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Impact of industrial effluents on the ground water contamination around industrial areas of Nanjunagud, Mysore district, India, and an effective strategy to treat using advanced oxidation process

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ABSTRACT: Nanjangud is a fast-growing industrial hub in Mysore district, India, with a huge number of diversified industries. The impact of industrialization has a profound effect on the environmental parameters especially water and soil. A systematic study of the Impact of industrial discharge on ground water contamination around industrial areas of Nanjunagud has been studied in detail with respect to the significant variation in the physico-chemical characteristics of the groundwater from a pure geological and environmental perspective. Both the geology of the area and industrialization have played a vital role in the deterioration of the environmental parameters, especially the groundwater that has become rich in TDS, EC, more acidic, increased total hardness, and so on. The authors have carried out the study related to the understanding of such a deterioration of groundwater quality and an effective treatment of the groundwater by the advanced oxidation process using hydrothermally synthesized zincite nanomineral particles in the presence of sunlight.

I. INTRODUCTION

Water is one of the basic and most valuable natural resources whose physico-chemical characteristics play a vital role in the sustainable development of life on the earth. Due to the fast-growing urbanization and population explosion, particularly in the third world countries, there are several other parameters like soil erosion, industrial pollution, and unhygienic conditions, etc., have a severe impact on the physico-chemical and biological properties of both surface and subsurface waters. The use of chemicals, fertilizers, pesticides, industrial discharges, domestic sewage, etc., disturb the ecosystems leading to the varying degrees of environmental degradation. Normally in pure geological systems, a natural balance is created between the soil and water (both surface and subsurface) and such a system is often disturbed by the anthropogenical activities [1-3]. In the present work, the area of investigation in the past had one of the most congenital ecosystems provided with an excellent soil rich in micronutrients derived from the underlying rocks belonging to the Precambrian era. This led to the growth and cultivation of a very special variety of banana, which is synonym with Nanjangud town's name. Similarly, a good variety of paddy and other fresh vegetables, cereals and so on were grown. The quality of water was equally good, unpolluted, because of the fresh water from river Kapila flowing across this town. However, with the fast industrialization and the establishment of an industrial hub around Nanjangud town leading to the generation of a huge quantity of solid and liquid wastes, sewage, effluents, etc. There is a greater possibility of extensive pollution of both soil and water. The present paper deals with the study of the impact of industrial effluents on water quality and water contamination. Although most of the industries claim to have upto tertiary treatment plants, there is a significant degradation of the water which might be due to discharge of even partially treated effluent water to the open fields. The water contaminated in the ground is almost irreversible, even though the soil and subsurface rocks act as the natural filters in order to retain a large part of colloidal and soluble ions. Similarly, the cationic exchange of ions also contributes to some extent to filter these effluents. But it also depends on the type of industrial discharge and the quantity of the effluent released to the open fields. The earlier workers have studied the impact of industrial discharge on the groundwater contamination from this industrial area especially on the physico-chemical characteristics and statistical analysis of ground water [4-6]. The study area viz. Nanjangud town is located at a distance of 23 Km from Mysore city at an elevation of 656 m with coordinates: 12.12ºN 76.68ºE. In the past two decades, Nanjangud has become an industrial hub with a large number of diversified industries like pharmaceuticals, textile, distilleries, heavy machinery, automobile, rubber / polymer, food, software, crushers, small scale mines, etc. Majority of these industries use extensively organics, dyes, yeast, molasses, chemicals, rubber, plastics, etc., which greatly affect the COD, BOD, TDS, colour, Mg, CO_3, total hardness, heavy metals contamination, and other related physico-chemical characteristics of ground water.

II. MATERIALS AND METHODS

Here the authors have studied the polluted water samples collected have been subjected to photocatalytic or advanced oxidation treatment to purify as an attempt to propose the treatment of the effluents at the industries itself before the discharge into the open fields, and or recycling of this industrial effluent and reuse for gardening, washing, cleaning purpose. The groundwater samples were collected for the study from the places adjacent to some selected pharmaceutical, textile, distillery, and bricks and crusher industry around Nanjangud town, Mysore District, India.

