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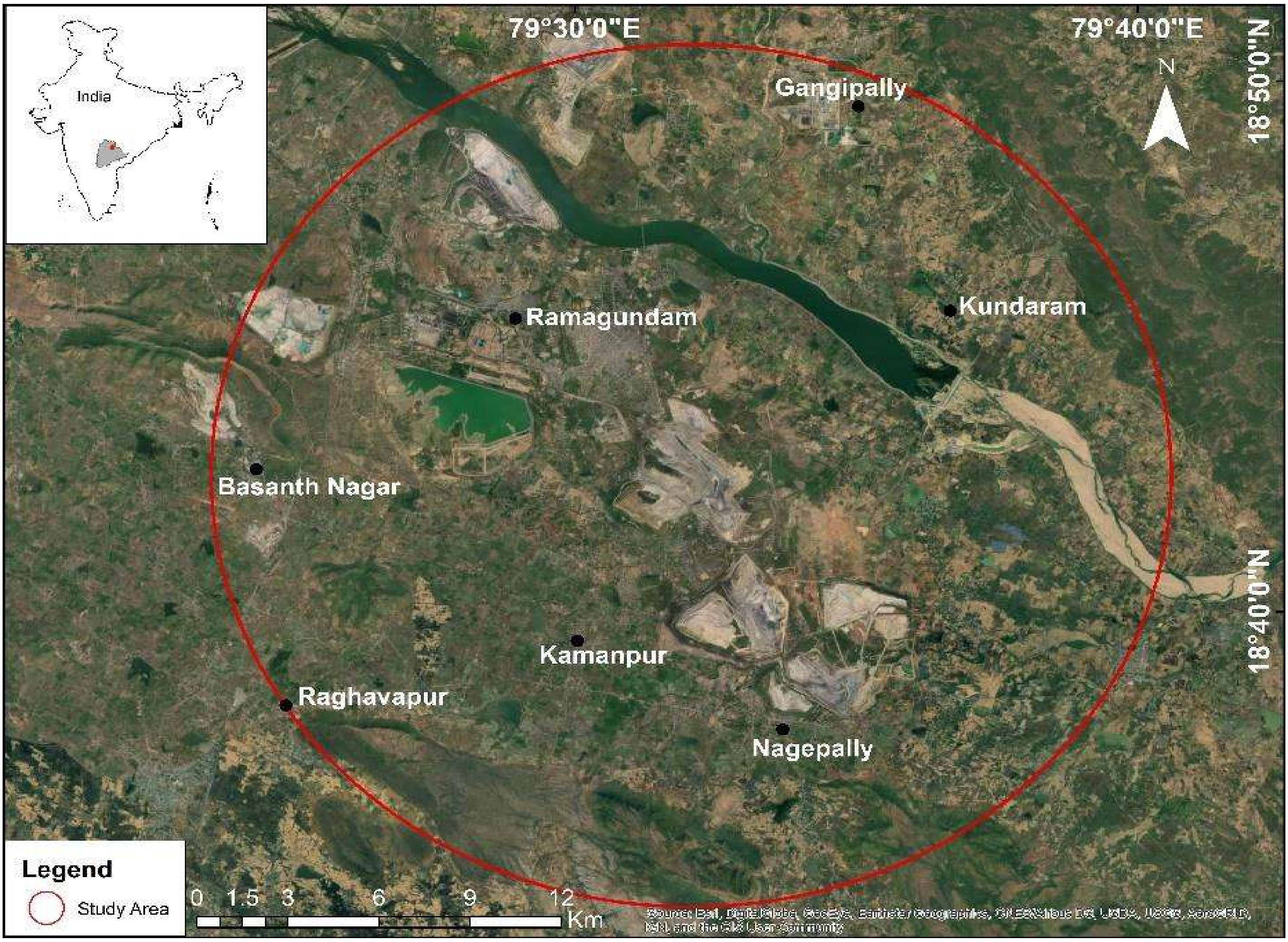

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AIMS AND OBJECTIVES OF IJEHS:

The IJEHS is an official publication of Save The Environment (STE). It publishes peer reviewed quarterly, original articles (Research paper, Review articles, Short Communication, Case studies, etc.) related to all fields of Environment and Health Sciences. It disseminates the scientific research and recent innovations.

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International Journal of Environment and Health Sciences

From The Editor's Desk…

The year 2020 was a difficult year for the mankind, but at the same time, it made us all realize that the power of unity and discipline is of utmost importance while managing the severest of crises. The COVID-19 pandemic impacted public health and environment alike. However, the year 2021 is being deemed to be the 'Year of Recovery'. All of us need to join hands together to tackle the aftermath of the pandemic and to ensure that we stay firm in our efforts to create a sustainable environment.

Surveys suggest that in order to ensure a better respiratory capacity and overall improved health, the necessity of clean air and pure water needs to be addressed more now than ever before. Perils linked to environmental risk factors have to be managed for a bluer and greener earth. In this outlook, propagating awareness for environmental sustainability has become the need of the hour. Formation of regulatory bodies and authorities to disseminate societal alertness towards environmental safety is on the rise.

With this perspective, the International Journal of Environment and Health Sciences (IJEHS) proposes to provide a reliable platform to discuss technologies and strategies for management of aforesaid environmental matters, especially for the current post-COVID-19 period. IJEHS will be quintessential to academicians, industry professionals and researchers who are actively engaged in the areas of environmental issues and related health effects. We are pleased to inform that ISSN for IJEHS is available as 2582-5283. IJEHS is referenced in Crossref, the official Digital Object Identifier Agency (doi 10.47062). IJEHS is now also indexed in the International Scientific Indexing (ISI).

We invite original research articles, short communications and critical reviews directed towards an academic, clinical and industrial audience. The first section of the journal focuses on burning environmental issues like pollutants and their fate, waste management, resource conservation, remediation technologies, etc. The second section includes all topics relevant to physiological impact of environmental risk factors and application of alternative medicinal approaches as remedial measures. Detailed scope can be found in the home page of the journal (www.stenvironment.org/journals). Notes on development of any novel and validated strategy or tool to address environmental challenges are welcome. Discussion on proceedings of conferences conducted on environmental themes and related health aspects will also be considered.

All submissions will be meticulously scrutinized by pioneers in the field to ensure publication of only articles of high quality and relevance. Authors are requested to take special precautions to avert plagiarism and redundancy. It is high time that we realize the gravity of circumstances and take potent steps to undo the adversities already triggered. In this pursuit, IJEHS expects to be the ideal platform to discuss sustainable ideas and potential solutions.

We thank all authors who have contributed to the journal and have consistently been with us in the past year. With this, I wish all our readers a Very Happy New Year, 2021 and I hope our audience and patrons shall come together in this effort to promulgate their part in resurrecting our valuable environment.

Dr. Kshipra Misra
Editor-in-Chief, IJEHS

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ASSESSMENT OF LAND USE/LAND COVER CHANGES FROM 2001 TO 2021 USING GOOGLE EARTH ENGINE IN RAMAGUNDAM MINING AREA, PRANHITA-GODAVARI VALLEY, SOUTHERN INDIA

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Abstract
Coal is one of the important primary sources of energy in India, which are generally extracted through open cast mining. However, coal mining activities, particularly open cast mining method are known to result in adverse environmental impacts such as vegetation loss, air pollution, ground water contamination along with changes in land use land cover (LULC) features. Hence, reliable temporal data on the impact of mining activities are required to aid in mine reclamation and management efforts. Assessment of LULC changes over the last two decades was carried out in this study in Ramagundam coal field, a part of the Pranhita-Godavari valley using Google Earth Engine (GEE) integrated with Geographical Information System (GIS). Landsat 5 and Landsat 8 multispectral satellite data of 2001 and 2021 with <5% cloud cover were used to classify LULC classes. The different land use classes mainly water body, vegetation, builtup and mining area in Ramagundam coal field are classified in GEE through supervised classification using Classification And Regression Tree (CART) classifier. The study reveals that the mining operations increased dramatically between 2001 and 2021. On the other hand, agriculture land has also risen as barren land has been turned to productive land as a result of some effective environmental policies. This study will aid policy makers and environmentalists in understanding nature of change in LULC features in the area so as to plan accordingly.

Keywords
Ramagundam Coal Field, GEE, GIS, CART, LULC.

INTRODUCTION

Coal is India's most vital resource and principal source of energy, accounting for 0.8 percent of the world's total reserves and producing 40% of the electricity globally (Tiwary, 2001). Coal mining operations are carried out to extract coal from the subsurface using either open cast or underground mining methods. Mineral resources are most important and fundamental pillars of any country's economy (Sekerin et al., 2019) but unplanned mines cause deforestation, land degradation, population displacement and air pollution (Patra and Sethy, 2014; Awotwi et al., 2017). Coal mining activities, particularly open cast mining method are known to result in adverse environmental impacts such as vegetation loss, air pollution, ground water contamination. As a result, appropriate management of mining sites is a critical requirement for environmental preservation, for which required information may be generated through field surveys and utilising satellite data. Field surveys are expensive, time-consuming, and involve a lot of manual work that can be prone to mistake, while satellite remote sensing data based surveys are comparatively less expensive and can be utilised not only for near real-time monitoring of mines but also for historical analysis of changes taking place in a given area. It has been recognised that Land use Land Cover (LULC) maps prepared by satellite data play vital role towards natural resources management (Wentz et al. 2006; Soffianian et al. 2015).

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LULC mapping using satellite images has become very popular in the last decades (Sen et al. 2015). Remote sensing and GIS tools have been used widely in the mining industry for various purposes such as mineral exploration, modelling, monitoring, mine planning, and environmental impact assessment (Vander Meer et al. 2012; Karan et al. 2016). The need for monitoring and quantifying changes by remote sensing techniques particularly using satellite images has been well recognised. In India, LULC change due to open cast coal mining had been studied in various parts of India such as in Singrauli, MP (Khan and Javed, 2012), Raniganj (Samanta, 2015), Jharia Coalfield (Prakash and Gupta, 1998), etc. However, traditionally used per-pixel satellite image classification for the purpose of LULC mapping by user results in insufficient sample size and poor generalisation (Zhao and Du, 2016). Google Earth Engine (GEE) is now widely used cloud computing platform for LULC classification as GEE uses Google server's massive computing functions for high computing power and large storage capacity, along with self-programming classification algorithms, to perform automated LULC classification (Stromann et al., 2020; Pan et al., 2021).

This study tries to measure the changes caused by coal mining in the Ramagundam area during the last 20 years using GIS and GEE. Since 1974, the Coal Fields have been exposed to substantial underground and opencast mining (*The Hindu* April 15, 2018). As a result, it is important to conduct a thorough investigation in this particular coalfield to understand the nature and pattern of changes, if any.

