GROUNDWATER NITRATE CONTAMINATION & ASSOCIATED HUMAN HEALTH RISK ASSESSMENT IN LUCKNOW DISTRICT, UTTAR PRADESH

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ABSTRACT

Present study aimed to look into the excessive nitrate concentration in grounwater of 6 regions of Lucknow district which have been previously reported with high nitrate concentrations in groundwater. Each regions is thoroughly investigated by taking 3 different sampling points (handpumps) in the December month, 2019. Out of 6 regions, 4 regions have shown an elevated nitrate concentrations but the obtained concentarions are far below the previously reported concentrations of nitrates in the groundwater. The health risk analysis for the excessive intake of nitarate contaminated water is done by applying USEPA HHRA(Human Health Risk Assessment) model for differnt age groups i.e infants(0-6 months), children(7 month-17 years) and adults(18- 60 years). Result of this study suggests that infants and children are at higher risk for health hazards in comparison to adults. Highest hazard quotient for infants and children is reported in Khujauli village as this region also reported with highest nitrate concentrations among all the studied regions. This HHRA study have found that local residents consuming water from these handpumps are most vulnerable to health hazrds due to ingestion of excess nitrate through drinking water.

Keyword: - *Nitrates, Groundwater, Human Health Risk assessment*

1. INTRODUCTION

1.1 General

Nitrate is the extremity product of the biological nitrification process and it is the most pervasive chemical contamination in the aquifers of the world. The major concern regarding nitrate is that it's contamination level is increasing drastically. The distribution of nitrate in the groundwater is impacted by various factors. They include availability of sources, composition of vadose zone and their thickness, irrigation, flow of groundwater, precipitation, concentration of dissolved oxygen, aquifer heterogeneity. Nitrogen compounds occurs in the water in the form of nitrite(NO_2^-),ammonia(NH_3^+), nitrate(NO_3^-) and the ammonium ion(NH_4^+). Nitrogen is also present in organic compounds such as proteins and their derivatives including pyrimidines and purines, and urea. Groundwater is a crucial natural resource of water for meeting the the agricultural, domestic and industrial demand in almost all the countries of the world. It is the most prevailing assumption that quality of drinking water is mostly related to human health. However it is found that in developing countries, consumption of contaminated drinking water are causing serious health hazards. Diseases emerging from contaminated drinking water has increased the risk of mortality and morbidity mostly in children and infants. Therefore evaluation of water quality now has become crucial aspect for the public health, social and economic growth of the territories. In past few decades, quality of groundwater has been threatened from industrial growth, intensive agriculture, unplanned urbanization and extreme population pressure. The elevated nitrate concentration in the groundwater is mainly contributed from the nonpoint sources and point sources. The nonpoint sources are mainly precipitation and dry deposition, manure applications, agrarian activities, whereas Dairy lagoons and sewarage septic tank are important point sources. The consumption

of high nitrate contaminated water causes methemeoglobinemia in infants which is also called Blue baby syndrome. It depletes the oxygen carrying capacity of the blood which results into cyanosis of infants(WHO 2011, BIS 2012).

1.2 Health hazards due to intake of excess nitrates.

Infants under 6 months of age are prone to a disease called Methemoglobinemia which is caused due to ingestion of elevated nitrate concentrations in drinking water. Conversion of nitrates to nitrite followed by conversion to ammonia is crucial metabolic pathway of nitrates. It has been reported that bacteria present in stomach, saliva and small intestine converts 5% to 10% of the nitrate intake into nitrite and this conversion reaction is pH dependent. The Nitrate reduction does not take place when pH is below 4 and above 9. In this disease, nitrate are reduced to nitrite with the help of bacteria in the intestinal tract. nitrite then invades the blood stream and it further combines with hemoglobin to form methemoglobin. This Methemoglobin then reduces the oxygen carrying capacity of the blood Methemoglobinemia in its severe stage may cause brain damage and sometimes death also. Formation of nitrosamines due to intake of high nitrate contaminated water for longer duration may cause gastric problems in adult human. In various studies, animals have been tested positive for cancer due to presence of nitrosamines compounds in their body.