The collection of the ground water sample was carried out by using composite sampling around these four industries within a radius of ½ kilometer during the month February which is relatively a dry month from the bore wells, in 1 liter glass bottles, which were pre-washed with detergent and then with diluted HCl followed by nanopure water (Nanopure water, Elga, Model 2009, UK) with a conductivity of 18.2 $\Omega^{-1}cm^{-1}$. These water samples collected and tested on-site for *pH*, electrical conductivity (EC), total dissolved salts (TDS), total hardness (TH) using portable Elico, Model: Systonic, S-959, India, water analysis kit. Then these water samples were brought to the laboratory in a separate box maintained temperature at 4ºC. Figures 2.1 and 2.2 show the representative sites from where the bore well samples are collected. The bore well water was in some cases collected directly from the outlet as shown in Figure 1, and in some cases from the ground surface, where the bore well water was pumped and let on the ground as in Figure 2.

It is evident from Figures 2.1 and 2.2 that the ground water is highly contaminated due to the discharge from industries onto the open ground, and the color has changed from dark yellowish brown to light yellowish brown. Figure 2.3 shows a schematic representation of the hydrothermal synthesis of zincite nanomineral particles, which were later used in the treatment of this contaminated ground water. The hydrothermal synthesis of zincite nanomineral particles was carried out using General Purpose Autoclaves made up of SS316 stainless steel, provided with a Teflon liner of 30 ml capacity [7]. The water samples were subjected to other tests like *pH*, concentration of Na, K, Ca, Mg, CO_3, HCO_3, NO_3, Cl, and SO_4, COD, BOD, and estimation of heavy metals like Fe, Ni, Cd, Pb. Also, groundwater samples from locations adjacent to the four industries have been subjected to advanced oxidation treatment using the hydrothermally synthesized zincite nanominerals particles.

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Figure 2.1. Ground water collected from the bore well adjacent to one of the industries

Figure 2.2. Water sample adjacent to one of the industries

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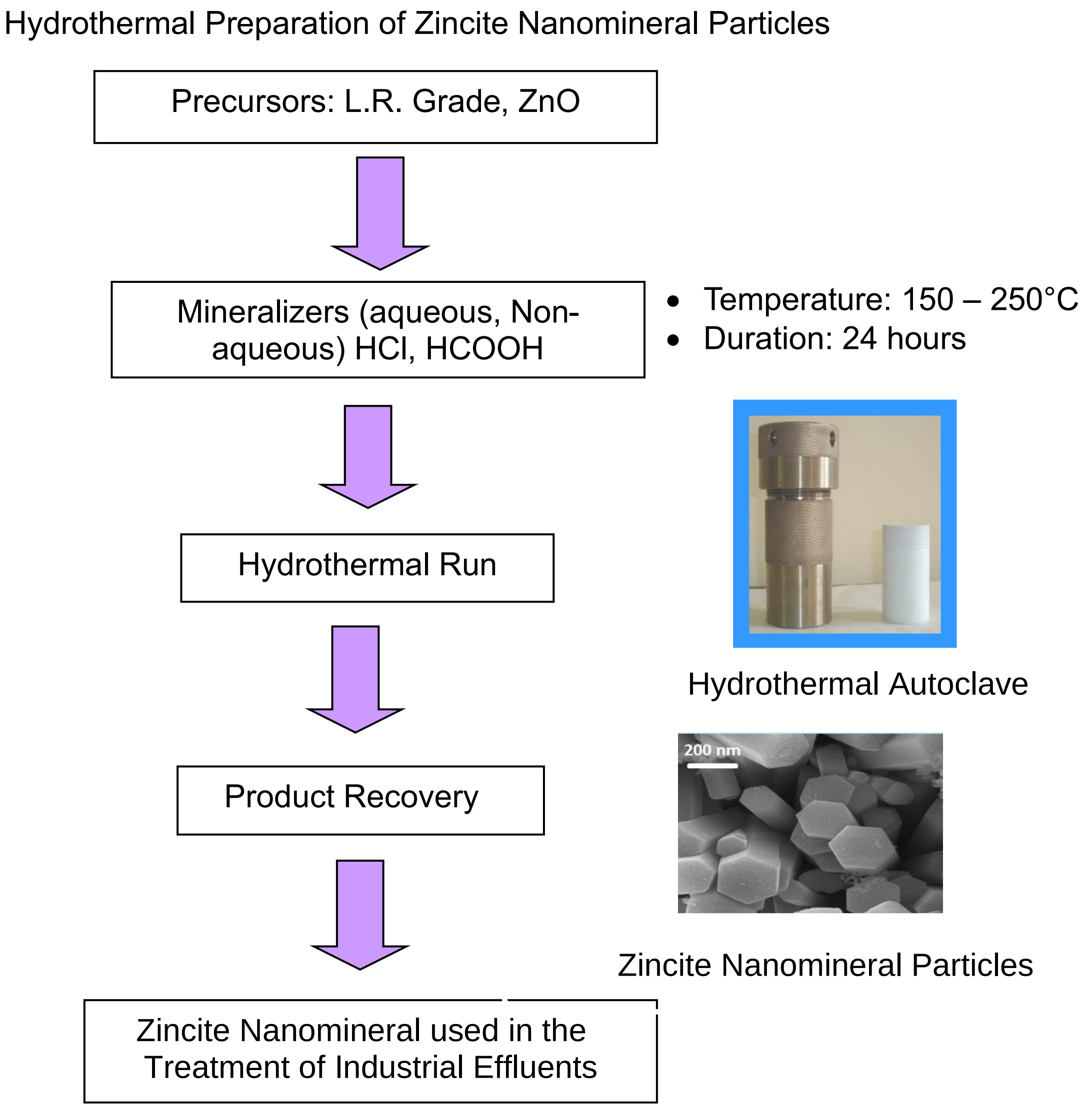

