African Journal of Environmental Science and Technology Vol. 2 (9). pp. 265-271, September, 2008
Available online at http://www.academicjournals.org/AJest
ISSN 1996-0786 © 2008 Academic Journals

Full Length Research Paper

Occurrence of elevated nitrate in groundwaters of Krishna delta, India

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Accepted 28 August, 2008

Nitrate concentrations were measured in the groundwater samples of Krishna delta, India. The results indicate a large variation of nitrate from 10 - 135 mg/l. In 79 groundwater samples, about 39% shows high nitrate contents (>50 mg/l), which is more than the permissible limits in drinking water. In north Krishna delta 49% and in south Krishna delta 26% water samples were found to exceed the permissible limits. This study indicates that groundwater of north Krishna delta is more polluted than south. Nitrate pollution level is found more in dug wells compared to hand pumps/bore wells. In this region 49% dug wells and 31% hand pumps have exceeded the desirable limits. The possible sources for the high nitrate level in groundwater were identified as excessive utilization of nitrogenous fertilizers for agricultural purposes.

Key words: Nitrate pollution, groundwater, Krishna delta, India.

INTRODUCTION

The presence of high nitrate concentration (>50 mg/l) in groundwater would normally indicate pollution of groundwater. The World Health Organization (WHO, 1993) standard was originally set at 45 mg/l nitrate has been adjusted to 50 mg/l (Chettri and Smith, 1995; Canter, 1997). Since presence of excess nitrate ions in groundwater is harmful to health, their occurrence in high concentrations in groundwater is a matter of great concern. The leaching of nitrates from agriculture land has been a major research focus in past two decades. It is well-known that inorganic nitrogen fertilizers, septic tanks, poor dug wells and defective sewerage systems are the suspected major sources of nitrate in groundwater systems (Piskin, 1973; Canter, 1997, Lindsay, 1997).

It is well established, if nitrates are consumed more than the permissible limit (> 50 mg/l), it may lead to several types of diseases (Reddy, 1981; Dudley, 1990). Chemically during nitrate-water reaction, the nitrates are converted into nitrites and such reactions take place in the digestive system of human body. The nitrates oxidize the hemoglobin to met-hemoglobin and cause for several types of disease, which mostly depend on duration and quantity of nitrite consumption (Perlistein and Attala, 1976; Dudley, 1990). The Met-hemoglobin is a pigment, which is incapable of acting as oxygen carrier in blood vessels. The consumption of nitrate rich water cause a large number of diseases like dizziness, abdominal disorder, vomiting, weaknesses, high rate of pulptation, mental disorder and even stomach cancer etc. (Perlistein and Attala, 1976; Reddy, 1981; Thind, 1982; Burt et al., 1993).

The study area lies within the Krishna delta, which is very fertile for the agricultural point of view. The sand plain aquifers are the main source of water for agriculture and domestic purposes. The deltaic aquifers are recharged by direct infiltration of precipitation. Dug wells, bore wells and hand pumps are the major drinking water source in this delta. As a part of research and development activity in the delta particularly for the assessment of groundwater quality, 79 groundwater samples were collected and analysised. The purpose of this work is to determine the extent of nitrate in groundwater in selected regions of north and south Krishna delta and to study the possible source of nitrate pollutants and suggest possible measures for the protection of groundwater quality in the delta.

