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# Ground water quality in industrial agglomeration-An overview

Sharmila A *, Nagendra Prasad B C **, Dayananda H S***
**(Department of Civil Engineering, Vidyavardhaka College of Engineering, Mysore, Karnataka, India*
*** (Department of Civil Engineering, Maharaja Institute of Technology, Thandavapura, Mysore, India*
****(Department of Civil Engineering, Vidyavardhaka College of Engineering, Mysore, Karnataka, India*
*Corresponding author: Sharmila A*

**ABSTRACT**
Groundwater is an important source of domestic water supply, agriculture and industries. In the absence of fresh surface water resources, groundwater is exploited to meet the demand exerted by various sectors. Large scale industrial growth has caused serious concern regarding the susceptibility of ground water contamination due to waste materials. There is lack of proper monitoring and enforcement on gorund water quality. To minimize the effect of industrial discharge on ground water, wastewater should be treated before disposal. Water quality management is an issue that must be given top priority. Hence, there is need for environmental education, adequate regulations and proper management of industrial wastewater. In this review paper, an attempt is being made to collate and compile the research papers on ground water pollution due to industrial effluents, heavy metals, groundwater quality, statistical analysis, water quality index and models to assess vulnerability of ground water are presented.
**Keywords -** Ground water, Industrial effluent, Water quality, Vulnerability, Statistical analysis

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## I. INTRODUCTION

Ground water has long been considered as one of the purest forms of water available in nature and meets the overall demand of rural and semi-urban people. Groundwater is an important source for domestic water supply, agriculture and industry. In the absence of fresh surface water sources, groundwater is exploited to meet the demand exerted by various sectors. Large scale industrial growth has caused serious concern regarding the susceptibility of ground water contamination due to industrial waste materials.

Waste materials near the industries which are subjected to reaction with percolating rain water leaches into the aquifer system and degrade the ground water quality. The industrial effluents contain appreciable amounts of both inorganic and organic chemicals and its byproducts. It also include pathogens, metals, salts, ammonia, pesticides pharmaceuticals, endocrine disruptors etc., and cause adverse impacts on the surrounding water resources. Even today, most of the industries do not have proper wastewater treatment plants and discharge industrial effluents in unlined channels and streams and thereby causing enormous contamination of air, water and soil. Municipal solid waste and industrial waste are the main cause for pollution of ground water and surface water. In many parts of the country, available water is non-potable because of the presence of impurities and high concentration of heavy metals.

The principle involved in waste movement through the soil is governed by Darcy's Law and the same is presented here.

Darcy's Law

Henry Darcy (1856) systematically studied the movement of water through sand columns. It explains the rate of flow, i.e., volume of water per unit time, Q is directly proportional
to the cross sectional area, A and head loss, Δh and inversely proportional to the length of the flow path, L.

$$Q \propto \frac{A(\Delta h)}{L}$$

Darcy's law can be written as:

$$Q = -\frac{KA(\Delta h)}{L} \quad \text{----------(1)}$$

where K=Hydraulic conductivity of the porous medium and –ve sign indicates that Q occurs in the direction of the decreasing head.

Here, $\frac{(\Delta h)}{L}$ = Hydraulic gradient.

## II. ABOUT NANJANGUD INDUSTRIAL AREA

Nanjangud Industrial area is a home to many industries which is spread across 532 acres (2.15 $km^2$). It is one of the most important industrial area situated near Mysore in the state of Karnataka. Nanjangud is rated as the fastest growing industrial area. There are 36 major, medium and small scale industries. It includes textiles, paper and pulp, electroplating, pharmaceutical and granite etc. which are located on the banks of Kabini river, a major tributary of Cauvery river[4].

According to Nanjangud Industries Association (NIA), Nanjangud is the second highest tax-paying taluk in the State after Bangalore. Nanjangud taluk has the potential to emerge as an important industrial center in the state next to Bangalore. Water quality analysis is one of the most important aspect in groundwater studies. To monitor the water resource and ensure sustainability, National and International criteria and guidelines established for water quality standards are being used. Hence, evaluation of groundwater quantity and quality is important for the development and planning future water resources.

The research studies carried out by early researchers is summarized below. It speaks about the impact of industrial wastewater discharge in various industrial areas.

Pramod Kumar[1] focused on environmental impact assessment of industrial effluent on groundwater. Samples of groundwater and soil were collected in different seasons (pre-monsoon, monsoon and post-monsoon) of Buria nalla. Chloride content was lowest during the monsoon season. Sulphate concentration remained same in all the season. Potassium showed highest concentration in winter. Zinc values range between 0.12-0.49mg/L and was maximum during the pre-monsoon season in all the samples. Author concluded that addition of effluents to the aquatic ecosystem is a worldwide problem and is more acute in industrialized countries where millions tons of pollutants are discharged into ground water.

