

QUALITY ASSESSMENT OF SURFACE WATER OF ANASAGAR LAKE, AJMER (RAJASTHAN, INDIA) AND THEIR PURIFICATION USING SEAWEED DERIVED GRAPHENE NANOSHEETS

AKHILESH RAWAT*, MUKESH SHARMA A* AND C. P. SINGH CHANDEL B**

Department of Chemistry, University of Rajasthan, Jaipur 302 004 (Rajasthan) India.

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ABSTRACT

The water is considered as the most important molecule for the development and nourishment of life on the earth. Water is the first necessity of humans in almost all activities such as drinking, domestic, irrigation, recreational and industrial activities. Water quality and pollution are recognized as an enormous issue in big cities. This work presents the water quality assessment and purification of surface water of Anasagar Lake, Ajmer (Rajasthan, India). Anasagar Lake is a freshwater lake located in the center of the Ajmer city and the lake is highly polluted due to the municipal waste of Ajmer city. For the physicochemical analysis, six surface water samples were collected from six different sampling sites of Anasagar Lake during the period of March 2017. Various physicochemical parameters such as temperature, pH, electrical conductivity (EC), total dissolved solids (TDS), fluoride (F⁻), sulfate (SO₄⁻) and nitrate (NO₃⁻) were evaluated using standard analytical procedures. Seaweed derived graphene nanosheets (GNs) were tested for the purification of highly contaminated water samples. The GNs has successfully removed all toxic contaminants from surface water samples of Anasagar Lake. The concentration of all constituents of GNs treated water was found to be under the limit as compared with the water quality standards of WHO and BIS. The GNs treated water has been found to be safe for irrigation, recreation, animal drinking, and domestic activities.

KEY WORDS : Anasagar Lake (Ajmer), Surface water, Water pollution, Physico-chemical analysis, Seaweed derived graphene nanosheets, Water purification

INTRODUCTION

Water is the most essential and unique molecule of the entire world and crucial importance for all living beings. It is the most natural and precious matter, since, it is necessary for all living beings and it is a primary component for the development and nourishment of life on the Earth (Kershaw *et al.*, 2000; De, 2000; and Valsami-Jones, 2004). In nature, water exists in three different physical states including liquid, solid (ice form) and gas (Anslyn *et al.*, 2006 and Cotton *et al.*, 1982). The surface run-off water is largely contaminated from turbidity, industrial wastes, agricultural wastes, pathogenic organisms, municipal wastes, etc. (Walker *et al.*, 2019). Hence, such surface water is not a purest

form of water and considered to be unsafe for all living beings. Water pollution is a major problem for the whole world and the natural water bodies has largely contaminated from the toxic substances of municipal waste, sewage effluent, industrial and agricultural wastes, which is dumped directly into the water bodies without any pretreatment.

Many studies have been reported the water quality parameters of various resources in India and the purification of water using various techniques. Mathur *et al.* (2011) reported the physicochemical properties of groundwater of Ajmer city and surface water of Anasagar Lake, Ajmer, Rajasthan (Mathur *et al.*, 2010 and Mathur *et al.*, 2011). Ramkumar *et al.* (2018) has been reported the physicochemical analysis of sewage effluent and industrial waste

contaminated water of Chembarambakkam Lake situated near Chennai city (Ramkumar *et al.*, 2018). Tailor *et al.* (2010 & 2011) reported the groundwater quality parameters and the adverse effect of fluoride contaminated groundwater of Malpura, Tonk District, Rajasthan (Tailor *et al.*, 2010 and Tailor *et al.*, 2011). The water quality properties of groundwater of Vuyyuru, Krishna District, Andhra Pradesh and their suitability for drinking has been reported by Lalitha and co-workers (Lalitha *et al.*, 2017). Sharma *et al.* (2017) has been reported the removal of fluoride and other toxic contaminants from high fluoride-containing drinking groundwater of Govind Garh region, Ajmer District (Rajasthan, India) using seaweed derived non-toxic graphene nanosheets (GNs; SAR-Fe-700) (Sharma *et al.*, 2017).

