INNSPUB

Journal of Biodiversity and Environmental Sciences (JBES)
ISSN: 2220-6663 (Print) 2222-3045 (Online)
Vol. 17, No. 4, p. 1-9, 2020
http://www.innspub.net

RESEARCH PAPER OPEN ACCESS

Groundwater quality and vulnerability assessment in Savar, Dhaka, Bangladesh

Md. Menarul Islam Mridul[1], Mohammad Emadul Huda[1], Mala Khan[2], Sujit Kumar Roy[3], Samia Akter[4], Mohammad Mahbub Kabir[*4], Snigdha Shetu Paul Mouna[4]

[1]*Department of Environmental Sciences, Jahangirnagar University, Dhaka, Bangladesh*

[2]*Designated Reference Institute for Chemical Measurements, BCSIR, Dhaka, Bangladesh*

[3]*Institute of Water and Flood Management (IWFM), Bangladesh University of Engineering and Technology (BUET), Dhaka, Bangladesh*

[4]*Department of Environmental Science and Disaster Management, Noakhali Science and Technology University, Noakhali, Bangladesh*

Article published on October 24, 2020

Key words: Groundwater, Pollution, Inverse distance weighting (IDW) techniques, NO_3^-, NO_2^-

Abstract

Inland soil and water pollution are common phenomena of the last few decades where industrial and domestic waste, excess agrochemical use and industrial effluent discharge are practiced in an unplanned manner. Thus various types of anionic pollutants can be leached down to the groundwater and contaminate the aquifer which plays a crucial role in human health, safety and security. The present study was carried out to determine the concentration of F^-, Cl^-, Br^-, NO_2^-, NO_3^-, SO_4^{2-} and PO_4^{3-} in groundwater within different locations of Saver, Dhaka by Ion Chromatography (IC). A total of fifty-seven (57) groundwater samples including double and triple were collected from twenty different locations of Savar Thana and make it twenty samples by getting their average value. Most of the location the value of Br, NO_2, PO_4 has found below the detection limit (BDL). On the other hand, sample concentrations of studied anions in groundwater were in the range of F^-(0.76mg/L to BDL), NO_3^- (13.64mg/L to BDL), Cl^- (18.33mg/L to .40mg/L), and SO_4^{2-} (74.63mg/L to 0.65mg/L). Nitrate (NO_3) from Golap Gram and Rustompur ghat exceeded the standard of Bangladesh and the US. EPA but did not exceed the WHO standard of drinking water. The rest of the study area showed that the concentration of studied anions in groundwater was within the permissible limit of national or international drinking water standard and suitable for intended purpose. The present study showed that the agro-industrial area poses much threat of groundwater contamination than the Industrial area. This study can further be used as a reference to monitor and manage the total groundwater suitability.

***Corresponding Author:** Mohammad Mahbub Kabir ✉ mahbubkabir556@gmail.com

Introduction

Groundwater refers to the water that occurs below the earth's surface and the main source of groundwater is infiltration mostly depend on rainfall. The chemical quality of the groundwater is modified by several factors, such as interaction with solid phases, residence time of groundwater, seepage of polluted river water, mixing of groundwater with pockets of saline water and anthropogenic impacts (Giridharan *et al.,* 2006). Recently, there has been a tendency for groundwater quality deterioration, which has been caused by human activities (Dragon, 2008). The quality of water is of vital importance for humans since it is directly linked with human welfare (Gupta *et al.,* 2008). Poor water quality adversely affects plant growth and human health. Groundwater is an important natural resource with high economic value and social significance. Groundwater supplies almost half of all drinking water in the world, and plays a key role in food production, accounting for over 40% of the global consumptive use in agricultural irrigation (Siebert *et al.,* 2010). Agricultural land use represents the largest diffuse pollution threat to groundwater quality on a global scale (Zhou *et al.,* 2015).