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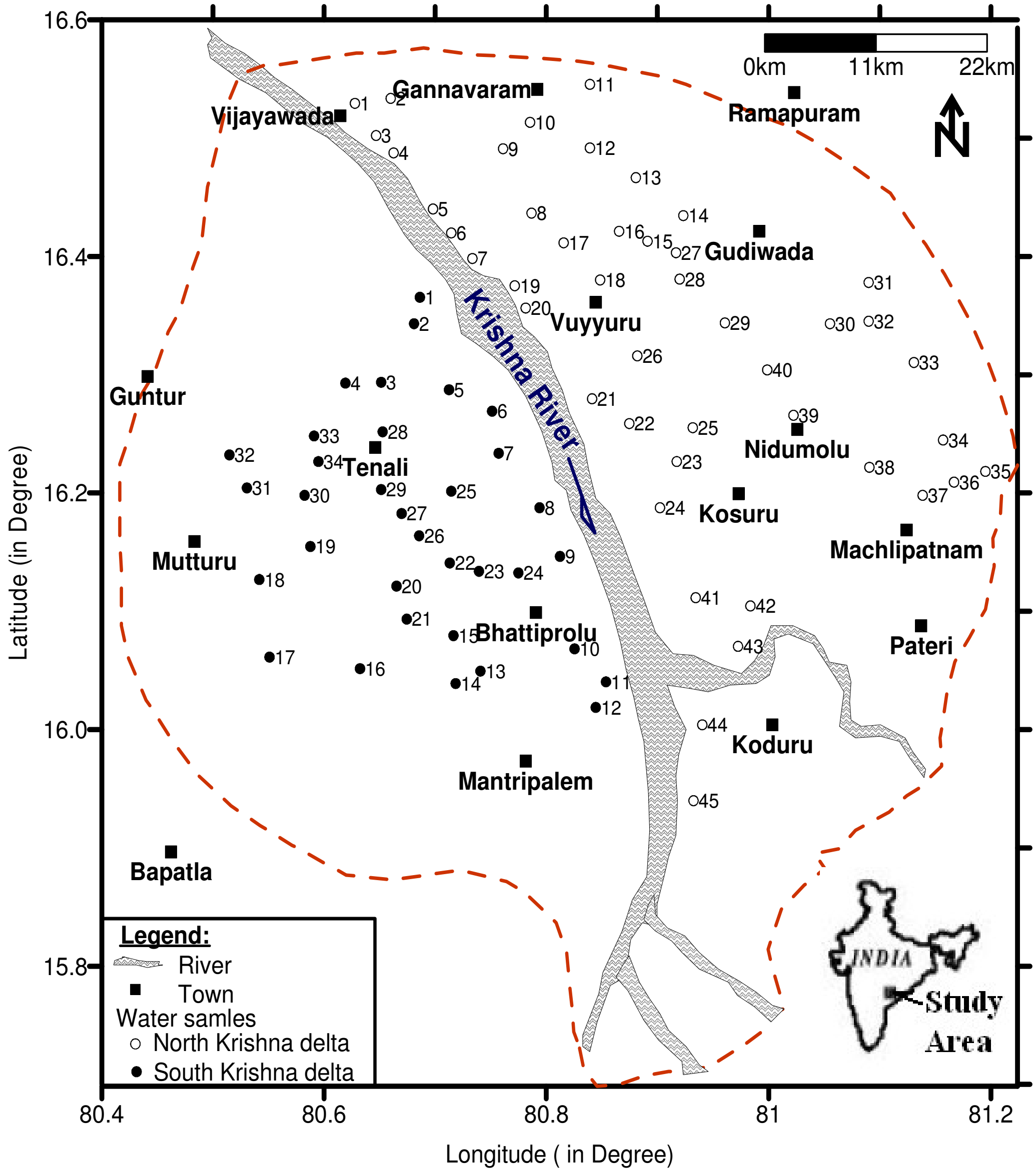

Figure 1. Location of groundwater samples, Krishna delta, India.

MATERIALS AND METHODS

About the area

Krishna Delta (Longitude: 80^{0}24$'$ - 81^{0}13$'$E, Latitude: 15^{0}42$'$ - 16^{0}35$'$N) is formed by the holy river Krishna, close to the Bay of Bengal in the east coast of India. The river Krishna originates from the Western Ghats near Mahabaleswar, Maharashtra. After covering a distance of 480 km in Maharashtra, 291 km in Karnataka and 510 km in Andhra Pradesh (a total distance of 1281 km) it emerges into the Bay of Bengal and forms a delta (Figure 1). A large number of townships such as Tenali, Vijayawada, Guntur, Machlipatnam, Nizampatnam and Repalle are located in the delta region. The right side of the Krishna river is known as North Krishna Delta and the left side is known as South Krishna Delta. Most of the soil of this delta region is alluvium (Saxena et al., 2004). The flood basin on the right bank of the Krishna river is covered with black clay and grey clay underlain by brown silty clays and fine sands. The sand plain aquifers are the main source of water for agriculture and domestic purposes. The deltaic aquifers are recharged by direct infiltration of precipitation. The dug wells, bore wells and hand pumps are the major drinking water source in the Krishna delta (Saxena et al., 2003; Mondal et al., 2008). Average annual rainfall is 1050 mm and temperature is 28°C.