Anasagar Lake (Ajmer) is the extremely beautiful artificial lake situated in the center of the Ajmer city, Rajasthan, India. Anasagar Lake was built by the king of Ajmer, Ana Ji Chauhan, who was the grandfather of King Prithvi Raj Chauhan, between 1135-1150 AD with the help of local populates and now it is known as Anasagar Lake named after its founder. It is one of the largest and most popular lakes in Rajasthan, India. Anasagar Lake is the biggest in Ajmer city, with the total geographical area of ~13 square kilometers and the maximum depth of the lake is ~4.4 meters with the total water storage capacity of 4.75 million cubic meters (Jain *et al.*, 2013). The present work is based on the physicochemical analysis and purification of surface water of Anasagar Lake (Ajmer). For the physicochemical analysis, six surface water samples were collected from six different sampling sites of Anasagar Lake (Ajmer) during the pre-monsoon season of the year 2017. Various physical parameters such as temperature, pH, electrical conductivity (EC) and total dissolved solids (TDS) were analysed at the sampling site. The other chemical parameters such as Sulphate (SO_4^{2-}), nitrate (NO_3^-) and fluorides (F^-) were analysed in the research laboratory using standard analytical procedures. The non-toxic functionalized graphene nanosheets (GNs; SAR-Fe-700) were synthesized from fresh seaweed *Sargassum tenerrimum* using Fe-containing deep eutectic solvents and further successfully utilized for the removal of fluoride from fluoride-contaminated drinking water (Sharma *et al.*, 2017). Here in this work, the seaweed derived GNs were successfully tested for the purification of highly turbid contaminated water of Anasagar Lake (Ajmer). The concentration of all

toxic constituents was found to be under the limit as compared with the water quality standards of WHO and BIS. The purified water has been found to be safe for irrigation, recreation, and domestic uses.

MATERIALS AND METHODS

Study area

The present study was conducted for Anasagar Lake (Fig. 1b), a shallow freshwater lake, situated in the center of the Ajmer city, Rajasthan (India). Geographically, the Anasagar Lake (Ajmer) coordinates between 26.475° North latitude and 74.625° East latitude.

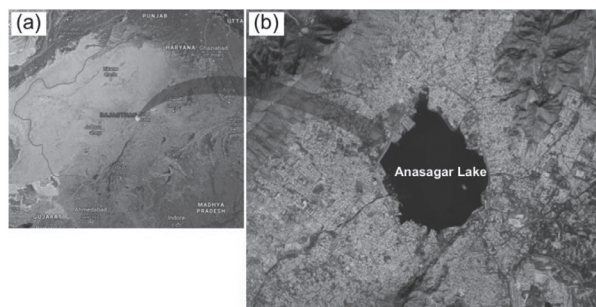


Fig. 1. (a) Satellite map of Rajasthan with the location of Anasagar Lake (Ajmer) and (b) the second image demonstrating the satellite view of study area (Anasagar Lake) in the center of Ajmer city.

Water sample collection

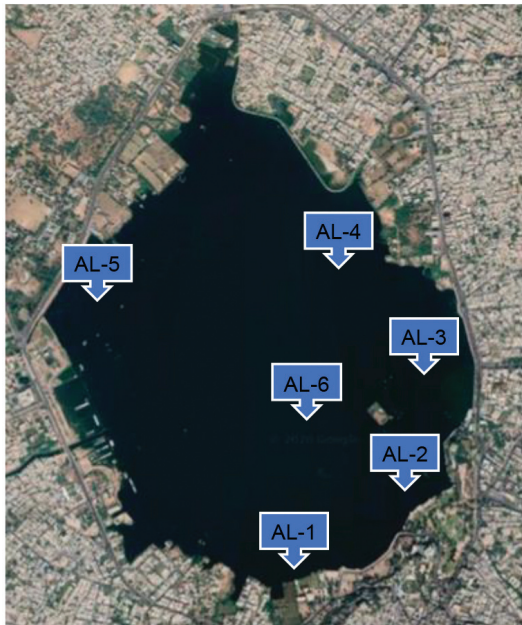
Surface water samples were collected from six different sampling sites of Anasagar Lake (Ajmer), see Table 1 for the name of sampling sites and Fig. 2 for the highlighted sampling sites in the satellite map of Anasagar Lake (Ajmer).

The surface water samples were collected during pre-monsoon seasons during the year 2017. All the water samples were collected and stored under following the standard procedures. The surface water samples were taken in well-cleaned polyethylene bottles with 2L capacity and screw-capped, which were previously soaked in 10% nitric acid aqueous solution followed by thoroughly rinsed with deionized water for several times to minimize the contamination of bottle's material.

The sites for water sampling were selected carefully to collect water samples that must be representative of the whole location. To collect the water samples of effluents ensured that no accidental contamination occurs during sampling. Bottles should be filled, and air bubbles should be

Table 1. List of surface water (open source) sampling sites in Anasagar Lake (Ajmer).