The problems of groundwater quality are more acute in areas that are densely populated and thickly industrialized and have shallow groundwater tube wells so, Determination of groundwater quality is important to observe the suitability of water for a particular use. (Arumugam and Elangovan, 2009; Shivran *et al.,* 2006). For better management of groundwater, it is essential to improved understanding of the controlling processes and, where possible, the natural, geologically controlled baseline chemistry. In order to understand the pollution trends and impacts on an aquifer, it is necessary to have knowledge of the natural baseline quality with an acceptable degree of confidence (Edmund *et al.,* 2003). Globally, there is a scarcity of its availability and day by day increasing the struggle for scarce water resources (Olukanni *et al.,* 2015). Groundwater is free from pollution and microbes that is incredibly helpful for domestic use, small town, and agricultural farm.

Groundwater has been an important water resource throughout the ages. Groundwater is also not unlimited like any other natural resource (Gbadebo, 2010). Groundwater quality in urban areas of the country India is under pressure and increased enormously due to excessive urban stresses by making water unsafe for drinking purposes (Dahariya *et al.,* 2016). The over-extraction of groundwater is the major cause of groundwater salinization and arsenic pollution in the coastal area of Yun-Lin, Taiwan (Liu *et al.,* 2003). Groundwater chemical characteristics are controlled by natural geochemical processes but also, to a lesser extent, by anthropogenic activities (Embaby *et al.,* 2016).

A number of subsequent studies in Slovakia, Bulgaria, Germany, and the USA have reported a correlation between various measures of nitrate intake through Groundwater and effects on thyroid function, but all suffer from methodological and data problems that preclude definitive conclusions being drawn (Gatseva and Argirova, 2008; Hampel *et al.,* 2008; Tajtáková *et al.,* 2006; Ward *et al.,* 2010). High fluoride concentrations may, therefore, be expected in groundwater from calcium-poor aquifers and in areas where fluoride-bearing minerals are common (Edmunds *et al.,* 1996). In India, around one million people suffer from serious and incapacitating skeletal fluorosis (Susheela *et al.,* 1988). Chloride levels in unpolluted waters are often below 10mg/L and sometimes below 1mg/L (Water, Health, & Canada, 1979). Chloride in water may be considerably increased by treatment processes in which chlorine or chloride is used. A normal adult human body contains approximately 81.7g chloride (Water *et al.,* 1979). Chloride toxicity has not been observed in humans except in the special case of impaired sodium chloride metabolism, e.g. in congestive heart failure. The average daily intake of sulfate from drinking-water, air, and food is approximately 500 mg, food being the major source. However, in areas with drinking-water supplies containing high levels of sulfate, drinking-water may constitute the principal source of intake (WHO, 2004). Specifically, the study was carried out (1) to access the physicochemical quality of the groundwater from the selected study area (2) to compare the physicochemical parameter values with World Health Organization (WHO), U. SEPA standard (1994), and BD standard for drinking water (3) to make spatial distribution map of the study area using ArcGIS.

Materials and method

Study area

The sampling site selected for the present study was within Savar Thana with 20 different locations of the following map Fig. 1 Savar is the second-largest (total area 280 km^2) Upazila in the Dhaka district and is rapidly growing in the context of urbanization and industrialization. Geographically it is situated at the northern edge of Dhaka, between 23.8820° N to 90.2808° E.

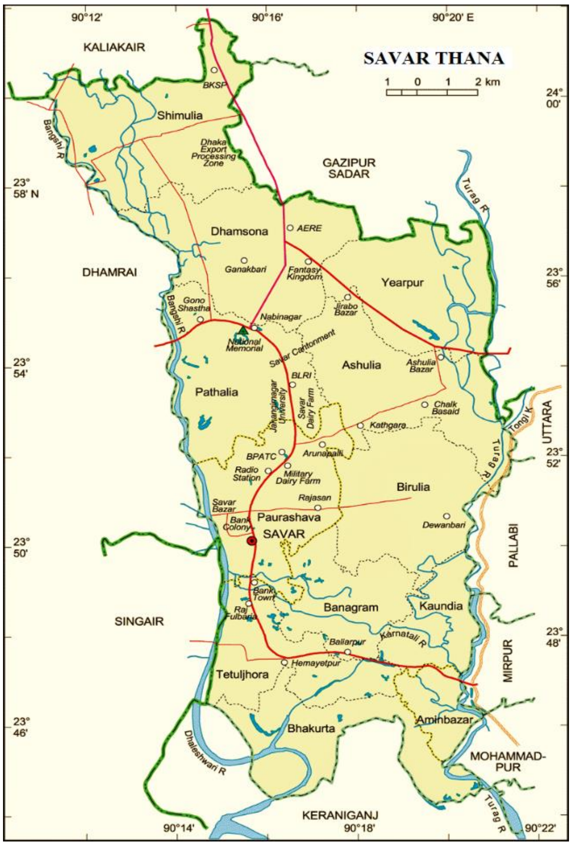

Fig. 1. Location Map of the Study Area.

