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Impact of industrialization on physico-chemical characteristics of soil around Nanjangud, Karnataka, India and perspective strategies for enhancing the soil fertility

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ABSTRACT: Nanjangud, Karnataka state, India, is an important town both from geological and environmental aspects. It has become one of the fast-emerging industrial hubs in Karnataka state facilitating the existence and emergence of highly diversified industries. The impact of industrialization on the soil has a great significance for the human activity as the physico-chemical characteristics of the soil have been completely altered, which has a direct bearing on the soil fertility. In the present work, the authors have studied the physico-chemical characteristics of soil in detail using different analytical tools. It was well-known in the past that the soil mineralogy derived from the parent rocks, the abundant water availability from the Kabini river flowing across and the sediment accumulation from the action of Kabini river had made the soil in this region highly fertile. The impact of industrialization in this area on the soil physico-chemical characteristics and fertility has been studied in detail and proposed the strategies for enhancing the soil fertility in this work.

I. INTRODUCTION

Soil is one of the abiotic factors along with water, it supports many forms of the life on earth and is also a dynamic natural body resulted from the pedogenic processes giving definite, physico-chemical, mineralogical, and biological properties. Owing to rapid urbanization, industrialization and population explosion, leading to soil degradation, soil erosion, soil pollution, and unhygienic conditions, which have an adverse impact on soils productivity, nutrient status, soil organic matter, soil fertility, toxicity, etc. Pollutants from various sources linked with anthropogenic activities could contaminate the soil, domestic sewage, pesticides, fertilizers, discharge of effluents, likely to imbalance the ecosystems in particular soil. Over 7.5 m ha arable lands globally turn into degraded lands due to deforestation, and associated climate change. It is to be noted that India has about 329 m ha total geographical area and out of which 179.9 m ha of TGA is considered as degraded which has a direct impact on the agricultural productivity. Similarly, it is estimated that more than 5000 tons of top soil is eroded annually [1-3]. Generally soil from an urbanized area will have major physico-chemical differences in comparison with a soil from natural ecosystems. Therefore, the study of the physico-chemical characteristics of soil is very important for pedology and human health [4-5]. India has vivid diversity of landforms, landscapes, geological formations and rich natural resources, right from Kanyakumari to Kashmir. Even Karnataka state, has a rich diversity and equally fertile soils [6].

Normally diversity in soils differs due to variations in physical, morphological, chemical and biological characteristics, which in turn varies with the parent rock material, organic constituents and human activities. Further the major, minor and trace elements present in the soil also contribute to the quality of the soil in particular fertility. Today the

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occurrence of a virgin soil is almost a rarity due to the impact of urbanization and the addition of inorganic, organic fertilizers, which greatly contribute to the concentration of heavy metals in the soil [7]. The present authors have selected very important and equally fertile land near Mysore, and in particular the industrial areas of Nanjangud. The study area is about 23 kms from Mysore city at an elevation of 656 m with coordinates: 12.12^{o}N 76.68^{o}E. Nanjangud is witnessing a rapid industrialization especially from the past 30 years that has led to the major impact on the soil fertility. There are several major and minor industries like pharmaceutical, textile, distilleries, heavy machinery, automobile, rubber/polymer, food software, crushers, small scale mines, etc. have greatly altered the physico-chemical characteristics of soil including its *pH*, organic carbon, total cationic and anionic content, total nitrogen and phosphorous, soil moisture, water holding capacity, porosity, permeability, major, minor elements, electrical conductivity and so on [8]. Nanjangud is made up of oldest rocks of Karnataka carton, representing the ancient supracrustals belonging to the Sargur supergroup with a wide spectrum of lithology showing an age of 3.2 Ga [9-11]. Besides, the river Kabini and its tributaries running almost at right angles to the NS trend to the Sargur supracrustals has eroded and deposited sediments whose major, minor and trace elements load serve as the additional contributors besides the anthropogenic inputs in altering the soil quality [12,13]. Sargur high grade terrain essentially made up of amphibolites, quartzites and a wide range of manganiferous calc-silicates, hornblende granulites, garnet pyroxenes, fuchsite quartzite and calc- silicate rocks correlated this geological sequence with charnockite series [14,15]. In course of time, these rocks have undergone extensive weathering and erosion. The area under investigation has red to brownish soil, which is rich in quartz, feldspar, hematite, and biotite as major components followed by various other mafic and calc-silicate minerals. Such a rich mineral assemblage has made this soil highly fertile. The present authors have chosen particular regions in this area with extensive industrial activities, which in turn have degraded the soil characteristics significantly and also reduced the fertility of the soil. The areas chosen are located at a radius of 7 kms from Nanjangud town covering an area of over 2000 acres. The present authors have carried out these systematic studies within an area of about 9 acres from each industrial estate areas, and collected the soil samples from depths up to 5 feet to investigate the soil parameters like *pH*, porosity, electrical conductivity and estimation of important components like N, P, K, Ca, Mg, and organic carbon. Such an investigation will yield highly useful information related to soil degradation process and also the possible reasons for such a rapid degradation process or chemical activity due to the effluent action. About 1/4th of the Nanjangud is of hilly region and remaining part is a plain land covered by Kabini river - a tributary of river Cauvery. In fact, the Kabini river is a major source of water for domestic, industrial, agricultural and other purposes. The major crops produced in this area are paddy, ragi, jowar, ground nut, cotton, sugarcane, tur and bajra.

