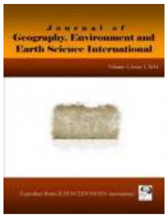

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Spatio-temporal Variations in Nitrate in Bore Wells of Baramati Area, India

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Author's contribution

The sole author designed, analyzed and interpreted and prepared the manuscript.

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ABSTRACT

Groundwater is the main source of drinking water for many small agricultural communities. Nitrate concentration in groundwater is a major problem in Nira River basin area, which is mainly due to the run off or seepage of chemical fertilizers from the agricultural field. A total of 45 water samples were collected in the period of post-monsoon (POM) winter 2013 and pre-monsoon (PRM) summer 2014 seasons from bore wells. The water samples were analysed using standard methods of APHA suggested for analysis of nitrate. Groundwater quality parameter varies spatially in different seasons. In the present study, spatio-temporal variation in nitrate levels in bore wells of Baramati Tahsil area is examined. The results of analysis showed that nitrate concentration in POM and PRM was above the maximum permissible limit of WHO and BIS recommended for drinking purpose. In POM 74% groundwater samples from canal irrigated area and 11% from non-canal-irrigated area were above the standard limit of WHO and BIS. In PRM 66.67% and 11% samples respectively from canal irrigated and non-canal-irrigated area were above the maximum permissible limit of WHO and BIS (45 mg/l). This indicates that peoples especially children using the water from bore wells with higher concentration of nitrate than standard limit, stands a high risk of methemoglobinemia (sometimes referred to as "Blue baby syndrome"). In canal irrigated area

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concentration of nitrate was found higher than the non-canal-irrigated area. This may due to the use of more nitrogenous fertilizers by farmers in their farms, improper disposal of animal and human wastes in canal irrigated area as compared with non-canal-irrigated area. The groundwater of such bore wells was not suitable for drinking purpose without treatment at the time of analysis. Nitrate containing groundwater is more effective and useful for irrigation purpose. The nitrogen can be removed from drinking water by using treatment such as ion exchange, biological de-nitrification and reverse osmosis.

Keywords: Nitrate concentration; pre-monsoon; canal irrigated area; bore well, WHO.

1. INTRODUCTION

Nowadays many people of India and also from the world faces drinking water problem. These problems include international and regional disputes over water, water scarcity, contamination, unsustainable use of groundwater, ecological degradation and the threats of climate change [1]. Twenty countries (most of them in Africa and the Middle East) suffer chronic water scarcity, causing severe damage to food production and stunted economic development. In 2025 one-third of the global population is expected to live in chronic water shortage areas [2]. Nitrate concentration in groundwater of study area is a major problem, which is mainly due to the run off or seepage of chemical fertilizers from the agricultural field and other anthropogenic factors.

Nitrate is an important plant nutrient. Metabolic waste of aquatic community and dead organism add to the nitrogenous organic matter. In ground water, nitrates may be added by leaching from soil and by contamination. The main contributor for nitrate in groundwater is the nitrogenous fertilizers of both animal and chemical origin and also sewage and industrial waste.

Water-related diseases have largely been eliminated from developed countries; they remain a major concern in many developing countries. While data is incomplete, the World Health Organization assessment showed that, there are 4 billion cases of diarrhea each year in addition to millions of other cases of illness associated with the lack of access to clean water. Since many illnesses are undiagnosed and unreported, the true extent of these diseases is unknown [3]. About 2.3 billion in the world suffer from diseases that are linked to water [4,5].

Many researchers worked on the groundwater quality of bore wells for drinking and agricultural purposes. They inferred that water from bore well was polluted through physical processes, geochemistry of the environment and anthropogenic activities. Consequently, consumers of such waters are exposed to series of health risks [6-10].