Study Area

The study area, Ramagundam coalfield is a part of Godavari Sub-Basin located in the north-western part of Pranhita-Godavari valley. The Ramagundam Coal belt is oldest coal belt of the eleven coal belts of Pranhita-Godavari Valley. To detect the impact of mining activities the Ramagundam Coal Belt and the surrounding areas a circular region of 15-kilometer radius has been identified from the mine area. The selected window is confined between 18°35' N - 18° 50' N latitudes and 79° 25' E - 79° 40' E longitudes in the Karimnagar district of Telangana state, India (Fig 1). The average annual rainfall in the Karimnagar district is 950 mm. Granites, Gneisses, Sandstone, Limestone, Shale, Quartzite's are the major rock types occurring along with the coal seams in the district. The location map of the area is shown in Figure 1. The Gondwana basins of Peninsular India are located along noticeable stream valleys, in particular the Son, Damodar, Mahanadi, Godavari, and Satpura. Prominent lineaments, faults and high heat flow values are the characters of some of these Gonwana basins (Acharya, 2000). The Gondwana Basin of Pranhita-Godavari Valley has been divided into four sub-basins, namely, the i) Godavari, ii) Kothagudem, iii) Chintalapudi, and iv) Krishna-Godavari coastal tract (Raja Rao, 1982). In Ramagundam, the succession of the Lower Gondwana is classified as Talchir, Barakar, Barren and Kamithi Formation. These Lower Gondwana succession overlie either the Archean Gneissic Complex or Sullavai and Pakhal groups of rocks (Raja Rao, 1982).

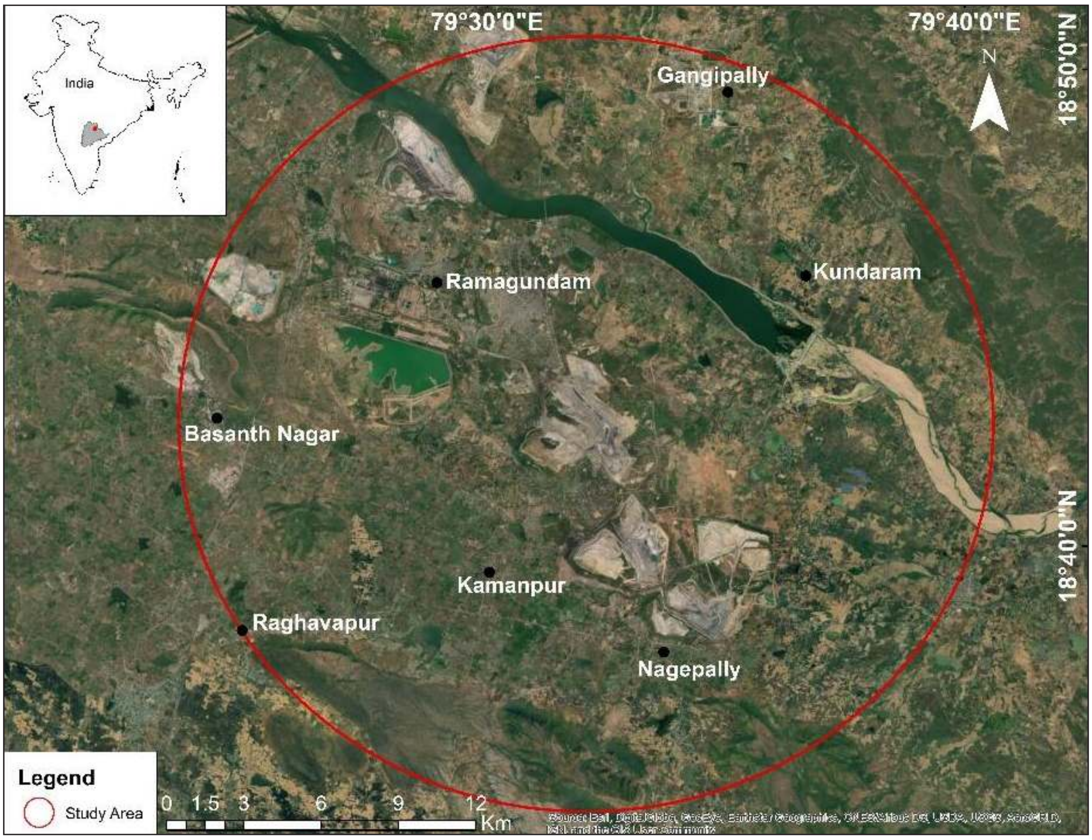

Figure 1: Location map of the study area. (Source: Google Earth Engine).

METHODOLOGY

Ramagundam Coal Belt area is digitised and 15km buffer has been created in GIS environment. Landsat 5 and Landsat 8 satellite data dated 04 March 2001, 02 March 2006, and 11 March 2021 with less than 5% cloud cover are used to generate LULC maps of the area. Total of four classes i.e., water body, vegetation, built-up and mining as suggested by Bhuvan-NRSC (National Remote Sensing Centre) are used for supervised classification in GEE platform. GEE is a cloud-based platform that combines host of geospatial datasets and computes power for running user algorithms (Python and JavaScript based). A specific LULC code has been executed to perform pixel-based supervised classification with 50 signature files of each classes. CART (Classification And Regression Tree) classifier has been used that creates set of decision trees and produces accurate LULC map (Belgiu and Drăguț 2016; Pelletier et al., 2016). To enhance the accuracy of the LULC maps Google earth assisted stamping are carried out. Finally, all the LULC thematic maps are exported and there areas have been calculated in GIS environment.

RESULTS AND DISCUSSION

Evaluating LULC is a critical component of modern land management. Since satellite pictures have shown to be a reliable data source with useful temporal resolution, the comparison of time-sequential data is used to study changes in land-use patterns using remotely sensed data, (Garg et al. 1990). The Ramagundam mine's 15-kilometer buffer zone is utilised to delineate various classes in 2001 and 2021 (Figs. 2 and 3). Areas of four classes are tabulated in km² in Table 1. The total net change and percent change of area of the four classes during 2001 – 2021 were determined (Table 1). The net change of classes is also shown in Fig.4.

Table 1: Summary of LULC classification of Ramagundam coalfield area statistics for the years 2001 and 2021.

Class	2001 (Area in km^2)	2021 (Area in km^2)	Changes (Area in km^2)
Built-up	28.4	71.29	42.88
Vegetation	636.14	534.38	-101.76
Mines and overburden	15.19	60.5	45.3
Water bodies	27.15	40.7	13.55

Table 1 clearly depicts that that changes in Land use and Land Cover classes have occurred in Ramagundam Coal Field from 2001 to 2021 (Figs 3 and 4). Mines and overburden have increased from15.19 km² to 60.50 km² indicating that the mining activities have increased. This may be due to discovery of new mines in the area. These mines are strewn over the vegetation, resulting in a loss in vegetation and a greater risk of land degradation. Vegetation area (crop, forest and scrub area are combined into one class) have changed from 636.145 km² to 534.384 km² with the total change of

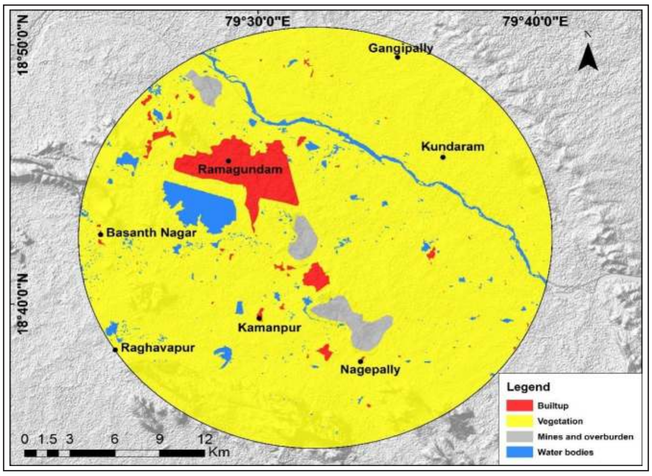

Figure 2: Photographs of some collection sites. (a-h) in and around TMCH; and (i) inside KCH.

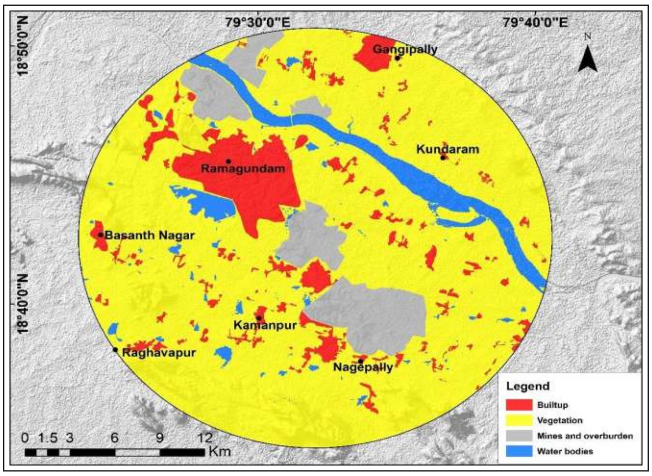

Figure 3: LULC Map of the study area of the year 2021.

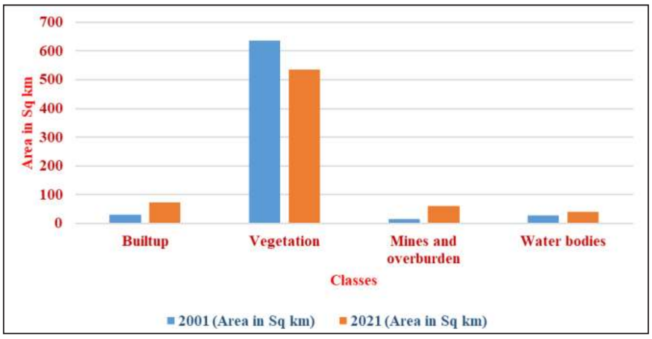

Figure 4: Bar diagram showing the net change in LULC classes in the study area during the period from 2001 to 2021.

101.761 km². Negative sign in Table 1 indicate the reduction in the areas. It clearly shows that most of Vegetation class is converted into Built up class and Mines and Overburden Class. Built-up class has increased from 28.4 to 71.29 km² due to population growth in the area during the period of this study. It has been observed that some lands have been turned to either a permeable layer or a barren area with waste building materials. In the case of a water body, there is a minor rise in pond water area. But in the case of river, the dam stores a large quantity of water at the upper reaches in the study region. There is total increase of 13.55 km² have been observed in the area (Figs 2 and 3; Table 1).

CONCLUSION

This study aims to investigate land use/land cover changes occurred in Ramagundam coal field between the years 2001 and 2021 using remote sensing and GIS. Landsat data and GEE were used in this study to highlight the consequences of coal mining in Ramagundam coal field in terms of changes in LULC classes. The main change observed for the time period of 2001-2021 was that the area of the Ramagundam coal field have seen several shifts in land-use patterns, which may be understood in processed Landsat data (Figs 2. 3 and 4). The use of satellite remote sensing data in this study yielded useful information on the deforestation trend in the mining landscape. Some forest regions have been converted to plain lands, either for mining or agriculture. According to the LULC maps, increased mining operations have already had major impact on settlement and forest cover. The results are in tune with the observations of Khan and Javed (2012) who have observed an increase in settlement as a result of population growth and people from other states seeking work. The study reveals that the mining operations increased dramatically between 2001 and 2021 (Figs. 2 and 3). On the other hand, agriculture land has also risen as some of the areas mapped as barren land classhabeen turned to agriculture class. Outcome of this study could also be useful to policy makers and environmentalists in understanding nature of change in LULC features in the area.