1.3 Lucknow district at a glance.

Lucknow district is the capital of Uttar Pradesh and it extends over an area of 2528 square kilometre on both side of the Gomti river. Entire Lucknow district has been divided into eight development blocks and four tehsils. The population of Lucknow district as per Census 2011 is 4589838 out of which male population is 2394476 and female population is 2195362. There are a total of 835 villages and 511 gram panchayats in Lucknow district. Lucknow district is a part of plains of Central Ganga and Lucknow city is a part of sub basin of Sai Gomti.. Behta Nadi, Akhadi Nala, Jhilingi Nala and Kukrail Nala are the tributaries of Gomti river. Similarly Bankh Nala and Nagwa Nala are the tributaries of Sai river. Around 56% of the the total area of Lucknow district is under intensive cultivation. . The Lucknow district is a part of of Ganga basin and is having flat Alluvial terrain.

2. MATERIAL AND METHODOLOGY

2.1 Study region description.

Previous studies suggests elevated level of nitrate concentration in a few villages and urban areas of Lucknow district which is needed to be reinvestigated for the current scenario. Since the villagers and poor people residing in urban areas consume shallow groundwater through handpumps directly without any treatment therefore such villagers and people consuming shallow groundwater in urban areas are at high risk of health hazards.

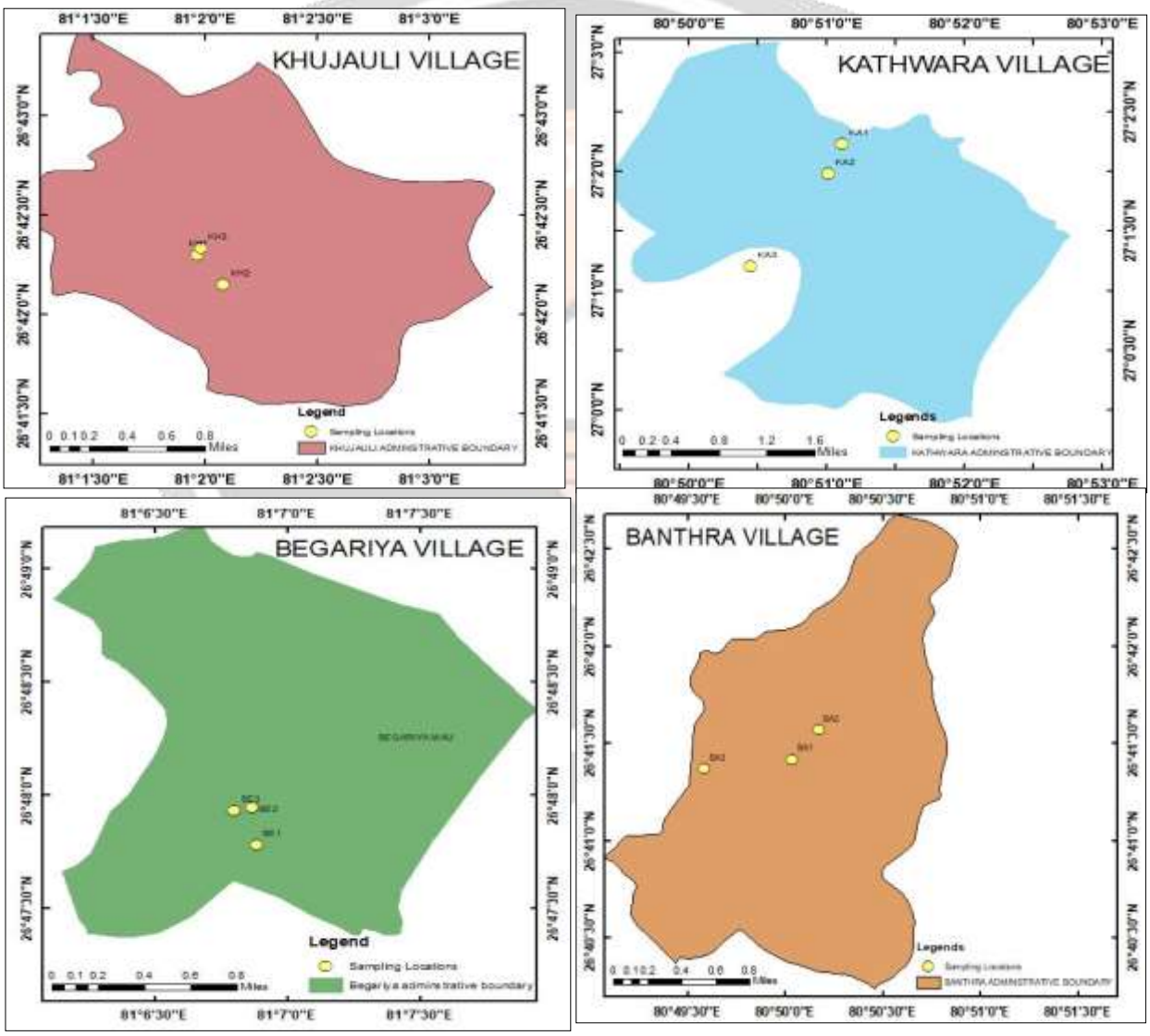
Table 2.1 Block wise previously recorded nitrate concentrations