Increased industrial activity, and demographic explosion resulting in the environmental pollution with domestic and municipal waste water and agricultural runoff inputs into Kabini river has in turn disturbed the equilibrium of its ecosystems, besides seriously affecting environmental components such as air, water, land, flora and fauna, human settlements and health of people. The industrial effluents discharge has increased the threat of sediment accumulation and resulting in the environmental pollution. Furthermore, pollution of sediments is a serious problem that effects the environment in several ways resulting hazards to plants and animals in and around water ways.

Kabini river is a good example of a site where contributions of pollutants from natural (lithogenic) source and anthropogenic activity and contribute pollutants two or three-fold over the normal values, because, it is bordered by numerous industries which discharge a large quantity of effluents into it. The present paper deals with a systematic study of the physico-chemical characteristics of soil from the industrial areas of Nanjangud, as the soil is degraded and it has an impact on the top soil particularly leading to low and unstable crop yields and in some places totally no crops. Although the net irrigated land area in India has increased from about 22 M ha in 1950 to more than 51 M ha at present, the rapid urbanization has a major impact on the soil characteristics. Urbanization and industrialization along with the agricultural activities play a predominant role in the economy of any nation. Hence the soil erosion and degradation have become an integral part of urbanization and industrialization. However, it is very essential to periodically evaluate and monitor precisely the magnitude of soil degradation and its impact on the environment. Also, it is necessary to study the strategies to enhance the soil fertility and quality through modern methods like soil decontamination, removing the top layer of soil and using several soil catalysts and adsorbents, the addition of phosphatic clay and other remedial measures to enhance the quality of soil.

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II. MATERIALS AND METHODS

About 20 soil samples were collected from a depth of 30 cms by cone and quarter method in the two industrial areas of Nanjangud taluk (Figure 1) [16].

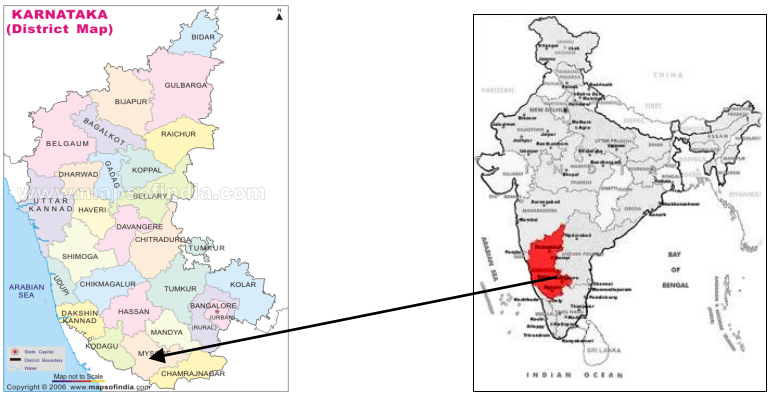

Fig.1 Map of Karnataka State showing the location of Nanjangud town [16].