Health problems from nitrates in water sources are becoming a serious problem. In over 150 countries, nitrate from fertilizers seeped into wells, fouling the drinking water [11]. Nitrate is one of the most commonly identified groundwater contaminant [12]. It is primarily regulated in drinking water because excessive levels can cause methaemoglobineamia (blue-baby syndrome). Nitrate levels have been increasing in drinking water supplies in most countries [13]. Environmental protection agency (EPA) in 1990 indicated that 250,000 water supply sources had maximum contaminant levels (MCL) for nitrate [14]. The World Health Organization (WHO), 2004 found that 30% of the 2,000 sources surveyed in world had more than 24 mg /l. Removal of nitrates from drinking water is an important and developing area of research. Technology development has occurred in this area, but further optimization of current technologies is required. Biological denitrification reactor operation in regard to microbiological characteristics of biologically denitrified water demands attention. RO and ED performance data for nitrate removal is limited and the impact of rapid advances in these technologies should be examined [15].

2. MATERIALS AND METHODS

2.1 Study Area

Baramati Tahsil area belongs to western part of Maharashtra. It belongs to Pune division. It is located 100 km towards east from district headquarters Pune. It is 240 km from state capital Mumbai towards east (Fig. 1). Baramati Tahsil area has its head quarter at Baramati town. Baramati Tahsil area lies between 18°04´ to 18°32´ north latitudes and 74°26´ to 74°69´ east longitudes. It is located at altitude of 550 meters above mean sea level [16].

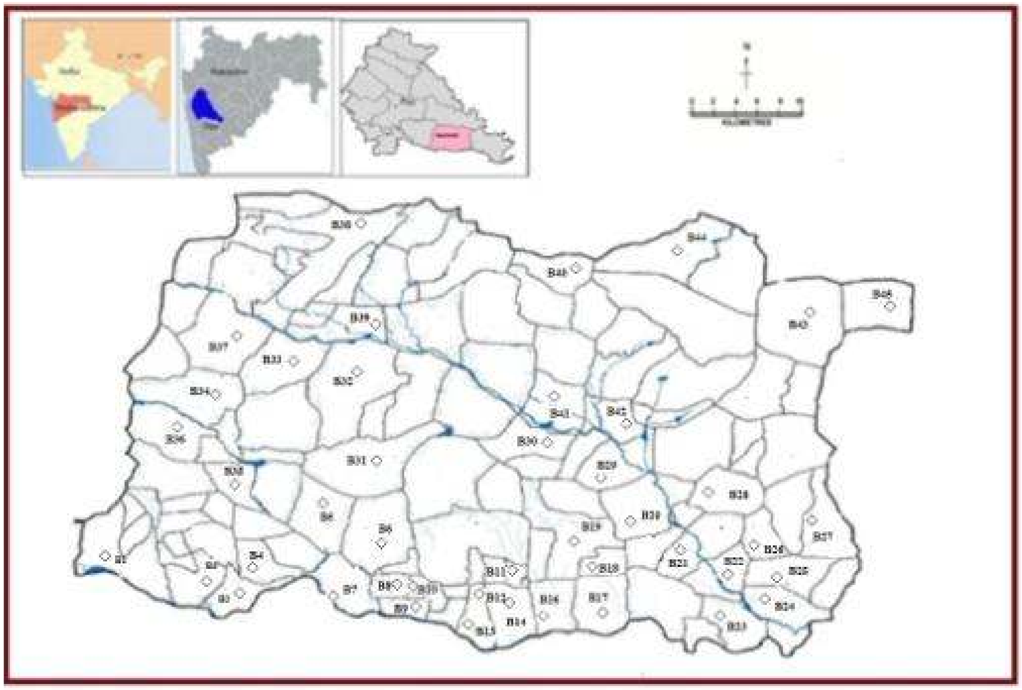

Fig. 1. Location map of the study area

The climate of the Baramati Tahsil area is slightly different in canal-irrigated and canal-non-irrigated area. The winter season is from December to about the middle of February followed by summer season up to May. June to September is the south-west monsoon season, whereas October and November constitute the post-monsoon season. The mean minimum temperature is about 12°C and mean maximum temperature is about 39°C. The average annual rainfall for the period 2001 to 2012 of Baramati Tahsil was 502 mm [17].

2.2 Sampling Sites

Groundwater samples from different bore wells of forty-five sampling sites of Baramati Tahsil area were selected randomly by considering the topography and anthropological activities of the study area (Fig. 1).

