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An Appraisal of Hazard Index Due to Nitrate Exposure in the Groundwaters of Bellandur, Bangalore, India

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ABSTRACT

Nitrate contamination of drinking water has become a massive public health concern since excessive nitrate concentrations are found to cause several health disorders. The present study was undertaken to investigate the nitrate levels in the groundwaters of Bellandur during the pre- and post-monsoon periods of 2017, compare the analysis results with the drinking water standards as per the Bureau of Indian standards (BIS) and assess the potential risk to human health by evaluating by using the Hazard Index (HI) with respect to nitrates. This was achieved by subjecting 30 groundwater samples each, collected from the study area, during the pre and post monsoon seasons. The analysis results reveal that 53.33% of the samples contain nitrate in excess of 45 mg/l, the maximum allowable limits of drinking water laid down by BIS. The hazard index (HI) was evaluated by computing the Chronic Daily Intake (CDI). Results reveal that 14 samples in the post-monsoon and 12 samples in the pre-monsoon have a hazard index greater than unity (1), which indicates a high level of risk due to nitrate exposure in the groundwater endangering the respondents due to excessive nitrate concentrations in the groundwater.

Introduction

One of the most important resources of water is the groundwater found underneath the surface in the spaces of the pore of the formations of ruptured rocks (Jamaludin et al., 2013). Any contamination that can percolate the soil and rocks has the potential to reach the groundwater beneath (Sampson et al., 2012.) Amongst the several contaminants in water, inorganic nitrogen compounds are very burdensome. They are easily soluble which makes their removal from water very difficult (Adam Pawełczyk, 2012). Nitrate is one of the most hazardous parameters indicating the pollution of water sources, especially groundwater. As per the Bureau of Indian standards, the maximum permissible concentration of nitrate in drinking water is 45mg/l) and its presence in excess, in groundwater is extremely harmful to health and hence a very serious issue. The major sources of nitrate in groundwater are the use of inorganic fertilizers of nitrogen; poorly maintained dug wells, septic tanks, and defunct sanitary systems (Piskin, 1973., Canter, 1997., Lindsay, 1979). In addition to agricultural practices, there are several other potential sources increasing the concentrations of nitrate in groundwater. A vast majority of these sources are due to urbanization, as a result of urban development. Nitrate sources can be group in diffuse sources (parks and gardens, atmospheric deposition), intense point sources (industrial chemical spills or landfill leachate) and multi-point sources such as leaking sewers and septic tanks (Learner, 2003). Nitrate may also reach the aquifers by leakage of sewer and on-site disposal systems such as septic tanks. The major sources of nitrate in aquifers throughout the world are mostly related to wastewater disposal (on-site systems and leaky sewers) and solid waste disposal (landfills and waste tips).

Health effects of nitrates on human beings

Groundwater forms a major source for drinking purposes. Excess nitrates consumption is found to cause a disease called blue babies or methemoglobinemia in infants (Prakasa Rao and Puttanna, 2000) characterized by the skin turning blue. If untreated, this could result into a very serious condition and the affected baby may eventually die. There are several other health issues associated with nitrate ,such as oral cancer (Badawi et al.,1999), colon and rectum cancer, and many other gastrointestinal cancers (Paul et al.,1999., Peter, 1998., Leaf and Steven,1996), Alzeimer's disease (Tohgi et al., 1998), absorptive and secretive functional disorders of the intestinal mucosa and changes in maturation, differentiation and apoptosis in intestinal crypts (Ireneusz et al., 1998), reduced casein digestion (Jan, 1998., Govannoni et al.,1997., Irvine et al., 1993), neural tube defects (Li et al., 1996), cytogenetic effect in children (Aspasia et al., 1996), Non- Hodkins's lymphoma (Helen, 1994., Micheal, 1998) and hypertrophy of thyroid (Van, 1994).

Apart from infants, the most sensitive to methemoglobinemia are pregnant women, people deficient in the enzyme converting methemoglobin back to normal hemoglobin, and adults with low stomach acidity (Seńczuk, 2005). It has been seen that the nitrate levels in several areas of the city has been recorded as high as 300 mg/l, which is attributed to the groundwater contamination by sewage. At Shampura, not only are the nitrate levels found to be nearly 20 times the permissible limit, but the Ambedkar Medical College receives 500 cases of nitrate related diseases every year from the surrounding slums.