Groundwater sampling

The regions for the study of nitrate in groundwater cover both the urban and rural areas of Krishna delta (Figure 1). In total 79 groundwater samples, 37 were collected from dug wells, 39 from hand pumps, 2 from bore wells and 1 from the river Krishna. The depths of the water in dug wells are in between 1.7 to 20 m, whereas 8 to 35 m in hand pumps. The water samples were collected in double stopper 100 ml polythene bottles. The precise locations of the sampling points were determined in the field

Table 1. Place of sample collection, source, depth, Nitrate and pH, North Krishna Delta, India.

Sample No.	Locality	Type of well	Depth of well (m)	Nitrate (mg/L)	pH
1	Vizayawada-I	H.P.	13.0	10	7.7
2	Ramavarepalle	H.P.	10.0	60	7.8
3	Vizayawada-II	H.P.	35.0	42	7.5
4	Vizayawada-III	D.W.	4.0	10	7.6
5	Chdavaram	B.W.	53.0	10	7.5
6	Krishna river	River water	---	10	7.2
7	Royyuru	H.P.	15.0	40	7.6
8	Kantipadu	D.W.	8.0	40	7.5
9	Uppuluru	H.P.	16.0	54	7.7
10	Kesoropalle	D.W.	3.6	104	7.8
11	Bapeshwaram	B.W.	60.0	116	7.7
12	Tarogupalle	H.P.	16.0	116	7.9
13	Indupalle	D.W.	4.9	88	7.7
14	Venkatpragudu	H.P.	16.0	56	7.5
15	Bollapadu	H.P.	25.0	88	7.6
16	Koturu	D.W.	2.9	46	7.5
17	Nappalle	H.P.	20.0	10	7.6
18	Vuyyuru	H.P.	15.0	10	7.6
19	Vallurupalem	H.P.	20.0	10	7.6
20	Vallurupalem	H.P.	10.0	56	7.7
21	Meduru	H.P.	8.0	24	7.5
22	Krishapuram	D.W.	2.1	20	7.8
23	Movva	H.P.	28.0	10	7.6
24	Kudali	H.P.	25.0	51	7.8
25	Paddapudi	H.P.	10.0	10	7.6
26	Kapileshwaram	H.P.	12.0	72	7.8
27	Modumuru	H.P.	17.0	56	7.7
28	Elamoru	D.W.	4.0	52	7.7
29	Pammaru	H.P.	25.0	10	7.7
30	Gollavaluru	H.P.	10.0	20	7.9
31	Angaluru	H.P.	13.0	25	8.0
32	Kavataram	D.W.	1.7	18	7.9
33	Vallamunudu	D.W.	1.8	108	8.0
34	Pedana	D.W.	1.9	125	8.3
35	Manganpudi	D.W.	3.6	86	7.6
36	Chilkapudi	D.W.	2.5	122	7.9
37	Sultanpur	D.W.	2.1	56	8.2
38	Gudore	D.W.	2.3	120	7.8
39	Nidumolu	D.W.	2.5	44	7.9
40	Juthovaram	H.P.	25.0	40	7.8
41	Chellapalle	D.W.	2.1	62	7.8
42	Gollapalem	D.W.	2.2	63	8.4
43	Kalkenpeta	D.W.	3.4	130	7.8
44	Avanigadda	H.P.	8.0	10	7.6
45	Nayalanka	H.P.	26.0	10	7.6

(D.W: Dug well; B.W: Bore well, H.P: Hand pump and pH: $-\log_{10}H^+$)

through the development of GARMIN-12 Channel Instrument, based on the principles of Global Positioning System (GPS), and the exact longitude and latitude of the sampling. The location of the sampling points is shown in Figure 1.