Nearly 2 Kg of soil was packed separately in a polythene bag and transported to the laboratory for a systematic analysis of all the soil parameters. The samples were subjected to various analyses using analytical instruments and the details are given in Table 1.

Table 1. Techniques used in the analysis of soil from the Industrial areas of Nanjangud, Karnataka

Characterization Techniques	Method Employed	Instrument Used
Particle Size Analysis		Sieves and Hygrometer
Mineralogy	XRD	Powder X-ray diffractometer (Rigaku Corporation - Japan) MODEL-Smart Lab 3Kw
Major and Minor elements	XRF	M/s Philips, The Netherlands, Model No. PW 2400
Major Functional Groups	FTIR	Shimazdu, Japan
pH	*pH* Meter (Soil: Water)	Elico, pH LI 617
Electrical Conductivity	Conductivity meter (Soil: Water)	Elico Kit, Model Systonic, S-959, India
CEC	Sodium saturation method	Systronics, Model 1027, India
Percent Organic matter	Walkley- Black's wet oxidation method	
Total Nitrogen	By calculation	
Available phosphorous	Olsen's method	Systronics Spectrophotometer-104, India
DTPA Extracted heavy metals Fe	ICP Labtam Australia,	Thermo Scientific Model, iCAP 7600 ICP- OES, USA
DTPA Extracted heavy metals Cu	ICP Labtam Australia,	Thermo Scientific Model, iCAP 7600 ICP- OES, USA
DTPA Extracted heavy metals Zn	ICP Labtam Australia,	Thermo Scientific Model, iCAP 7600 ICP- OES, USA
DTPA Extracted heavy metals Pb	ICP Labtam Australia,	Thermo Scientific Model, iCAP 7600 ICP- OES, USA
DTPA Extracted heavy metals	ICP Labtam Australia,	Thermo Scientific Model, iCAP 7600 ICP- OES,

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Mn		USA
Sodium	Flame Photometer	Systronics, Model 1027, India
Potassium	Flame Photometer	Systronics, Model 1027, India

Figs. 2.a,b show the agricultural land areas in and around Nanjangud, and these photographs show the land areas, which were known for the cultivation of special variety of banana known as Rasthali Nanjangud rasabale. Today the soil is completely contaminated and has no fertility and become a barren land today.

a)  b) 

Fig. 2.a,b: Barren land with contaminated soil from two different industrial estates areas of Nanjangud.

The powder X-ray diffraction studies revealed the mineralogy of soil, FTIR spectroscopy gave information on the major functional groups available in the soil samples collected, and DTPA (diethylenetriaminepentaacetic acid) extractable heavy metals analysis of the soil samples yielded rich information on various major, minor and heavy elements present in the soil which indicate the soil quality and degradation. The DTPA (diethylenetriaminepentaacetic acid) micronutrient extraction technique is a non-equilibrium extraction method for estimating the potential availability of Zn, Mn, Fe, and Cu with greater efficiency in the soil. Also, it has been tested for heavy metals like Pb, Ni, Cd, etc.

III. RESULTS AND DISCUSSION

As mentioned earlier there are two major industrial estates in Nanjangud area: Nanjangud and Thandya industrial areas spreading to about more than 1000 acres having all major, medium, and small-scale industries of diversified categories causing pollution in all three components of the environment. Four representative soil samples collected from both industrial estates have been subjected to powder X-ray diffraction study. The X-ray patterns were recorded between 10 and 80^o, 2θ with a scanning speed of 1^o per minute and a step size of 0.01^o/sec. The powder X-ray diffraction patterns of four representative soil samples are shown in Fig.3.1.