ACKNOWLEDGEMENT

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ASSESSMENT OF GROUNDWATER QUALITY FOR DRINKING PURPOSE IN RAI BLOCK, SONIPAT DISTRICT, HARYANA, INDIA

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Abstract
Water is important for survival of living beings on the planet Earth. Drinking water quality should be as per drinking water standards to avoid the health effects. Anthropogenic activities have deteriorated the groundwater quality. In urban areas groundwater quality is more or less not suitable for drinking purpose. Shallow water table areas are more prone to water pollution due to anthropogenic activities. Rai block is located in Sonipat district of Haryana. The block covers an area of 280.49 sq.km. In the present study 20 groundwater samples in Rai block were collected in the month of January, 2019. The samples were analyzed using Field Water Testing Kit prepared by Tamil Nadu water Supply and Drainage Board, Chennai for twelve chemical parameters-pH, alkalinity, hardness, chloride, total dissolved solids (TDS), fluoride, iron, nitrate, nitrite, ammonia, phosphate and residual chlorine. Chemical analysis of groundwater samples show that pH 6.5 to 9, alkalinity 100-2700 mg/l, hardness 130-920 mg/l, chloride 20 - 750 mg/l, TDS 828-3350 mg/l, fluoride 1-3 mg/l, iron nil to 5 mg/l, ammonia 0.5 - 1 mg/l, nitrite 0.2-1.0 mg/l, nitrate 45-100 mg/l, phosphate nil to 2 mg/l and residual chlorine nil to 0.2 mg/l. Groundwater is non-potable at Rasoi-2 (pH 9, alkalinity 860 mg/l, fluoride 2 mg/l, iron 5 mg/l, ammonia 1mg/l, nitrate 100mg/l), Rasoi-1 (alkalinity 2700 mg/l, TDS 3350 mg/l, fluoride 3 mg/l, nitrate 100 mg/l), Jakholi-3 (alkalinity 780 mg/l, nitrate 100 mg/l), Nathupur (alkalinity 850 mg/l, fluoride 3 mg/l, ammonia 1 mg/l), Bahalgarh (Hardness 920 mg/l, TDS 2388 mg/l, fluoride 2 mg/l, ammonia 1mg/l), Jatheri-1 (Hardness 700 mg/l), Liwaspur (Hardness 800 mg/l, TDS 2064 mg/l, ammonia 1 mg/l), Sabauli (fluoride 3 mg/l, nitrate 100 mg/l), Nangal Kalan (fluoride 3 mg/l, ammonia 1 mg/l, nitrate 75 mg/l), Patla-2 (iron 3mg/l, ammonia 1 mg/l), Jakholi-2 (iron 1 mg/l, nitrate 100 mg/l, phosphate 2 mg/l), Sewli-1(ammonia 1mg/l), Rai-1(ammonia 1 mg/l), Jat Joshi (ammonia 1 mg/l), Jat Joshi-2 (ammonia 1 mg/l). The study is highly useful for monitoring groundwater quality for drinking purpose in the study area.

Keywords
Groundwater, quality, drinking, Rai, Sonipat, Haryana.

INTRODUCTION

Water is important for survival of human beings and other living beings on the planet earth. In the present developmental activities water is polluted and not fit for drinking purposes. In industrial and high population density areas groundwater is polluted and not suitable for drinking purpose as per BIS drinking water standards. The need of the hour is to protect this precious natural resource for future generations. On various aspects of groundwater quality many workers have done good work Agrawal (2009), Ana et al. (2018), Balakrishnan, et al (2011), Das and Nag (2015), Durgadevagi, et al. (2016), Hussain and Prasad (2013). Jeihouni, et al. (2014), Mahadevaswamy, et al. (2011), Okoye, et al. (2016), Pandian and Jeyachandran (2014),

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Patel and Dhiman (2011), Rajesh, (2016), Sarkar, et al. (2012), Satyanarayana, et al. (2013), Saxena and Saxena (2015), Sengupta and Dalwani (2008), Shahida and Ummatul (2015), Sheikh and Kumari (2017), Sinha, et al. (2018), Subramani, et al. (2012), Thomas et al. (2015), Topper and Horn (2011), Vashisth (2017).

STUDY AREA

Rai block is located in Sonipat district of Haryana. The block covers 280.49 sq.km area. Geologically the block has soils of quarternary age. Rai is an industrial area with many types of industries working in the area. It is located on national highway adjacent to Delhi.

OBJECTIVE

The main objective was to assess groundwater quality for drinking purpose in the study area.

MATERIALS AND METHODS

Twenty groundwater samples were collected in plastic bottles from different parts of the Rai block in the month of January, 2019. Groundwater samples were analyzed using Field Water Testing Kit prepared by Tamil Nadu Water Supply and Drainage Board, Chennai for twelve chemical parameters- pH, alkalinity, hardness, chloride, total dissolved solids, fluoride, iron, ammonia, nitrate, nitrite, phosphate, residual chlorine. Chemical data entered in excel software and prepared the bar graphs of each parameter for all the sample location. Results were compared with BIS drinking water standards to know the pot-ability and non-potability of groundwater for drinking purpose.

RESULTS AND DISCUSSION

Results of twenty groundwater samples are given in Table 1 and BIS drinking water standards are given in Table 2. Parameter wise groundwater quality is given below:

Table 1: Results of chemical analysis of groundwater samples (in mg/l except pH).

Sample Location	Latitude	Longitude	pH	Alka linity	Hardness	Chlo ride	TDS	Fluo ride	Iron	Amm onia	Nit rite	Nit rate	Phos phate	Residual Chlorine
Rasoi-2	28 54'25"	77 6'45"	9	860	570	20	1380	2	5	1	1	100	0	0.2
Rasoi-1	28 54'6"	77 6'44"	7	2700	300	350	3350	3	0	0.5	1	100	0	0
Bahalgarh	28 57'29"	77 5'36"	7.5	400	920	670	2388	2	0	1	0.5	45	0	0
Sewli-1	28 55'47"	77 7'37"	7.5	600	600	50	1500	1	0	1	0.5	45	0	0
Rai-1	28 56'27"	77 5'53"	7.5	350	430	550	1596	1.5	0	1	0.5	45	0	0
Jakholi-1	28 55'45"	77 8'58"	7	450	600	250	1560	1.5	0	0.5	0.5	45	0	0
Jatheri-1	28 55'19"	77 4'24"	7	600	700	350	1980	1.5	0	0.5	0.5	45	0	0.2
Sewli-2	28 55'20"	77 7'33"	7.5	400	250	110	912	1	0	0.5	0.5	45	0	0
Jakholi-3	28 55'58"	77 8'29"	7.5	780	300	100	1416	1	0	0.5	1	100	0	0.2
Sewli-3	28 55'47"	77 7'35"	7.5	380	250	60	828	1	0	0.5	0.5	45	0	0
Pritampura	28 54'7"	77 5'54"	6.5	420	130	530	1296	1.5	0	0.5	0.5	45	0	0.2
Patla-2	28 55'21"	77 8'26"	7.5	500	290	250	1248	1	3	1	0.5	45	0	0
Nathupur	28 54'6"	77 6'20"	7.5	850	370	190	1692	3	0	1	1	100	0	0
Jat Joshi	28 58'7"	77 4'7"	7.5	370	360	280	1212	1.5	0	1	0.5	45	1	0
Jat Joshi-2	28 58'7"	77 4'29"	7.5	430	380	350	1392	1.5	0	1	0.5	45	0.5	0
Jakholi-2	28 55'30"	77 8'55"	6.5	100	240	750	1308	1.5	1	0.5	1	100	2	0.2
Sabauli	28 53'23"	77 5'42"	7.5	270	250	350	1044	3	0	0.5	1	100	0	0
Liwaspur	28 57'53"	77 5'11"	8.5	520	800	400	2064	1.5	0.3	1	0.5	45	0	0
Patla	28 54'53"	77 8'19"	7	340	500	180	1224	1	0	0.5	0.2	45	0	0
Nangal Kalan-1	28 54'23"	77 7'24"	7.5	240	450	80	924	3	0	1	1	75	1	0

Table 2: Drinking water standards (IS 10500:2012).

S. No.	Parameter	Potable		Non-Potable
		Desirable	Permissible	
1.	pH	6.5 to 8.5	--	<6.5 to >8.5
2.	Total Hardness (mg/l)	<200	200-600	>600
3.	Iron (mg/l)	<0.3	--	>0.3
4.	Chloride (mg/l)	<250	250-1000	>1000
5.	Total Dissolved Solids (mg/l)	<500	500-2000	>2000
6.	Nitrate (mg/l)	<45	--	>45
7.	Nitrite (mg/l)	<1.0	-	> 1.0
8.	Fluoride (mg/l)	<1.0	1.0-1.5	>1.5
9.	Phosphate (mg/l)	<1.0	-	> 1.0
10.	Residual Chlorine (mg/l)	<0.2	0.2-1	>1.0
11.	Ammonia (mg/l)	<0.5	--	>0.5
12.	Alkalinity (mg/l)	<200	200-600	>600

i. pH

pH is a measure of acidity or basicity of water. Water is potable between the range 6.5 to 8.5 and non-potable below 6.5 and above 8.5. pH ranges 6.5 to 9 in the study area. In the study area pH is desirable at nineteen sample locations and non-potable at Rasoi-2 sample location (pH 9). (Table 1, Table 2, Figure 1).

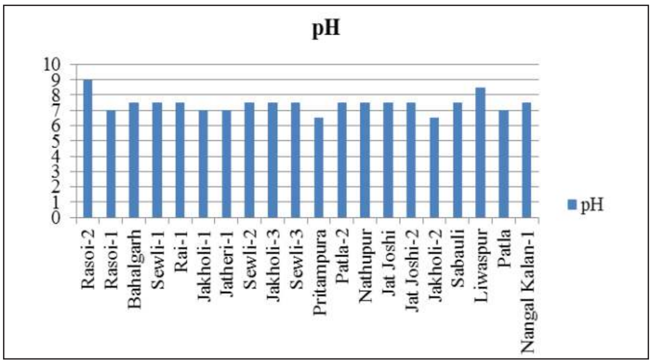

Figure 1: pH in groundwater samples

ii. Alkalinity

Alkalinity is a measure of water's ability to neutralize acids. In the study area alkalinity varies from 100 mg/l to 2700 mg/l. At one sample location (Jakholi) alkalinity 100 mg/l is desirable (<200mg/l), at fifteen sample locations alkalinity is permissible (200-600 mg/l) and at four sample locations alkalinity is non-potable (>600 mg/l) (Table 1, Table 2, Figure 2).

iii. Hardness

Hard water has high concentration of calcium and magnesium carbonates. In the study area hardness varies from 130 mg/l to 920 mg/l. Hardness is desirable at one sample location (Pritampura 130 mg/l), permissible at sixteen sample locations and non-potable at three sample locations (Table 1, Table 2, Figure 3).

