

Influence of carcinogenic industrial pollutants on groundwater quality of RIICO industrial area of Bhiwadi (Alwar), Rajasthan, India

Rajesh Kumar Yadav* and Monika

Department of Chemistry, Government Raj Rishi College, Alwar 301 001 (Rajasthan) India.

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ABSTRACT

The groundwater is the primary source of freshwater in Alwar (Rajasthan) and needs of freshwater of Bhiwadi town (Alwar) for drinking, domestic, irrigation and industrial utilization are accomplished by the groundwater resources such as open well, tube-well, and hand pumps. The characterization of contaminated sites of RIICO industrial area of Bhiwadi (Alwar) was investigated by analyzing the groundwater that broadly affected and contaminated by the industrial wastewater. Ten groundwater sites of RIICO industrial area of Bhiwadi (Alwar) was investigated during the period of March-May of the year 2019. The groundwater samples were characterized for the numerous physicochemical parameters and carcinogenic substances following the standard operating procedures. The results of the study has shown that the considerable variations in the physico-chemical parameters was observed for the groundwater of RIICO industrial area of Bhiwadi (Alwar). Some of the groundwater sampling sites (B-4 to B-10) were found to contaminated due to large number of careless industrial activities around the sampling sites. Six sampling sites such as B-4, B-5, B-6, B-8, B-9 and B-10 found to have exceeded amount of carcinogenic and toxic chemical substances that comes from industrial wastewater and the groundwater is found to unsuitable for human and animal drinking and for irrigational purpose.

Key words : RIICO Industrial area, Bhiwadi (Alwar), Groundwater, Physicochemical analysis, Carcinogenic industrial pollution.

Introduction

The industrial water pollution is a prevalent ecological difficulty and due to extensive industrial water pollution, the human beings and surrounding ecosystems face enormous number of severe problems (Adejumoke *et al.*, 2018; Li *et al.*, 2021). The careless dumping and handling of industrial waste and pollutants has led to introduce an extensive variety of toxic carcinogenic substances, heavy metals and dangerous chemicals into the natural water resources (Briffa *et al.*, 2020; Fazzol *et al.*, 2017; Kim *et al.*, 2015). Many researchers have reported the

presence of heavy metals, pesticides and numerous hazardous chemicals in groundwater resources near industrial areas and such contaminants are causing cancer in human beings (Malyan *et al.*, 2019). Arsenic (As), lead (Pb), cadmium (Cd), uranium (U), radon (Ra), pesticides and numerous hazardous chemicals are the primary carcinogenic contaminants found in the groundwater resources in various states of India (Malyan *et al.*, 2019; Dash *et al.*, 2017; Datta and Kaul, 1976; Duggal *et al.*, 2014, 2017, 2018; Choubey *et al.*, 2003; Singh, 2001). These contaminants are often detected in the various kind of chemical industries wastewater (Malyan *et al.*, 2019;

Sankhla and Kumar, 2019). Therefore, the management and control of industrial wastewater is the principal challenge for human society now a days. Groundwater is the most appreciated and major natural renewable source of freshwater.

The purity and composition of groundwater resources alters with the depth and extensive industrial water pollution on the earth surface (Frape *et al.*, 2003; Yongjin *et al.*, 2015). The groundwater resources are largely contaminated, and groundwater contaminations are globally considered as a serious problem for human beings, since the polluted water is not safe for human drinking and other purposes (Sharma and Bhattacharya, 2017). Bhiwadi (Alwar) is a growing industrial hub located nearby the national capital region (NCR), New Delhi. It has more than 800 industrial units and these industrial units carelessly discharge wastewater without any pre-treatment (Rajput *et al.*, 2017; Saini *et al.*, 2015; Yadav *et al.*, 2012). The groundwater of Alwar district were found to be poor in quality and also contaminated with the industrial toxic contaminants, since it has many growing industrial zones (Kumar and Saini, 1998; Agarwal and Sharma, 2015). Therefore, the groundwater of RIICO industrial area of Bhiwadi town has to be analyzed and also find out the potability of groundwater for human consumption and irrigational utilization.