The commonly occurring minerals in this industrial area are quartz, biotite, hornblende, chlorite, hematite and and a host of clay group of minerals like kaolinite, gypsite, montmorillonite, etc. The mineral assemblages correspond to the primary rocks of the area. Although there is a presence of carbonates in the soil, the minerals have got decomposed without leaving the trace of carbonate mineral assemblage. Figs.3.2a,b show the FTIR spectra for the two representative samples from each industrial estate. The functional groups appearing in the spectra are mainly OH, CO, Mo, and SiO, for both samples. The FTIR studies clearly indicate the degradation of the parent soil.

The present authors have studied soil characteristics of samples collected from both industrial areas and measured *pH*, electrical conductivity cation exchange capacity, and also the % total organic matter and % of total nitrogen. Using the spectrophotometric techniques, the availability of P, K, Na, has been measured. Similarly, using DPTA extraction method, the heavy metal concentration has been evaluated. The *pH* values vary from 5.28 to 7.25 and electrical

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conductivity ranges from 0.1 to 0.5 mmohs/cm. Table 2 shows the physico-chemical characteristics determined using various analytical techniques in the present work from the soil samples collected from Nanjangud industrial areas.

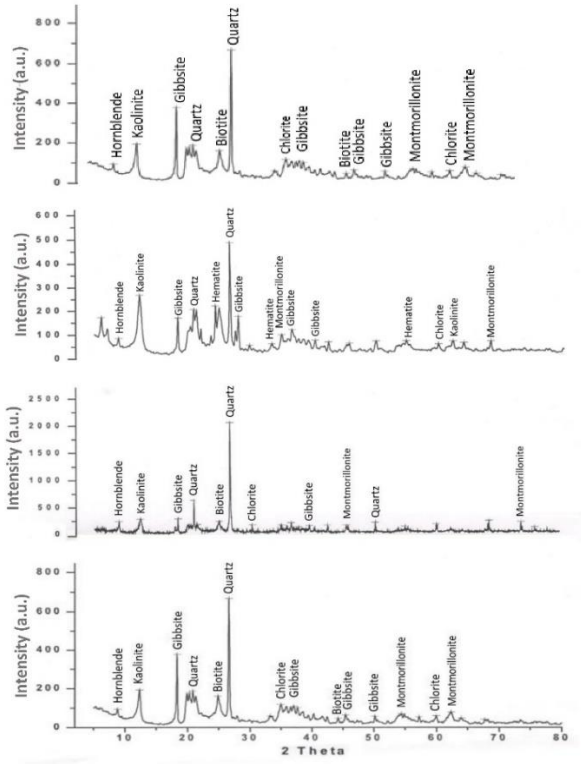

Fig. 3.1. Powder X-ray diffraction patterns for four representative samples from industrial areas of Nanjangud, Karnataka.

The DPTA extraction method for the heavy metals like Cu, Zn, Pb, Fe, Mn, Cd, Ni, has shown that the soil not only contains these elements derived from the ultramafic rocks and minerals belonging to rocks from Sargur supracrustal group, but also from the industrial effluents, organic chemicals, petrochemicals, alkali, chlorine, fertilizers, electroplating, cement, asbestos, textile, milk products, leather tanning, etc. These results match well with the earlier published works [17-20].

The Cr concentration in the study area varies from 128.36 mg/g to 489.35mg/g. Whereas Fe ranges from 1342.81 mg/g to 1947.65 mg/g, where Cu varies from 42.41 mg/g to 182.35mg/g. The concentration of Mn Nanjangud soil areas ranges from 258.89 mg/g to 511.73 mg/g. The concentration of Ni varies from 29.4 mg/g to 297.23 mg/g. The concentration of Zn which is an important micronutrient in the soil ranges from 16.57 mg/g to 197.84 mg/g and lastly the concentration of Pb which has a serious impact on the soil ranges from 39.47 mg/g to 1527.44 mg/g.

The above studies confirm the contamination of soil due to the industrialization and improper disposal of the waste from various industries and agricultural activities in and around Nanjangud area. The trace metals, heavy metals and

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the organics used in the fertilizers can find a comfortable storage in the soil. Over a period of time, such a contamination of soil makes the soil infertile with least humic acids, and totally degraded due to the enrichment of heavy metals in the soil [21,22]. The authors [21] have studied this in detail taking the example of paddy crops and Rasthali Nanjangud Rasabale.