Hydrogeology of the Study Area

The study area actually is located on the southwestern fringe of the Madhupur Tract. Geomorphology of the study area does not, however, represent a continuous block of either uplifted Madhupur Tract. This area rather represents the junction between overlapping older Madhupur tract and recent Flood-plain deposits. The Hydrology of the study area is governed by rainfall intensity and distribution, permanent or ephemeral water bodies and rivers or canals. It is quite alarming that there has been a constant decline in the groundwater level since 2005, with the common rate of declination concerning about 0.6 m/year. The groundwater level is comparatively higher in the northern and western parts and lower in the southeastern part of the study area due to huge water extraction in Dhaka city (Ahmed *et al.,* 2011). The regional groundwater depth-contour for the wet and dry seasons infer that there is a huge cone of depression in the southeastern side of the study area in Dhaka city (Akther *et al.,* 2010).

Sample Collection

A total of 57 drinking water samples were collected from 20 different locations of Savar Upazila for being collect as double and triple. During the time of sample collection, all the samples were collected in 250ml plastic bottle which was rinsed a few days before by deionized water and air-dried. All the samples were carried through an icebox and several ice gel was used to preserve the sample readily at 4^{o}C or below. Twenty-seven samples of drinking water were collected for this study on 27 March 2017 and thirty more samples of drinking water were collected on 1st April 2017 in order to determine the concentration of F^-, Cl^-, Br^-, NO_2^-, NO_3^-, SO_4^{2-}, PO_4^{3-} around the study area. It is difficult to obtain the exact length of the sampling well.

Through consulting with the local people during sampling it could be said that all the studied well length could be 150-250 feet from the surface. During sampling, groundwater samples were collected after few minutes of pumping the well. When the field measurements are done, the samples were stored in 250ml plastic containers and leveled with sample Identity, type, date, and location on the sticker tag. The bottles were entirely filled with sample so that no air was trapped inside that can react with the sample to alter its characteristics.

Sample Preparation

After the collection of the sample, all the samples were preserved in the refrigerator at 4ºC as soon as possible. All samples were subjected to equilibrate to room temperature before analyzing. The required materials for sample preparation are Analytical balance, Pipets, 2L volumetric flasks, beakers, Filter (0.45µm), Syringe, plastic vials, etc. The sample was equilibrating to room temperature before analyses the sample by Shimadzu Ion Chromatography (CDD – 10A sp Conductivity Detector). 57 plastic vials (containers for the sample to be placed in the tray of the instrument) were rinsed with deionized water and air-dried. The samples were filtered with Micro Pore Filter (0.45µm) with the help of Syringe. About 1.5ml of filtrated water samples were taken plastic vials from each of the sample bottles which were already equilibrated to room temperature. After that, all the filtrated sample which were taken into plastic vials were subjected to instrumental analysis. De-ionized water was used for all the washing, dilution and volume preparation during the analysis with Ion Chromatography. Sample preparation procedure for F^-, Cl^-, Br^-, NO_2^-, NO_3^-, SO_4^{2-}, PO_4^{3-} were the same as given above preparation technique. According to location average value of the double and triple sample is selected as the fixed value for the next analysis.

Shimadzu Ion Chromatography Operating Condition

Mobile phase 0.2856g $NaHCO_3$ and 0.3816g Na_2CO_3 in filtered 2 L DI water, Column condition is anion exchange cartridge (P/N 228- 40605- 91), Column temperature 30ºC, Flow rate 1ml/min, Pump pressure 64kgf, Sample injection 10 µL, Run time 16 min.

Data analysis

Microsoft Office Excel 2016 and ArcGIS 10.3 was used for data analysis and presentation. Several descriptive statistical measures such as minimum, maximum and mean were analyzed for categorizing and describing the variables. ArcGIS was used to interpolate data of different locations and different variable.