This study has reported the collection of groundwater samples from the industrially affected areas and their physicochemical analysis including the estimation of carcinogenic substances in groundwater samples. For the quality evaluation and carcinogenic substance estimation, ten groundwater samples were collected from RIICO industrial area

of Bhiwadi town during March-May of the year 2019. The physicochemical parameters and toxic industrial carcinogenic substances were estimated using the standard operating procedures of American Public Health Association (APHA, 1989). The study has showed that the groundwater samples of few locations of RIICO industrial area of Bhiwadi town were found to have exceeded amount of toxic carcinogenic substances. Therefore, the groundwater of B-5 to B-10 of Bhiwadi (Alwar) were found to be polluted and contaminated with toxic carcinogenic substances due to large number of industrial activities near these locations. The groundwater of B-5 to B-10 sampling sites Bhiwadi (Alwar) do not imitate with the permissible limit of World Health Organization (WHO) and Bureau of Indian Standards (BIS), India. Therefore, the groundwater samples of B-5 to B-10 sites are found to be unsuitable for human consumptions and for irrigational purpose.

Materials and Methods

Description of the study area: This study was conducted for groundwater analysis of RIICO industrial area of Bhiwadi town of Alwar district, Rajasthan (Fig. 1). Bhiwadi is a north-east town of Tijara tehsil of Alwar district of Rajasthan and geographically coordinated between 28.21° North latitude and 76.87° East longitude. RIICO industrial area, Bhiwadi is a growing industrial hub of Alwar (Rajasthan) located very close to National Capital Region (NCR), New Delhi and 90 km away from Alwar city.

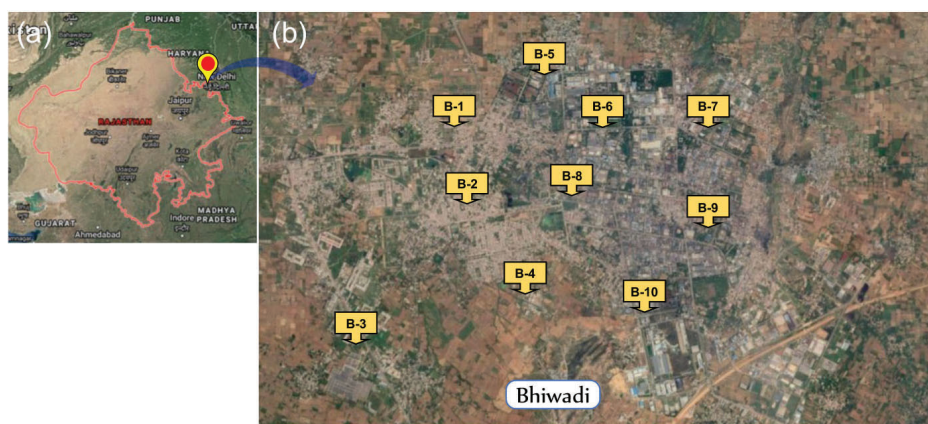


Fig. 1. (a) Satellite map of Rajasthan showing the exact location of RIICO industrial area, Bhiwadi (Alwar) and (b) Satellite view of Bhiwadi town (RIICO industrial area) with highlighted groundwater sampling sites.

Description of the groundwater sampling sites:

Groundwater samples were collected from ten distinctive sampling sites of RIICO industrial area, Bhiwadi (Alwar) and characterised the samples in research laboratory to obtain the experimental analytical data of groundwater. See Table 1 for the list of sampling sites and Fig. 1b for the groundwater sampling sites highlighted in the satellite map of Bhiwadi (RIICO industrial area). The highlighted sampling site's code number in Fig. 1b is also mentioned in Table 1 along with the full name of groundwater sampling site.

Description of groundwater sample collection:

The groundwater samples were collected from various sampling sites of RIICO industrial area of Bhiwadi (Alwar) by applying the previously stated sampling procedures. In this study, the groundwater samples were carefully collected from various kind of groundwater sources such as open wells, tube wells and hand pumps of RIICO industrial area of Bhiwadi (Alwar) during the period of March-May of the year 2019. The sampling sites were selected carefully, and the sites must be representative of the whole geographical area. All the groundwater samples were taken in well cleaned and screw capped polyethylene bottles of 2L capacity. The groundwater samples were collected carefully and stored in dark and cool place in the research laboratory before doing the final analysis.

Physicochemical characterization of groundwater samples:

The collected groundwater samples were evaluated for various physicochemical parameters along with toxic carcinogenic substances. The physicochemical and carcinogenic parameters of water is important to sustain the quality and potability of water. The collected groundwater samples were preliminarily analysed for various physicochemical parameters such as pH, EC, temperature and TDS at the time of sampling using a pH meter and a portable Water Quality Analyzer kit. For the remaining

analysis, the groundwater samples were brought to the laboratory and stored in freeze at standard temperature and pressure before performing the analysis. The physicochemical parameters such as fluoride (F^-), chloride (Cl^-), nitrate (NO_3^-) and toxic heavy metal industrial constituents of groundwater samples of RIICO industrial area of Bhiwadi town were tested in laboratory. Fluoride and chloride were analysed by Ion selective method, and nitrate were analysed by spectrophotometric method. All the physicochemical parameters were analysed as per the WHO and APHA standard methods (APHA, 1989).