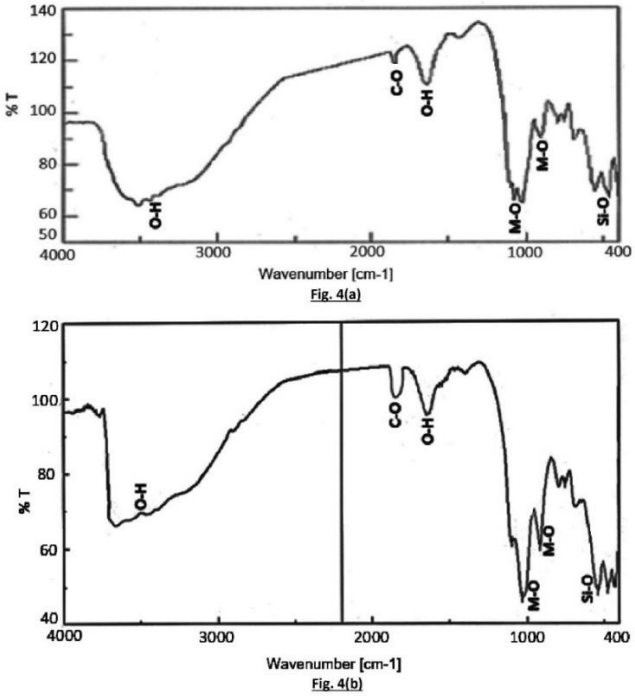

Fig.3.2a,b. FTIR spectrum of representative sample of soil from Thandya industrial area (a); FTIR spectrum of representative sample of soil from Nanjangud industrial area.

Table 2: Physico-chemical characteristics of soil from the industrial areas of Nanjangud, Karnataka

Sl.No	*pH*	EC (mmoh/cm)	CEC (me/100g)	Organic matter (%)	Total N	P (Available) (Kg/ha)	K (Available) (Kg/ha)
1	5.28	0.02	16.24	1.81	0.05	54.25	100.17
2	5.26	0.01	18.12	1.99	0.06	55.02	102.12
3	5.45	0.02	17.41	2.41	0.07	56.01	112.14
4	5.75	0.01	18.22	2.56	0.11	57.05	115.16
5	5.95	0.02	19.01	2.75	0.13	58.08	117.01
6	6.02	0.03	19.76	2.90	0.16	59.07	119.04
7	6.05	0.04	20.05	2.77	0.17	60.03	120.05
8	6.07	0.05	21.06	2.95	0.18	61.05	180.75
9	6.78	0.04	23.08	3.05	0.14	70.06	220.05
10	7.01	0.03	24.01	3.01	0.12	73.98	235.06
11	7.10	0.02	22.06	2.97	0.11	77.85	255.98
12	6.43	0.01	15.78	2.44	0.16	87.09	305.98

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13	5.87	0.02	16.78	2.89	0.14	93.06	315.98
14	5.26	0.01	19.84	3.56	0.18	112.98	345.98
15	6.67	0.02	22.43	2.88	0.12	82.08	326.89
16	7.51	0.04	17.98	3.55	0.17	85.98	313.65
17	7.34	0.03	25.98	2.11	0.14	92.78	288.90
18	6.98	0.02	17.98	3.87	0.11	94.89	299.67
19	5.08	0.01	14.87	2.77	0.18	117.89	145.98
20	7.48	0.04	18.91	2.01	0.15	121.90	188.09