Methodology

Measurement of pH was done by the portable pH-meter. Nitrate analyzer were used to measure the nitrate concentration in mg/L of

Table 2. Place of sample collection, source, depth, Nitrate and pH, South Krishna Delta, India

Sample No.	Locality	Type of well	Depth of well (m)	Nitrate (mg/L)	pH
1	Vallbhapuram	H.P.	23.0	30	7.8
2	Imani	H.P.	27.0	48	7.4
3	Attola	H.P.	13.0	52	7.8
4	Kolakaluru	D.W.	3.0	38	7.6
5	Chivaluru	H.P.	10.0	30	7.8
6	Thuruluru	H.P.	8.0	10	7.5
7	Anathavaram	H.P.	24.0	10	7.4
8	Kolluru	H.P.	17.0	10	7.6
9	Denapudi	H.P.	33.0	24	8.2
10	Karumuru	D.W.	3.0	40	7.5
11	Petaru	D.W.	3.0	18	8.0
12	Repallur	H.P.	15.0	10	8.0
13	Rajavolu	D.W.	3.8	32	8.0
14	Gollapallu-I	D.W.	3.8	68	7.8
15	Gollapallu-II	D.W.	3.0	75	8.2
16	Inturu	D.W.	2.0	40	7.8
17	Nanadivelugu	D.W.	4.0	10	7.8
18	Munnupalle	H.P.	8.0	62	7.5
19	Sunduru	H.P.	16.0	10	8.0
20	Marlaluru	D.W.	3.7	40	8.1
21	Panchalva	D.W.	3.5	110	8.3
22	Peravil	D.W.	4.5	20	7.6
23	Chevali	D.W.	4.6	28	7.8
24	Kodimaru	D.W.	3.3	24	8.2
25	Jampani	H.P.	10.0	42	7.8
26	Mulpur	D.W.	4.4	10	7.6
27	Kuchipidi	D.W.	4.4	50	7.5
28	Tenali	D.W.	20.0	105	7.8
29	Channavaranur	D.W.	15.0	135	7.5
30	Eolapalli	H.P.	8.0	20	7.6
31	Chebrolu	D.W.	4.4	105	7.8
32	Narakoduru	D.W.	9.5	33	7.8
33	Jagarlamudi	H.P.	12.0	62	7.9
34	Molluluru	H.P.	25.0	35	7.6

(D.W: Dug well; B.W: Bore well, H.P: Hand pump and pH: $-\log_{10}H^{+}$)

groundwater (Saxena, 1991). The results of nitrate concentrations are shown in Tables 1 and 2.

RESULTS AND DISCUSSION

The studies carried out on the nitrate contents have shown that concentration varies from 10 - 135 mg/l. The nitrate concentration in different ranges, classified these water samples into six categories and shown in Figure 2. This figure shows, 27% samples of north Krishna delta and 21% of south Krishna delta have low nitrate (≤10 mg/l); 22% samples of north and 47% of south in between 11 to 45 mg/l; 27% samples of north and 21% of south are in between 46 to 75 mg/l; 7% samples in north, but there is no sample in south which have nitrate of 76 to 100 mg/l. It seems to be at a high pollution level and the water can be used other than drinking purposes. 16% in north and 9% in south of water samples have a high value of nitrate (101-125 mg/l) and extremely high nitrate content (>126 mg/l) is reported in 2% of groundwater samples in both the regions. The isolevels of nitrate concentration have been drawn and shown in Figure 3. This figure indicates that the behavior of nitrate enrichment is high in Gudiwada, Gannavaram, Kosuru, Nidumolu and Muchlipatnam areas of north Krishna delta. The south Krishna delta, which is near to sea coast, is free from ni-