2.3 Sample Collection

Water samples from the selected sites were collected in a good quality polyethylene bottle of one-litre capacity during the period post-monsoon (POM) winter 2013 and pre-monsoon (PRM) summer 2014 seasons. Forty-five groundwater samples (B1- B27 from canal-irrigated area and B28-B45 from non-canal-irrigated area) were selected for collection of groundwater samples for nitrate analysis.

2.4 Nitrate Analysis

The chemical composition of water in various water bodies is rarely constant in different seasons. Therefore, it is essential to test water frequently so that any small change in water quality is noted. It is also known that a seasonal change in environmental condition is the major source of variation in the water chemistry [18]. Considering this, groundwater samples from selected sampling stations were collected in triplicate; twice in a year covering pre-monsoon (summer) and post-monsoon (winter) seasons. Various methods are used for the determination of nitrates.

In the present study, Brucine method [19] was employed. Nitrate and brucine react to produce yellow colour, the intensity of which can be measured at 410 nm. The reaction is highly dependent upon the heat generated during the reaction. However, reaction for a fixed time at a constant temperature can control heat. The method is suitable for the samples having a very wide range of salinity. In a hard glass test tube, 10 ml sample, 2 ml NaCl (30%) were added and samples were kept in wire rack. Then 10 ml of sulphuric acid was added. After mixing thoroughly it was followed by the addition of 0.5 ml brucine reagent. The wire rack was placed in hot water bath for about 20 minutes. Finally, the reading was taken by cooling the solution at 410 nm. Nitrate concentration was estimated by comparing the absorbance with standard curve. Prepared a standard curve between concentration and absorbance by taking the dilutions from 0.1 to 1.0 mg N/l at the interval of 0.1 and employing the same procedures for the other groundwater samples [19]. The result obtained was compared with standard parameters suggested by WHO [20] and BIS [21].

3. RESULTS AND DISCUSSION

Nitrate concentration of groundwater of study area in winter 2013 ranges from 11.70 to 71.40 mg/l having average 40.68 mg/l. Standard deviation was ±16.51 while median was 42.70. In summer 2014 nitrate value ranges from 14.60 to 60.50 mg/l having average 39.14 mg/l and deviation in nitrate concentration was found to be ±13.82 (Table 1).

67 to 74% samples in canal-irrigated area and 11% samples in non-canal-irrigated area showed higher concentration of nitrate (>45 mg/l) recommended by WHO and BIS. The surrounding area of the sampling sites was irrigated. Sugarcane is the main crop in this area. Percolation of water from field was observed in the ground, which increased the nitrate concentration. Hence, nitrogen fertilizers used in the irrigated area are the possible cause of nitrate pollution of groundwater. Minimum nitrate amount was observed in Paravadi area (S.N. B43) which is included in non-canal-irrigated area where fertilizer use by farmers was low while Maximum nitrate concentration was observed in Shirasane village area (S.N. B12) which is included in canal-irrigated area where fertilizer use by farmers was more (Table 1).

In the rural areas of Baramati Tahsil, at certain places nitrate concentration was more. This is attributed to the nitrogen excretion by cattle in the farm (i.e. animal wastes) and dairies where large number of buffalo and cows are housed in relatively small areas. An excreta of these animals get accumulated and is leached by rainfall and other water sources causing high nitrate pollution of water. The extent of such groundwater pollution depends on bio-degradation, soil and rock strata characteristics through which percolation takes place. Thus, nitrate pollution in the study area is a combined effect of agricultural activity and animal wastes.

In the village Shirasane 71.40 mg/l of nitrate concentration was observed, which is situated on the bank of Nira River (S. N. B12). Groundwater sample number B1, B2, B3, B5, B6, B7, B8, B9, B11, B12, B13, B14, B15, B16, B17, B18, B19, B21, B22, B23, B24, B25, B26, B28, B29 showed higher value of nitrate above permissible limit (45 mg/l) of BIS and WHO. Fig. 2 clearly indicates the concentration of nitrate present in canal-irrigated and non-canal-irrigated area of Baramati region.

