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Groundwater Analysis in North India: A Review

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---ABSTRACT---
It has been documented by several researches that the monitoring of groundwater quality is necessary after a regular period of time. In current review, unusual occurrence of metal and chemical related problems has been studied in North India and deterioration of groundwater quality was observed. This review aims to compare the pollution level in groundwater, responsible for poor water quality. A total of nine areas and several samples from different point sources were studied for physicochemical analysis (pH, conductivity, alkalinity, hardness, TDS, DO, nitrate, phosphate, sulphate, chloride, fluoride, sodium, potassium) and heavy metal analysis (arsenic, cadmium, chromium, cobalt, copper, iron, lead, manganese, nickel, zinc).The observed range of pH (5.6-8.82), alkalinity (71-1199.7mg/L), hardness (81-3808mg/L), fluoride (0.01-6.4mg/L) and heavy metals like arsenic (2.94-7.451mg/L), cadmium (0.001-0.48mg/L), chromium (0.002-1.143mg/L) were studied. Whereas limits prescribed by BIS/WHO for above analysis & water quality are widely different. By further reviewing the available literature for past ten years, it was found that water quality near landfill sites and industrial areas is comparatively poor and proper treatment of industrial effluents is necessary before dumping it to sites. The level of pollution is also affected by industrial effluents, agricultural activities, seasonal variation etc. Prolonged use of heavy metal contaminated water causes chronic diseases in the human population. Based on water quality at most of sampling stations, water was found unsuitable for drinking. The overall goal of this study is to investigate the impacts of using contaminated water on human health and water aesthetics.
Keywords: *Chronic diseases, Groundwater quality, Heavy metals, Industrial effluents, Point source.*

I. INTRODUCTION

Water is an essential component of our ecosystem. Water after air is the most important requirement for the survival of life. Easy access to safe drinking water is the prime importance to everyone. Groundwater is the main natural resource to fulfill this requirement. There is uneven distribution of fresh water within continents. Asia subcontinent has only 36% of world's fresh water resources although has more than 50% of world' population [1]. In India, a major part of extracted groundwater (89%) used for irrigation, 9% of it for domestic use & rest of 2% for industrial use [2]. Rural domestic groundwater requirement is greater than urban domestic groundwater requirement as many of times rural population do not get water through water distribution system of the country/city [3]. Groundwater in its pure form looks clean and clear but many natural & anthropological activities are polluting it. The three main factors which affect the quality of groundwater are agriculture, industries and urbanization. By monitoring the impact of industrialization, a strategy can be made to improve water resource management [4]. A plethora of chemicals are found in high concentration in the groundwater. These chemical constituents enter the hydrological cycle through different types of agricultural, industrial, domestic effluents and landfill leachates. High level of fluoride, nitrate, arsenic, heavy metals, organic matters and high salinity of water present in aquifers is a matter of great concern [5, 6]. Dumping of industrial wastes in landfill sites increase the toxicity level of soil at that place & leachate from these landfill sites contaminate the groundwater [7]. A negative correlation has been found between the value of TDS, EC, Na+ and the distance from the landfill sites. High level of metal ions were detected in leachates, originate from the landfills [8]. The level of groundwater contamination is fluctuating in different regions. The deterioration of groundwater quality in many cities of India was studied and need immediate remediation [9, 10]. Heavy metals are present in the industrial effluent of almost all type of industries like paper, textile, paint, cement, electronics, automobiles etc. The disposal of these effluents without proper treatment releases a great amount of heavy metals in the environment. Infiltration of water takes these metals and mix with ground aquifers. Once these metals mix with the groundwater, remains in the aquifers for a long time [11] and present in every step of a food chain. Acute and chronic, both type of disease are developed due to intake of contaminated water. North India is a densely populated area. A large number of industries are present to fulfill the increasing demand of the population. Sugar, textile, paper, beverages, paint, agricultural tools, home appliances, automobiles, electronics are few important industries of this area. The dumping of industrial and agricultural wastes is deteriorating the quality of groundwater. The fluoride conc. of groundwater is very high in some villages of Haryana causing dental fluorosis among the population [13] studied the poor groundwater quality of Najafgarh area of Delhi by using geostatistical concepts. Results of study made by [14] revealed that the chemical parameters of groundwater like BOD, DO, alkalinity etc. have increased beyond the permissible limit given by WHO near sugar mills.