Figure 2.3. Schematic diagram of the hydrothermal synthesis of zincite nanomineral particles [7]

III. RESULTS AND DISCUSSION

The present authors discuss here the work carried out in two parts:

i) Analysis of groundwater collected from bore wells adjacent to the industries.

ii) Sunlight assisted advanced oxidation process employed to treat the contaminated groundwater samples using the hydrothermally synthesized zincite nanomineral particles.

pH was measured on-site itself and also this value was compared with the values measured in the laboratory for the same water samples. The values did not differ. The *pH* values of waters collected from four bore wells BW1, BW2, BW3, BW4, showed slightly acidic *pH* (Figure 3.1). The values range from 6.2 to 7.2. However, the water was odourless and color was slightly turbid.

Similarly, the electrical conductivity was measured to check the concentration of soluble ions, and the electrical conductivity values range from 700-2010 mOhm/cm (Figure 3.2). The electrical conductivity is a measure of the alkali ions present and their concentration directly influences the electrical conductivity values. These higher values are due to

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the direct contamination of partially treated effluent discharged into the open ground and in turn the contamination with the ground water. The Total dissolved salts (TDS) estimate for ground water samples showed higher values ranging from 1506 to 3217 mg/L which is not suitable for the drinking purpose and also total hardness value range from 63 to 170 mg/L (Figure 3.3). This is due to higher concentration of Ca and Mg in particular even for the domestic purpose such high concentration of Ca and Mg cannot be considered as suitable as it gives scaling the water pipelines, tapes, and other plumbing commodities. The standard volumetric method was employed to determine the concentration of Ca and Mg [8]. Besides, it also leads to health hazards like kidney stone formation, hair fall and also some dermatological problems. Estimation of heavy metals has been carried out using AAS technique which showed the presence of Fe, Cd, Pb, Ni, although the industries range from pharmaceutical, textiles, distillery, and bricks and crusher industries, the concentration of heavy metal can be considered as topic of discussion as an interest from geological perspective. The industrial discharge rich inorganics, carbonates, chlorides, and nitrides, interacts with the underlying Precambrian rocks and remove these heavy metals form the rocks due to water-rocks interaction. These Precambrian rocks belong to the Sargur high-grade terrain essentially made up of amphibolites, quartzites and a wide range of manganiferous calc-silicates. The geological studies on this area have been carried out in detail and described hornblende-granulites, garnet pyroxenes, fuchsite quartzite and calc-silicate rocks and correlated this geological sequence with charnockite series. The terrain has a rich assemblage of rare carbonate silicate minerals, feldspathoids and banded iron ore formation, particularly banded hematite quartzites, which have gone subsequent weathering and erosion [9-11]. Such a rich mineral assemblage has made the soil of this region highly fertile. Table 3.1 shows the analytical data obtained for these groundwater samples collected from four different bore wells located adjacent in the Nanjangud industrial area. The chemical oxygen demand (COD) analysis was carried out to measure the organic strength of these ground water samples collected from four ground wells. The dichromate reflux method has been used to estimate the COD. The COD of raw samples range from 2180-2427 with an average of 2300-2358 mg/L (Figure 3.5). This value of COD is very high and it indicates the industrial discharge has percolated in the ground and contaminated the groundwater. The nitride concentration is also above the permissible limit. The groundwater samples collected from the four bore wells adjacent to the four industries selected have been subjected to Advanced Oxidation Process (AOP) treatment and the COD parameters before and after AOP for these four groundwater samples, using hydrothermally synthesized zincite nanoparticles taken in different concentrations in the presence of sunlight. Depending on the concentration of the contaminated groundwater and the time of exposure to sunlight, it was found that zincite nanoparticles effectively improves the physico-chemical characteristics of water. Table 3.2 shows the COD values of four bore well water samples before and after AOP studies carried out using the zincite nanomineral particles in different concentration in the presence of natural sunlight.

