Journal of Basic and Applied Engineering Research
p-ISSN: 2350-0077; e-ISSN: 2350-0255; Volume 3, Issue 8; April-June, 2016, pp. 653-657

http://www.krishisanskriti.org/Publication.html

Analysing the Impact of E&P Operations on Ground Water with Respect to Heavy Metals in North Santhal, Balol, Lanwa and North Kadi Fields of Mehsana Asset, Gujarat

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Abstract—*Groundwater is an important water resource for domestic and agriculture in both rural and urban parts of India. Once polluted, a groundwater body could remain so for decades, or even for hundreds of years, because the natural processes of through-flushing are slow. In aquatic environments–metals can be termed as 'conservative pollutants', which once added to the environment are there forever and cannot be broken down to harmless substances by bacterial action as many of the organic pollutants are. They are leached or introduced into the aquatic systems as a result of the weathering of soils and rocks, from a variety of man-made sources, which involve mining, processing or use of metals or substances that contain metal contaminants. Therefore, monitoring of ground water is an essential module to analyse the impact of man-made activities.*

In order to determine the effect of Oil and Gas operations on the environment, notably on ground water quality, water samples were collected from nearby tube wells and compared against the produced water of the respective field. Water samples were collected from North Santhal, Balol, Lanwa and North Kadi fields along with few tubewell water samples located near to these installations. These samples were analysed for Ba, Cr, Co, Ni, V, Mn, Fe, Zn, Se, Ag, Cu, Pb, Cd, As, Be, Ga, Tl and Hg. In this study, all the measured metals in bore well water samples collected from all four fields are much less than those standards set by EPA and Indian standard for drinking water specifications. However, metals like Barium, Selenium, Copper and Arsenic were seen at concentrations close to these standard specifications in produced water samples and ETP water samples. Therefore, it is recommended that adequate care needs to be taken while discharging these water samples to the surrounding environment/ water bodies.

1. INTRODUCTION

India is endowed with a rich and vast diversity of natural resources, water being one of them. Water is nature's most wonderful, abundant and useful compound. Of the many essential elements for the existence of human beings, animals and plants, water is rated to be of the greatest importance. Without food, human can survive for a number of days, but water is such an essential part of life that without it one cannot survive. Availability of quality freshwater is one of the most critical environmental issues of the twenty first century. Groundwater is an important water resource for domestic and agriculture in both rural and urban parts of India. The quantity and the suitability of groundwater for human consumption and for irrigation are determined by its physical, chemical and bacteriological properties. Two principal features of groundwater bodies distinguish them from surface water bodies. Firstly, the relatively slow movement of water through the ground means that residence time in ground waters are generally longer than in surface waters. Once polluted, a groundwater body could remain so for decades, or even for hundreds of years, because the natural processes. Secondly, there is considerable degree of physico-chemical and chemical interdependence between the water and the containing material. Monitoring of ground water regime is an effort to obtain information on ground water levels and chemical quality through representative sampling.

In the Mahsana district of Gujarat, ground water occurs in confined, unconfined and semi confined conditions. Groundwater is exploited in the area by deep tube wells going beyond 400 m depth. Day-by-day groundwater condition is deteriorating in the area due to over exploitation. The withdrawal of ground water is 350 crore cubic meters per annum thereby creating an average annual deficit of ground water as 125 crore cubic meters. North Gujarat is the most stigmatic for the over withdrawal of ground water with water lift in many talukas particularly in Mahsana district having approached critical level of over 500 m. Due to over withdrawal of ground water, ground water table is going down by 2 to 4 meters per year.

Mehsana Asset, ONGC was established in November 1967 as a small project. Exploration activities have been started in 1964 and oil production commenced from 1969. Presently, Mehsana Asset has emerged as the highest onshore producing Asset of ONGC that produces light as well as heaviest crude in India. It has consistently achieved the highest oil production figures amongst all onshore Assets year after year. While producing oil and natural gas, produced water is one of the important by-product which should be monitored and managed effectively. On the other hand, heavy metals are one of the contaminant of produced water which is known as conservative pollutant. Once introduced in the aquatic system, it is very difficult to break down naturally and remains for a longer period.

Therefore, the present paper focuses on the monitoring of produced water and ground water from nearby borewell with respect to heavy metals. Effort has been made to get one comparative study of produced water and ground water from nearby bore wells so that conclusion can be made if any contamination of produced water is there to the nearby ground water.