In the study area, nitrate concentration was found higher in winter than the summer. The high values of nitrate can cause nitrate toxicity. The ground water from Nira River side villages such as Korhale, Sangvi, Late, Dhekalwadi, Shiravali, etc. have high concentration of nitrate. It was observed that majority of groundwater samples from canal-irrigated area are unsafe for drinking purpose. Ocheri Maxwell et al. [22] stated that nitrate concentration greater than 45 mg/l is undesirable in domestic water supplies; they found different sources of nitrate such as fertilizers, animal wastes and wastes from residual areas and septic tanks have been investigated. Most humans over one year of age have the ability to rapidly convert methemoglobin back to oxyhemoglobin; hence, the total amount of methemoglobin within red blood cells remains low instead of relatively high levels of nitrate/nitrite uptake. However in infants under six months of age, the enzyme systems for reducing methemoglobin to oxyhemoglobin are incompletely developed and methemoglobinemia can occur.

Adults can tolerate higher levels of nitrate-nitrogen with little or no documented adverse health effects and may be able to drink water with nitrate-nitrogen concentrations considerably greater than the 10 mg/l level with no acute toxicity effects. In this study therefore, attempt was made to assess the level of nitrate in bore wells among two seasons in Baramati area, Pune, India. In the Baramati area bore wells are mostly used to withdraw groundwater.

The groundwater resources contaminated with high levels of nitrate (>45 mg/l as nitrate or 10 mg/l as nitrate-N) are a human hazard. Incidents of nitrate pollution of groundwater have been reported by several workers like Hill [23] and Baalousha [24].

Table 1. Nitrate from groundwater of Baramati area, Pune, India

Sample no.	Sampling sites	Winter 2013 (POM) mg/l	Summer 2014 (PRM) mg/l	Average of two seasons mg/l	Standard Deviation (S.D.)
B1	Nimbut	47.00	46.00	46.50	±0.71
B2	Murum	46.00	60.50	53.25	±10.25
B3	Wanewadi	47.20	42.50	44.85	±3.32
B4	Hol	42.70	42.00	42.35	±0.49
B5	Wadgaon	46.50	40.50	43.50	±4.24
B6	Korhale Bk.	51.00	47.00	49.00	±2.83
B7	Korhale Kh.	65.10	45.70	55.40	±13.72
B8	Late	69.50	60.30	64.90	±6.51
B9	Malwadi	55.20	48.20	51.70	±4.95
B10	Pingalewasti	41.30	39.40	40.35	±1.34
B11	Dhumalwadi	50.40	46.80	48.60	±2.55
B12	Shirasane	71.40	56.80	64.10	±10.32
B13	Kambleshwar	68.20	60.20	64.20	±5.66
B14	Sangavi	46.00	47.00	46.50	±0.71
B15	Shiravali	58.30	50.00	54.15	±5.87
B16	Khandaj	48.10	42.50	45.30	±3.96
B17	Pahunewadi	40.10	45.00	42.55	±3.46
B18	Malegaon Bk.	42.30	46.80	44.55	±3.18
B19	Baramati	41.50	50.80	46.15	±6.58
B20	Gunawadi	41.20	41.00	41.10	±0.14
B21	Dorlewadi	49.50	43.10	46.30	±4.53
B22	Mekhali	52.20	55.80	54.00	±2.55
B23	Songaon	57.40	48.10	52.75	±6.58
B24	Zargadwadi	49.00	47.00	48.00	±1.41
B25	Pimpli	54.60	52.00	53.30	±1.84
B26	Katewadi	53.20	51.50	52.35	±1.20
B27	Jalochi	32.40	33.20	32.80	±0.57
B28	Medad	46.80	45.20	46.00	±1.13
B29	Anjangaon	62.00	58.00	60.00	±2.83
B30	Barhanpur	24.60	25.50	25.05	±0.64
B31	Karhawagaj	33.20	32.60	32.90	±0.42
B32	Jalgaon Kp.	34.10	32.20	33.15	±1.34
B33	Mudhale	24.50	24.90	24.70	±0.28
B34	Lonibhapkar	13.40	15.60	14.50	±1.56
B35	Tardoli	27.80	30.20	29.00	±1.70
B36	Murti	20.00	14.60	17.30	±3.82
B37	Palasi	20.80	21.70	21.25	±0.64
B38	Modave	24.50	26.80	25.65	±1.63
B39	Moregaon	35.40	34.20	34.80	±0.85
B40	Supa	14.60	16.80	15.70	±1.56
B41	Baburdi	26.80	23.50	25.15	±2.33
B42	Undawadisupe	14.80	18.60	16.70	±2.69
B43	Parawadi	11.70	18.50	15.10	±4.81
B44	Shirsuphal	14.50	17.60	16.05	±2.19
B45	Nimbodi	13.60	15.30	14.45	±1.20
Average		40.68	39.14	39.91	±1.08
Maximum		71.40	60.50	65.95	±7.71
Minimum		11.70	14.60	13.15	±2.05
Median		42.70	42.50	42.60	±0.14
Standard deviation		±16.51	±13.82	±15.71	±1.91