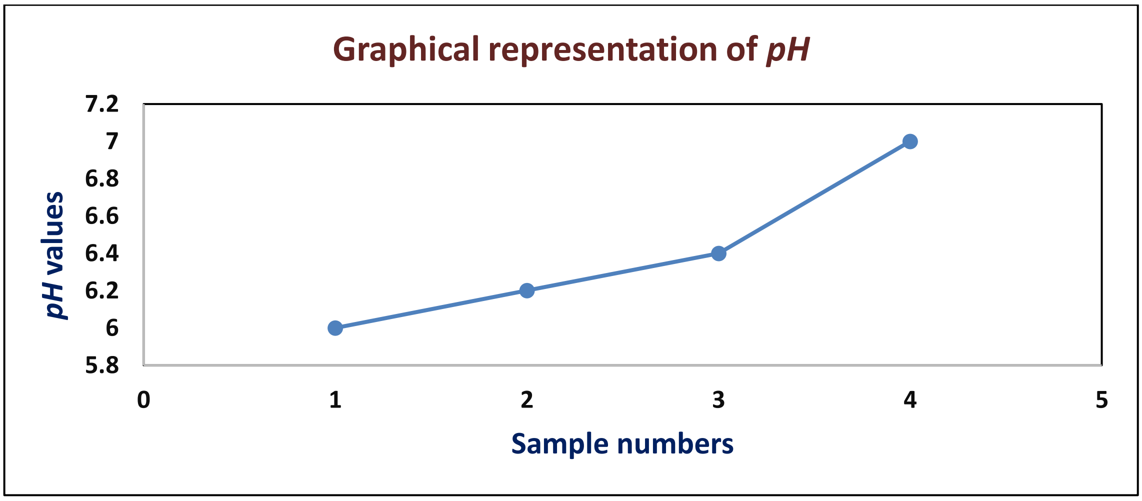

Figure 3.1. *pH* of groundwater samples collected from four bore wells

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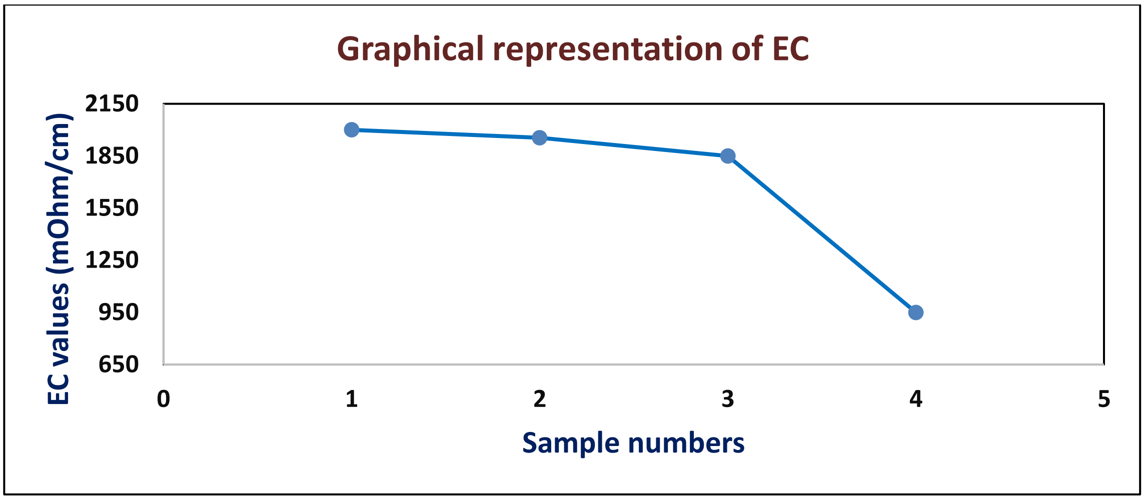

Figure 3.2. Electrical conductivity groundwater samples collected from bore wells