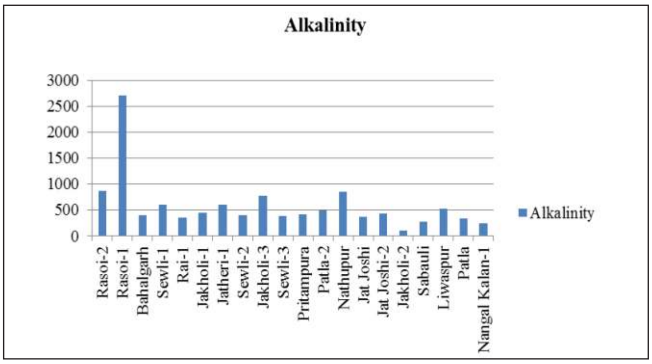

Figure 2:Alkalinity (mg/l) in groundwater samples .

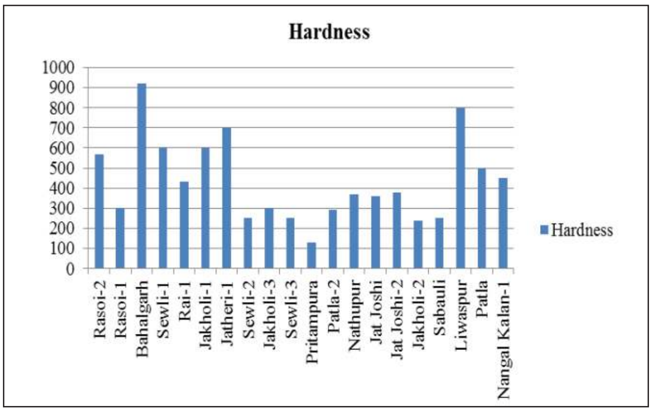

Figure 3:Hardness (mg/l) in groundwater samples.

iv. Chloride

Chloride is available in nature as salts of sodium (NaCl), potassium (KCl), and calcium (CaCl2).Chloride is an anion and formed when the element chlorine gains an electron or when a compound such as hydrogen chloride is dissolved in water or other polar solvents. In the study area, chloride varies from 20 mg/l to 750 mg/l. At eight sample locations chloride is desirable (<250 mg/l) and at twelve locations

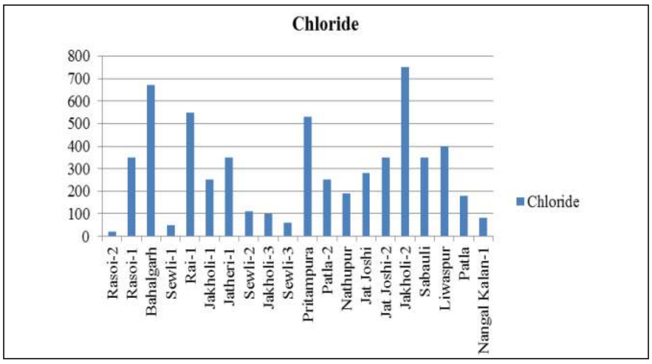

Figure 4: Chloride (mg/l) in groundwater samples.

chloride is permissible (250-1000 mg/l) (Table 1, Table 2, Figure 4).

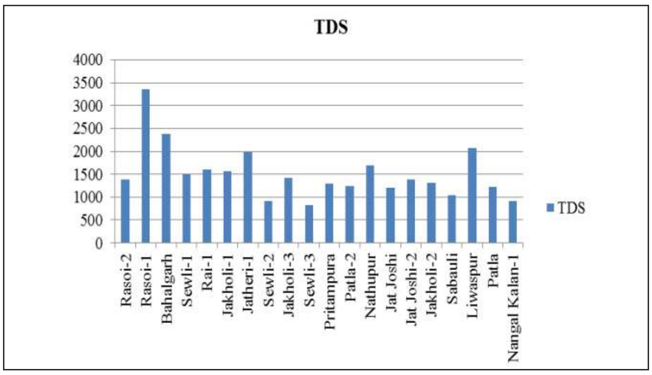

Figure 5: Total dissolved solids (TDS) (mg/l) in groundwater samples.

v. Total Dissolved Solids (TDS)

Total dissolved solids (TDS) represents the combined content of all inorganic and organic substance in water. In general, the TDS concentration is the sum of the cations and anions ions in the water. In the study area, TDS varies from 828 mg/l to 2388 mg/l. At seventeen sample locations TDS is permissible (500-2000 mg/l) and three sample locations non-potable (>2000 mg/l) (Table 1, Table 2, Figure 5).

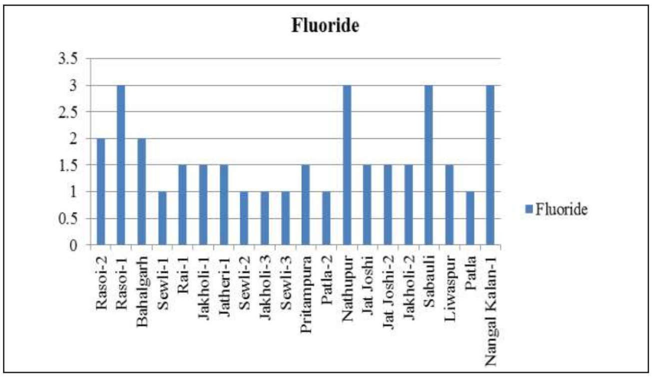

Figure 6: Fluoride (mg/l) in groundwater samples.

vi. Fluoride

Fluoride occurs naturally in soils and rocks. Fluoride more than 1.5 ppm in drinking water causes dental cavities, skeletal weakness and other bone diseases. In the study area, fluoride varies from 1 mg/l to 3 mg/l. At six sample locations fluoride is desirable (<1 mg/l), eight sample locations permissible (1-1.5 mg/l) and six sample locations non-potable (>1.5 mg/l) (Table 1, Table 2, Figure 6).

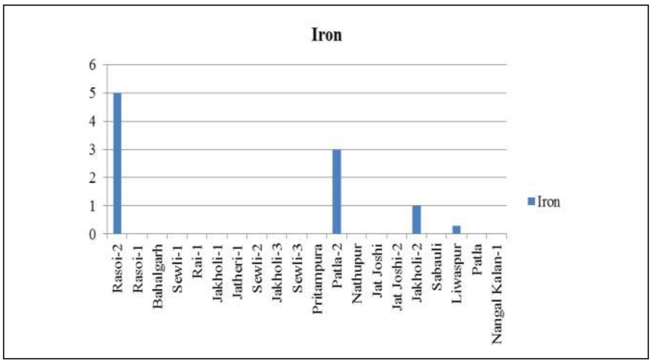

Figure 7: Iron (mg/l) in groundwater samples.

vii. Iron

Iron is commonly found in nature in its oxides form and occurs in soils,sediments and rocks. Iron is the second most abundant metal in the Earth's crust. In the study area iron varies between nil to 5 mg/l. At seventeen sample locations iron is desirable (<0.3 mg/l) and three sample locations non-potable (>0.3 mg/l) (Table 1, Table 2, Figure 7).

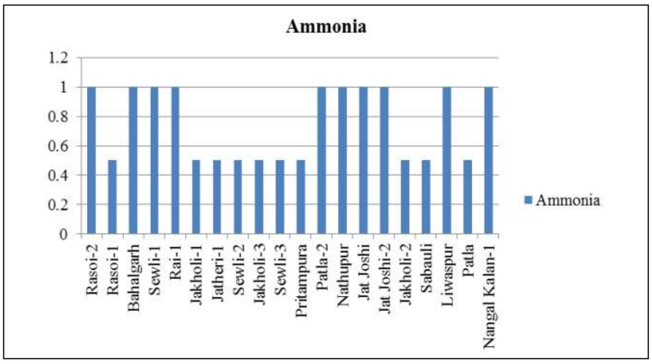

Figure 8: Ammonia (mg/l) in groundwater samples.

viii. Ammonia

Ammonia is a compound contains nitrogen and hydrogen. In the study area, ammonia varies from 0.5 to 1 mg/l. At ten sample locations ammonia is desirable (<0.5 mg/l) and ten sample locations non-potable (> 0.5 mg/l) (Table 1, Table 2, Figure 8).

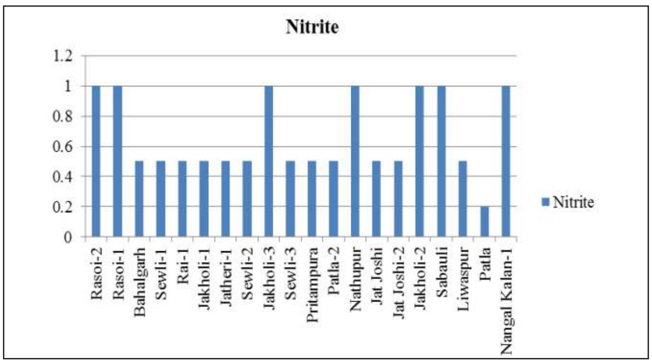

Figure 9: Nitrite (mg/l) in groundwater samples.

ix. Nitrite

Nitrite is ion having chemical formula NO2. In the study area, nitrite varies from 0.2 mg/l to 1 mg/l. At all the twenty sample locations nitrite is desirable (<1 mg/l) (Table 1, Table 2, Figure 9).

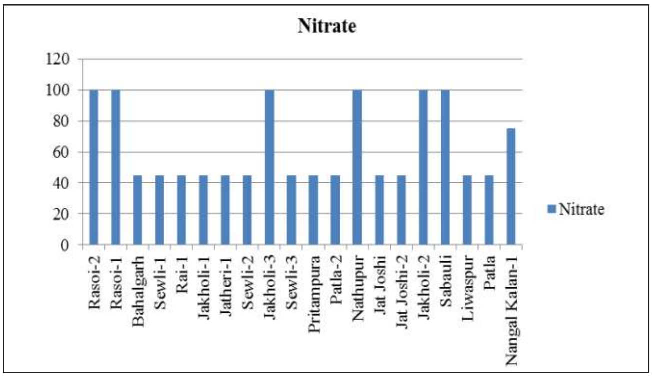

Figure 10: Nitrate (mg/l) in groundwater samples.

x. Nitrate

Nitrate (NO3) is inorganic compound. High nitrate level in drinking water can cause blue baby disease (Methemoglobinema) especially in infants less than six months old. In the study area nitrate varies from 45 mg/l to 100 mg/l. At thirteen sample locations nitrate is desirbale (<45 mg/l) and seven locations non-potable (> 45 mg/l) (Table 1, Table 2, Figure 10).