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Emphasizing on the need for a re-look at environmental health, the doctors opine that the civic authorities need to inform the public, including medical practitioners, about possible geographical clusters that might pose hazards to health and it is the Government's social responsibility to give this information to the appropriate authorities, doctors and citizens so they can take action as without a holistic understanding of a disease, doctors may treat the patients symptomatically and send them back into an environment from where they contracted the problem (The Hindu, 2007).

Thus, the aim of the current study undertaken to assess the quantum of nitrate contamination in the study area, appraise the health risk of exposed population and suggest mitigative measures for the same.

Materials and methods of analysis

Details of the study area

The study area Bellandur lies in the southern part of Bangalore, covering 24 square kilometers and is covered in the toposheet 57H/9 as per Survey of India.

The study area forms a gently undulating terrain with only a few Nallas running from SW to NE. No ridges or hillocks are present in the area. The highest contour is 900 m and lowest is 800 m, thus a drop of 100 m is observed in the area.

The area comprising of Madiwala, Agara, Koramangala, Challaghatta and Bellandur come under the existing sewerage zone that is sewage from Koramangala, Madiwala and Agara all drain into Bellandur tank and treated waste water from Challaghatta treatment plant also drains into Bellandur tank. At present there is no catchment for these tanks as the Nallas on the upstream side are converted into settlements. Since the tank is dry, they have become a store house for the sewage coming from different parts of the city. The BWSSB is also conveniently directing the raw sewage through storm water drains into Bellandur tank. Close to 200 industries are located in the study area.

Sampling and analysis

The analysis was carried out by identifying 30 groundwater sampling stations and collecting samples from these stations comprising both the open wells as well as borewells during the month of April in pre-monsoon as well as during October (post-monsoon) season of 2017 in two litre PVC containers. These were sealed properly, made airtight and later analyzed for nitrates, using a UV- visible spectrophotometer, in compliance with the Standard Methods for the Examination of Water and Wastewater (APHA, 2002). Fig 1 depicts the location map of Bellandur along with the sampling stations.