II. LITERATURE SURVEY

Shikha Bisht, B.A. Patra et al. [15] studied the quality of drinking water from four different locations in Ghaziabad. Physicochemical and elemental analysis was done to assess the potability of water. Fluoride content was found higher than permissible limit (IS10500) in all the samples ranging from 1.66 to 4.68 mg/L. Nitrate content was high in Jatwara (187.583mg/L) whereas the standard value for nitrate ion is 100 mg/L. Aluminium and Iron content was more than the permissible limit in Sahibabad sample 228.88 & 4598.76 ppb respectively. All other physicochemical parameters were found to be in safer limit. They concluded that the water from these areas can be used for drinking after removal of excess of fluoride, nitrate, aluminium & iron.

Manjeet, B P Singh and J K. Sharma [16] have studied the potability of groundwater in various villages of Gurgaon district of Haryana state. The main goal of the study was to assess the drinking quality and fluoride conc. of groundwater. The permissible limit of fluoride ion in drinking water as per WHO guidelines 1.0mg/L and as per Indian standards 1.5mg/L. 24% of samples taken have the fluoride conc. above the standard limits and 43% of samples have lesser conc. High fluoride conc. is due to the availability and solubility of fluoride minerals like apatite, fluorite and mica. Industrial development is also responsible for high fluoride ion conc. Consumption of fluoride rich water results in dental fluorosis, teeth mottling, skeletal fluorosis and deformation of bones.

R.K. Dubey, Zakir Husain et al. [17] studied the ground water quality of Dwarka district of national capital of India and expresses the quality of water in terms of water quality index (WQI). They calculated the WQI on the basis of several parameters including sodium, potassium, silicate and phosphate. The calculated value of WQI varies from 58.3 to 907.2. The max.value of WQI is for Dwarka sec. 12 and the min. Value of WQI is for Dwarka Sec. 6. The results showed that 30.77% of samples taken have been found unfit for drinking purpose, 46.15% of samples have very poor water quality and 19.23% of samples have been categorised into poor quality.

Sajal Singh & Athar Hussain [18] calculated the water quality index of 47 groundwater samples from Greater Noida city to assess the potability of water. Eleven parameters (pH, Ca, Mg, TDS, chloride, nitrate, sulphate, fluoride, bicarbonate, Na and K) were used to calculate the WQI. The calculated value of WQI ranges from 53.69 to 267.85. 96% of water samples showed good water quality except samples from the location CHI-3 & near Radisson hotel. The samples from these two locations showed high value of EC, TDS, Na^+, Mg^+ and Cl^-. The water samples from Echar village found best for drinking purpose.

Rakesh Bhutiani et al. [19] studied the groundwater samples of 18 locations in Haridwar. They analysed the presence of five heavy metals (Cr, Co, Ni, Fe and Zn) in the samples. Principal Component Analysis & Hierarchial Cluster Analysis was done to pollution source apportionment. In more than 94% of samples heavy metals were detected. Max. Conc. of all the heavy metals analysed (except Zn) were higher than the guideline limit given by WHO & BIS. High conc. of Fe during monsoon season is due to increased rusting of pipes and more dissolution of metal in rain water. No carcinogenic effect has been noticed in the population of that area.

Archana, Parvinder Kaur et al. [20] analyzed the quality of municipal water in Delhi-NCR region. They chose the four water purifying techniques available in the market (Tap attachment, Candle filter, Membrane filtration and Reverse osmosis) and applied each technique to each sample. One unprocessed and four processed samples were analyzed for their chemical and microbial quality. Chemical parameters include pH, alkalinity, electrical conductivity, total hardness, turbidity and TDS. For microbial quality MPN (Most Probable Number) presumptive test, Presence-Absence test were carried out. The results better rated the water samples from N. Delhi, E. Delhi, W. Delhi, Alipur, Narela and Central New Delhi. The water quality of these areas is better than the surrounding areas (NCR). R.O. technology was found best among the four selected technologies.