Hemalatha D S and Dayananda H S[2] reviewed on impact of human activities on river water quality. River pollution has become a natural phenomenon, which has triggered by anthropogenic activities. When wastewater discharged into natural water, its organic matter gets oxidized by dissolved oxygen present in natural waters. The study presented self-purification and Streeter-Phelps model. Authors have studied to develop the Streeter-Phelps equation for DO sag curve and to suggest guidelines for setting up of standards with respect to Kapila river water quality.

Hydro-geochemical studies were carried out in Vishakhapatnam industrial area to assess the ground water quality by Shaik Rameeza et al[3]. It was observed from the study that the concentration of chlorides, suspended solids and hardness exceeded the Standard limit. The study revealed that the water was slightly alkaline (pH: 6.5 – 8.5), moderately hard (Total Hardness: 64 – 292), and TDS values ranged from 380 – 1600 mg/L. As per the analysis report it was observed that, suspended solids exceeded the standard limits (1180 mg/L - 2300 mg/L). Authors concluded that the quality of water in and around the industrial belt reached alarming stage.

Nangare P B et al[4] investigated to assess the quality of groundwater in Ichalkaranji area by extensive survey and laboratory analysis. Three representative areas [Industrial area (IA), Mixed area (MA) and Residential area (RA)] were selected for the collection of water samples. Twenty seven sampling stations were selected. All the parameters except hardness and TDS were within prescribed limits. The industrial polluted zone demarcated on Isoplyth map showed the TDS and hardness values. The various parameters analyzed signifies that an immediate attention should be given to prevent pollution and measures should be adopted before supplied to consumer. The authors concluded textile Industrial waste as main source of groundwater pollution.

## III. ASSESSMENT OF WATER QUALITY

The research studies on impact of industrial effluents on groundwater quality are dealt in the following section.

Total hardness is defined as the sum of calcium and magnesium hardness in mg/L as $CaCO_3$. Research work carried out by Vasanthavigar M et al[5] showed the concentration of total hardness during post monsoon ranged from 50 to 2,159 mg/L and about 64% of the groundwater samples exceed the permissible limit. Total hardness ranged from 112 to 910 mg/L as $CaCO_3$ representing 32% of samples during pre-monsoon. Total hardness were due to weathering of carbonates minerals such as calcium and magnesium. Higher Total hardness were observed during post-monsoon when compared to pre-monsoon due to dissolution of minerals by infiltration into groundwater.

Wagh C H[6] investigated the quality of groundwater in Industrial Estate area of Ichalkaranji. It was found that the area nearer to the Dr. Ambedkar chowk was highly polluted and represented high TDS value and high hardness showing the TDS value having range of 800 – 1200 mg/L which exceeded beyond the limit set by Pollution Control Board (PCB). The major two polluted parameters, i.e. COD and BOD were mostly affected the groundwater quality. Author concluded that the major portion of industrial waste area is demarcated as polluted area and remaining area is also likely to be polluted in future. Hence proper treatment is necessary to the effluents coming from the various textile industries and its disposal to the municipal sewers.

Nitrate is naturally occurring inorganic ions present in the environment. The decomposition of organic materials in soils releases ammonia. This ammonia oxidizes to form nitrate. Wells with high levels of nitrate can contribute to significant exposure. Nitrates can change normal hemoglobin to methemoglobin. Nitrate content was found exceeded the desirable limit in 80% of the groundwater samples analyzed in Kancheepuram by Balakrishnan M et al[7]. Nitrate found to be very high and linked with anthropogenic activities. The user specific water quality indices (USWQI) of each groundwater sample were evaluated. The USWQI of the groundwater samples varied from 85 to 30 for drinking purpose and 89 to 50 for irrigation purpose. The results showed that, the groundwater quality categorized under 'good' for irrigation purpose and 'fair' for drinking purpose.

Yadav R N et al[8] assessed ground water quality of South-West zone of Bhiwadi industrial area (Alwar) Rajasthan. Results revealed that the fluoride concentration for pre-monsoon samples varied from 0.6 to 6.9 mg/L and samples from Public school and Alupur area sample have higher fluoride values than the permissible limits. The fluoride range for the post monsoon samples was found to be 0.9 to 7.3 mg/L and samples from Trade Centre, Alupur, Milkpur Gujar and group Housing have higher fluoride values than the permissible limits.