Entry	Name of location	Sample code
1.	Ramprasad Ghat area, Anasagar Lake (Ajmer)	AL-1
2.	Baradari area, Anasagar Lake (Ajmer)	AL-2
3.	Chaupati area, Anasagar Lake (Ajmer)	AL-3
4.	Sagar Vihar area, Anasagar Lake (Ajmer)	AL-4
5.	Mittal Hospital area, Anasagar Lake (Ajmer)	AL-5
6.	Lake island, Anasagar Lake (Ajmer)	AL-6

**Fig. 2.** Satellite view of Anasagar Lake (Ajmer) and surface water sampling sites

avoided. The bottle containing samples should be tightly closed with a screw cap to avoid evaporation and all the samples were kept in the refrigerator. Sample bottles should be properly protected from any outside contamination. Before filling the sample, bottles were rinsed twice or thrice with the water being collected. Whenever possible samples were collected below the surface of the water.

Physicochemical characterization of water samples

The water samples were collected from six different sampling sites of Anasagar Lake (Ajmer, Rajasthan) and were analysed for the determination of the degree of contamination concerning various standard physicochemical parameters. The physicochemical parameters play a significant role in classifying and assessing water quality (Tank *et al.*, 2010). The water samples collected were initially analysed for pH, EC and TDS at the sampling site using a portable Water Quality Analyzer kit and by pH meter (Mettler-Toledo).

Sulfate (SO_4^{2-}), nitrate (NO_3^-) and fluorides (F^-) were analysed by the Volumetric titration method, Spectrophotometer (ELICO-CL-54D) and Ion-selective method, respectively. All the physicochemical parameters were analysed as per the American Public Health Association (APHA) standard methods.

Procedure for the purification of water samples

In a typical water purification procedure, 0.625 g of GNs (SAR-Fe-700) was added in 50 mL of surface water sample of Anasagar Lake (Ajmer). The water sample-GNs solution was then homogenized for 5 min in ultrasonic water-bath. The homogenized water sample-GNs solution was then shaken at room temperature for 120 min at a constant speed. After that, the suspension was filtered through a Whatman filter paper of 0.45 μm and the obtained filtrate was then analysed in the laboratory for the identification of contaminants.

RESULTS AND DISCUSSION

Anasagar Lake (Ajmer) is a historical and extremely beautiful place situated in the center of the Ajmer city, Rajasthan. The major problem of the lake is the heavy water pollution due to the municipal sewage waste that is dumped directly into the lake without any pre-treatment. The physicochemical properties such as colour, odour, pH, EC, TDS and chemical composition of water has changed due to the water pollution. The colour of the water has changed to unnatural yellowish green (Fig. 3) and has an unpleasant odour due to municipal sewage pollution. Therefore, various physicochemical observation is necessary to find the water quality parameters of surface water of Anasagar Lake (Ajmer).

To observe the physicochemical parameters of surface water of Anasagar Lake (Ajmer), the water samples were collected from six different open source sampling sites, the name of sampling site with the given sample cods are mentioned in Table

1 and see Fig. 2 for the highlighted sampling sites in the satellite map of Anasagar Lake. The collected surface water samples of Anasagar Lake (Ajmer) were initially analysed for temperature, pH, EC, and TDS at the sampling site and later analysed in the laboratory for the fluoride, sulfate, and nitrate using standard analytical procedures.

The observed physicochemical parameters of surface water samples of Anasagar Lake (Ajmer) are illustrated in Table 2. All the observed values are also compared with the standard values as recommended by the World Health Organization (WHO, 2017) and Bureau of Indian Standards (BIS, 2012).

Surface water quality parameters of Anasagar Lake (Ajmer)

Water temperature: The temperature of Anasagar Lake (Ajmer) water was found in the range of 28.2 °C to 29.9 °C during water sampling in March 2017. The seasonal changes in water temperature greatly affect the quality of water, aquatic life, and solubility of solid constituents in water. The high water temperature increase the solubility of solid constituents of sewage effluents and further increase the water pollution in Anasagar Lake (Ajmer).

pH of water: The pH of water samples of Anasagar Lake (Ajmer) was found in the range of pH 7.8 to pH 8.6 during water sampling in March 2017 (Table 2). The pH values of water Anasagar Lake (Ajmer) is found to be above pH 7.0, i.e., the water of Anasagar Lake (Ajmer) is alkaline in nature. The alkaline nature of water is the result of alkaline municipal waste and due to the formation of carbonates in water.