The present authors have discussed various strategies adapted worldwide and proposed a possible mechanism to decontaminate the polluted soil. The decontamination of soil is not a new theory as it is in practice from the past 3 decades. However, an impetus for such decontamination studies on various soils across the globe began with the soil decontamination process during 2013 following a major earthquake followed by a Tsuanami, which destroyed Fukushima, Daichi nuclear power plant in the Tohoku region of Japan 2011. The soil decontamination activities are mainly targeted towards agricultural landscapes and some residential areas. In fact more than 26 countries have taken up the soil decontamination process and many more countries including India, are now preparing an inventory which will be managed at regional and national levels. Usually the soils get contaminated with hydrocarbons, solvents, pesticides, herbicides, wood preservatives, like TNT, etc. There are 3 soil remediation and decontamination process involved: physical decontamination, Bioremediation, and humic acid based products. The physical decontamination is carried out popularly using techniques soil washing, and soil extraction, done exsitu. However, such strategies are more expensive and also not effective for DNAPLs (Dense non aqueous-phase liquids) like petroleum residues. On the other hand bioremediation is a very lengthy process and difficult to monitor control, also this route shows inconsistency associated with toxicity, biodegradability. The bioremediation involves the use of living microorganisms like bacteria and fungi to break down organic pollutants in the soil. In contrary to the above methods, the humic acids-based products are highly suited. Since humic acid are nontoxic and biodegradable. These humic acids are low oxygen demand and have an excellent fixation and adsorption properties for xenobiotics soil. In fact, some countries adopt thermal desorption process, which is very effective for hydrocarbon contamination [23].

The European countries are making a good process on in tackling contamination where as Japan is still grappling with environmental impact of Fukushima even after decade to get rid of radioactive cesium contamination in and around Fukushima much of the topsoil has been removed and decontaminated the soil by adapting various strategies even with type of crops also matters with reference to the pollution has some plants and crops have an affinity to particular group of elements for ex: Mushroom. The other strategies are to add zeolites and related materials to improve the fertility through cation exchange property and captures undesired elements in the contaminated soil [24,25].

India has taken up the soil decontamination ignition through Indo-European, partnership which provides the innovative technology for better farming and market access, Algaenergy, a Spanish based company joins Krushi Rasayan Exports of India to develop biostimulants in order to boost soil health using microalgae, which increases the crop yields ten times and improve the quality of crops and reduces the use of chemicals, and fertilizers in farming. Similar partnership exists between United Kingdom, biotechnology and biological sciences research council with Thailand, National Sciences Research Council with Thailand, National Science Technology to boost rice crop production. The use of Burkholdria ambifaria bacteria has a capability to serve as bio-pesticides against crop infestation. Hence, there is an urgent need to decontaminate the soil in and around industrial area in Nanjangud to rejuvenate the soil fertility and reintroduction of the special variety of Rasthalli Banana crop.

IV. CONCLUSION

The study of physico-chemical characteristics of soil from the two industrial estates of Nanjangud town, Karnataka state, India, has yielded very interesting results depicting the contamination of the soil due to the industrialization. The cation exchange property, electrical conductivity, *pH*, presence of heavy and trace metals, percent organic matter, total nitrogen and available Na, K, P, have been completely altered from that of the virgin soil derived from the parent rocks belonging to Sargur supracrustals and ultra-mafic rocks of charnockite series. The soil was once known for special

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variety of crops and today the top soil is contaminated and totally infertile. The presence of various heavy and trace metals along with the physico-chemical characteristics of the soil cries for an urgent attention and to initiate the necessary actions to decontaminate the soil which has become a most popular program world-wide in recent years. Such an initiation would bring remedial measures and enhance the soil fertility, which would boost the farming sector.

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Dr. Namratha. K, Secured First Rank, Distinction, Won **FIVE Gold Medals and One Cash Prize** in the Master's Course during 2007-2009, from the University of Mysore, India. Working as Guest Faculty at DOS in Earth Science from September 2019 to till date. Teaching experience in Indian Stratigraphy, Marine Geoscience, Environmental Geology, Fuel resources and Sequence Stratigraphy, Analytical Techniques in Geology. She has13 years Research experience in the fields of Mineralogy, Experimental Mineralogy, Nanogeoscience, Environmental Science, research experience in treating industrial effluents and photocatalytic applications. She has Carrying out collaborative research with other reputed researchers within India and abroad. India. Dr. Namratha widely travelled and presented Research papers at USA, Australia, Spain, China, Taiwan, Hong Kong, Columbia, Mexico, Singapore, Thailand, Malaysia, South Africa, and France. Dr. Namratha has published 88 Research papers in well reputed Peer-reviewed International Journals with high impact factors and has **1405** citations and an h-Index of **23**. Dr. Namratha has **4** International patents filed.