Result and discussion

Groundwater quality offers a transparent image of the usability of the water for various purposes. The standard quality for drinking water has been specified by the World Health Organization (WHO), United States Environmental Protection Agency US. EPA and Bangladesh Standard. It has given the permissible and fascinating limits for the presence of various elements in groundwater Table 1. Statistical evaluation of groundwater quality parameters can be seen as chemical compositions of groundwater relating to Savar Thana.

Table 1. Concentration of anions in groundwater around the study area.

Area	Sample ID	F (mg/L)	Cl (mg/L)	Br (mg/L)	NO_2 (mg/L)	PO_4 (mg/L)	NO_3 (mg/L)	SO_4 (mg/L)
Jadur chor (H)	GW1	0.71	0.47	BDL	BDL	BDL	0.35	1.76
Bank colony	GW2	0.72	0.67	BDL	BDL	BDL	0.78	2.09
Ulail mongaon	GW3	0.55	0.44	BDL	BDL	BDL	1.61	0.99
Amin Bazar	GW4	0.59	2.58	BDL	BDL	BDL	2.34	20.53
Baliarpur	GW5	BDL	2.86	BDL	BDL	BDL	8.63	BDL
Bakurta	GW6	0.44	3.19	BDL	BDL	BDL	0	15.41
Razfulbari	GW7	0.68	1.24	BDL	BDL	BDL	1.17	3.77
Tatuljhara	GW8	BDL	9.51	BDL	BDL	BDL	2.98	18.66
Hemaitpur Schoolpara	GW9	0.76	0.44	BDL	BDL	BDL	0.39	0.92
Shadhupara	GW10	0	18.33	36.60	BDL	BDL	BDL	74.63
Paragram	GW11	0.51	1.67	BDL	BDL	BDL	5.51	BDL
Golap Gram	GW12	0.31	0.48	BDL	BDL	BDL	10.93	BDL
Rustompur ghat	GW13	BDL	5.23	BDL	BDL	BDL	13.64	BDL
Biruliya	GW14	0.28	0.68	BDL	BDL	BDL	1.56	BDL
Diry farm	GW15	0.5	0.4	BDL	BDL	BDL	5.18	BDL
pathaliya	GW16	0.21	0.47	BDL	BDL	BDL	7.64	BDL
Golap Gram Maithur	GW17	0.5	0.57	BDL	BDL	BDL	0.43	BDL
Aycha Norda	GW18	0.1	2.01	BDL	BDL	BDL	0.92	2.08
Razashon	GW19	0.3	0.65	BDL	BDL	BDL	1.56	0.65
Yearpur	GW20	BDL	1.78	BDL	BDL	BDL	3.16	1.39
Minimum		0	0.40	36.60	0.00	0.00	0.00	0.65
Maximum		0.76	18.33	36.60	0	0	13.64	74.63
Mean		0.45	2.68	36.60	-	-	3.62	11.91
Std. Deviation		0.22	4.18	0.00	-	-	3.85	20.22
WHO Standard (2004)		1.5	250	-	3	-	50	250
US. EPA Standard (1994)		4			1	-	10	250
BD Standard		1	150-600		<1	6	10	400

According to Table 1, the highest value of fluoride is 0.76mg/L in the area of Hemaetpur Schoolpara the value was close to the Bangladeshi standard. Varies concentration of chloride was also found among the study area. Where the minimum value was 0.40mg/L and the maximum value was 18.33mg/L which do compromise with the Bangladeshi standard. Most of the area the Bromide was below the detection limit (BDL) except Shadhupara area where the value was 36.60mg/L. Again the NO_2 and PO_4 were BDL all over the study area. Nitrate found in the area of Rustompur ghat and Golap Gram exceeded the value of the US. EPA standard (1994) and Bangladesh standard. Some areas Sulfate was BDL and some have a high concentration limit. High concentration of Sulfate was found in the area of Shadhupara value 74.63mg/L.

Examining the distribution of the data

Inverse Distance Weighted (IDW) is a method of interpolation that estimates cell values by averaging the values of sample information points within the neighborhood of every process cell. The nearer some extent is to the middle of the cell being calculable, the additional influence, or weight, it's within the averaging method. This methodology assumes that the variable being mapped decreases in influence with distance from its sampled location.