Total Dissolved Solids (TDS): The TDS of water are the amounts of dissolved inorganic constituents of water. The permissible limit of TDS in drinking water is 500 mg/L and 600 mg/L as prescribed by WHO (WHO, 2017 and BIS (BIS, 2012), respectively. The TDS of surface water of Anasagar Lake (Ajmer) was found in the range of 953 mg/L to 1120 mg/L during water sampling in March 2017 (Table 2). All surface water samples exceeds the permissible limit of TDS. The excess TDS in water indicates the water pollution in Anasagar Lake (Ajmer). The high value of TDS in surface water may cause laxative and constipation effects in human beings.

Electrical Conductivity (EC): The EC of water is a useful parameter to estimate the quality of water and it depends on the concentration of ions and dissolve solids. The EC of surface water of Anasagar Lake (Ajmer) was found in the range of 1912 $\mu\text{S}/\text{cm}$ to 2175 $\mu\text{S}/\text{cm}$ during water sampling in March 2017 (Table 2). The maximum permissible limit of EC for drinking water is 400 $\mu\text{S}/\text{cm}$ as prescribed by WHO (WHO, 2017). The EC of all water samples of Anasagar Lake (Ajmer) exceeds the higher permissible limit (Table 2). The higher EC of surface water of Anasagar Lake (Ajmer) clearly indicates that the water is highly polluted and contains high amount of ions and dissolve solids.

Fluoride (F⁻): The maximum permissible limit of fluoride in drinking water is 1.5 mg/L as prescribed by WHO and BIS. The fluoride content of the surface water samples of Anasagar Lake (Ajmer) was found in the range of 0.771 mg/L to 1.191 mg/L (Table 2). The concentration of fluoride in all surface water samples of Anasagar Lake (Ajmer) found within the permissible limit.

Sulfate (SO₄²⁻): Sulfate is mainly found in all type of

Table 2. Physicochemical parameters of various surface water sample of Anasagar Lake (Ajmer) collected during March 2017 and their comparison with drinking water standards of WHO and BIS.

Entry	Water sample name/code	Physicochemical Parameters					
		pH	EC	TDS	Fluoride	Nitrate	Sulfate
1.	Water (WHO Standards)	6.5 – 8.5	400	600	1.5	50	250
2.	Water (Indian Standards)	6.5 – 8.5	–	500	1.0 – 1.5	45	200 – 400
3.	AL-1	8.6	2127	1108	1.132	14.60	553.00
4.	AL-2	8.6	2128	1097	1.121	12.00	536.70
5.	AL-3	8.4	2085	1062	1.136	15.90	548.90
6.	AL-4	7.8	1912	953	0.771	9.68	511.50
7.	AL-5	8.6	2175	1120	1.191	16.40	524.00
8.	AL-6	8.6	2120	1090	1.015	11.71	543.60

Note: EC and TDS measures in mS/cm and parts per million (ppm), respectively; and fluoride, nitrate and sulfate measures in mg/L.

water and it is derived from the dissolution of salts of sulfuric acid. The sulfate concentration in Anasagar Lake (Ajmer) was found in the range of 511.50 mg/L to 553 mg/L (Table 2). The permissible limit of sulfate in drinking water is 250 mg/L and 200–400 mg/L as prescribed by WHO and BIS, respectively. All surface water samples of Anasagar Lake (Ajmer) exceeds the permissible limit of sulfate. The high sulfate content in water is because of oxidation of sulfur containing municipal sewage and salts.

Nitrate (NO_3^-): Nitrate concentration of surface water samples of Anasagar Lake (Ajmer) was found in the range of 9.68 mg/L to 16.40 mg/L. The permissible limit of nitrate for drinking water is 45 mg/L to 50 mg/L as prescribed by BIS and WHO. All the surface water samples from the Anasagar Lake (Ajmer) found with in permissible limit as prescribed by BIS and WHO.

Purification of surface water of Anasagar Lake (Ajmer)

The physicochemical properties, unnatural colour and unpleasant odour of surface water suggest that the surface water of Anasagar Lake (Ajmer) is highly polluted due to municipal sewage of Ajmer city. Because of water pollution, the water of Anasagar Lake (Ajmer) is not safe for animal drinking, irrigational and recreational activities. The polluted water of Anasagar Lake (Ajmer) is broadly affecting the aquatic ecosystem and living beings. The unpleasant odour of Anasagar Lake (Ajmer) is because of toxic gases which affecting the surrounding human societies and also increase the air pollution in the surrounding area of Anasagar Lake (Ajmer).