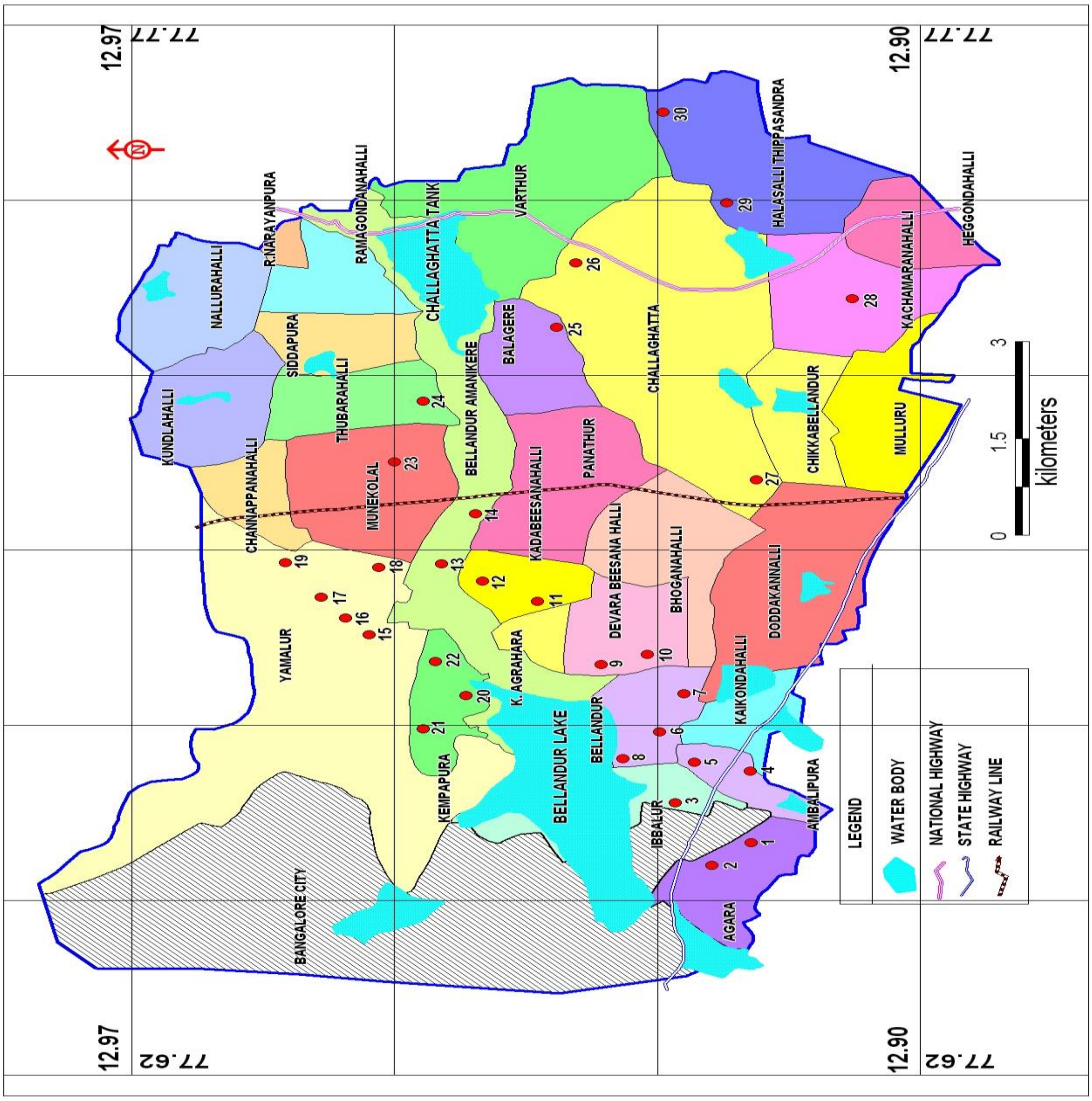

Figure 1. Location map of Bellandur area showing the sampling stations.

Health hazard and nitrate health risk evaluation

The health hazard assay was aimed at determining the tolerability of the risk faced by the population exposed to nitrate content from groundwater used in supply systems. Hazard characterization consists of determining the Hazard Index (HI), which is an indicator of the existing risks from consuming a given substance. The individual risk of developing a negative effect becomes higher along the values of HI (Rojas Fabro et al., 2015)

The US Environment Protection Agency (USEPA) established this relationship for HI (Díaz-Barriga, 1999). This is determined based on the Ingested Dose (ID) and the Reference Dose (RfD). The latter is defined as the concentration of a substance with no toxic effects on the individual over a determined period of time.

$$HI = \frac{\text{Injected dosage}}{\text{Reference dosage}}$$

To ascertain the exposure of nitrate in drinking water, the chronic daily intake (CDI) was first determined making use of the following equation:

$$CDI = \frac{\text{C x DI}}{BW}$$

Where,
CDI = Chronic Daily Intake (mg/kg/day),
C = Nitrate concentration in groundwater (mg/L),
DI = Average daily intake rate of water (L/day),
BW = Body weight of the exposed individual (kg).

To assess the significant exposure and overall potential for non-carcinogenic health effects caused by nitrate in drinking water, the Hazard Index (HI) was calculated using the following equation:

$$HI = \frac{\text{CDI}}{RfD}$$

where,
HI = Hazard Index,
CDI = Chronic Daily Intake (mg/kg/day),
RfD = Reference dose (mg/kg/day)

The RfD value that was used in this study was 1.6 mg/kg/day (USEPA, 2000), while the average body weight (BW) was assumed to be 70 kg. The average daily water intake (DI) was taken as 2 litres/day.

If the HI value equals or exceeds the unit, a hazard level of non-carcinogenic toxic effect exists. Higher the value of HI, the greater is the likelihood of adverse non-carcinogenic health impact (Alif Adham and Shaharuddin, 2014) and hence the issue needs to be addressed immediately (USEPA, 2013).