S.no	Block	Name of the Affected Village/City	Area Description	Previous studies Nitrate Concentration(mg/L)	Source
1	Mohanlalganj	Khujauli	Rural	206	[1]
2	Bakshi Ka Talaab	Kathwara	Rural	196	[1]
3	Sarojni Nagar	Banthra	Rural	220	[25]
4	Mohanlalganj	Begariya	Rural	250	[25]
5	Chinhat	Indira Nagar	Urban	56	[1]

				118	[25]
6	Sarojni Nagar	Cantonm ent	Urban	160	[1]

To thoroughly investigate the nitrate contamination in the selected villages and urban areas, 3 different sites are further selected from each area for samapling purpose and analysis i.e three different locations each from Kathwara, Khujauli, Banthara, Begariya, Indira Nagar and Cantonment. Groundwater samples were collected and analyzed from the proposed locations in december month, 2019.

Sampling locations in each selected regions:-



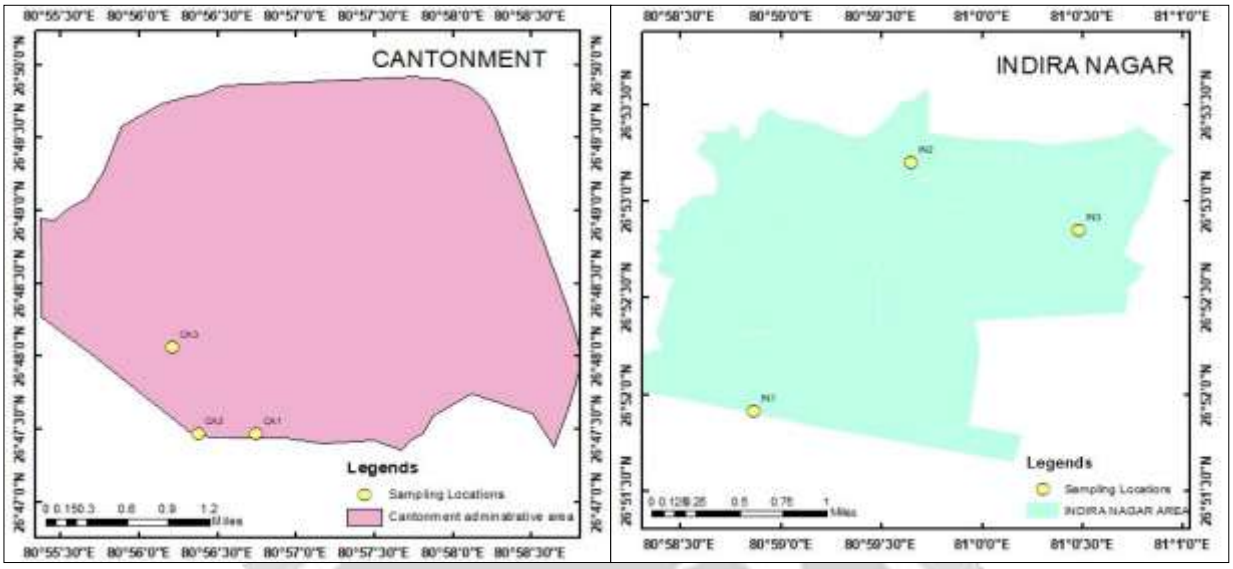


Fig 2.1 Sampling Locations in each selected regions.