Sulphate is measured by the nephelometric method in which the concentration of turbidity is measured against known concentration of synthetically prepared sulphate solution. Abhishek Mandloi[9] carried research work on impact of industries on ground water quality by comparison between an industrial (Mandideep) and non-industrial (Hoshangabad) area. The sulphate values in both the area varied from 42 to 99 mg/L and was found within the prescribed limit. On the basis of analysis carried out, it may be stated that the quality of tube well water is inferior as compared to Hand pump and Municipal water. It may be due to impact of industrial and domestic effluents.

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## IV IMPACT OF HEAVY METAL ON GROUNDWATER CONTAMINATION

The impact due to heavy metal discharge is dealt in the following section.

Jeje J O et al[10] study examined the status of heavy metals in wells and boreholes in Ife North Local Government Area of Osun State, Nigeria. The concentrations of chromium were found significantly high (6.5 mg/L). In order to sustain quality status of wells and boreholes in the area, routine monitoring and assessment by sanitary inspection officers was recommended.

Okegye J I et al[11] in Udege Mbeki mining District observed concentrations of Fe, Co, Pb and Cd were above the maximum permissible limit in the groundwater. The pollution level was estimated based on the geoaccumulation index, enrichment factor (EF) and heavy metal pollution index (HPI). Sources of the heavy metals in the waters were mainly anthropogenic.

The effect of effluents from two pharmaceutical industries designated as PC1 and PC2 on the ground water around Ikeja Industrial estate in Lagos was investigated by Babatunde A I[12]. The presence of the drug in groundwater samples signifies possible seepage of pharmaceutical effluents into groundwater. Dissolved heavy metals like Fe, Cr, Zn, Mg, Cu, Pb, Ni and Cd of the effluents and well water were determined using Atomic Absorption Spectrophotometer. High levels of Fe and Cr were observed in both effluents and well water, while the concentrations of the other metals fall within the acceptable limits.

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## V. WATER QUALITY INDEX

The research paper published related to water quality index is dealt in this section.

Water quality Index (WQI) is a dimensionless number that combines multiple water-quality factors into a single number by normalizing values to subjective rating curves. Factors to be included in WQI model could vary depending upon the designated water uses and local preferences. Some of these factors include EC, TDS, DO, pH, BOD, COD, total coliform bacteria, temperature, and nutrients (nitrogen and phosphorus) etc. These parameters occur in different ranges and expressed in different units. The WQI takes the complex scientific information of these variables and synthesizes into a single number. The Water Quality Index (WQI) was calculated using the Weighted Arithmetic Index method. The quality rating scale for each parameter Qi is given by,

Water Quality Index $=\Sigma(Qi)Wi / \Sigma Wi$

An attempt made by Vasanthavigar M et al[13] to understand the hydrogeochemical parameters to develop water quality index in Thirumanimuttar sub-basin. A total of 148 groundwater samples were collected and analyzed for major cations and anions. The domination of cations and anions was in the order of Na>Mg>Ca>K for cations and $Cl>HCO_3>SO_4$ in anions. The overlay of WQI with chloride and EC correspond to the same locations indicating the poor quality of groundwater in the study area.

Analysis on the underground water quality of Greater Noida region carried by Mohd. Saleem et al.[14] Nine physico-chemical parameters such as Calcium, Magnesium, Chloride, Sulphate, Total Hardness, Fluoride, Nitrate, Total Dissolved Solids and Alkalinity of Greater Noida region with the BIS and WHO were analyzed with corresponding weightage factor (Wi), In the study, 90% water samples were found good quality and only 10% water samples falls under moderately poor category. The water quality index ranges from 16 to 65. Authors concluded that there is a need of some treatment before usage and also required to protect that area from contamination.

## VI. STATISTICAL ANALYSIS

Ground water quality index (GWQI) is defined as a technique of rating that provides the composite influence of individual water quality parameters on the overall quality of water for human consumption (Md. Bodrud-Doza[15]) Groundwater samples were collected from 60 preselected sampling points in the Faridpur district of central part of Bangladesh. Based on GWQI, about 47% of the samples (28 location) belong to excellent to good water quality type, whereas 52% (29 location) exhibited very poor to poor water quality for drinking purposes in the study area.