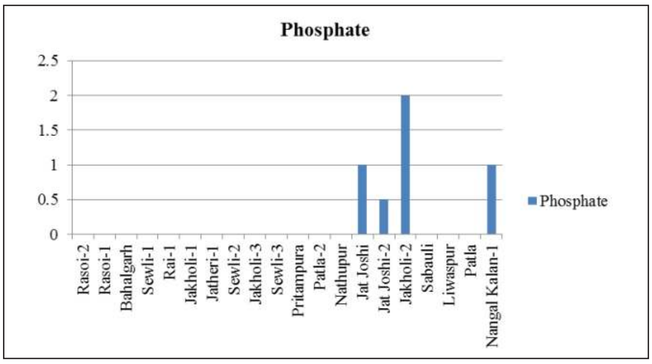

Figure 11: Phosphate (mg/l) in groundwater samples.

xi. Phosphate

Phosphate is a compound containing phosphorus. In the study area, phosphate varies from nil to 2 mg/l. At nineteen sample locations phosphate is desirable (< 1mg/l) and one sample location non-potable (>1 mg/l) (Table 1, Table 2, Figure 11).

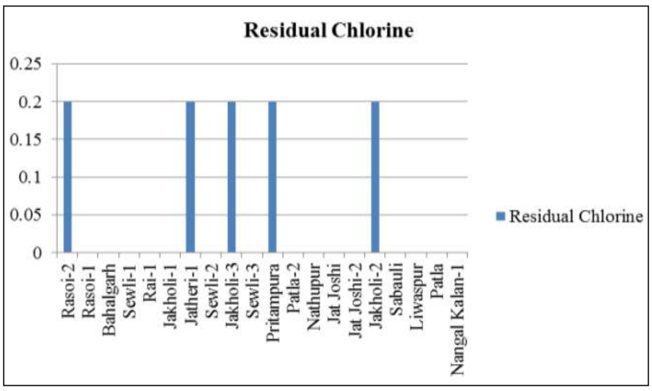

Figure 12: Residual chlorine (mg/l) in groundwater samples.

xii. Residual Chlorine

Presence of residual chlorine in drinking water indicates that a sufficient amount of chlorine is added to the water to deactivate the bacteria and viruses that cause diarrhea. In the study area, residual chlorine varies from nil to 0.2 mg/l. At all the twenty sample locations residual chlorine is desirable (< 0.2 mg/l) (Table 1, Table 2, Figure 12).

CONCLUSION

Groundwater is non-potable at fifteen sample locations viz. Rasoi-2 (pH 9, alkalinity 860 mg/l, fluoride 2 mg/l, iron 5 mg/l, ammonia 1 mg/l, nitrate 100mg/l), Rasoi-1 (alkalinity 2700 mg/l, TDS 3350 mg/l, fluoride 3 mg/l, nitrate 100 mg/l), Jakholi-3 (alkalinity 780 mg/l, nitrate 100 mg/l), Nathupur (alkalinity 850 mg/l, fluoride 3 mg/l, ammonia 1 mg/l), Bahalgarh (Hardness 920 mg/l, TDS 2388 mg/l, fluoride 2 mg/l, ammonia 1mg/l), Jatheri-1 (Hardness 700 mg/l), Liwaspur (Hardness 800 mg/l, TDS 2064 mg/l, ammonia 1 mg/l), Sabauli (fluoride 3 mg/l, nitrate 100 mg/l), Nangal Kalan (fluoride 3 mg/l, ammonia 1 mg/l, nitrate 75 mg/l), Patla-2 (iron 3mg/l, ammonia 1 mg/l), Jakholi-2 (iron 1 mg/l, nitrate 100 mg/l, phosphate 2 mg/l), Sewli-1 (ammonia 1mg/l), Rai-1(ammonia 1 mg/l), Jat Joshi (ammonia 1 mg/l), Jat Joshi-2 (ammonia 1 mg/l).Groundwater is potable at Patla, Pitampur,Sewli-2, Sewli-3 and Jakholi-1 sample locations. The study is highly useful for monitoring groundwater quality for drinking purpose in the study area.

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ANALYSIS OF SEASONAL AND ANNUAL TRENDS OF SULPHUR DIOXIDE AS AIR POLLUTANT IN BAREILLY CITY

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Abstract
According to a report published by Green Peace (2018), Bareilly city has been reported as one of the most seven polluted cities. Bareilly city do not have too much of industrialization but poor environmental management by the citizens and administration worsen the air quality during Diwali festival. Air monitoring of gaseous pollutant (sulphur dioxide) was done at Bareilly city as per CPCB guidelines from three monitoring stations (A, B and C) for a period of two years (2019-2020). During pre-monsoon season of 2019 all station reported SO_2 values below the specified limits of 60µg/m^3 but station A reported values on the higher side. When lockdown was imposed in March 2020 due to the outbreak of novel corona virus in India and there was significant cut down in SO_2. While conducting the two-way ANOVA test for SO_2 during both pre-monsoon and post-monsoon seasons from three stations at Bareilly in 2019, it was found that $F>F_{crit.}$ and p-value<0.05. This paper focuses on the monitoring, analysis and interpretation of SO_2 at Bareilly city.

Keywords
Bareilly, vehicular emissions, PM2.5, pre-monsoon, lockdown, coronavirus

INTRODUCTION

Air pollution isn't restricted to a state, country, region or continent, it could have significant effect on global climate and weather, acid rain issue since the 1970s is a well-aware problem for the world. Formation of acid rain takes place when SO_2 and oxides of nitrogen from the burning of excessive fossil fuels combine with the vapour in the atmosphere, forming mist of H_2SO_4 and HNO_3 that causes damage to water, forest, and soil resources. With the rise in the fossil fuel consumption, CO_2 levels in the atmosphere have increased steadily since 1900, and the rate continues to be on the rise. It has been predicted that if CO_2 levels are not reduced, average global air temperatures may rise another 4 °C (7.2 °F) by the end of the 21st century. This may lead to the melting of the polar ice caps, elevation in the level of sea water, and flooding of the coastal areas globally. Alterations in precipitation patterns caused by climate changes and global warming could cause adverse effects on agriculture and forest ecosystems, and higher temperatures and humidity might increase the incidence of disease in humans and animals in some parts of the earth. Globally we see that in recent decades the death rates from total air pollution have declined: since 1990 the number of deaths per 100,000 people have nearly halved. But, as we see from the breakdown, this decline has been primarily driven by improvements in indoor air pollution. (source, IHME, Global Burden of disease). In a report of WHO, 2018 it has been reported that due to both indoor and outdoor air pollution around seven million people die each year. The three biggest killers attributable to air pollution are stroke (2.2 million deaths), cardiac disease (2.0 million) and lung disease and cancer (1.7 million deaths).Ambient (outdoor) air pollution accounts for: 25 per cent of all deaths and disease from lung cancer, 17 per cent of all deaths and disease from acute lower respiratory infection, 16 per cent of all deaths from stroke 15 per cent of all deaths and disease from ischaemic cardiovascular disease and 8 per

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cent of all deaths and disease from chronic obstructive pulmonary disease .Air pollution doesn't just kill, however. It also contributes to other illnesses, hampers development and causes neurological dis-orderness. One study found that ambient PM2.5 contributed to more than three million cases of diabetes in 2016.Recent research from the United Nations Children's Fund (UNICEF) shows that inhaling in particulate air pollution can damage brain tissue and undermine cognitive development in young children – with lifelong implications. In India air pollution is very alarming in the currents scenario. According to (WHO -2018) and the fourth edition of State of India's Environment (SoE) released on World Environment Day, 5th June 2019 air pollution cause a death toll of an average of around 80 out of every one lakh children in India before they turn five. Urban air quality in megacities getting deteriorated day by day due to increase in industrialization and urbanization [1, 2].Population pressure can't be ruled out for a few reason. To satisfy out demand of population explosion natural resources are being harvested and transported. The rapid urban growth is also associated with transportation sector and road networks which supports various vehicular movements on roads [3]. Air pollution in India is predominantly caused from three sources namely vehicles [4], industrial and domestic sources. It was reported that air pollutants like NOx and PM concentration (approximately 17 % and 28 % of total) from vehicular emissions are contributed to the air pollution which was almost equal to the cumulative sources of industry, power plants and domestic sectors in Delhi, India [5]. However, over the last twenty years petrol and diesel consumption have hiked by 400 % and 300 %, respectively, which was mainly because of rise of vehicular numbers, DG sets, industries and waste incinerators [6 ,7]. The heavy traffic , thickly populated areas, jams, poor driving patterns ,improper town planning and congested and encroached roads have severe impact on the environment in urban areas [1, 8, 9, 10, 11].

Vehicular emissions is associated with a number of chronic and acute health effects [12, 13]. Various studies proved that health issues such as cancers, heart attacks and asthma are associated with NOx, SO_2 and PM emissions from vehicular exhaust [14, 15]. In urban areas, air pollution is affected mainly due to construction of buildings, traffic composition and meteorological conditions [16]. Air quality models and impact because of pollutant concentration assessment studies provide a tool to better understand the implications of pollutant emissions which could help us to decide, control and manage the environmental pollutions [17]. Air pollutant dispersion modeling has been accomplished with the aid of Gaussian Dispersion Plume models that, accounted for the spatial and temporal dispersion characteristics of various pollutants. However, line source models are generally used to assess the effects of roadway emissions and dispersion of the pollutants [18, 19]. Traffic estimation studies can either be done by on-site traffic counting (manually or installing CCTV camera or counter devices) [20, 21, 22], or derived from travel demand and traffic simulation models [23, 24, 25]. Emissions are often estimated considering average link speeds and average emission factors [20, 22, 23, 25] or real-time link drive-cycles [24]. Airborne particulate matter (PM) is a type of a colloidal solution composed of small droplets of liquid, dry solid fragments, and solid cores with liquid coatings. PM particles are not a single pollutant, instead it is a mixture of different chemical species. Therefore, PM2.5 comprises a portion of PM10. The primary source of Particulate matter is from anthropogenic activities such as burning of fossil fuel, vehicular emissions, road dust suspensions, wear out of brakes and tyres, ash from industries as well as incomplete construction work. Exhaust traffic related particles have been identified as a major contributor to ambient PM. Vehicular emissions are one of the major sources of outdoor air pollution in major cities of India. The number of vehicles on road has increased non-linearly over the past two decades has resulted in high levels of air pollution. In most of the major cities/towns there has been uncontrolled growth of vehicle population. High vehicle density in Indian urban centers results in air pollution buildup near the roadways and at traffic intersections. Older vehicles are predominant in vehicle vintage. Older vehicles release more air pollutants hence vehicles older than 15 years of registration are now been phased out and cannot move on roads in Delhi. But, in small cities still old vehicles are being operated on roads without a stringent check. Inadequate inspection and maintenance facilities result in high emission of air pollutants from vehicles. In order to reduce the emission of particulate matter and gaseous pollutants, regular inspection and maintenance of vehicles should be done. Also, vehicles in India easily get Pollution Under Control certificate. According to the Society of Indian Automobile Manufacturer (SIAM) [Table 1]automobile sale trend was studied over a period of five years as shown in the table below:

Table1: Automobile Domestic Sale Trends for the period of six years 2014 to 2020.