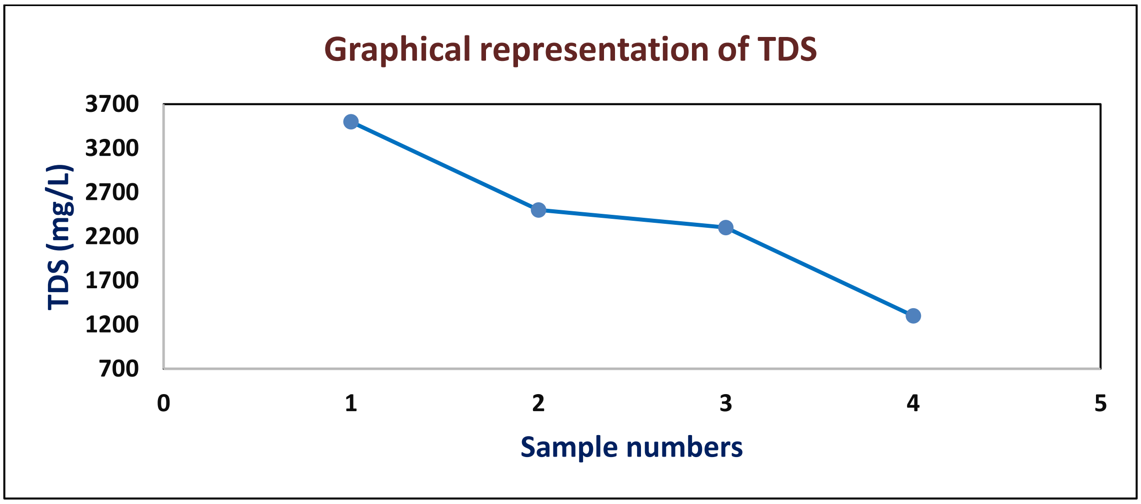

Figure 3.3. Total dissolved salts (TDS) concentration in groundwater samples

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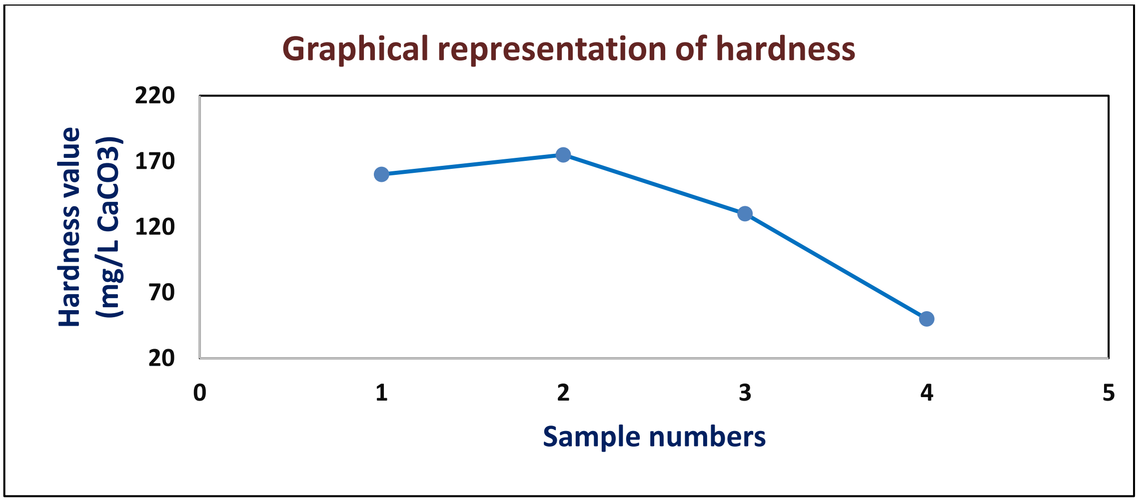

Figure 3.4. Total hardness values for groundwater samples

Table 3.1. Physico-chemical characteristics of groundwater samples

Physico-chemical characteristics	BW1	BW2	BW3	BW4
Color	Golden yellow	Light Golden yellow	Golden yellow	Golden yellow
Odour	Odorless	Odorless	Odorless	Odorless