Results and discussions

Groundwater chemical analysis

The analysis results of groundwater with respect nitrates in the study area during both pre-monsoon and post-monsoon are presented in Table 2. It is seen that 53.33% of the samples have nitrate concentration much higher than the upper limit of 45 mg/l stipulated by the BIS (2003). The mean, minimum and maximum, nitrate concentrations during pre-monsoon are found to be 394.0, 4.0 and 90.9 mg/l respectively and during post monsoon, 418.0, 6.0 and 101.7 mg/l respectively. The nitrate concentration range and mean nitrate values are presented in Table 2. Figure 2 depicts the nitrate contours during pre-monsoon while figure 3 indicates the nitrate contours in the study area. The concentration of nitrate is slightly higher during post-monsoon season, which may be due to the insufficiency in drainage conditions, much higher contact time of groundwater with the material of aquifer and excessive anthropogenic activities (Subba Rao, 2006). Also, the nitrate concentrations in open wells are much higher, than the one from borewells and hand pumps as indicated in Table 2.This may be mainly attributed to the poor structure and inadequate and incorrect maintenance.

Last but not the least, the indiscriminate discharge of such wastes from industrial, domestic /municipal activities in the neighbourhood, as well as leaking drains and inadequate sewage treatment would have led to the excessive levels of nitrates in the area.

Table 1. Nitrate concentrations in groundwater during pre and post-monsoon seasons.

Sample no	NO_3 concentration, mg/l (Pre- monsoon)	NO_3 concentration, mg/l (Post- monsoon)
1	66	82
2	210	224
3	54	52
4	18	27
5	24	33
6	102	104
7	290	335
8	126	155
9	32	40
10	10	10
11	22	28
12	6	8
13	84	97
14	58	68
15	50	54
16	280	284
17	6	6
18	394	418
19	32	40
20	78	92
21	32	40
22	52	66
23	266	292
24	230	252
25	20	20
26	28	35
27	55	62
28	40	48
29	36	41
30	28	38

Table 2. Nitrate concentration range and their mean values in groundwater.

SL NO	Source	No of samples	Range of Nitrate concentration, mg/l		Mean concentration of Nitrate (mg/l)	
			Pre-monsoon	Post-monsoon	Pre-monsoon	Post-monsoon
a	Open well	04	210- 394	224- 418	281.0	307.3
c	Hand pump	09	06- 266	06- 292	85.33	96.77
c	Borewell	17	04- 280	08- 284	49.24	55.94

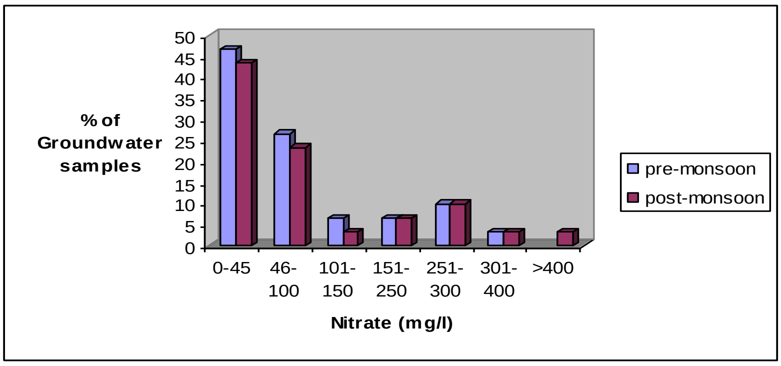

Figure 2. Sample percentage based on ranges of nitrate concentration.