Category	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20
Passenger Vehicles	2,601,236	2,789,208	3,047,582	3,288,581	3,377,389	2,773,575
Commercial Vehicles	614,948	685,704	714,082	856,916	10,07,311	717,688
Three Wheelers	532,626	538,208	511,879	635,698	7,01,005	636,569
Two Wheelers	15,975,561	16,455,851	17,589,738	20,200,117	21,179,847	17,417,616
Quadricycle#		0	0	0	627	942
Grand Total	19,724,371	20,468,971	21,863,281	24,981,312	26,266,179	21,546,390

Day by day the air quality which we are inhaling is being detoriated and getting even worsen. It has been found and reported that around ten million people from India[31] lose their lives due to air pollution. Around 30% of cardiac patient are affected due to air pollution[32]. School going children and new born babies are suffering from emphysema. Also senior citizen are suffering from breathlessness due to emission of pollutant. Hence a serious monitoring, analysis and remedial steps need to be taken in this regards. CPCB and also media reported that Bareilly [Figure 1] was thickly polluted and in UP the third most polluted city.

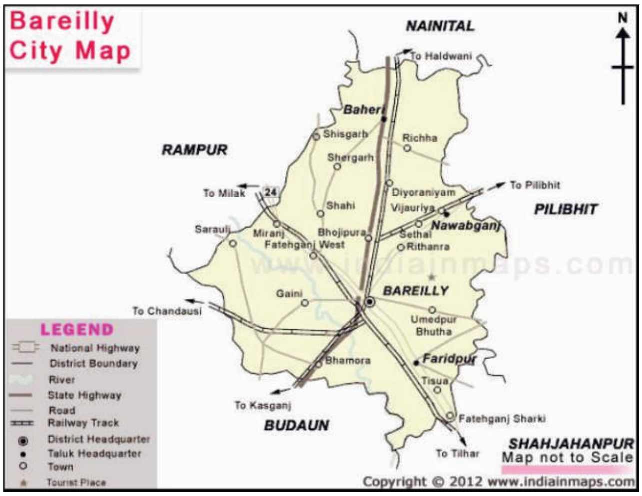

Figure 1: Bareilly Map (source : www.indiamaps.com)

There are more than 30 fuel pumps in Bareilly city [Figure 2] and due to large population there is huge consumption of fuel in the entire city.

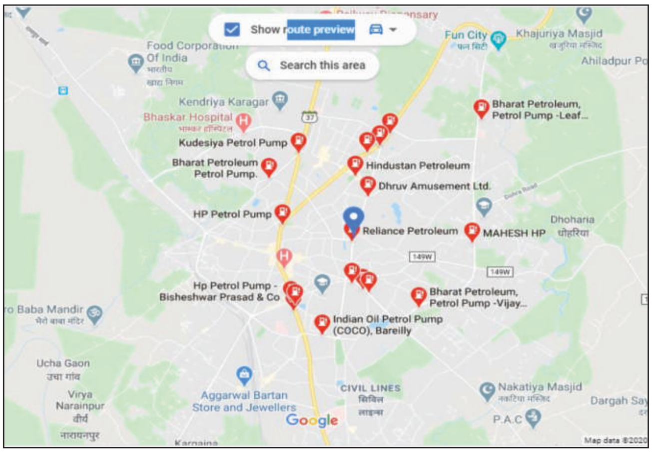

Figure 4: Fuel Station at Bareilly.
(Image taken from Google Maps)

Material and Methods to measure SO_2 in air

Modified West & Gaeke Method for the Measurement of Air Pollution: Sulphur dioxide.

In this procedure, Sulphur dioxide from aerial mixture was made to absorb in a solution of potassium tetrachloromercurate (TCM) with subsequent formation of a dichloro-sulphitomercurate complex, which resists oxidation by the oxygen in the air. This resultant complex is highly stable to strong oxidants like ozone and oxides of nitrogen hence the absorber solution may be stored for some time prior to analysis. The reaction between the dichloro-sulphitomercurate complex and para-rosaniline and formaldehyde resulted in pararosaniline methyl sulphonic acid. The absorbance of the solution is measured by means of a suitable spectrophotometer.

Pollutant	Time Weighted Average	Time Weighted Average	
		Industrial, Residential, Rural and other Areas	**Ecologically Sensitive Area (Notified by Central Government)**
Sulphur Dioxide (So_2), $\mu g/m^3$	Annual*	50	20
	24 Hours **	20	80

*Annual Arithmetic mean of minimum 104 measurements in a year, at a particular site, taken twice a week 24 hourly at uniform intervals.
**24 hourly or 8 hourly or 1 hourly monitored values, as applicable, shall be complied with 98% of the time in a year. 2% of the time, they may exceed the limits but not on two consecutive days of monitoring.

Concentration of sulphite solution:

$$C = \frac{(V1-V2) \times N \times K}{V}$$

Where,
C = SO_2 concentration in mg/ml
V1 = Volume of thiosulfate for blank, ml
V2 = Volume of thiosulfate for sample, ml
N = Normality of thiosulfate
K = 32000 (Milliequivalent weight $SO_2/\mu g$)
V = Volume of standard sulphite solution, ml

$C\ (SO_2\ \mu g/m^3) = (As - Ab) \times CF \times Vs / Va \times Vt$

Where,
C SO_2 = Concentration of Nitrogen dioxide, $\mu g/m^3$
As = Absorbance of sample
Ab = Absorbance of reagent blank
CF = Calibration factor
Va = Volume of air sampled, m^3
Vs = Volume of sample, ml
Vt = Volume of aliquot taken for analysis, ml

This paper focuses on the data organization of gaseous air pollutant SO_2 from three monitoring stations of Bareilly district. The air monitoring was carried out at the following three stations at Bareilly district. The field data obtained was recorded and analysed in the laboratory. All data obtained during the year 2019 during field research was organized, analysed, interpreted and represented in the form graphs and tables for better analysis and evaluation. Following are the monitoring stations /location [Figure 3] from where the air pollutants have been sampled for analysis.

Figure 3: Station A : Coco Pump, Civil lines Bareilly (28.8348 N/79.424 E),
Station B: DD Puram, Bareilly, 28.831N/79.428E,
Station C: IVRI Bareilly 28.393N/79.428E

Results and Discussions

The collection of data was done as per the CPCB guideline and methods were followed as discussed in chapter three. Table represents monthly average concentrations of SO_2 pollutants in µg/m^3 from three stations A, B and C respectively. The first six months of the year i.e. January 2019 to June 2019 are studied as Pre-monsoon season and from July 2019 to December 2019 are studied under Post Monsoon season.

Table 2: SO_2 data during Pre-monsoon and Post monsoon in 2019 from three stations.

Seasons	Months	STATION A 28.8348 N/ 79.424 E	STATION B 28.831N/79.428E	STATION C 28.393N/79.428E
PREMONSOON	January	32.6	19	11.34
	February	18.45	18	12.01
	March	27.25	19	10.31
	April	12.05	13	11.04
	May	32.25	21	10.01
	June	33.69	23	9.17
POST MONSOON	July	34.13	19	8.89
	August	29.13	18	9.32
	September	32.57	24	10.62
	October	46.6	23	13.31
	November	60.78	43	29.61
	December	57.61	37	20.05

PREMONSOON TRENDS OF SO_2

During the Pre-monsoon season, as can be seen from the following figure that all stations reported SO_2 concentration are below the maximum permissible limit of 60 µg/m^3 according to NAAQS. Station A, located on the highway, is considered to be heavy traffic site, where as station C being a residential site was considered to be control site or low traffic site. Station B is commercial cum residential site. The green worm in the following figure corresponds to station C which lies always below the curves corresponding to station A and station B during the entire pre-monsoon season. No regular trend is observed during the pre-monsoon season but the values remained below the maximum allowable limits.

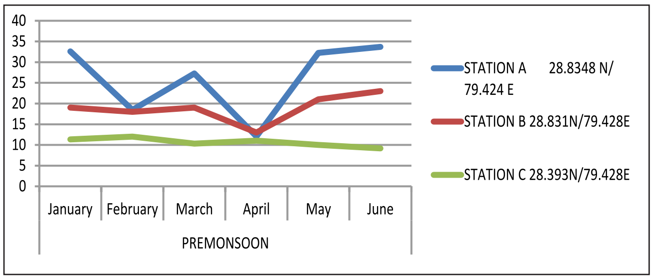

Figure 4: Pre-monsoon trends of SO_2 during 2019.

Post-monsoon comparative data for SO_2

During the post- monsoon season all station show an increasing trends till the month of November 2019 in the values of SO_2 concentration. As expected, the low vehicular site, Station C, reported the least value of SO_2 concentration during the entire post monsoon season.

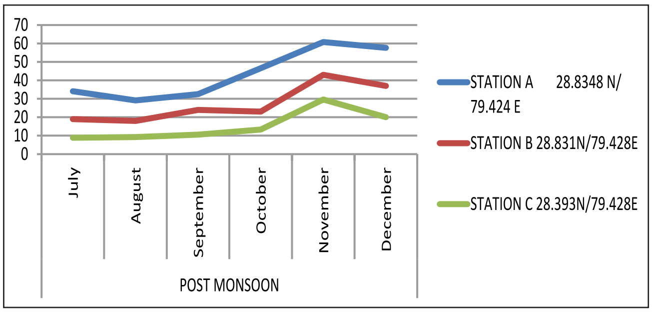

Figure 5: Pre-monsoon trends of SO_2 during 2019.

ANNUAL TRENDS (Pre and Post Monsoon) OF So_2 FOR THE YEAR 2019

Bareilly city do not have too much of industries emitting gaseous pollutants. The only major source of gaseous pollutant in the city is vehicular emissions, which can be verified from the annual trend analysis of SO_2 levels at the three air monitoring sites. Station A showed relatively large values of SO_2 as it is located on highway and is a heavy vehicular site. During the entire 2019 all stations reached their individual peak value only the month of November 2019 which is possibly due to the emission from fire crackers burned during Diwali festival.

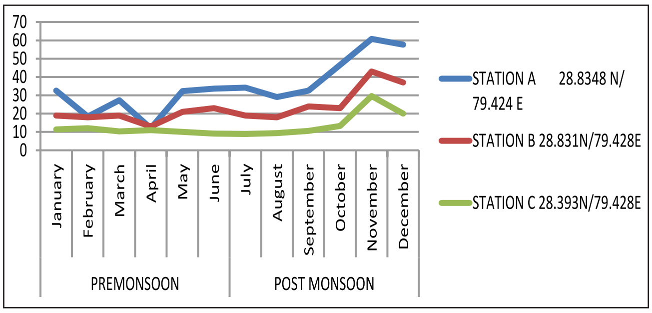

Figure 6: ANNUAL TRENDS (Pre and Post Monsoon) OF SO_2 FOR THE YEAR 2019

The gaseous pollutants studied during the course of research was SO_2. Bareilly city do not have too much of industrialization. SO_2 level were found to be less than the maximum allowable limits [Figure 3] when measured from the three air monitoring sites. For all the stations A, B and C respectively, the post-monsoon average has relatively higher SO_2 concentration in comparison to the pre- monsoon average values, and this can be depicted also by the annual average which is significantly higher than the pre-monsoon average. Station A averaged maximum with a value of 34.75 µg/m^3.