C. K. Jain, Bandyopadhyay et al. [21] assessed the groundwater and spring water quality of district Nainital, Uttarakhand for drinking purpose. They have taken forty water samples from the region under study and analyzed chemical, microbial and heavy metals characteristics of it. They found 10% of water samples have TDS value higher than the desirable limit of BIS (500 mg/L) but not higher than permissible limit of BIS/WHO (2000mg/L/1000mg/L) respectively. They concluded that high value of TDS is due to mineralization of groundwater. 30% of samples showed high value of alkalinity (76 to 380 mg/l in pre monsoon season & 71 to 354mg/L in post monsoon season). Spring water has alkalinity value within desirable limit. All other parameters were found in acceptable range. Nickel was found higher than the WHO limit (0.07mg/L) for drinking water in 60% of samples. Iron and Lead was found high only in one sample (due to local effect). All other metals were found within range. Proper treatment of spring water for microbial contamination was recommended before drinking.

Parul Gupta, Kiranmay Sharma [22] analyzed the quality of groundwater with respect to the depth in Delhi region. They selected 48 samples from eight selected sites for physicochemical analysis. Piezometers were used to measure the depth of groundwater. All the results were compared to the standard values given by APHA (1998). The results were in negative correlation with the depth of groundwater. Krigging method was used to generate variability maps. The prepared maps showed that the physicochemical values increased from North to South Delhi and groundwater depth decreases from South to North Delhi. This confirms the negative correlation between these two values.

III. MATERIALS AND METHODS

3.1 STUDY AREAS

North India lies in the Northern temperate zone of the earth. North India comprises of states of J & K, Uttar Pradesh, Punjab, Haryana, Himachal Pradesh, Uttarakhand, Delhi and Chandigarh. The states of Rajasthan, Bihar and Madhya Pradesh are not the part of North India but are culturally & linguistically similar. Geographical features of North India are Indus - Gangetic plain or Northern plain and Himalayan region. The northern plain has been formed by the interplay of 3 major river systems, namely the Indus, the Ganga and the Brahmaputra along with their tributaries. This plain is formed of alluvial soil and is very fertile. The Himalayas, geologically young and structurally fold mountains stretch over the northern borders of India. These mountain ranges run in a west-east direction from Indus to the Brahmaputra covers a distance of about 2,400 Km. The climate of this region is diverse ranging from 60^0C (in Thar Desert) to -45^0C (in Dras sector of J&K). The region receives rain and snow precipitation through two primary weather patterns the Indian monsoon (Indian Ocean) and the western disturbances (Mediterranean Sea, Caspian Sea and Atlantic Ocean). The location of study areas are given in “Table-1”.

Table-1: Location of Study Areas

Study areas in North India	Coordinates
Aligarh	27.8974°N, 78.0880°E
Delhi	28.7041°N, 77.1025°E
Ghaziabad	28.6692°N, 77.4538°E
Greater Noida	28.4744°N, 77.5040°E
Gurgaon	28.4595°N, 77.0266°E
Haridwar	29.9457°N, 78.1642°E
Kanpur	26.4499°N, 80.3319°E
Lucknow	26.8467°N, 80.9462°E
Nainital	29.3803°N, 79.4636°E

The two regions (Haridwar, Nainital) under study receive frequent rainfall. The quality of groundwater is greatly affected by the lithology of that area. This region is highly populated and a lot of industrial development has been done here. The consequences of increasing industrial activity and domestic waste are deterioration of groundwater quality and quantity both. The groundwater quality of Haryana, Delhi, Aligarh, Lucknow and Kanpur region was studied for various chemical parameters and heavy metals [23-27]. The effluent of tannery industries in Kanpur increases the chromium content of groundwater in that area. The increased conc. of Co, Cr, Fe and Ni in groundwater has been found in Integrated Industrial estate Haridwar. A comparative study of different heavy metals present in groundwater in different areas of this region is given in figure1.

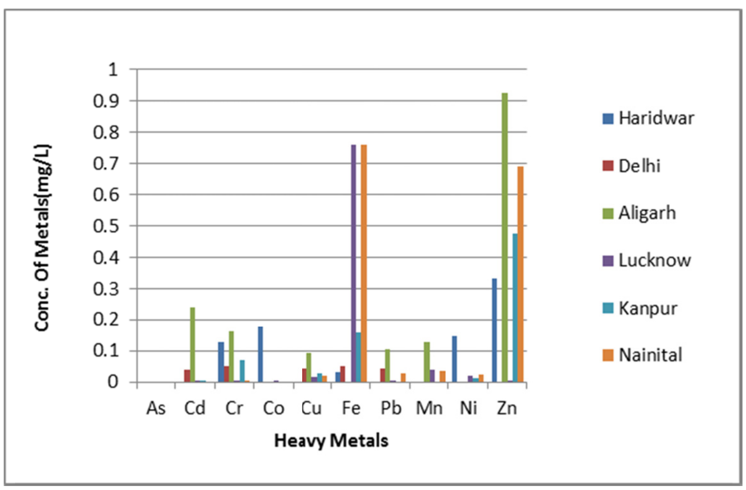

Figure. 1 Variation of concentration of different heavy metals in groundwater (areas under study)