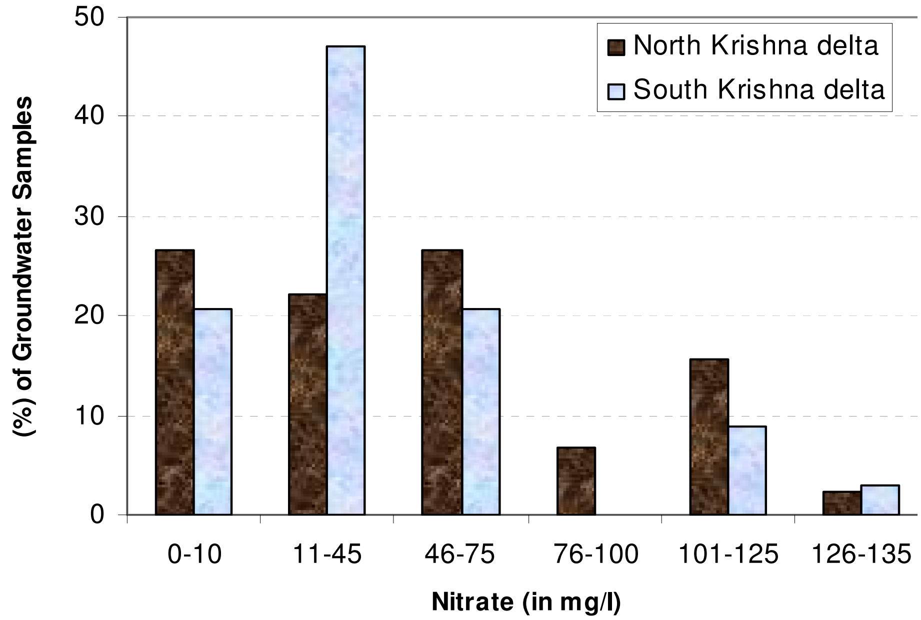

Figure 2. Sample percentage based on different ranges of nitrate concentration.

Table 3. Range of Nitrate concentrations and their mean values in groundwater samples of Krishna delta.

Sl. No.	Locality/type of wells	Number of samples	Range of nitrate conc. (mg/L)	Mean Conc. of nitrate (mg/L)
North Krishna delta				
(a)	Dug well	18	10-130	72
(b)	Bore well	2	10-116	63
(c)	Hand pump	24	10-116	37
South Krishna delta				
(a)	Dug well	19	10-135	52
(b)	Bore well	Nil	Nil	Nil
(c)	Hand pump	15	10-62	30

nitrate pollution except in and around Tenali town, Mutturu and west of Bhattiprolu. In general the possible sources of nitrate that lead to nitrite in groundwater are nitrogen rich sediments, interaction of groundwater with nitrogen rich industrial waste, inputs of organic nitrogen into soil, biological denitrogen fixation by micro organisms,inputs of human and animal waste, water in unused dug wells, stagnate water and nitrogenous inorganic fertilizers etc (Hammer, 1986; Dudley, 1990; Barnes and Smith, 1992). pH varies from 7.2 to 8.4. It indicates that groundwater is mildly alkaline.

During the field investigation, no such industries were found which could transport the nitrate rich industrial waste in the studied area. Krishna delta is known for its fertile soil, which is very much favorable for the cultivation of mainly paddy and sugarcane. The inorganic nitrogen-nous fertilizers are used to increase the growth rate of this agricultural production (Singh et al., 2004). The common inorganic nitrogen fertilizers, which are widely used in the region, are urea, calcium ammonium nitrates, ammonium chloride and calcium phosphates etc. The nitrogen content in these fertilizers is high and varies from 20 to 50%. Mostly these fertilizers are soluble in water and easily release nitrogenous mass (Burt et al., 1993). In chemical process, fertilizer reacts with water/moisture and decomposes into amino acid. These amino acids are degraded to ammonium sulphates and ammonium amines, which in tern oxidize to nitrites. In atmospheric condition nitrites are very unstable and soon converted into nitrates. In view of the nitrates solubility in water, they rapidly increase the nitrate pollution level in the groundwater. The range of nitrate in different water sources and their mean value are shown in Table 3. On the basis of Figure 2 and Table 3, it is observed that the