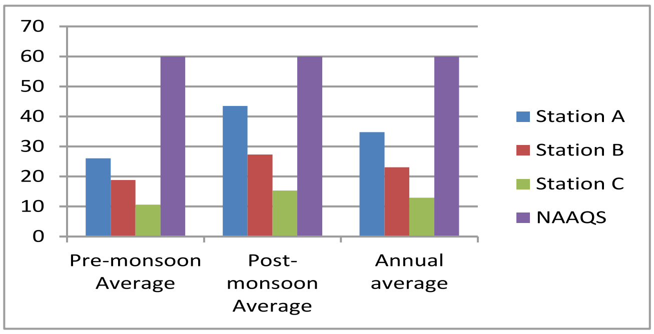

Figure 7: Seasonal and annual Average of SO2 concentrations during 2019. Two way ANOVA test

While conducting the two way ANOVA test for SO_2 during both pre-monsoon and post-monsoon seasons from three stations at Bareilly in 2019, it was found that F>F crit. and p-value<0.05 [Table 3] for both seasons and monitoring stations. This signifies that there is significant variation in mean value of gaseous pollutant (SO_2) during pre and post monsoon season. Also, the three monitoring locations have an appreciable difference in their mean values during pre and post monsoon.

Table 3: Two-way ANOVA for SO_2 during the pre-monsoon and post monsoon season 2019.

Source of Variation	F	P-value	F crit
Seasons	12.557189	0.0013151	4.1708768
Monitoring Stations	19.159153	4.353E-06	3.3158295
Interaction	1.7289299	0.1946913	3.3158295

Conclusions

A large number of health issues have been reported which are predominantly due to poor ambient air quality. From the analysis of the gaseous air pollutant SO_2 for the year 2019 from three monitoring locations depending on the traffic frequency in the vicinity of 11 km, it can be concluded that the concentration of gaseous air pollutant SO_2 in Bareilly city measured from station A were alarming during the winter season and were on the higher side in comparison to the other two stations B and C. Bareilly city do not have too much industrialization and hence emission of gaseous air pollutant sulphur dioxide largely depends on vehicular emissions which is evident from the sale of diesel and petrol fuel reported from the fuel pumps in the study area[26]. As expected, the Station A being a commercial and heavy traffic site showed SO_2 relatively higher concentration of SO_2 whereas station C being a residential site recorded much lower SO_2 values. Thus, it can be concluded that the possible cause of air pollutant PM2.5 in the city Bareilly could be vehicular emissions. The study carried out for air pollutant analysis is from a limited number of stations covering only an area of 11 km. On increasing the number of monitoring locations better estimate of air quality can be done. Currently, low attention is given to air pollution in spite that millions die due to air pollution all over the world. Air pollution should be thoroughly understood by developing countries and should be given priority. Long-term exposures to gaseous pollutants (up to 24-hours duration) are found to be associated with premature mortality, increased hospital admissions for heart or lung causes, acute and chronic bronchitis, asthma attacks, emergency room visits, respiratory disorders, and restricted activity days. Health of new born babies, children, and older adults with an existing history of heart or lung diseases are found to adversely effected. Health issues due to long-term (months to years) exposure to PM2.5 has been linked to premature death, particularly in patients who already have preexisting chronic heart or lung diseases, and reduced lung function growth in infants. In 2015 a review was published in the International Agency for Research on Cancer (IARC) that concluded that outdoor air pollution causes lung cancer [28]. WHO's IARC[29] have reported exhaust emission, particularly diesel exhaust, as deemed carcinogenic. Non-exhausted emission of traffic-related pollutants, wear out of tyre and brakes contributes as much and often more than tailpipe exhaust to the ambient outdoor air pollutants concentrations in cities [27] but no such conclusions have been made in this regard. The increasing level of gaseous pollutants such as SO_2 in tir two cities such as Bareilly could be alarming and may pose serious health hazards to the human health.

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POLYLACTIC ACID AND ITS COMPOSITES: SYNTHESIS AND ADVANCEMENTS

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Abstract
The bio-based polymer Poly-Lactic Acid (PLA) exists as one of the commercialized, environmentally sustainable, and bio-degradable products. Due to its inherent properties, it is currently being implemented in a variety of polymer-dependent industries such as automotive, electronics, packaging, 3D printing, etc. The knowledge of these properties and the process of production for such PLA-based bioplastics, in conjunction with modifications to said processes for appropriate application in specific areas, have catapulted scientific, technological, and commercial advances in this field. In this review, synthetic and bio-based lactic acid production process, recovery and polymerization into PLA, and various applications such as in tissue engineering and drug deliveries have been summarized. The major interest is given to PLA-based composites and their utilization. It provides an in-depth assessment of the various methods and techniques implemented for PLA production and use.

Keywords
Lactic acid; Fermentation; Polymerization; Polylactic acid; Polylactic acid composites.

ABBREVIATIONS
PLA: Poly Lactic acid; **LA:** Lactic acid; **L-LA:** L-lactic acid; **D-LA:** D-lactic acid;
LAB: Lactic acid Bacteria; **D-LDH:** D-lactic Acid Dehydrogenase; **L-DHA:** L-Lactic Acid Dehydrogenase; **MPEG–PLA**: Monomethoxy poly (ethylene glycol)–poly (lactic acid),
ND-ODA PLLA: Octadecylamine-functionalized Nanodiamond (ND-ODA) poly (L-lactic acid): **PGA:** Polyglycolic acid; **PEG:** Polyethylene Glycol; **NP:** Nanoparticle; **PDLLA:** Poly-D-L-lactic acid; **PDLA:** Poly - D-lactic acid

Introduction
Pollution is caused by the discharge of harmful pollutants in the natural environment . Among those pollutants, plastic is highly detrimental to not only the environment but to wildlife and human beings also. Plastics can be said to be originated in 1907, with the invention of Bakelite. This 'Material of a Thousand uses' brought about the rapid production of plastics, which resulted in 7.8 billion tonnes of plastics accounted for by the year 2015. This type of plastic is derived from the conventional petrochemical process that harms the environment and ecology in several ways such as the digestive toxicity to the organisms, use of toxic chemicals during production. This also leads to the upsetting of the food chain and climatic conditions due to the discharge of toxic gases upon combustion . The potential solution of plastic management is the accumulation of plastics in landfills. However, this causes land pollution, and its subsequent interaction with water forms toxic chemicals which then seep into groundwater causing its pollution . Estimations suggest that each year, up to 2.41 million tonnes of plastic enters the oceans .

Polylactic acid or poly-lactide is an environmentally sustainable, compostable, and biodegradable, biopolymer obtained from renewable resources. In 1932, Carothers proposed a lactic acid-derived aliphatic polyester. Among bio-based polymers, it is the most widely studied, utilized, renewably sourced aliphatic biopolymer. It provides an alternative to fossil fuel-based plastics and reduces the negative impact on the environment which results from the accretion of such non-degradable plastics. Polylactic acid (PLA) is obtained from the monomer lactic acid (LA) also

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known as '2-hydroxy propanoic acid'. PLA is one of the renewably sourced commodity polymers that is implemented to replace the currently using plastic material. United States Food and Drug Administration (FDA) identifies PLA in the category of generally recognized as safe (GRAS) , in addition to approving it to be in direct contact with biological fluids. Even among biopolymers, using PLA provides additional advantages such as the fact that its production utilizes carbon dioxide and better processability using fiber spinning, injection molding, etc. The life cycle of PLA is explained in Figure 1. Another strength attributed to PLA is its biocompatibility since PLA itself is not toxic or non-carcinogenic and neither are its degradation products which makes it an appealing choice for biomedical applications. Its biocompatibility can be attributed to the fact that PLA hydrolyses into α-hydroxy acid after implantation into the human body, gets assimilated into the citric acid cycle . It also has good physio-mechanical characteristics such as high tensile and elastic strength. Usage of PLA has been limited from the complete replacement of oil-based plastics due to drawbacks like flame retardancy, brittle nature, poor thermal and mechanical properties at higher temperatures, slow rate of degradation, etc. However, the production of tailor-based products or the use of PLA in conjunction with co-polymers specifically targets such limitations.

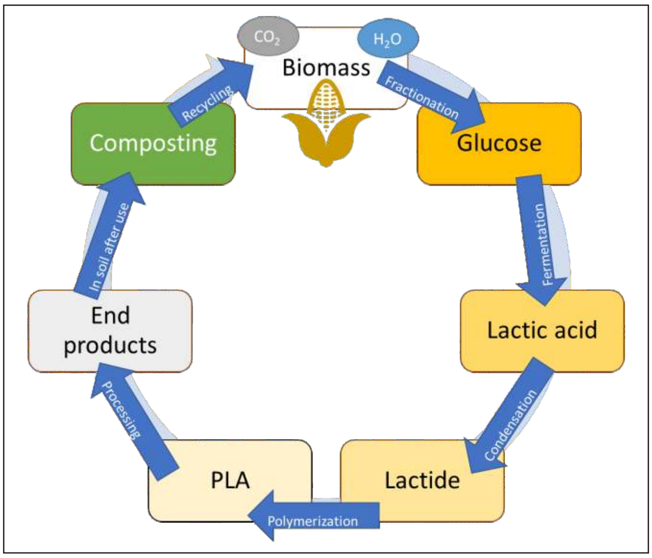

Figure 1: General life cycle of PLA showing stages of production and degradation.

PLA APPLICATIONS FOR COMMERCIAL USE AND MARKET

The drawbacks of oil-based plastics made it imperative to replace them and led to the inception of bioplastics. Due to an ever-increasing demand for plastics, immense social and scientific endeavors were taken to come with various biopolymers. According to the European Bioplastics market, 2.11 million tonnes of bioplastic were globally produced as of 2019 and in 2024, it is estimated to reach 2.43 million tonnes –(12). Among those biopolymers, PLA quickly became the most widely studied and utilized biopolymer due to the many exceptional advantages it has over other biopolymers such as the raw materials required being renewable, having lower energy consumption for production and transformation along with better processability, and a lower amount of toxic fumes being released upon incineration, etc (13). PLA had a worldwide global market value of 689 million USD and is estimated to reach 2.09 Billion USD by 2023 (14). Unique traits like its biocompatibility, thermoplastic processability, biodegradability, etc. coupled with the ability to alter its properties through modifications to suit specific needs have allowed for PLA to be employed in a variety of applications. The most commonly utilized biodegradable polymers employed in the biomedical include poly α-hydroxy acids like Polydioxanone, Polyglycolic acid, PLA, etc (15). PLA has been implemented in the manufacturing of various biomedical equipment like bioabsorbable implants, sutures, tissue engineering scaffolds, covering membranes, delivery system materials, etc.