3.2 SAMPLING & ANALYTICAL METHODS

Sources of groundwater are tube wells, bore wells, dug wells, hand pumps etc. In most of studies grab sampling method was used. Standard methods were used to analyze the various physicochemical parameters as well as seasonal variation ‘’Table-2 & Table-3’’.

Table-2: Physical Parameters for Groundwater Analysis

Parameters	Techniques for Analysis	Causes	Areas	Effects on Water Aesthetics
Temperature	Mercury thermometer (0.1^0C division)	Change in environmental temperature	Aligarh	Affect other parameters
Colour	Visual comparison	Presence of dissolved salts & suspended matter		Unpleasant
Odour	Qualitative human receptor	Organic & inorganic contaminants	Haridwar	Unpleasant
Transparency	Secchi disc	Dissolved ions & soil runoff		Unpleasant
Turbidity	Nephelometric turbidity meter	Soil runoff & organic matter	Aligarh, Kanpur	If turbidity is due to organic matter - high risk of gastrointestinal illness

Table-3: Chemical Parameters for Groundwater Analysis

Parameters	Analytical Technique	Source to Groundwater	Potential Health Effect	Areas	BIS (IS:10500: 2012) (unit*)		Range Found (min. –max.) (unit*)
					Desirable limit	Permissible limit	
pH	Potentiometric Analysis	Due to dissolved gases like CO_2, H_2S & NH_3	High pH causes the bitter taste& affect mucous membrane	Delhi Ghaziabad Gr. Noida Gurgaon Nainital Haridwar Aligarh	6.5-8.5	No Relaxation	6.83-8.21 7.19- 8.03 7.2-8.5 5.6-8.4 5.9-8.1 6.8 - 7.3 7.01- 8.82
Electrical Conductivity	Conductivity	Due to dissolved inorganic ions	High electrical conductivity makes the water unsuitable for drinking	Delhi Ghaziabad Gr. Noida Gurgaon Nainital	1500	-	322- 14580 - 710- 3,410 - 203-970
Alkalinity	Acid-Base Titration	Weathering of rocks (containing CO_3^{2-}, HCO_3^-, OH^-)	Slightly alkaline water is good for health	Delhi Ghaziabad Gr. Noida Gurgaon Nainital	200	600	333.25-1199.7 11.82-51.22 137- 287 102 -582 71-380
Total Dissolved solids	Gravimetric Analysis	Agricultural, industrial wastes	Indication of contamination	Delhi Ghaziabad Gr. Noida Gurgaon Nainital	500	2000	209 -9477 0.018-0.113 454–2,182 60- 3731 130-621
Total Hardness	Volumetric Analysis (EDTA	Dissolution of sedimentary	No health risk only create nuisance	Delhi Ghaziabad Gr. Noida	200	600	144 – 3808 49.92-291.84 91–678