Results and Discussion

Bhiwadi is a north-east town of Tijara tehsil of Alwar district (Rajasthan) and it is basically covered by a huge number of small, medium and large industrial units. RIICO industrial area of Bhiwadi (Alwar) is a growing industrial hub of Rajasthan because it is located very close to National Capital Region (NCR), New Delhi and availability of the infrastructure and resources. There are more than 800 industrial units including pesticides, textile, steel, pharmaceuticals, engineering, electronics, food processing, chemicals, waste material processing, etc. (Rajput *et al.*, 2017). RIICO industrial area of Bhiwadi (Alwar) were also monitoring water-polluting industrial units and lead-battery recycling industrial units that are carelessly discharging wastewater with any treatment. Therefore, it is necessary to assess the quality of groundwater of RIICO industrial area of Bhiwadi town (Alwar) with special reference to the impact of toxic carcinogenic substances in groundwater.

For the quality assessment of groundwater of RIICO industrial area of Bhiwadi town (Alwar, Rajasthan), ten groundwater samples were collected from ten different sampling sites of RIICO industrial area of Bhiwadi (Alwar) during the period of

Table 1. List of groundwater sampling sites of RIICO industrial area, Bhiwadi town (Alwar, Rajasthan) with their sample code number

Entry	Code	Name of Sampling Sites	Entry	Code	Name of Sampling Sites
1.	B-1	Vikas Nagar, Bhiwadi	6.	B-6	RIICO Office, RIICO, Bhiwadi
2.	B-2	Milakpur, Bhiwadi	7.	B-7	RIICO Green Park, RIICO, Bhiwadi
3.	B-3	Powergrid Road, Bhiwadi	8.	B-8	Sector 3, RIICO, Bhiwadi
4.	B-4	Sector 24, Bhiwadi	9.	B-9	Harchandpur, RIICO, Bhiwadi
5.	B-5	Jaquar Unit-II, RIICO, Bhiwadi	10.	B-10	Khijarpur, RIICO, Bhiwadi

March-May of the year 2019 (Table 1). The groundwater samples were initially analysed for pH, EC and TDS at the time of sample collection, and later analysed in the research laboratory for the fluoride, chloride, nitrate, DO, BOD and other toxic heavy metal elements using standard operating procedures of APHA (APHA, 1989). The observed physicochemical parameters and toxic carcinogenic substances of groundwater samples of RIICO industrial area of Bhiwadi town are illustrated in Table 2 and Table 3. All the observed parameters is compared with the permissible drinking water standards as recommended by the WHO-2017 and BIS-2012 (BIS, 2012; WHO, 2017). Groundwater quality parameters of RIICO industrial area, Bhiwadi (Alwar):

pH of groundwater: The pH of groundwater of RIICO industrial area of Bhiwadi (Alwar) were found in the range of 7.1 to pH 8.6 (Table 2). The lowest and highest pH value were obtained for the Powergrid Road (B-3) and Jaquar unit-II RIICO (B-5) sampling sites of Bhiwadi, respectively. All the groundwater samples are neutral to moderately alkaline in nature. The pH value of Jaquar unit-II RIICO (B-5) exceeds the maximum range of permissible limit of pH and other nine samples were found in between the minimum and maximum range of permissible limit of pH as prescribed by the WHO and BIS (BIS, 2012; WHO, 2017).

Electrical conductivity (EC) of groundwater: The EC of groundwater of RIICO industrial area of

Bhiwadi (Alwar) were found in the range of 1007 μ S/cm to 1622 μ S/cm (Table 2). The lowest and highest EC were recorded for the Powergrid Road (B-3) and Khijarpur RIICO (B-10) groundwater resources, respectively. The groundwater of all ten sampling sites of RIICO industrial area of Bhiwadi (Alwar) exceeds the maximum permissible limit of EC as prescribed by the WHO (WHO, 2017). Therefore, the groundwater of RIICO industrial area of Bhiwadi (Alwar) were found to have exceeded amount of dissolved solids and salts.