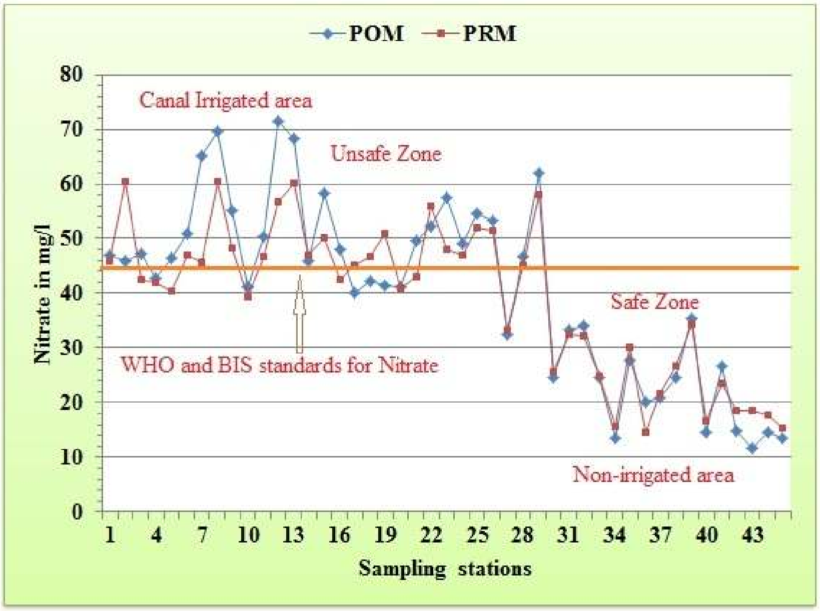

Fig. 2. Spatio-temporal variation in nitrate of groundwater from Baramati, Pune area

Urine deposited by grazing stock is the principal source of nitrate in the irrigated area. Because of the importance of nitrate as an essential element in the plant and animal nutrition, its concentration is of considerable interest in studies of human influence on the water chemistry. Natural nitrate concentration in groundwater ranges from 0.1 to 10 mg/l [25].

4. CONCLUSION

The data obtained by analysis of groundwater concludes that bore-wells in canal-irrigated area of Baramati Tahsil was polluted with nitrate. 70% bore-wells from canal-irrigated area was nitrate concentrations above WHO and BIS prescribed limit for drinking purpose in summer and winter season. In non-canal-irrigated area 11% bore-well water was nitrate concentration above WHO and BIS prescribed limit for drinking purpose. This implies that consumers of drinking water from these wells especially children stands a high risk of methaemoglobineamia (blue-baby syndrome). Nitrate level was noted to be higher in these bore-wells in the winter season than in the summer season. The source of nitrate in these bore-wells was attributed to the use of chemical fertilizers in urban farming, indiscriminate animal grazing, improper disposal of animal and human wastes and seasonal influence.

To reduce the rate of nitrate contamination, there should be control on use of land for various activities. Water from the wells may be used for agricultural purposes but not for drinking directly. The nitrogen can be removed from drinking water by using treatment such as ion exchange, biological de-nitrification and reverse osmosis. Groundwater from these sources was good for irrigation purpose because nitrate is a very important parameter required for the growth of plant.

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COMPETING INTERESTS

Author has declared that no competing interests exist.

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