pH	6.1	6.31	6.48	7.8
EC mOhm/cm	>2091	>1921	1807	1089
TDS mg/L	3217	2319	2429	1506
Ca mg/L	118	114	98	56
Mg mg/L	105	114.3	99.7	39.1
Hardness ($CaCO_3$) mg/L	160.53	169.46	132.13	63.19
HCO^-_3 mg/L	890	807	824	552
Chloride mg/L	639	761	638	187
COD mg/L	2248	2359	2314	2378
Nitrate, NO_3, mg/L	13	58	37	54
Fe mg/L	0.71	0.232	0.021	0.02
Pb mg/L	9.49	11.15	10.41	12.05
Mn mg/L	5.134	6.923	0.414	0.04

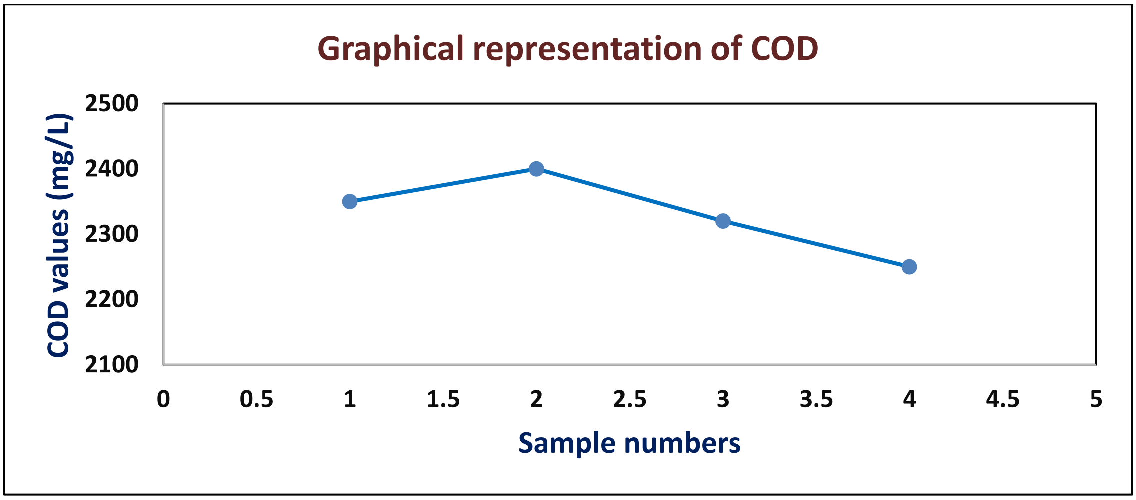

Figure 3.5. COD data of raw groundwater samples from four bore wells.