Total Dissolved Solids (TDS) of groundwater: The TDS of groundwater of RIICO industrial area of Bhiwadi (Alwar) were found in the range of 543 mg/l to 842 mg/l (Table 2). The lowest and highest TDS were recorded for the Powergrid Road (B-3) and Khijarpur RIICO (B-10) groundwater resources, respectively. The groundwater of all ten sampling sites of RIICO industrial area of Bhiwadi (Alwar) exceeds the maximum permissible limit of TDS as prescribed by WHO and BIS (BIS, 2012; WHO, 2017). Therefore, the groundwater of RIICO industrial area of Bhiwadi (Alwar) were found to unsuitable for human consumptions.

Fluoride (F⁻) in groundwater: The concentration of fluoride in groundwater samples of RIICO industrial area of Bhiwadi (Alwar) were found in the range of 2.4 to 5.7 mg/l (Table 2). The lowest and highest fluoride concentration were recorded for the Milakpur (B-2) and Jaquar-II RIICO (B-5) ground-

Table 2. Physicochemical parameters of various groundwater samples of RIICO industrial area of Bhiwadi town of Alwar district collected during March-May of the year 2019 and their comparison with WHO and BIS permissible water standards.

S. No.	Water sample/ Name of Sampling sites (Code)	Name of Parameters & Observations					
		pH	EC	TDS	F ⁻	Cl ⁻	NO ₃ ⁻
1.	Water (WHO Standards) *	6.5-8.5	400	600	1.5	250	50
2.	Water (BIS Standards)	** 6.5-8.5	-	500	1.0	250	45
3.	Vikas Nagar (B-1)	7.4	1182	612	3.1	512	48
4.	Milakpur (B-2)	7.9	1334	689	2.4	787	46
5.	Powergrid Road (B-3)	7.1	1007	543	3.4	623	43
6.	Sector-24 (B-4)	8.4	1413	766	5.2	901	66
7.	Jaquar-II, RIICO (B-5)	8.6	1587	819	5.7	986	89
8.	RIICO Office (B-6)	8.2	1467	811	4.5	799	70
9.	RIICO Green Park (B-7)	7.6	1155	618	3.8	578	74
10.	Sector-3, RIICO (B-8)	7.9	1401	798	4.6	659	86
11.	Harchandpur, RIICO (B-9)	7.8	1590	828	3.2	734	79
12.	Khijarpur, RIICO (B-10)	8.3	1622	842	2.7	778	76

Note: EC measure in μ S/cm; TDS, F⁻, Cl⁻, and NO₃⁻ measures in mg/L; EC = Electrical Conductivity; TDS = Total dissolve solids; * WHO-2017 drinking water standards (WHO, 2017); and ** BIS-2012 (IS 10500 : 2012) drinking water standards (BIS, 2012).

water resources, respectively. The fluoride in drinking water should be in between 1.0-1.5 mg/l as prescribed by WHO and BIS (BIS, 2012; WHO, 2017). The groundwater of all ten sampling sites of RIICO industrial area of Bhiwadi (Alwar) exceeds this permissible limit and therefore, the groundwater of all these ten sampling sites is found unsuitable and unsafe for human consumptions.

Chloride (Cl⁻) in groundwater: The concentration of chloride in groundwater samples of RIICO industrial area of Bhiwadi (Alwar) were found in the range of 512 to 986 mg/l (Table 2). The lowest and highest chloride concentration were recorded for the Vikas Nagar (B-1) and Jaquar-II RIICO (B-5) groundwater resources, respectively. The chloride in drinking water should be ~250 mg/l as prescribed by WHO and BIS (BIS, 2012; WHO, 2017). Therefore, the groundwater of all ten sampling sites of RIICO industrial area of Bhiwadi (Alwar) exceeds this maximum permissible limit and thus, the groundwater of all these sampling sites is found unsuitable for human consumptions.

Nitrate (NO₃⁻) in groundwater: The concentration of nitrate in groundwater samples of RIICO industrial area of Bhiwadi (Alwar) were observed in the range of 43 mg/l to 89 mg/l (Table 2). The lowest and highest nitrate concentration were recorded for the Powergrid Road (B-3) and Jaquar-II RIICO (B-5) groundwater resources, respectively. The maximum permissible limit of nitrate for drinking water is

specified as 45-50 mg/l as prescribed by WHO and BIS (BIS, 2012; WHO, 2017). The nitrate in nine groundwater samples of RIICO industrial area of Bhiwadi (Alwar) exceeds the maximum permissible limit, while Powergrid Road (B-3) groundwater samples found under the permissible limit. Nitrate in groundwater is most common problems due to industrial pollution and described to its conversion into carcinogenic N-nitroso compound that may cause colorectal cancer in human beings (Schullenger *et al.*, 2018; Ward *et al.*, 2018). Therefore, the exceeded amount of nitrate in drinking water is not suitable for human drinking.