Dr.M.B. Nayan is currently working as a Guest Faculty at M.Tech in Materials Science, Vijnan Bhavan, University of Mysore, Mysore. Nayan did his B.Sc., and M.Sc., from the Univ. of Mysore (2012) with First Class and Distinction and obtained his Ph.D., (Environmental Science, Nanotechnology, & Materials Science) from the Univ. of Mysore (2019). Dr. Nayan has spent one semester as a Ph.D. Research Fellow at the Dept. of Public Health, Florida International University, Miami, USA., and he was selected to participate in the Asian Winter School held in Japan, during March 2010 from among 150 applicants. He has received the Best Poster Award in the International Solvothermal and Hydrothermal Association (ISHA-2010) Conference held in Beijing, China, during 27-29 July, 2010. He underwent Research Training in the Institute of Mechanics, Chinese Academy of Sciences, Beijing, China, for TWO Weeks, in August 2010. Dr. Nayan has published 18 research papers in well reputed Peer Reviewed International Journals.

Prof. K. Byrappa, spent about 31 years at the University of Mysore in different capacities before becoming the Vice Chancellor of Mangalore University, Karnataka during June 2014 to June 2018. Currently from July 2018, he is the Pro-Vice Chancellor & Dean Research of Adichunchanagiri University. He is specialized in Earth Science, Materials Science, Nanotechnology, Nanobiotechnology, Crystal Growth, Crystal Structures, Crystal Engineering and Chemistry of Materials, and Environmental Engineering. For his outstanding contribution to the field of **Materials Science**, especially on Hydrothermal Processing of Advanced Functional

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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.** 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 **10500 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. Basavarajappa.H.T, has about **36** years of Teaching and Research experience in DOS in Earth Science. Prof. Basavarajappa. H.T. got in PG, Distinction and II Rank. University of Mysore, Department of Studies in Geology. Recipient of Gold medals and Cash awards. PG. Prof. H.T.Basavarajappa has specialized in Field Geology, Field mapping, Geochemical -analytical Studies, Fluid inclusion Studies, Rocks, Mineral, Gems, Ornamental stones and Decorative stones Prospecting identification Chemistry, analyses, Land scape designing, Maintenance of rock gardens, Applications of Geoinformatics and Remote Sensing, Geomorphological, Slope, Soil, Earth Quakes, Shear Zones, Structural Geotechnical , Rock stability, Hydrological, Urban Planning, Environmental Issues, Lithological classifications, advising in Advanced Education System. DIGITIZATION and Digital image processing and Cadastral level thematic mapping of the entire Karnataka state. **Softwares Known:** ERDAS, GEOMATICA, MAP INFO, Auto CAD Land Disk, Arc GIS, Vertical Mapper, and Window Movie Maker. **Prof. Basavarajappa has brought Centre for Advanced Studies in Precambrian Geology to DOS in Earth Science**. Prof. Basavarajappa H.T has published more than **370** Research papers in peer – Reviewed with high impact Factor International Journals. Written several Books and edited volumes, Proceeding books, chapters in books and Abstract in the credit. Presented and Published Abstracts and proceedings in conferences and seminars both national and international about **120** Research papers. Prof.H.T.Basavarajappa has travelled abroad widely in France and Germany for the international collaboration and Training on EPMA geochemical analysis. Received in 1998 Karnataka Advanced Applied Sciences (KAAS)Award. 2005 Vijayashree Award from Inter National Friendship Society, New Delhi. Prof. Basavarajappa, H.T established in the Department Research labs of Remote Sensing and GIS lab, Hyperspectral lab at present he is heading the Dean Faculty of Science and Technology, University of Mysore and Co-ordinator for new Course at Academic Year 2022-2023 on M.Sc Two years ESDM (Earth Science and Disaster Management) with PG Diploma 1&2.