2.2 Sampling procedure and analytical investigation.

The groundwater samples were collected in pre cleaned polyehtene bottles of 1000 mL capacity. Proper procedure was followed as described by APHA-AWWAWPFC (23rd edition) for the sampling and the analysis purpose of the selected parameter to avoid any contamination during collection, storage and precise determination of concentrations of the groundwater samples. Each selected hand pump for sampling was put on for at least 5 min to remove any contaminants. Each sample in the collected bottles was capped tightly to avoid leakage and contamination from any pollutants during handling and transportation. The bottles were adequately labeled by date and locations, the source of water i.e Hand pump, etc. to recognize sampling point during chemical analysis. All the collected samples were preserved in cold and transported to the laboratory where they were stored in the freezer at 4 °C until used for final chemical analysis. NO_3^-, were estimated by recording absorbance in spectrophotometer.

2.3.Determination of Nitrate concentration:

We use calibration curve for the determination of nitrate concentraion of unknown samples. To prepare Calibration curve, take out 50 ml from each standard(Blank, 2, 4, 6, 8, 10)ppm in separate volumetric flask. Add 1 N HCL(1ml) in each volumetric flask of standards and than take absorbance to create standard calibration curve to find the equation. Next take 50 ml of the samples in volumetric flask(if turbid, filter it). Add 1ml 1N HCL and take absorbance at 220 and 275 nm. Nitarte concentaration is detrmined as:

Nitrate(ppm) = (Absorbance at 220nm – 2 × Absorbance at 275nm) ÷ (factor obtained from calibration curve)

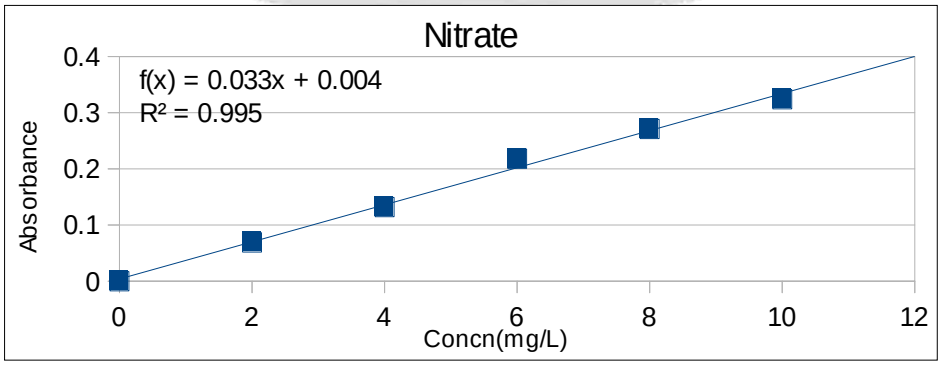


Fig 2.2 Standard calibration curve obtained for nitrate concentration determination

2.4 Health risk assessment.

USEPA human health risk assessment model is used to calculate the noncarciogenic risk of nitrate for different age groups(Infants, Children and Adult) by combining the calculations of Dermally Adsorbed Dose(DAD) and Chronic Daily Intake(CDI). Hazard quotient for each age group is determined for december month, 2019.

Oral hazard quotient(HQ1): Oral hazard quotient gives the health risk value for the chronic daily intake due to ingestion of excessive nitarte contaminated water using the following equation:

$$CDI = (C \times IR \times ED \times EF) \div (BW \times AT)$$

where C is Concentraion of Nitrate; IR is Ingestion rate; ED is exposure Duration; EF is exposure frequency; BW is Body weight and AT is average time. Hazard quotient 1(HQ1) is calculated by following equation

$$HQ1 = CDI \div RFD1$$

Where RFD1 is oral reference dose of nitate.