Arsenic (As) and Mercury (Hg) in groundwater: Arsenic (As) and mercury (Hg) was not detected in the groundwater resources of RIICO industrial area of Bhiwadi (Alwar) (Table 3).

Cadmium (Cd) in groundwater: The concentration of cadmium in groundwater samples of RIICO industrial area of Bhiwadi (Alwar) were observed in few samples in the range of 0.005 mg/l to 0.031 mg/l (Table 3). The lowest cadmium concentration was recorded for Harchandpur (B-9) and Khijarpur (B-10), and highest cadmium concentration was recorded for the RIICO Office (B-6) groundwater resources. The groundwater sources such as B-4 to B 6 and B-8 to B-10 has the higher concentration of cadmium which is above the permissible limit of cadmium for drinking water. The higher concentration of cadmium is due to the careless discharging

Table 3. General toxic heavy metal parameters of various groundwater samples of RIICO industrial area of Bhiwadi town (Alwar) collected during March-May of the year 2019 and their comparison with WHO and BIS permissible water standards.

No.	Water sample/ Name of Sampling sites (Code)	Name of Parameters & Observations							
		As	Cd	Cr	Cu	Hg	Ni	Pb	Zn
1.	Water (WHO Standards)*	0.01	0.003	0.05	2	0.001	0.02	0.01	3
2.	Water (BIS Standards) **	0.01	0.003	0.05	1.5	0.001	0.02	0.01	5
3.	Vikas Nagar (B-1)	ND	ND	ND	1.02	ND	ND	ND	1.55
4.	Milakpur (B-2)	ND	ND	ND	0.91	ND	ND	0.01	1.09
5.	Powergrid Road (B-3)	ND	ND	ND	1.11	ND	ND	ND	1.29
6.	Sector-24 (B-4)	ND	0.008	0.05	2.07	ND	0.04	ND	2.00
7.	Jaquar-II, RIICO (B-5)	ND	0.019	0.09	4.19	ND	0.12	0.03	1.88
8.	RIICO Office (B-6)	ND	0.031	0.07	2.85	ND	0.03	0.03	2.34
9.	RIICO Green Park (B-7)	ND	ND	0.01	0.81	ND	0.01	ND	1.48
10.	Sector-3, RIICO (B-8)	ND	0.011	0.03	1.15	ND	0.03	0.01	2.12
11.	Harchandpur, RIICO (B-9)	ND	0.005	0.05	1.78	ND	0.07	0.02	1.78
12.	Khijarpur, RIICO (B-10)	ND	0.005	0.04	1.00	ND	0.03	0.01	2.31

Note: All parameters measures in mg/L; ND = Not detected; * WHO-2017 drinking water standards (WHO, 2017); and ** BIS-2012 (IS 10500 : 2012) drinking water standards (BIS, 2012).

of industrial pollutants, i.e., toxic heavy metal industrial waste. Cadmium was reported to have carcinogenic effect in human beings and grouped as Group-1 carcinogens that cause cancers to human beings and animals (Briffa *et al.*, 2020; Grant and Middleton, 1990; Caeiro *et al.*, 2005). Therefore, the groundwater of such resources of RIICO industrial area of Bhiwadi (Alwar) are polluted and not suitable for human consumption and also responsible for cancers in human beings and animals.

Chromium (Cr) in groundwater: The concentration of chromium in groundwater samples of RIICO industrial area of Bhiwadi (Alwar) were observed in few samples in the range of 0.01 mg/l to 0.09 mg/l (Table 3). The lowest and highest concentration of chromium were observed for RIICO Green Park (B-7) and Jaquar-II (B-5) groundwater resources, respectively. The groundwater sources such as B-5 and B-6 has the higher concentration of chromium which is above the permissible limit of chromium for drinking water as prescribed by WHO and BIS (BIS, 2012; WHO, 2017). Chromium was reported to have carcinogenic effect in human beings and also grouped as Group-1 carcinogens that cause cancers to human beings and animals (Briffa *et al.*, 2020; Grant and Middleton, 1990; Caeiro *et al.*, 2005). Therefore, the groundwater of such resources of RIICO industrial area of Bhiwadi (Alwar) are polluted and not suitable for human consumption.

