. Total Hardness of waters collected during post monsoon season from all the four mandals exceeded the permissible limit indicating the encrustation nature of waters which make the waters unsuitable for domestic purpose. Total Alkalinity of waters from all the two mandals exceeded the permissible limit of drinking water standards and can cause unpleasent taste to the waters.

Calcium ion concentration of waters durig post monsoon season are on higher side of drinking water standards and can cause encrustation on water supply systems and make the waters unsuitable for domestic purposes. Magnesium concentration in waters of post monsoon season are also on higher side of drinking water standards. Sodium ion concentration in waters of post monsoon season from Polavaram mandal exceeded the limit of WHO drinking water standards, while Sodium ion concentration is within the permissible limit in waters of the remaining three mandals. Potassium ion concentrations in waters of all mandals are within the permissible limit of WHO drinking water standards. The levels Chloride, Fluoride, Sulphate and Nitrate are within the permissible limit of drinking water standards. Phosphate ion concentration is at non detectable level.

The analytical results revealed that the waters are associated with higher levels of TDS, Hardness, Alkalinity, Calcium and Magnesium. The waters are to be treated by using available sophisticated methods like Ultra filtration and Nano filtration to reduce the dissolved solids TDS from waters which can minimise the other parametric levels also for safeguarding the health of the rural public who consume these waters for drinking and domestic purposes.

The drinking water sample collected after treatment from Buttayagudem has MPN count 76 100mL^{-1} and the Biochemical tests indicate that the presence of *Enterobacter species*. The drinking water sample of Gopalapuram Mandal has MPN count >210 100 mL^{-1} and the Biochemical tests revealed that the presence of *Enterobacter and Klebsiella species*. Treated drinking water samples collected from four Mandals are observed not only with MPN count but also with other pathogenic *bacterial species* like *Enterobacter, Klebsiella* indicating the microbiological contamination. Hence the waters may cause waterborne diseases like diarrhea, typhoid, pneumonia, bacteremia, respiratory tract infections, urinary tract infections, skin and soft-tissue infections, ophthalmic infections etc [3].

APPLICATION

The analytical results revealed that the water is contaminated with higher levels of TDS, Hardness, Alkalinity, calcium and magnesium. The water is to be treated by using available sophisticated methods like Ultra filtration and Nano filtration to reduce the dissolved solids TDS from water which

can minimize the other parametric levels also for safeguarding the health of the rural public who consume these water for drinking and domestic purposes.

CONCLUSION

The analytical results of Physicochemical analysis of waters indicate that the waters are chemically contaminated with higher levels of TH, TA, $Ca^{2+}$and Mg^{2+} which can indirectly cause health problems viz., stones in kidneys due to higher levels of Ca^{2+}, higher levels of Mg^{2+} can cause laxative effect on waters, higher concentration of TA can cause unpleasant taste to waters and Lower concentration of metal ions indicates the absence of metal toxicity of waters. Microbial analysis revealed the presence of b*acterial species* like *Enterobacter* and *Klebsiella* in water indicating the bacterial contamination of water. Proper treatment methods like disinfection and sterilization are to be employed for the prevention of Microbial contamination before considering the use of water for drinking purposes [**10**]. Hence the quality of waters is to be conserved to protect the health of the public residing in the rural habitations [**11**].

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