	Titration)	rocks(Ca,Mg) & soil runoff		Gurgaon Nainital			50.47- 2984.2 81-438
Dissolved oxygen	Winkler Azide Titration	_	Low DO indicate the microbial & chemical contamination	Delhi Ghaziabad Gr. Noida Gurgaon Nainital	-	-	-
Nitrates	Ion selective electrode method	Septic tank, Fertilizers, Animal waste	Blue baby syndrome & affect oxygen carrying capacity of blood	Delhi Ghaziabad Gr. Noida Gurgaon Nainital	45	No Relaxation	10.8 – 147 5.37-187.58 3.2- 15.1 43-1920 [23] 0.1-16
Sulphates	Nephelometry/ UV Spectrometer	Sea water, mineral dissolution, industrial wastes, domestic sewage	Changes the taste and odour of water. High conc. Cause laxative effect	Delhi Ghaziabad Gr. Noida Gurgaon Nainital	200	400	10 – 1046 19-76 2-1300 - 2.3-140
Phosphates	Spectrophotometric	Due to detergents, fertilizers and weathering of rocks	High conc. causes renal disorder, damage blood vessels and induce aging process	Delhi Ghaziabad Gr. Noida Gurgaon Nainital	-	-	2.98-18 - - - 0.05-0.36
Chlorides	Argentometric Titration	Mainly due to salt dissolution	Changes the taste of water	Delhi Ghaziabad Gr. Noida Gurgaon Nainital	250	1000	53.2-6309 2.931-363.887 33.2–675.6 - 2-13
Fluorides	SPADNS** Spectrophotometric	Due to industrial wastes (e.g. coke, glass, ceramic, fertilizer etc.)	Low conc. cause tooth decay but high conc. Cause dental fluorosis, skeletal fluorosis.	Delhi Ghaziabad Gr. Noida Gurgaon Nainital	1.0	1.5	0.22 - 4.64 1.66-4.68 0–1.70 0.02- 6.4 0.01-0.66
Potassium	Flame Emission Photometric Analysis	Mineral leaching	High conc. causes chest tightness, nausea and vomiting.	Delhi Ghaziabad Gr. Noida Gurgaon Nainital	-	-	1.0 - 32 - 3.9- 29.7 - 0.6-5.2
Sodium	Flame Emission Photometric Analysis	Dissolution of underground rocks and washing products	Health risk to the patients of high blood pressure	Delhi Ghaziabad Gr. Noida Gurgaon Nainital	-	-	4 - 2417 - 2.5 - 995.5 - 1-14

* Unit of all analysis is in mg/L except pH and electrical conductivity (µS /cm)
**sodium 2-(parasulphophenylazo)-1, 8- dihydroxy-3, 6-naphthalenedisulphonate

Now a days the presence of heavy metals in groundwater has great consideration as these metals are nonbiodegradable, accumulate in water for a long time and causes chronic diseases. These heavy metals enter the ground aquifers through different natural and anthropological activities. Some of heavy metals are essential to human beings in small quantities but excess of these metals can cause diseases. Study of various quantitative analysis of metals in groundwater samples was done in different areas "Table-4" and results were compared with the standard values given by WHO/BIS.

Table-4: Heavy Metals present in Groundwater

Heavy Metals	Areas	Toxicity Level (In Mg/L)	Standard limit for drinking water			Effects of heavy metal toxicity on humans
			WHO (In Mg/L)	BIS (IS 10500 :2012) Acceptable limit (In Mg/L)	BIS (IS 10500 :2012) Permissible limit (In Mg/L)	
Arsenic	Ghaziabad	2.94-7.451	0.05	0.01	0.05	Excessive and prolonged exposure causes Arsenicosis (skin lesions, pigmentation of skin, patches on palm & soles), skin cancer, and internal cancer (Bladder, kidney & lungs).
Cadmium	Delhi [24] Ghaziabad Aligarh[25] Lucknow[26] Kanpur [27]	0.01-0.07 0.019-0.128 0.00 -0.48 0.0016(summer) 0.0015(monsoon) 0.0024(winter) 0.001- 0.054	0.005	0.003	No Relaxation	Mainly affects kidney and lungs. Carcinogenic (Lungs & prostrate), causing osteomalacia (softening of bones).
Chromium	Haridwar Nainital Delhi Ghaziabad Aligarh Lucknow Kanpur	0.003-0.26 0.002-0.007 0.01- 0.09 0.299-1.143 0.00- 0.33 0.004(summer) 0.0039(monsoon) 0.005(winter) 0.06- 0.085	0.05	0.05	No Relaxation	Cr (III) is essential to human body. Cr (VI) is very toxic causes kidney and liver damage, ulcers on the skin when intake in high concentration
Cobalt	Haridwar Lucknow	0.003-0.36 0.0035 (summer) 0.0039(monsoon) 0.0037(winter)	_	_		High conc. causes Vomiting and nausea vision problem, heart Problem and thyroid damage.