Dermal hazard quotient (HQ2): This hazard quotient gives the health risk value due to to absorption of Nitrate through skin and it is calculated as dermally adsorbed dose (DAD). It's unit is described as nitrate absorbed through skin area contact per kg weight of body per day (mg kg^{-1} day^{-1})

$$DAD = (C \times Ki \times SA \times ED \times EF \times EV \times CF) \div (BW \times AT)$$

where where C is Concentration of Nitrate; Ki is sermal adsorption; EF is exposure frequency; SA is skin surface area; ED is exposure duration; CF is unit conversion factor; EV is bathing frequency; AT is average exposure time; BW is average body weight. Skin surface area is calculated as :

$$SA = (0.012 \times BH^{0.6}) \div BW^{0.45}$$

where BH is body height and BW is body weight. Hazard quotient 2 is calculated as

$$HQ2 = DAD \div RFD2$$

where RfD2 is dermal reference dose of nitrate and DAD is dermally adsorbed dose.

Finally total health hazard quotient is calculated by adding HQ1(Oral) and HQ2(Dermal) hazard quotient. Both are unit less and is expressed as:

$$\mathbf{THQ = HQ1 + HQ2}$$

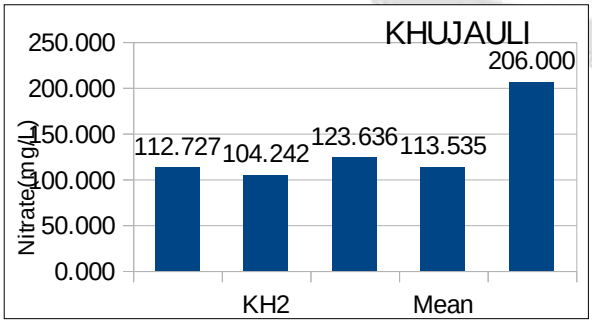
Table 3.3 Parameters and values for HHRA computation

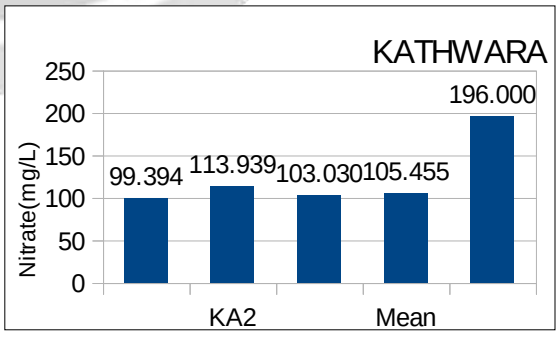
Parameters	**Description**	**Adult**	**Children**	**Infants**	**Units**	**References**
EF	Exposure frequency	365	365	365	days	[15],[16],[19]
ED	Exposure duration	30	6	0.5	Years	[9]
IR	Ingestion rate	2000	1500	250	$mL\ day^{-1}$	[8]

AT	Average exposure time	10950	2190	182.5	days	[9]
BW	Average body weight	57.5	18.7	6.9	kg	[7]
BH	Average body height	161.2	122.07	62.43	cm	
SA	Skin surface area	15683.78	8007.1	3419	cm^2	[10]
EV	Bathing frequency	1	1	1	Time/day	[11]
CF	Unit conversion factor	0.002	0.002	0.002	L cm^{-3}	
Ki	Dermal adsorption	0.001	0.001	0.001	cm h^{-1}	
RfD1	Oral reference dose for nitrate	1.6	1.6	1.6	mg kg^{-1} day^{-1}	[21]
RfD2	Dermal reference dose for nitrate	0.8	0.8	0.8	mg kg^{-1} day^{-1}	
C	NO_3^- Concn				mg L^{-1}	
HQ1	Oral hazard quotient				Unitless	[18], [19]
HQ2	Dermal hazard quotient				Unitless	
HQ	Total hazard quotient				Unitless	