Copper (Cu) in groundwater: The concentration of copper in groundwater samples of RIICO industrial area of Bhiwadi (Alwar) were observed in the range of 0.81 mg/l to 2.19 mg/l (Table 3). The lowest and highest concentration of copper were observed for RIICO Green Park (B-7) and Jaquar-II (B-5) groundwater resources, respectively. The groundwater sources such as B-4, B-5, B-6 and B-9 has the higher concentration of copper which is above the permissible limit as prescribed by BIS (BIS, 2012). Copper was classified as Group-3 carcinogens (Briffa *et al.*, 2020; Grant and Middleton, 1990; Caeiro *et al.*, 2005). Therefore, the groundwater of such resources of RIICO industrial area of Bhiwadi (Alwar) are polluted and not suitable for human consumption.

Nickel (Ni) in groundwater: The concentration of nickel in groundwater samples of RIICO industrial area of Bhiwadi (Alwar) were observed in few samples in the range of 0.01 mg/L to 0.12 mg/L (Table 3). The lowest and highest concentration of nickel were observed for RIICO Green Park (B-7)

and Jaquar-II (B-5) groundwater resources, respectively. The groundwater sources such as B-4 to B-6 and B-8 to B-10 has the higher concentration of nickel which is above the permissible limit as prescribed by WHO and BIS (BIS, 2012; WHO, 2017). Nickel compounds was classified as Group-1 carcinogens and has potential to produce a large number of health problems in human beings such as cancer, skin allergy, lung fibrosis, etc. (Briffa *et al.*, 2020; Grant and Middleton, 1990; Caeiro *et al.*, 2005; Kasprzak *et al.*, 2003). Therefore, the groundwater of such resources of RIICO industrial area of Bhiwadi (Alwar) are not suitable for human consumption.

Lead (Pb) in groundwater: The concentration of lead in groundwater samples of RIICO industrial area of Bhiwadi (Alwar) were observed in few samples in the range of 0.01 mg/l to 0.03 mg/l (Table 3). The lowest lead concentration was recorded for Milakpur (B-2), Sector-3 (B-8) and Khijarpur (B-10), and highest was recorded for the Jaquar-II (B-5) and RIICO Office (B-6) groundwater resources. The groundwater sources such as B-5, B-6 and B-9 has higher concentration of lead which is above the permissible limit of lead for drinking water as prescribed by WHO and BIS (BIS, 2012; WHO, 2017). Lead was reported as possibly carcinogenic and also classified as Group-2B carcinogenic materials (Briffa *et al.*, 2020; Grant and Middleton, 1990; Caeiro *et al.*, 2005). The higher concentration of lead is due to the industrial pollutants around the groundwater sampling sites and therefore, the groundwater of these sampling sites is not suitable for human drinking.

Zinc (Zn) in groundwater: The concentration of zinc in groundwater samples of RIICO industrial area of Bhiwadi (Alwar) were observed in the range of 1.09 mg/l to 2.34 mg/l (Table 3). Zinc in all ten groundwater samples was found below the maximum permissible limit for drinking water as prescribed by WHO and BIS (BIS, 2012; WHO, 2017).

Conclusion

RIICO industrial area of Bhiwadi (Alwar) is a rapidly growing industrial hub and located nearby the national capital region (NCR), New Delhi. The large number and unplanned industrial units in RIICO industrial area are the major problem that carelessly dumping industrial pollutants and further contaminated the groundwater resources. The groundwater is the primary source of freshwater in Bhiwadi

(Alwar) and exploited groundwater for numerous purposes. The present study investigated the carcinogenic substances and other industrial contaminants in the groundwater samples of ten sampling sites of RIICO industrial area during the period of March-May of the year 2019. The results of the present study has concluded that the considerable variations in the physicochemical parameters was observed for the groundwater of RIICO industrial area of Bhiwadi (Alwar). Some of the groundwater sampling sites (B-4 to B-10) were found to contaminated due to large number of careless industrial activities around the sampling sites. Six sampling sites such as B-4, B-5, B-6, B-8, B-9 and B-10 found to have exceeded amount of carcinogenic and toxic chemical substances that comes from industrial wastewater. Therefore, the groundwater of seven sampling sites out of ten are found to unsuitable for human consumptions, animal drinking and irrigational purpose as observed in the present study.

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