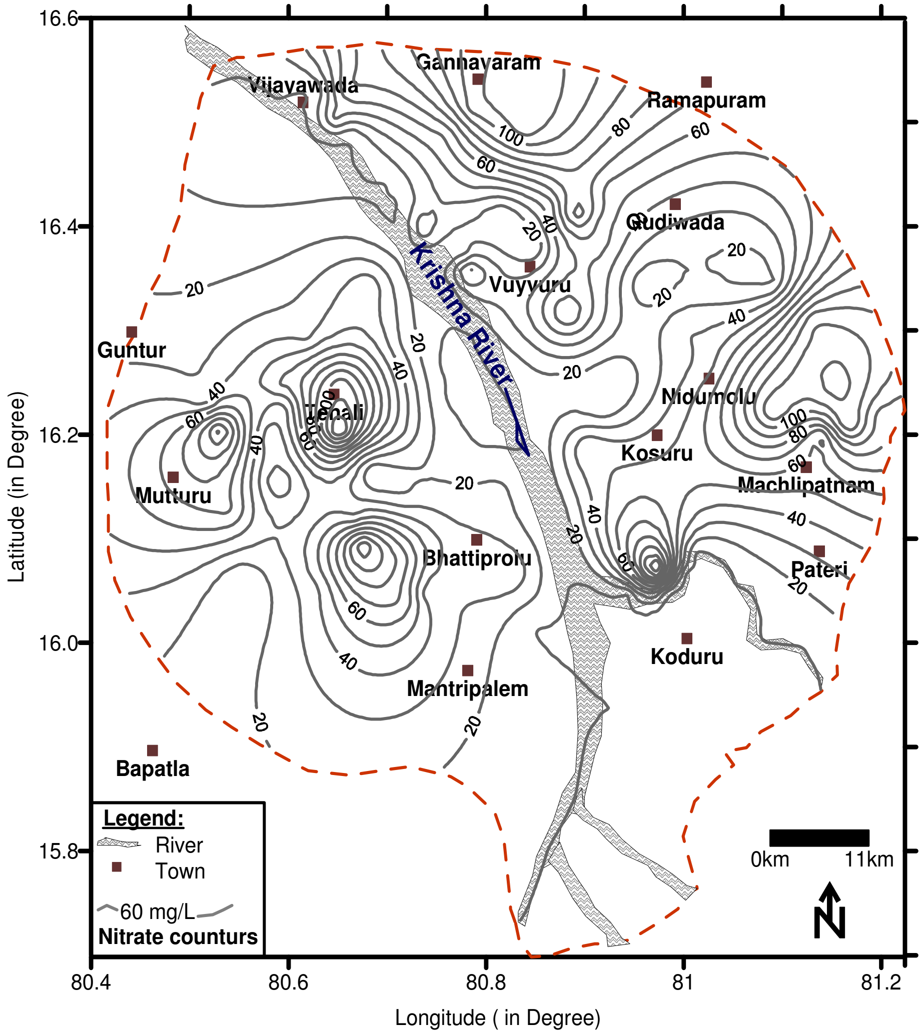

Figure 3. Isolevels of nitrate concentration in Krishna delta.

groundwater of north Krishna delta is more polluted than south. Field study and personal communication with concern people indicate that high quantity of inorganic nitrogen fertilizers was used in this region. The nitrate data also indicate pollution level is more in dug wells compared to hand pumps/bore wells (Table 3). It is mainly because of poor dug wells structure. In practice nitrogen fertilizers are supplied in the agriculture field at a period before the crop grows but some time the crop yields may not be as high as anticipated because of unrealistic yield or adverse weather condition and this can result in runoff and leaching of residual nitrate in the soil and in turn pollute the groundwater.

Conclusions

Groundwater of north Krishna delta is more polluted than south Krishna delta in term of nitrate. Its level in this region 49% dug wells and 31% hand pumps have exceeded the desirable limits, which indicate that dug wells are more nitrate contents compared to hand pumps/bore wells. The high nitrate level in groundwater is due to excessive utilization of nitrogenous fertilizers, insecticides and pesticides for agricultural purposes. To reduce the nitrate level immediately the following steps can be adopted: High nitrate content of poor dug wells can be reduced by the maintenance of it's structure, Leaching of nitrate from the inorganic fertilizers can be minimized by control use of nitrogenous fertilizers and de-nitrification technique is useful to reduce the nitrate content of groundwater.

ACKNOWLEDGEMENTS

Authors are grateful to Dr. V.P. Dimri, Director, National Geophysical Research Institute, Hyderabad, for his kind permission to publish this paper and the anonymous reviewer for providing his the valuable suggestions to improve the manuscript.

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