The groundwater quality map

Fig. 2A, 2B, 2C, and 2D shows the spatial distribution of fluoride, chloride, nitrate, and sulfate, concentrations in the study area, respectively. A groundwater quality map was created following the value shown in Table 1, which are produced as a result of IDW interpolations. The spatial integration for final water quality mapping was carried out using the ArcGIS Spatial Analyst extension.

Fluoride

Fluoride found most often in groundwater and has become one of the foremost vital toxicological environmental hazards globally. The occurrence of fluoride in groundwater is due to weathering and leaching of fluoride-bearing minerals from rocks and sediments (Jha *et al.*, 2013).

Fluoride found in the groundwater represented in Fig. 2A which showed more green color low fluoride and more red more fluoride in different concentrations of fluoride value. The maximum value in the area of GW9 0.76mg/L. Map showing the interpolation result that the east, west, and south area has a high range of Fluoride concentration.

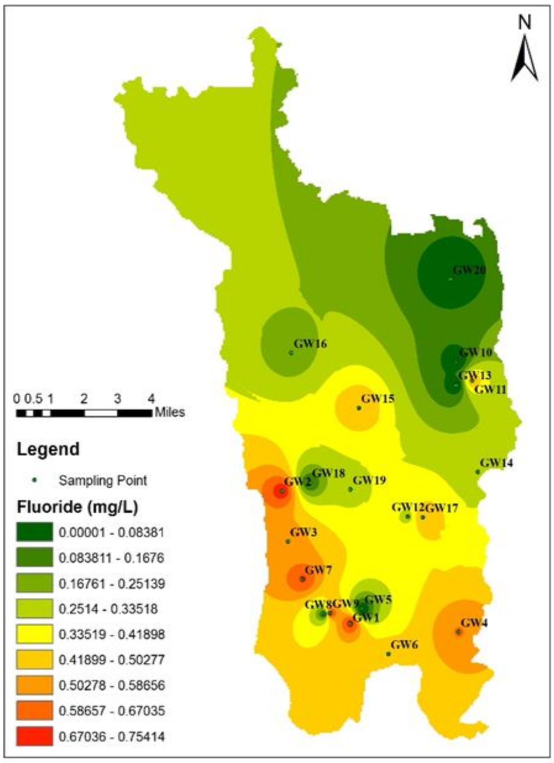

Fig. 2A. Spatial Distribution of Florien.

Chloride

Chlorides occur altogether natural waters in wide variable concentrations. The chloride content ordinarily will increase because the mineral content will increase. The chloride ion happens in natural waters in fairly low concentrations, sometimes less than 100mg/L, unless the water is brackish or saline. No health-based guideline value is proposed for chloride in drinking water. High concentrations of chloride give a salty taste to water and beverages. However, chloride concentrations in excess of about 250mg/L can give rise to a detectable taste in water (WHO, 2004). Findings from the Fig. 2B the maximum concentration in Chloride in the Northeastern area of Savar.