3 RESULT AND DISCUSSION

3.1 Nitrate concentrations for various regions:





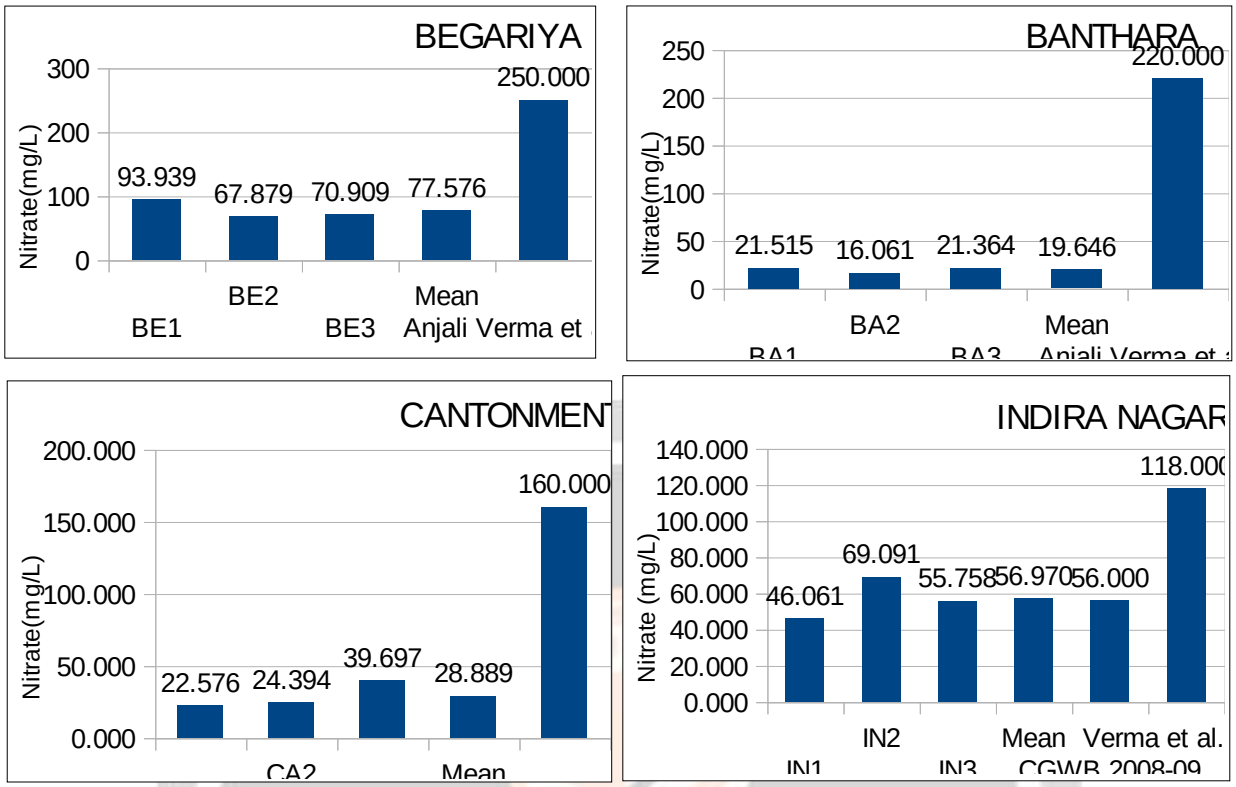


Fig 3.1 : Graphical representation of Nitrate concentrations in all the regions.

Nitrate concentration is reported highest in Khujauli village and lowest is reported in Banthra. But this obtained highest nitrate concentration region is much lesser than the previously reported studies(206 mg/L, CGWB 2009).

3.2 Health risk associated with nitrate in groundwater.

Health risk assessment for adults(greater than 18 years), children(7month to 17years) and infants(0-6month) was calculated based on the United States environmental protection agency model(USEPA). With the help of this model, non carciogenic health hazard is computed as Total hazard quotient(THQ) which included summing up of Oral Hazard quotient(HQ1) and Dermal Hazard quotient(HQ2). Guidelines of USEPA, ICMR etc are strictly followed to calculate the hazard quotient.