2. METHODOLOGY

Total fourteen samples were collected for the present study out of which six samples from the bore wells nearby ONGC installations and rest 8 produced samples from North Santhal, Balol, Lanwa and North Kadi fields of Mehsana district by adopting appropriate sampling procedures. The comprehensive sampling details are described in Table 1. Sampling method used for the collection of groundwater samples is Grab sampling method. All the samples were collected in a 1 L Tarson sample bottle after running the water for 2 to 3 minutes from the valve. Sufficient care was taken that the Tarson bottles were properly rinsed 2 to 3 times with the sample water before collecting the same so as to avoid any kind of contaminant in the bottle affecting the quality of the sample. The samples were acidified with 5% HNO_3 solution. The heavy metal analysis was carried out at IPSHEM, Goa using Agilent Technologies made Inductively Coupled Plasma – Mass Spectrometer (ICP-MS) and the concentrations found are given in Table 2.

Table 1: Sampling details

Sample No.	Sample Details	Sample No.	Sample Details
	North Santhal field		**Lanwa Field**
1	Borewell-1 at North Santhal CTF	9	Borewell at Lanwa Field
2	Borewell-2 at North Santhal CTF	10	Produced Water of Lanwa Field collected at NS CTF
3	ETP in-let at North Santhal CTF	11	ETP out-let at Lanwa Field
4	ETP out-let at North Santhal CTF		**North Kadi Field**
	Balol Field	12	Borewell near North Kadi
5	Borewell at Balol GGS-I	13	ETP in-let at North Kadi
6	Borewell(main) at Balol Field	14	ETP out-let at North Kadi
7	ETP out-let at Balol Field		
8	Produced Water of Balol Field collected at NS CTF		

Table 2: Heavy Metal Concentrations in Water Samples

Sl No.	Heavy Metals (ppb)														
	Ba	Cr	Co	Ni	V	Mn	Fe	Zn	Se	Ag	Cu	Pb	Cd	As	Hg
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	60.11	1.62	1.24	0.89	11.20	0.47	8.52	146.68	0.32	0.58	3.89	0.82	0.00	2.57	0.31
2	84.73	1.21	0.70	0.57	16.32	0.48	6.91	60.80	0.42	0.22	5.01	0.00	0.00	3.58	0.28
3	846.82	1.75	0.99	0.98	2.56	52.15	4.56	93.70	2.58	0.06	27.50	0.33	0.01	5.91	0.15
4	1505.78	1.88	0.49	1.33	2.75	47.22	12.86	90.12	4.77	0.05	53.66	0.34	0.00	6.13	0.16
5	23.66	0.50	0.29	0.63	2.15	0.00	4.98	119.36	5.36	0.04	16.78	0.32	0.08	2.21	0.10
6	38.21	0.49	0.28	0.73	4.74	0.00	11.27	194.83	6.43	0.11	13.28	0.19	0.01	2.77	0.08
7	1561.12	1.23	0.42	1.10	4.40	0.16	147.62	85.11	4.06	0.07	35.38	0.09	0.00	6.15	0.24
8	1750.36	3.52	0.36	1.14	3.33	196.94	11.31	86.88	5.31	0.07	43.53	0.15	0.00	7.86	0.80
9	19.09	5.02	0.20	0.41	8.60	0.21	3.96	451.20	9.09	0.16	27.72	0.20	0.04	1.93	0.03
10	2075.63	1.72	1.17	1.13	3.53	55.64	3.25	291.66	6.55	0.14	34.58	0.23	0.01	6.73	0.12
11	1803.00	1.27	0.44	1.35	3.22	3.30	214.15	275.34	7.09	0.11	60.33	0.05	0.00	6.37	0.05
12	36.07	1.76	0.16	3.48	2.53	0.79	10.25	588.21	9.78	0.15	35.15	0.14	0.08	0.89	0.02
13	1463.69	3.14	0.93	1.53	4.79	72.36	18.85	355.27	6.96	0.13	86.71	0.07	0.01	6.95	0.30
14	1251.85	3.50	0.74	1.56	3.56	52.15	103.58	233.81	8.50	0.13	64.28	0.06	0.00	6.83	0.08

3. RESULTS AND DISCUSSION

The results of laboratory analysis revealed the concentrations of metals like Barium, Chromium, Cobalt, Nickel, Vanadium, Manganese, Iron, Zinc, Selenium, Silver, Copper, Lead, Arsenic and Mercury in collected water samples and shown in table 2. Beryllium (Be), Gallium (Ga) and Tellurium (Tl) were found nil in all collected water samples.

3.1. Impact of heavy metals

Heavy metals are natural components of the Earth's crust. They cannot be degraded or destroyed. To a small extent they enter our bodies via food, drinking water and air. As trace elements, some heavy metals (e.g. copper, selenium, zinc, Manganese and iron) are essential to maintain the metabolism of the human body. However, at higher concentrations they can lead to poisoning. Heavy metal poisoning could result, for instance, from drinking-water contamination (e.g. lead pipes), high ambient air concentrations near emission sources, or intake via the food chain. Heavy metals are dangerous because they tend to bioaccumulate which means an increase in the concentration of a chemical in a biological organism over time, compared to the chemical's concentration in the environment. Compounds accumulate in living things any time they are taken up and stored faster than they are broken down (metabolized) or excreted. Heavy metals can enter a water supply by industrial and consumer waste, or even from acidic rain breaking down soils and releasing heavy metals into streams, lakes, rivers, and groundwater.