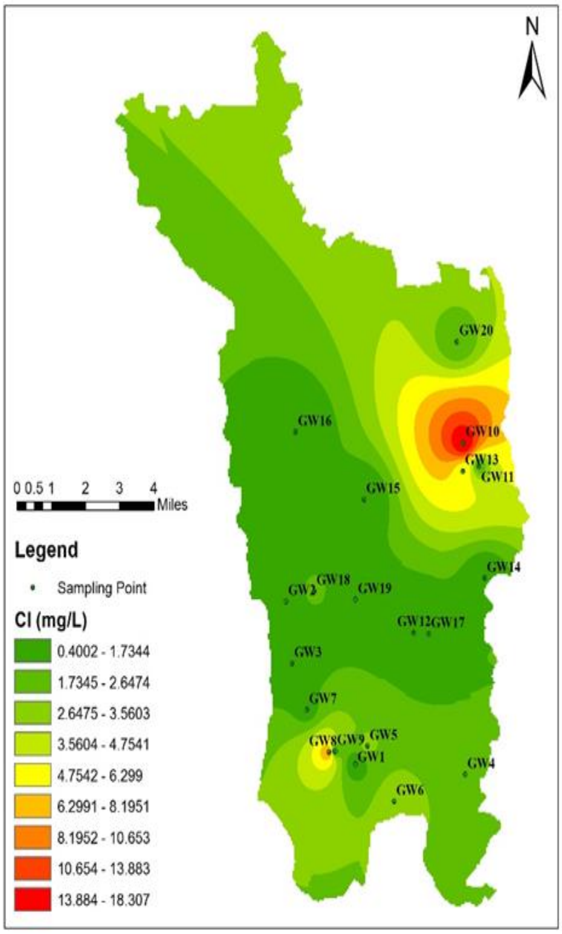

Fig. 2B. Spatial Distribution of Chlorine.

Nitrate

Nitrate will reach each surface water and groundwater as a consequence of agricultural activity through fertilizers and manures, from waste product disposal and from reaction of gas waste product in human and animal excretion, as well as septic tanks. Some groundwater may also have nitrate contamination as a consequence of leaching from natural vegetation. Groundwater concentrations generally show relatively slow changes (WHO, 2004). Agricultural sewage irrigation areas showed strong health risks, but that those of the area were relatively small. Moreover, children's health risks are greater than those of adults (Su *et al.*, 2013). According to WHO guidelines up to 50mg/L concentration has a great health impact. The study shows in Fig. 2C that the concentration of chloride is most in the northern area. Due to Agro-industrial practice nitrate concentration is raising as Savar Thana, a highly industrialized zone of Dhaka district (Hasan *et al.,* 2019).

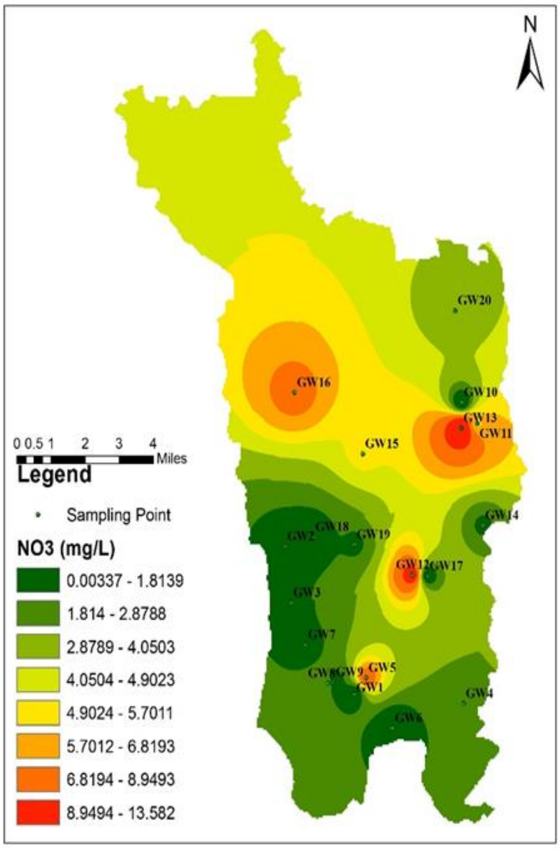

Fig. 2C. Spatial Distribution of Nitrate.

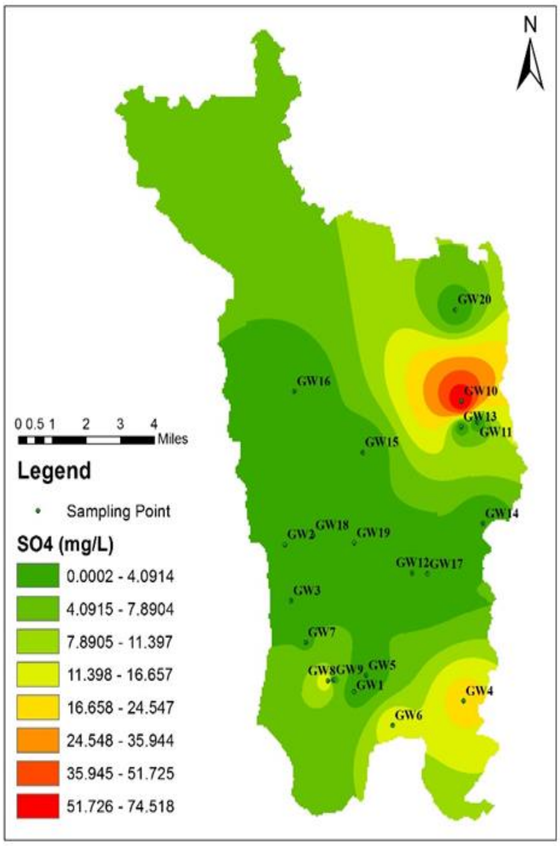

Fig. 2D. Spatial Distribution of Sulfate.