Saadia R. Tariq et a[16] worked on multivariate analysis of trace metal levels in tannery effluents in relation to soil and water, The multivariate statistical analysis of the data based on Principal Component Analysis (PCA) and Cluster Analysis (CA) evidences the contamination of the soil and water by the tannery effluents that are being discharged indiscriminately without any pretreatment. Study concluded that Na, Ca, Mg, K, Fe and Cr were present as major pollutants in the groundwater of Kasur with alarmingly high concentration levels, Strong positive linear correlations were found between Na, Mn, Cr, Fe and Mg.

Multivariate statistical assessment of heavy metal pollution sources of groundwater around a lead and zinc plant was investigated by Abbas Ali Zamani et al[17]. As a case study groundwater contamination in Bonab Industrial Estate (Zanjan-Iran) for iron, cobalt, nickel, copper, zinc, cadmium and lead content was investigated using differential pulse polarography (DPP). Cadmium was detected in 65% of the samples and 17% were polluted by this metal. All samples contained detectable levels of lead and iron with 9% and 13% of the samples higher than maximum contaminant level (MCLs). Nickel was also found in 78% of the samples. Multivariate statistical techniques were applied for interpreting the experimental data and giving a description for the sources. Cluster analysis identified five clusters among the studied heavy metals. Cluster 1 consisted of Pb, Cu, and cluster 3 included Cd, Fe; also each of the elements Zn, Co and Ni was located in groups with single member. The same results were obtained by factor analysis. Statistical investigations revealed that anthropogenic factors and notably lead and zinc plant and pedo-geochemical pollution sources were influencing water quality in the study area.

## VII. MODELS IN ASSESSING VULNERABILITY OF GROUNDWATER

The works related to assessment of vulnerability of groundwater is projected in the following section.

To validate modified DARSTIC and GALDIT models, a comparison study was carried out by Nabila Allouche[18] between nitrate concentration and water resistivity respectively. The study reveals a positive correlations between nitrate concentration and modified DRASTIC index with a Pearson correlation value of 80%. High nitrate values occurred in highly vulnerable zones.

Research work carried out by Murali K et al[19] in Coimbatore South taluk, Tamilnadu to develop an empirical model DRASTIC to identify the vulnerability index owing to groundwater contamination with increasing population, industrialization and agricultural activities. The results revealed that vulnerability index range from 64 to 150 and is classified into three classes i.e., 64-80, 80 to 120 and 120 to 150 corresponding to low, medium and high vulnerability zones respectively. The groundwater vulnerability potential map showed that the majority of the western part and some areas of central region fall under high vulnerability followed by medium vulnerability in the central and eastern regions of the study area.

GIS based DRASTIC model were used to assess intrinsic aquifer vulnerability to pollution and Groundwater Risk Assessment Model (GRAM) to assess the risk of groundwater pollution by Sangam Shrestha et al[20] in basin of Kathmandu Valley. Seven hydrogeological factors were used in DRASTIC model to produce DRASTIC Index (DI) map which represent intrinsic groundwater vulnerability pollution of the area. It was found that more than 50% of the groundwater basin area in the valley is susceptible to groundwater pollution and that areas are mostly in Northern groundwater district. Low and very low vulnerable areas account for only 13% and are located in Central and Southern groundwater districts. Authors concluded source of pollution is wastewater from industries and the hydrogeological properties for that areas does not provide barrier to hazards. More than half of groundwater basin area in the valley is under ‘moderately high’ and ‘high’ vulnerability zones.

## VIII. CONCLUSION

In many parts of India, available groundwater is non-potable due to the presence of impurities and heavy metal in high concentration. Though several steps have been initiated by Government of India, quality of the water resources seems to be far from satisfactory. This is mainly due to lack of coordination between various governing bodies and industries, lack of enforcement, improper operation and maintenance of treatment plants, indiscriminate discharge of untreated wastewater in an unscientific and non-engineered way on land or to nearby water bodies. Hence, the quality of groundwater has shown deterioration in its quality from past few years at several places in India.

Ground water contamination has emerged as one of the Nation's primary environmental concerns. Reliable, rapid, and cost-effective detection and remedial action can contribute to minimize the adverse impacts of groundwater contamination. Continuous groundwater monitoring is required for establishing a planned monitoring network in the study area for regular assessment of the water quality which will be useful in proper management of the groundwater resources. There is need for environmental education, adequate regulations and proper management of industrial wastewater by private and the government agencies. Policies need to be explored and promoted to safeguard groundwater resource for future use. Hence there is urgent need for detail investigation of the groundwater quality in and around Nanjangud industrial area. Evaluation of quality of groundwater due to clustered industrial, agricultural and human activities helps the researchers and environmental regulators to initiate mitigative measures.

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