Research studies appear to have been made of the amounts of each metal concentration that can be tolerated in drinking water, but because of its toxic effects on the heart, blood vessels and nerves, a level with a large safety factor has been set which explains how it is fatal to humans in high doses. For example, Barium can accumulate in the liver, lungs and spleen at more than more than 550 milligrams. Similarly, for all measured metals particular concentration is set by various agencies through various research studies at which impact of these metals on aquatic environment is minimum.

Iron occurs naturally in many groundwater supplies. It is essential in human and animal diets, but high levels may impart an objectionable taste or odour to water. Animals may be sensitive to changes in iron concentrations in their drinking water. Dairy cows may not drink enough water to maintain optimum milk production if the water is high in iron. Dissolved iron in water used for washing and sanitizing milk-handling equipment may impart an oxidized or cardboard-like flavor to the

As far as Cadmium is known, it is biologically a non-essential, non-beneficial element of high toxic potential. Evidence for the serious toxic potential of cadmium is provided by;

1. Poisoning from cadmium contaminated food and beverages;
2. Epidemiological evidence that cadmium may be associated with renal arterial hypertension under certain conditions;
3. Epidemiological association of cadmium with "Itai-itai" disease in Japan
4. Long-term oral toxicity studies in animals.

Arsenic is perhaps unique among the heavy metalloids and oxyanion-forming elements in its sensitivity to mobilization at the pH values typically found in ground waters (pH 6.5–8.5) and under both oxidizing and reducing conditions. Arsenic can occur in the environment in several oxidation states 3 (-3, 0, +3 and +5) but in natural waters is mostly found in inorganic form as oxyanions of As (III) or As (V). Organic Arsenic forms may be produced by biological activity, mostly in surface waters; however this occurs where waters are significantly impacted by industrial pollution.

The toxic effects of Mercury depend on its chemical form and the route of exposure. Methylmercury [CH_3Hg] is the most toxic form. It affects the immune system, alters genetic and enzyme systems, and damages the nervous system, including coordination and the senses of touch, taste, and sight. Methylmercury is particularly damaging to developing embryos, which are five to ten times more sensitive than adults. Exposure to methylmercury is usually by ingestion, and it is absorbed more readily and excreted more slowly than other forms of mercury.

(i). Barium

The prescribed permissible limit of Ba concentration in drinking water standard is 700 ppb (IS 10500-2012) and the maximum contaminant level set by the EPA and used by the PADEP is 2000 ppb, observed concentrations of Ba was found to be lower side in bore well water samples. However, observed levels of Ba present in produced water are on higher magnitude, though these water resources are never going to be used as drinking water without prior treatment. Therefore, a close watch needs to be kept on Ba concentrations in produced water before draining in to surrounding environment, despite present quantities in ground water samples are unable to cause health effects in humans and hence, are not considered to be harmful.

(ii). Chromium

The prescribed permissible limit of Cr concentration in drinking water standard set by EPA is 100 ppb and 50ppb by IS 10500-2012, observed concentrations of Cr was found to be much lower side. Therefore, present levels of Cr observed in water samples are orders of magnitude lower than those shown to cause health effects in humans and hence, are not considered to be harmful.

(iii). Cobalt

There is no prescribed permissible limit of Co concentration in drinking water standard set by either EPA or IS 10500-2012, observed concentrations of Co was found to be normal in given geographical conditions. According to research findings globally, the concentration of Cobalt in surface and groundwater generally lies between 1 and 10 ppb in populated areas; concentration may be higher in areas that are rich in cobalt-containing minerals or in areas near mining. In most drinking water, cobalt levels are less than 1–2 ppb. Therefore, present levels of Co observed in present water are orders of magnitude lower than those shown to cause health effects in humans and hence, are not considered to be harmful.

(iv). Nickel

The prescribed permissible limit of Ni concentration in drinking water standard is 20 ppb (IS 10500-2012), observed concentrations of Ni was found to be lower side. Therefore, levels of Ni observed in present water samples are orders of magnitude lower than those shown to cause health effects in humans and hence, are not considered to be harmful.

(v). Vanadium

There is no prescribed permissible limit of Vanadium concentration in drinking water standard set by either EPA or IS 10500-2012, observed concentrations of Vanadium was found to be normal in given geographical conditions. Therefore, levels of vanadium observed in present water are orders of magnitude lower than those shown to cause health effects in humans and hence, are not considered to be harmful.