Sulfate

Sulfates occur naturally in numerous minerals and are used commercially, principally in the chemical industry. They are discharged into water in industrial wastes and through atmospheric deposition; however, the highest levels usually occur in groundwater and are from natural sources (WHO, 2004). According to WHO standard 250mg/L is the maximum limit of sulfate in drinking water. Fig. found from this study 2D presenting the concentration of sulfate in different sampling location. Where sampling point GW10 showing maximum concentration of sulfate in the northeastern area of Savar.

Conclusion

Recently, the globally important groundwater resources have become under great risk because of the rapid increases in population, modern land use applications (agricultural and industrial) and demands for water supply which endanger both water quality and quantity. Assessing and observation the standard of groundwater is thus, vital to make sure and safe use of those resources for the assorted functions. Groundwater pollution is a growing environmental problem, particularly in developing countries. The urbanization method threatens groundwater quality because of the impact of domestic and industrial waste disposal. This results in aquifer deterioration, since some of the waste products, including sewage and cesspool may be discharged directly into the aquifer system. Savar, a densely populated and rapidly growing industrial hub in Bangladesh.

Remaining the constraints of the current study, it should be all over that the groundwater vulnerability map of the study area may be effective in providing broad-scale data on the inclined areas of groundwater contamination, even supposing the groundwater quality within the study area was found to be smart, significantly within the extremely and moderately vulnerable zones, is indicative of the introduction of pollutants from evolution sources, and thus the groundwater resources area remain under potential risk of contamination within the close to future. Periodic observation of groundwater quality within the high and moderate vulnerable zones is crucial for early detection and to stop any deterioration of the groundwater resources. Government initiative is also essential though this purpose.

References

Ahmed KM, Sultana S, Hasan MA, Bhattacharya P, Hasan MK, Burgess WG, Hoque MA. 2011. Groundwater quality of upper and lower Dupi Tila aquifers in the megacity Dhaka, Bangladesh. IAHS-AISH Publication **342,** 71-74.

Akther H, Ahmed MS, Rasheed KBS. 2010. Spatial and temporal analysis of groundwater level fluctuation in Dhaka city, Bangladesh. Asian Journal of Earth Sciences **3(4),** 222-230.

Arumugam K, Elangovan K. 2009. Hydrochemical characteristics and groundwater quality assessment in Tirupur region, Coimbatore District, Tamil Nadu, India. Environmental Geology **58(7),** 1509-1520.

Dahariya NS, Ramteke S, Sahu BL, Patel KS. 2016. Urban Groundwater Quality in India. Journal of Environmental Protection **07(06),** 961-971.

Dragon K. 2008. The influence of anthropogenic contamination on the groundwater chemistry of a semi-confined aquifer (The wielkopolska buried valley aquifer, Poland). Water Resources Management **22(3),** 343-355.

Edmunds WM, Smedley PL. 1996. Groundwater geochemistry and health: An overview. Geological Society, London, Special Publications **113(1),** 91-105.

Edmunds WM, Shand P, Hart P, Ward RS. 2003. The natural (Baseline) quality of groundwater: A UK pilot study. Science of the Total Environment **310(1-3),** 25-35.

Embaby A, Razack M, Lecoz M, Porel G. 2016. Hydrogeochemical Assessment of Groundwater in the Precambrian Rocks, South Eastern Desert, Egypt. Journal of Water Resource and Protection **08(03),** 293-310.

Gatseva PD, Argirova MD. 2008. High-nitrate levels in drinking water may be a risk factor for thyroid dysfunction in children and pregnant women living in rural Bulgarian areas. International Journal of Hygiene and Environmental Health **211(5-6),** 555-559.