Copper	Nainital Delhi Ghaziabad Aligarh Lucknow Kanpur	0.001-0.041 0.01- 0.08 0.0476-2.037 0.00 0.19 0.0020(summer) 0.0476(monsoon) 0.0035(winter) 0.012-0.045	1.0	0.05	1.5	Essential trace element but at high conc. causes liver and kidney damage, give a bitter taste to water.
Iron	Haridwar Nainital Delhi Ghaziabad Lucknow Kanpur	0.003-0.6 0.040-1.479 0.01 -0.09 186.53-4598.76 0.8257(summer) 0.6234(monsoon) 0.8283(winter) 0.07 - 0.250	0.3	0.3	No Relaxation	Give a metallic taste to water.
Lead	Nainital Delhi Ghaziabad Aligarh Lucknow	0.005-0.053 0.01- 0.08 0.004-0.435 0.00 -0.21 0.0063(summer) 0.0051(monsoon) 0.0064(winter)	0.05	0.01	No Relaxation	Children are more vulnerable to lead exposure. Cause delayed physical and mental development. At high conc. cause convulsions, coma & death.
Manganese	Nainital Ghaziabad Aligarh Lucknow	0.001-0.071 3.36-62.54 0.00- 0.26 0.0236(summer) 0.0470(monsoon) 0.0451(winter)	0.1	0.1	0.3	Relatively nontoxic to humans, only affect water aesthetics.
Nickel	Haridwar Nainital Lucknow Kanpur	0.005- 0.29 0.010-0.038 0.0168(summer) 0.0149(monsoon) 0.0258(winter) 0.01 - 0.044	0.07	0.02	No Relaxation	Acute exposure causes nausea, vomiting, diarrhea and long exposure damages heart & liver.
Zinc	Haridwar Nainital Ghaziabad Aligarh Lucknow Kanpur	0.01- 0.66 0.015-0.675 0.013- 0.318 0.01 1.84 0.0045(summer) 0.0042(monsoon) 0.0067(winter) 0.095 -0.380	5.0	5.0	15	Essential trace element, causes no health effect at low conc.

IV. WATER QUALITY INDEX

Water Quality Index is a tool to monitor the quality of water. It is a numerical figure which is assigned to the sample of water according to their quality.WQI summarizes a lot of data into a simple form which is easily understandable. From the WQI value, the possible uses of water can be stated.

High value of WQI means the poor quality of water. Depending upon WQI value, water quality is tabulated in "Table-5".

Table-5: Quality of Water on the basis of range of WQI

WQI value	Water quality
< 50	Excellent water
50-100	Good water
100-200	Poor water
200-300	Very poor water
> 300	Water unsuitable for drinking purpose

WQI value of groundwater in Gr. Noida was found between 53.69 and 97.06 in most of the samples except two samples (152.24 & 267.85). On this basis, water quality of this region is good and can be used for drinking after sufficient treatment. In Delhi region WQI value ranges from 58 to 907. At most of the station value was above 100 hence proper treatment was recommended before drinking.

V. DISCUSSION AND RECOMMENDATION

The groundwater quality of an area is influenced by the mineral content of that area and the pollutants. The quality of water is also affected by weather-change. The current study revealed that value of chemical parameters decrease after the monsoon season due to the dilution of groundwater aquifers but heavy metal conc. increase due to more dissolution of metals. In Lucknow average conc. of chemical parameters was found high in summer season (phosphate-0.15mg/L, sulphate-40.15mg/L, alkalinity-351.80mg/L, chloride-45.41mg/L, hardness-330.60mg/L and pH 7.91) but nitrate conc. was high in monsoon season (17.12mg/L) due to leaching of fertilizers with rain water. Metal conc. was high in winter season "Table-4". In Haridwar the conc. of Co, Cr, Fe and Ni "Table-4" was found high in most of the samples due to industrial development. In contrast to Haridwar, the conc. of metals was less in Nainital although has the somewhat similar climate. This is due to less industrial development in that area. The chromium content in groundwater of Kanpur is high due to effluent from tannery industries. The contamination of groundwater in this area has become a public health hazard. In Aligarh groundwater is alkaline and hard in nature with high metal ion concentration. The study of these areas gives a strong relation between the water quality and various anthropogenic activities in that area.

The results of this study suggests few remediation for groundwater, which can be classified into four categories 1) minimized the generation of waste material 2) Proper treatment of waste material before dumping 3) Decontamination of water before consumption 4) Alternative uses of waste material like solid waste material can be used in construction of roads and filling of pits. Sewage water can be used in electricity generation and for cooling purpose in industries. Monitoring of water quality should be done at regular intervals and proper treatment of water is necessary before drinking it.

VI. CONCLUSION

The detailed study of groundwater quality in North India region showed that at most of the places water is heavily polluted and not fit for human consumption. This review states that value of most of the physicochemical parameters are beyond the standard limits given by WHO/BIS. The deterioration of water quality is mainly due to increasing number of industries, to fulfill the demand & supply as per the population growth.

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