(vi). Manganese

The prescribed permissible limit of Manganese concentration in drinking water standards set by EPA and IS 10500-2012 is 100 ppb, observed concentrations of Mn was found to be much lower side. Therefore, Levels of Mn observed in present water are orders of magnitude lower than those shown to cause health effects in humans and hence, are not considered to be harmful.

(vii). Iron

The prescribed permissible limit of Fe concentration in drinking water standard set by IS 10500-2012 is 300 ppb, observed concentrations of Fe was found to be lower side. Therefore, present levels of Fe observed in water samples are orders of magnitude lower than those shown to cause health effects in humans and hence, are not considered to be harmful and moreover these water resources are never going to be used as drinking water without prior treatment.

(viii). Zinc

The prescribed permissible limit of Zn concentration in drinking water standard is 5000 ppb (IS 10500-2012), observed concentrations of Zn was found to be much lower side. Therefore, present levels of Zn observed in water samples are orders of magnitude lower than those shown to cause health effects in humans and hence, are not considered to be harmful.

(ix). Selenium

The prescribed permissible limit of Se concentration in drinking water standard is 10 ppb (IS 10500-2012), observed concentrations of Se was found to be lower side in all water samples. However, observed levels of Se present in produced water and bore-well water samples except in North Santhal field are close to the magnitude, though these water resources are never going to be used as drinking water without prior treatment. Therefore, a close watch needs to be kept on Se concentrations in produced water before draining in to surrounding environment.

(x). Silver

The prescribed permissible limit of Ag concentration in drinking water standard is 100 ppb (IS 10500-2012), observed concentrations of Ag was found to be much lower side. Therefore, present levels of Ag observed in water samples are orders of magnitude lower than those shown to cause health effects in humans and hence, are not considered to be harmful.

(xi). Copper

The prescribed permissible limit of Cu concentration in drinking water standard is 50 ppb (IS 10500-2012), observed concentrations of Cu was found to be lower side in bore well water samples. However, observed levels of Cu present in produced water are on higher magnitude, though these water resources are never going to be used as drinking water without prior treatment. Therefore, a close watch needs to be kept on Cu concentrations in produced water before draining in to surrounding environment.

(xii). Lead

The prescribed permissible limit of Pb concentration in drinking water standard is 10 ppb (IS 10500-2012), observed concentrations of Pb was found to be much lower side. Therefore, present levels of Pb observed in water samples are orders of magnitude lower than those shown to cause health effects in humans and hence, are not considered to be harmful despite these water resources are never going to be used as drinking water without prior treatment.

(xiii). Cadmium

The prescribed permissible limit of Cd concentration in drinking water standard is 3 ppb (IS 10500-2012), observed concentrations of Cd was found to be much lower side.

Therefore, present levels of Cd observed in present water are orders of magnitude lower than those shown to cause health effects in humans and hence, are not considered to be harmful despite these water resources are never going to be used as drinking water without prior treatment.

(xiv). Arsenic

The prescribed permissible limit of total As concentration in drinking water standard is 10 ppb (IS 10500-2012), observed concentrations of As was found to be much lower side in bore well water samples. However, observed levels of As present in produced water are on higher magnitude than bore well water samples, though these water resources are never going to be used as drinking water without prior treatment. Therefore, a close watch needs to be kept on As concentrations in produced water before draining in to surrounding environment to prevent possible contamination of drinking or surface water.

(xv). Mercury

The prescribed permissible limit of Hg concentration in drinking water standard is 1 ppb (IS 10500-2012), observed concentrations of Hg was found to be lower side in bore well water samples and produced water samples as well. However, Hg levels in produced water samples are on higher magnitude than bore well water samples, though these water resources are never going to be used as drinking water without prior treatment. Therefore, a close watch needs to be kept on Hg concentrations in produced water before draining in to surrounding environment to prevent possible contamination of drinking or surface water.

4. CONCLUSION

The measured metals in bore well water samples collected from all four fields are much less than those standards set by EPA and Indian standard for drinking water specifications. However, metals like Barium, Selenium, Copper and Arsenic were seen at concentrations close to these standard specifications in produced water samples and ETP water samples. Therefore, it is recommended that adequate care needs to be taken while discharging these water samples to the surrounding environment/ water bodies. Though, it is noticed that all metals in ground water samples have concentrations which are less than the drinking water standard (IS 10500 – 2012). This clearly shows that the produced water is not mixing with the ground water. In other words, the exploration and production operations are not contaminating the ground water in North Santhal, Balol, Lanwa and North Kadi.

5. ACKNOWLEDGEMENT

The authors are grateful to the ONGC's management for encouraging for preparation and presentation of this paper. They also wish to acknowledge ED-HoI, IPSHEM for his continuous guidance and support.

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