Gbadebo AM, Akinhanmi TF. 2010. Gender issues in management and use of groundwater resources : a case of abeokuta metropolis. Journal of Applied Sciences in Environmental Sanitation **5(2),** 191-199.

Giridharan L, Venugopal T, Jayaprakash M. 2008. Evaluation of the seasonal variation on the geochemical parameters and quality assessment of the groundwater in the proximity of River Cooum, Chennai, India. Environmental Monitoring and Assessment **143(1-3),** 161-178.

Gupta S, Mahato A, Roy P, Datta JK, Saha RN. 2008. Geochemistry of groundwater, Burdwan District, West Bengal, India. Environmental Geology **53(6),** 1271-1282.

Hampel R, Zöllner H, Glass Ä, Schönebeck R. 2003. Kein Relevanter Zusammenhang Zwischen Nitraturie und Strumaendemie in Deutschland. Medizinische Klinik **98(10),** 547-551.

Hasan M, Islam MA, Hasan MA, Alam MJ, Peas MH. 2019. Groundwater vulnerability assessment in Savar Upazila of Dhaka district, Bangladesh — A GIS-based DRASTIC modeling.

Jha SK, Singh RK, Damodaran T, Mishra VK, Sharma DK, Rai D. 2013. Fluoride in groundwater: Toxicological exposure and remedies. Journal of Toxicology and Environmental Health - Part B: Critical Reviews **16(1),** 52-66.

Liu CW, Lin KH, Kuo YM. 2003. Application of factor analysis in the assessment of groundwater quality in a blackfoot disease area in Taiwan. Science of the Total Environment **313(1-3),** 77-89.

Olukanni DO, Mnenga MU. 2015. Municipal Solid Waste Generation and Characterization: A Case Study of Ota, Nigeria. International Journal of Environmental Science and Toxicology Research **3(1),** 1-8.

Rádiková Ž, Tajtáková M, Kočan A, Trnovec T, Šebökova E, Klimeš I, Langer P. 2008. Possible Effects of Environmental Nitrates and Toxic Organochlorines on Human Thyroid in Highly Polluted Areas in Slovakia. Thyroid **18(3),** 353-362.

Shivran HS, Kumar D, Singh RV. 2006. Improvement of water quality through biological denitrification. Journal of Environmental Science and Engineering **48(1),** 57-60.

Siebert S, Burke J, Faures JM, Frenken K, Hoogeveen J, Döll P, Portmann FT. 2010. Groundwater use for irrigation - A global inventory. Hydrology and Earth System Sciences **14(10),** 1863-1880.

Su X, Wang H, Zhang Y. 2013. Health Risk Assessment of Nitrate Contamination in Groundwater: A Case Study of an Agricultural Area in Northeast China. Water Resources Management **27(8),** 3025-3034.

Susheela AK, Das TK. 1988. Fluoride toxicity and fluorosis: Diagnostic test for early detection and preventive measures adopted in India. Abstracts, International Symposium on Environmental Life Elements and Health," Beijing. 89.

Tajtáková M, Semanová Z, Tomková Z, Szökeová E, Majoroš J, Rádiková Ž, Langer P. 2006. Increased thyroid volume and frequency of thyroid disorders signs in schoolchildren from nitrate polluted area. Chemosphere **62(4),** 559-564.

Umar R, Khan MMA, Absar A. 2006. Groundwater hydrochemisry of a sugarcane cultivation belt in parts of Muzaffarnagar district, UttarPradesh, India. Environmental Geology **49(7),** 999-1008.

Ward MH, Kilfoy BA, Weyer PJ, Anderson KE, Folsom AR, Cerhan JR. 2010. Nitrate intake and the risk of thyroid cancer and thyroid disease. Epidemiology (Cambridge, Mass.) **21(3),** 389-395.

Federal-Provincial Working Group on Drinking Water (Canada), Canada. Health, & Welfare Canada. 1979. Guidelines for Canadian drinking water quality, 1978 Vol. 1. Health and Welfare Canada.

WHO. 2004. Guidelines for Drinking-water Quality.

Zhou Z, Ansems N, Torfs P. 2015. A Global Assessment of Nitrate Contamination in Groundwater. International Groundwater Resources Assessment Centre. Internship report. 1-27.