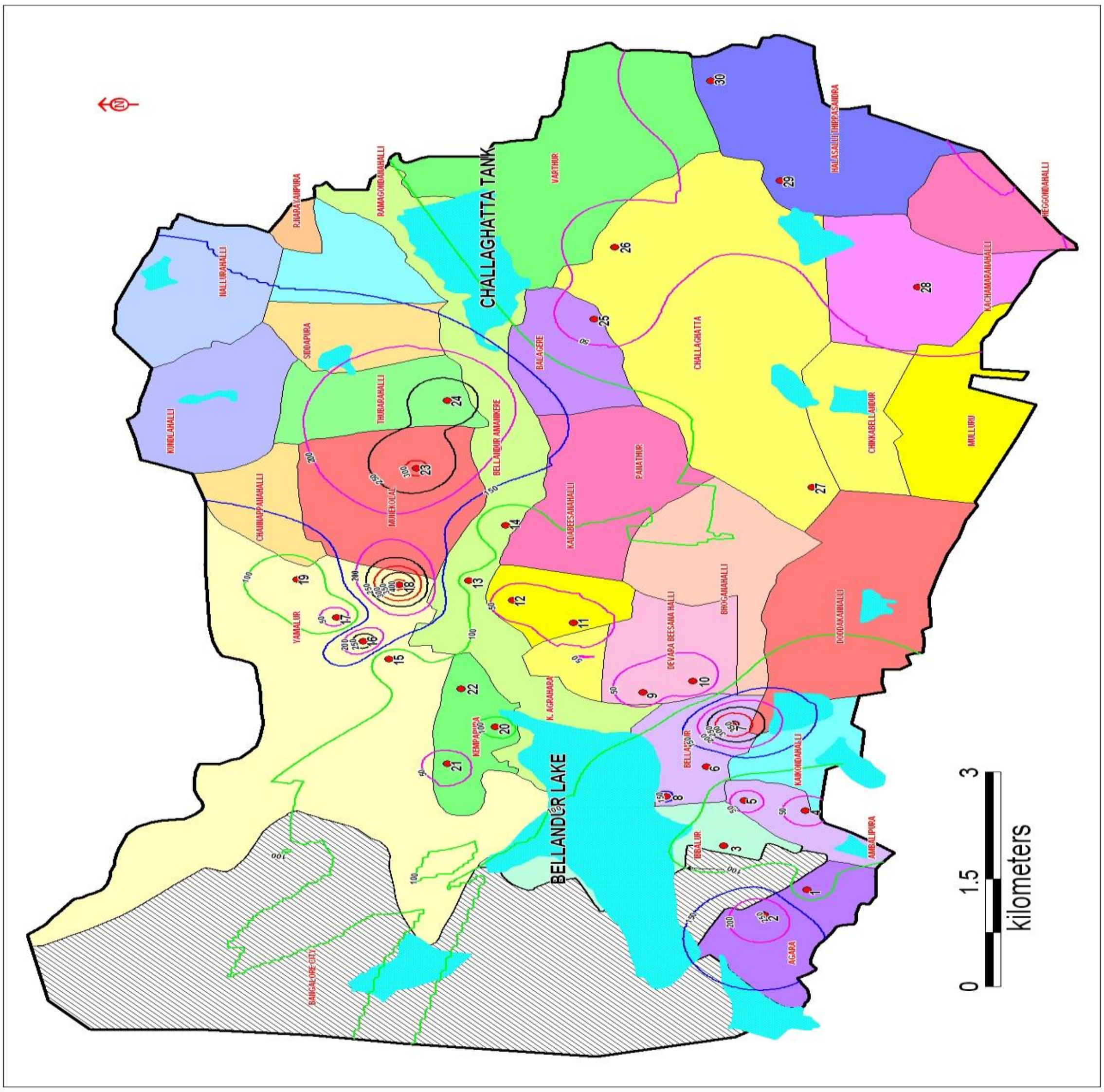

Figure 3. Nitrate contours in the study area.

Hazard characterization and Health Risk assessment

Chronic daily intake data was employed to estimate the individual daily exposure of nitrate. The Mean, minimum and maximum values for CDI and HI was mg kg / day, with the average body weight of 70 kg and daily water intake of 2.00 L /day. Tables 3 and 4 present the results of hazard index analysis for pre-monsoon season and post-monsoon respectively while the integrated HI analysis results for pre-monsoon and post-monsoon seasons are presented in Table 5.

A Hazard Index reading of greater than 1 should be referred to further evaluation (Joel, 2014).

The results reveal that 14 samples in the post-monsoon and 12 samples in the pre-monsoon have hazard index greater than 1, which indicates a significant risk level from nitrate exposure in the groundwater endangering the respondents due to excessive nitrate concentrations in the groundwater. The range of HI obtained in this study was 0.11-7.45. The mean HI values during pre and post monsoon was noticed to be 1.62 and 1.81 respectively. From the analysis, it is seen that 40 % and 46.67% of the samples have HI values above the excessive limit of 1 which indicates that the risk of adverse effect of nitrate pollution in groundwater in the study areas is quite severe and measures need to be taken to abate this hazard and protect the people from the threats of consuming this water.