Table 3.2. Characteristic data of Advanced Oxidation Process

Groundwater Sample	Initial COD mg/L	Exposure Time (mins)	Final COD mg/L
BW1	2390	120	214
BW1	2390	150	190
BW2	2219	120	230
BW2	2219	150	193
BW3	2206	120	250
BW3	2206	150	210
BW4	2314	120	224
BW4	2314	150	192

IV. CONCLUSION

The present study clearly shows that the groundwater from the adjacent areas of the Nanjangud industrial hub has slowly deteriorated in terms of its physico-chemical characteristics, especially with respect to the higher concentration of TDS, total hardness, nitrate, sulphate, lower *pH*, turbidity, higher COD, etc. Although, the subsurface geology of the terrain is highly suitable for the pure and mineral rich soil and ground water, the organics from the discharged waste water has caused the rock – water interaction leading to the contamination of the ground water. The proposed advanced oxidation process for the treatment of contaminated or poor quality groundwater using the hydrothermally synthesized zincite nanomineral particles in the presence of sunlight has been proved highly effective. Such studies have greater prospective in the near future.

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Dr. Namratha.K, Secured First Rank, Distinction, won FIVE Gold Medals and One Cash Prize in the Master's Degree in Geology during 2007-2009 from the University of Mysore, India. She obtained her Ph.D. from the University of Mysore, and worked as a Research Associate for 5 years and currently working as a Guest Faculty at Department of Studies in Earth Science from September 2019 till date. She has 12 years research experience in the field of Nanogeoscience, Experimental Mineralogy and Environmental Geology, Carrying out collaborative research with other reputed researchers within India and abroad. Dr. Namratha has widely travelled and presented Research papers in several international conferences held in USA, Australia, Spain, China, Taiwan, Hong Kong, Colombia, Mexico, Singapore, Thailand, Malaysia, South Africa, and France. Dr. Namratha has published over **87** research papers in well reputed peer-reviewed International Journals with high impact factors and has 1400 citations to her credit and an h-Index of 22.

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Prof. K. Byrappa, is a Senior Professor and the former Vice Chancellor of Mangalore University, Karnataka. Currently he is the Pro-Vice Chancellor & Dean Research, Adichunchanagiri University, Karnataka. He is specialized in Materials Science, Nanotechnology, Experimental Mineralogy, Environmental Science and Engineering, Nanobiotechnology, Crystal Engineering and Chemistry of Materials. For his outstanding contribution to the field of **Materials Science**, especially on Hydrothermal Processing of Advanced Functional Materials, Prof. Byrappa has been now recognized as one of the **Top 2% Scientists in the World** as per the recent survey conducted by the prestigious **Stanford University, USA,** and also **listed as top 2% currently active researchers in the world as per the Eslevier Publishers Survey.** One of his papers published in Elsevier, UK, International Journal has received Excellent Article 2020 Award. A renowned academician and researcher Prof. Byrappa has over 500 research publications (with 34 Book Chapters & Reviews) in peer reviewed International journals with over 10300 citations and is known as a World Authority in Hydrothermal Technology, with 4 patents filed, and one more international patent is in the process of filing. He has edited 10 Books and authored a famous ***Handbook of Hydrothermal Technology***, published by Elsevier Publishers, UK in **Two Editions, and Third Edition is in preparation**. Prof. Byrappa has received several national and international awards like Sir CV Raman Birth Centenary Award from the Prime Minister of India, during 2017, Lifetime Achievement Award from the International Solvothermal and Hydrothermal Association, Japan recently, and many more. He is the fellow of many Indian and Foreign academia in recognition of his contribution to science.

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