For the purification of surface water of Anasagar Lake (Ajmer), the seaweed derived non-toxic GNs (SAR-Fe-700) were used in this study. Sharma *et al.*, (2017) were reported the synthesis of GNs from fresh seaweed *Sargassum tenerrimum* using Fe-containing deep eutectic solvents and successfully utilized for the removal of fluoride and other toxic substances from highly contaminated water (Sharma *et al.*, 2017). The GNs (SAR-Fe-700) is a green, sustainable and non-toxic material and also found to be cost effective for the purification of water (Sharma *et al.*, 2017). In the typical procedure, the GNs were added to the surface water sample of Anasagar Lake (Ajmer) followed by sonication for 5 min and shake at room temperature for 120 min at constant speed. The water sample is then filtered

through Whatman filter paper and the filtrate is used for the further analysis in laboratory. The filtrate is found to be colourless (Fig. 3) and slightly odourless.

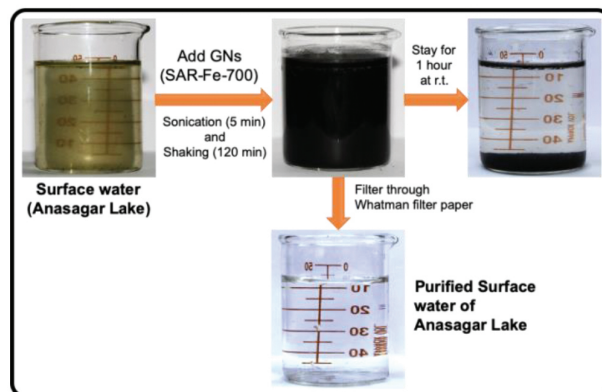


Fig. 3. Photographical demonstration of surface water sample of Anasagar Lake and their purification process using GNs (SAR-Fe-700).

The GNs treated water was analysed for the physicochemical parameters such as pH, EC, TDS and sulfate. The pH of GNs treated was found in the range of 6.5 to pH 6.9 (Fig. 4a). Therefore, GNs treated water becomes slightly acidic in nature. The EC, TDS and sulfate of GNs treated water sample of Anasagar Lake (Ajmer) was found in the range of desirable limit suggested by WHO and BIS (Fig 4b-d). After that the purified surface water of Anasagar Lake (Ajmer) is found to be safe for the irrigational and recreational activities and also safe for animals drinking.

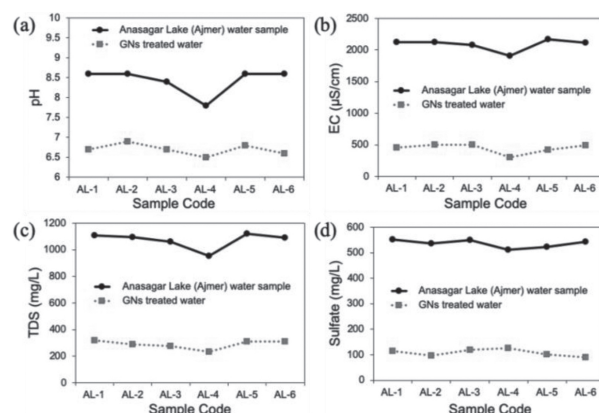


Fig. 4. (a) pH, (b) EC, (c) TDS and (d) Sulfate of surface water sample of Anasagar Lake (Ajmer) before and after treatment with GNs.

CONCLUSION

On the basis of present study, it was concluded that

all the surface water samples of Anasagar Lake (Ajmer) are not consistent with WHO and BIS standards of drinking water. The surface water sample of Anasagar Lake (Ajmer) were collected and analysed for the water quality parameters following standard analytical procedures. It is revealed that the physicochemical parameters such as pH, electrical conductivity, total dissolved solids and sulfate were found above the WHO and BIS standards of drinking water. Fluoride and nitrate fall under the permissible limit of drinking water. The study revealed that the surface water of Anasagar Lake (Ajmer) is highly contaminated due to the municipal sewage of Ajmer city. To remove the contaminants from water, seaweed derived graphene nanosheets (GNs) were tested and it successfully removed all toxic contaminants, unpleasant odour and unnatural colour from surface water samples of Anasagar Lake (Ajmer). After treatment with GNs, the physicochemical parameters of surface water samples were found to be consistent with drinking water standards of WHO and BIS. Thus, the GNs treated water of Anasagar Lake (Ajmer) has been found to be safe for irrigation, recreation and domestic activities and also safe for animal drinking.

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