Table 3. Results of Hazard Index (HI) analysis for pre-monsoon season.

Sample no	Nitrate concentration,mg/l	Chronic daily intake, CDI, mg/kg/day	Hazard index, Hi
P1	66	1.88	1.18
P2	210	5.99	3.74
P3	54	1.54	0.96
P4	18	0.51	0.32
P5	24	0.68	0.43
P6	102	2.91	1.82
P7	290	8.27	5.17
P8	126	3.59	2.24
P9	32	0.91	0.57
P10	10	0.29	0.18
P11	22	0.63	0.39
P12	6	0.17	0.11
P13	84	2.39	1.50
P14	58	1.65	1.03
P15	50	1.43	0.89
P16	280	7.98	4.99
P17	6	0.17	0.11
P18	394	11.23	7.02
P19	32	0.91	0.57
P20	78	2.22	1.39
P21	32	0.91	0.57
P22	52	1.48	0.93
P23	266	7.58	4.74
P24	230	6.56	4.10
P25	20	0.57	0.36
P26	28	0.80	0.50
P27	55	1.57	0.98
P28	40	1.14	0.71
P29	36	1.03	0.64
P30	28	0.80	0.50

Table 4. Results of Hazard Index (HI) analysis for post-monsoon season.

Sample no	Nitrate concentration, mg/l	Chronic daily intake, CDI, mg/kg/day	Hazard index, Hi
P1	82	2.34	1.46
P2	224	6.38	3.99
P3	52	1.48	0.93
P4	27	0.77	0.48
P5	33	0.94	0.59
P6	104	2.96	1.85
P7	335	9.55	5.97
P8	155	4.42	2.76
P9	40	1.14	0.71
P10	10	0.29	0.18
P11	28	0.80	0.50
P12	8	0.23	0.14
P13	97	2.76	1.73
P14	68	1.94	1.21
P15	54	1.54	0.96
P16	284	8.09	5.06
P17	6	0.17	0.11
P18	418	11.91	7.45
P19	40	1.14	0.71
P20	92	2.62	1.64
P21	40	1.14	0.71
P22	66	1.88	1.18
P23	292	8.32	5.20
P24	252	7.18	4.49
P25	20	0.57	0.36
P26	35	1.00	0.62
P27	62	1.77	1.10
P28	48	1.37	0.86
P29	41	1.17	0.73
P30	38	1.08	0.68

Table 5. Integrated HI analysis results for pre-monsoon and post-monsoon seasons.

Sample No.	HI, Pre-monsoon	HI, Post-monsoon
P1	1.18	1.46
P2	3.74	3.99
P3	0.96	0.93
P4	0.32	0.48
P5	0.43	0.59
P6	1.82	1.85
P7	5.17	5.97
P8	2.24	2.76
P9	0.57	0.71
P10	0.18	0.18
P11	0.39	0.50
P12	0.11	0.14
P13	1.50	1.73
P14	1.03	1.21
P15	0.89	0.96
P16	4.99	5.06
P17	0.11	0.11
P18	7.02	7.45
P19	0.57	0.71
P20	1.39	1.64
P21	0.57	0.71
P22	0.93	1.18
P23	4.74	5.20
P24	4.10	4.49
P25	0.36	0.36
P26	0.50	0.62
P27	0.98	1.10
P28	0.71	0.86
P29	0.64	0.73
P30	0.50	0.68

Conclusion

The high nitrate levels in the study area calls for protecting the groundwater supplies from nitrate contamination as it becomes crucial to safeguard the people from various health threats and minimize potential liability. Poorly constructed and improperly located wells are generally prone to higher nitrate levels. Hence new wells should be located upstream, minimum 100 feet away from septic systems feedlots, and chemical storage sheds. Fertilizer and irrigation practices should cater to correct crop uptake requirements so as to reduce groundwater contamination by nitrates. Controlling the use of nitrogenous fertilizers can minimize the leaching of nitrate. Treatment measures such as ion exchange, reverse osmosis and distillation could be employed to reduce nitrate, though they are quite expensive. Continuous monitoring programmes coupled with health education schemes go a long way in abating this problem in agricultural as well as other areas susceptible to excessive nitrate contamination.

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