Table 3.2 THQ

REGION	ADULT	CHILDREN	INFANT
KHUJAULI	2.541	5.798	2.706
KATHWARA	2.360	5.386	2.513
BEGARIYA	1.736	3.962	1.849
BANTHRA	0.440	1.003	0.468
INDIRA NAGAR	1.275	2.909	1.358
CANTONMENT	0.647	1.475	0.688

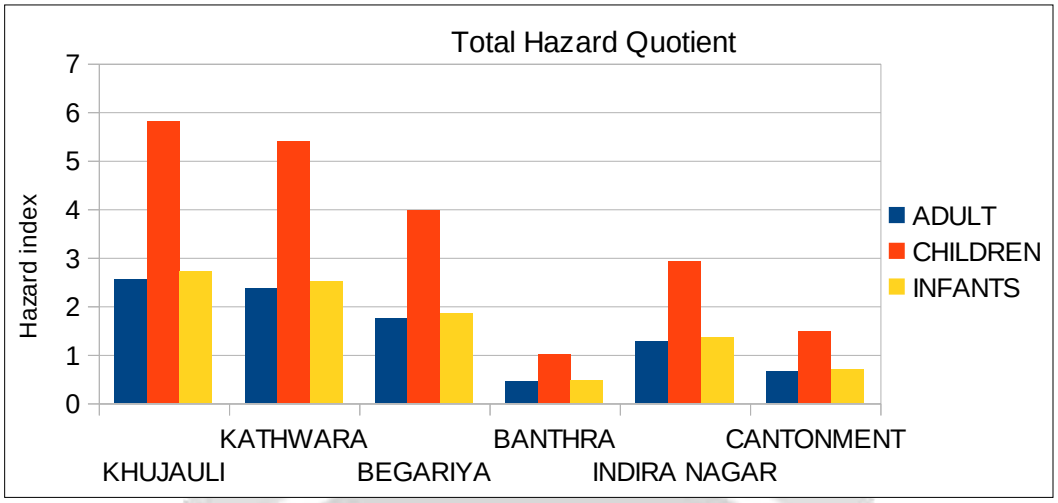


Fig 3.2 Total hazard quotiet for all the regions.

In all the studied regions, it is found that infants and children are more prone to health hazards in comparison to adults. Total hazard quotient was higher for children and infants whereas adults are at lesser risk of health hazards arising due to excessive nitrate in drinking water. Overall analysis of THQ of all the studied regions, Children and infants of Khujauli village are at highest risk of health hazards due excessive contamination of nitrate among all the regions.

4 CONCLUSIONS

Analytical chemical analysis of groundwater samples are done from various selected regions on the basis of historical data of previous studies of lucknow district. In this present study 4 villages and 2 urban area are selected which were found to be extinsively polluted by nitrate in the various previous studies. 3 sampling locations are selected in the vicinity of each selected regions. Banthara village and Cantonment are reported the nitrate concentration well within the pernissible limit. Health risk assessment for various age groups(infants, children and adults) is done to find out total hazard quotient defined as numerical value of the health risk arising due to intake of excess nitrate in drinking water. This study finds out that all the age groups are are higher risk of health hazards(>1) in excess nitrate affected araes i.e Kathwara, Begariya, khujauli and Indira Nagar. THQ result of the study araes suggest that children and infants are at higher risk followed by adults. Oral Hazard quotient(HQ1) are much higher than Dermal Hazard quotient(HQ2) thus giving a indication of increased nitrate associated health risk due to consumption of excess nitrate contaminated water. Taking consideration of all the findings from this study, it is proposed that a thorough investigation is required for nitrate concentaraions in the groundwater coming out through handpumps in all the neighbours villages and urban areas of the selected sites so as to get a wider scenario of nitrate contamination in the shallow groundwater. Also medical data of the affected areas can be correlated with the nirate concentrations and health risk assessment data for better interpretation.

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