Tissue Engineering

It is the biomedical engineering field focusing on the development of substitutes for the maintenance, restoration, and improvement of tissues. The major advantages of this field include no requirement of a donor and a lack of transplant rejection (16). Metals as materials for use in tissue engineering had good mechanical properties but did not possess any biodegradability (17). Biostable materials such as PLA were initially utilized as scaffolds for the culturing of cells, which were then transplanted into the tissue. However, in recent times, such materials are developed as supports since they dissolve or degrade from the site of transplantation, resulting in an unimpaired patch of natural tissue (18). PLLA fibers have been proposed for tendon and ligament reconstruction and for a stent in urological and vascular surgery since these applications require a long retention time of strength (19). A three-dimensional PLA porous scaffold has been manufactured for the culturing of various types of cells, for use in cardiovascular disease treatment through cell-based gene therapy, and other orthopedic or neurological ailments ——(2022). Zhang et al. (2011) produced an ND-ODA/PLLA composite similar to the human cortical bone as also an improved alternative for drug delivery through surface modifications (23). BioSeed®-C made from Vicryl (PLA/PGA), is one of the examples of clinically used biopolymer scaffolds and is utilized in cartilage repair (24). Shim et al. (2010) presented a 3D-electrospun scaffold as a favorable cell infiltration and bone formation substrate utilizing a rabbit calvarium defect model and highlighting its use in tissue engineering (25). Ritz et al. (2017) presented 3D-printed discs and cages composed of PLA and filled or coated with collagen promoting cell growth, proliferation, and induction of neo-vessel formation (26). Presently, 3D printing has found its niche application in tissue engineering due to its ability to provide patient-specific biomedical devices using anatomical data (27). Several 3D printed - PLA-based composite scaffolds with improved biocompatibility have been developed for bone repair (2831).

Drug delivery systems

Pharmaceutical companies are constantly trying to innovate and improve the targeted delivery of drugs, maximizing their therapeutic effect and minimizing any side effects. PLA features allow it to be used in the manufacturing of microparticles (MP), nanoparticles (NP), pellets, microcapsules, etc. It was observed that properties like drug loading, release profiles, particle size, etc. could be controlled through ranging ratios of blends MPEG–PLA (32). PLA has been implemented as microspheres in facial reconstructive surgery and transcatheter arterial embolization (33, 34). Electrospun nanofibers PLA/poly (butylene adipate) blend was developed for the regulated release of teriflunomide, an anti-rheumatoid agent (35). PLA-PEG NP was presented as nasal protein carriers via nasal administration(36). PLA vesicles have been manufactured in the form of insulin carriers via oral administration (37). A copolymer of PLA and ethylene-vinyl acetate have been produced as drug carriers, where the amount of PLA regulated the amount of drug released (38). PLA-based commercial products are also available in the dermatological field with Sculptra® as a dermal filter for non-surgical facial rejuvenation(39).

Medical implants

PLA is also implemented in implants such as pins, plates, wires, screws, etc. PLA has been successfully used to manufacture screws and plates for the treatment of fractures (40). Ocular implants were created using PLA and polyvinyl pyrrolidone (PVP) blends (41). Blends of PLLA/PDLLA and their potential in orthopedic or dental implants have also been studied (42). 3D printing was utilized to create an economical PLA/hydroxyapatite screw implant to make it more feasible for clinics, who could print the implant themselves(43).

Other commercial applications

Due to the similar properties of PLA to commercially available plastics, it is a good environmentally friendly alternative for packaging applications. The economic feasibility of PLA as such an alternative has been highlighted in a detailed manner by Fahim et al. (2019). It has been concluded that by replacing all synthetic plastic products with PLA-based products, the global GHG emissions can be reduced by 800 million tons (44). NatureWorks LLC is at the forefront of the PLA production market and its Ingeo™ is implemented in a variety of applications such as 3D printing, cosmetics, household products, construction, packaging, electronics, and appliances, etc (45, 46). Kasirajan et al. (2019) created a PLA/Chitosan-based composite bioplastic using *Prosopis juliflora*, which is an invasive weed in agricultural fields in Asia (47). PLA is also applied in active antimicrobial packaging for application in food packaging, through incorporation or coating with antimicrobial agents (48). Futerro which is a subsidiary of Galactic, a leading Belgian Biotechnology Company, produces PLA fibers for packaging applications (49, 50). Corbion NV, the parent company of PURAC, produces a range of products like standard, high heat, low heat PLA, and PDLA for use as nucleating agents, under the name of Luminy®, in partnership with the Total S.A. It also produces PLA-based components such as air filters, interior trim parts, etc. under the name of Plantura™, along with Röchling Automotive. It also partners with Synbra and SULZER to produce PLA-based Bio foams (5154). Arjmandi et al. (2017) highlight recent developments in PLA nanocomposites for their application in the automotive industry (55). Kenaf fibre-reinforced PLA is used in spare tire covers and is also utilized in mobile phone shells (56). The above-mentioned instances are few examples of the wide-ranging nature of the applicability of PLA and its potential as an alternative to synthetic plastics.

Lactic acid synthesis

The synthesis of lactic acid (LA) generally takes place chemically or by microbial fermentation. In the case of purity, chemically produced lactic acid has less purity due to the formation of racemic mixtures while through microbial production, the pure form could be obtained. L- and D- forms of LA, are the two enantiomers. L-Lactic acid is optical pure in comparison to D-LA and is utilized for producing high crystalline polylactic acids having high melting temperatures (57). The manufacturing process of PLA includes the fermentation of lactic acid in the presence of suitable microorganisms. The overall manufacturing process of PLA is shown in **Figure 2**. The lactic acid is recovered from the fermentation broth using separation techniques such as 2-D electrodialysis or membrane filtration. After purification and recovery, the monomer of lactic acid is changed to a polymer state by polymerization.

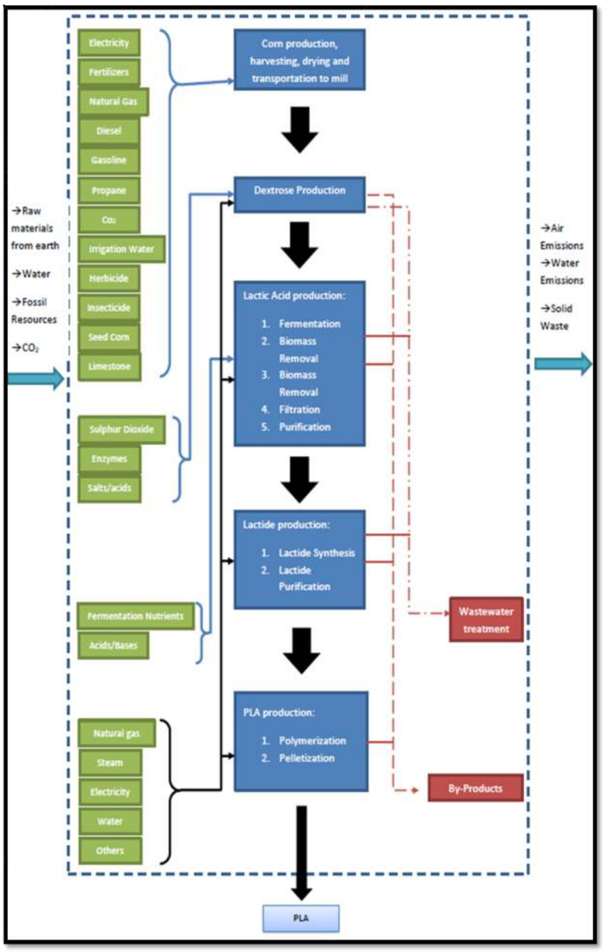

Figure 2: Clarified depiction of PLA manufacturing with the inclusion of a wastewater treatment plant inside the system boundary. The inputs are shown on the right side whereas the emissions at the left

Chemical synthesis of lactic acid

The lactonitrile route is proposed as the conventional route for LA production. The first step involves the addition of hydrogen cyanide to acetaldehyde under high pressure and the presence of a base that results in the formation of Lactonitrile. Further Lactonitrile is recovered from the crude and purified by distillation. Lactic acid is formed when Lactonitrile is hydrolyzed in the presence of strong acids such as HCl and H_2SO_4. Methyl lactate is formed via lactic acid esterification in the presence of methanol. Then, it is further hydrolyzed via water when the acid catalyst is present, to form lactic acid, along with methanol as an end product (57). Monsanto, Texas, USA was the initial manufacturer of LA by chemical synthesis in 1963. The method is expensive and requires several by-products that are obtained from fossil fuel-based industries. Another limitation is the formation of the racemic mixture(58).

Biological synthesis of lactic acid

Industrially, LA is mainly produced by bacterial fermentation because of the advantages such as the use of low production cost compared to chemical synthesis, renewable sources are used as substrates, and produces optically pure isomers of LA. The process involves the breakdown of sugars by micro-organisms into products like ethanol, lactic acid, and citric acid. The use of pure substrates yields optically pure products but thereby increases the production cost (58). Different substrates have been studied for LA production as mentioned in Table 1.

Table 1: Renewable sources used for the production of Lactic acid.

Substrate	Method	Yield	Refs
Cassava	Simultaneous saccharification and co-fermentation	112.5 g L-1	(59)
Sugarcane bagasse	Simple fermentation	55.99 g L-1	(60)
Agro-industrial waste	Batch fermentation	89.4 g L-1	(61)
Cheese whey	Hydrolysis and fermentation	51.2 g L-1	(62)

Based on the bacteria used the process is classified into two broad categories: Homo-fermentative and Hetero-fermentative method. Due to its higher product yield and low by-product formation, the homo-fermentative method is generally used in industries. L.bulgaricus, L. amylophilus, L. delbrueckii are some of the Lactobacillus species at a temperature range of 38- 42 °C, pH ranges between 5.4-6.4 and the concentration of oxygen is kept low. Theoretically, 1.8 moles of LA are produced from 1 mole of hexose, which is around 90 g of LA is produced from 100 g of glucose. By-products are formed at low levels (63). The hetero-fermentative method is characterized by the production of ethanol, mannitol, glycerol, carbon dioxide, and acetic acid, as by-products. The phosphoketolase pathway or 6 phosphogluconate pathway is used by the obligatory hetero-fermentative lactic acid bacteria (LAB), while both the pathways are used for the production of LA by facultative heterofermentative mode (58). LAB requires a complex nutrient supply as its ability to synthesize Vitamin B and amino acids is very low. Simple sugars such as maltose, glucose are used to feed the bacteria. Depending on the operating conditions, LAB may produce both isomers in small quantities, but generally, only one type of isomer is produced by LAB. Fermentation efficiency is affected by parameters such as temperature, pH, vitamin, nitrogen source, substrate, and choice of micro-organisms being the most important parameter. Filamentous fungi such as Rhizopus are also used for the production of LA. Rhizopus can utilize glucose for conversion into LA in an aerobic system. The presence of amylolytic enzymes in Rhizopus species allows the conversion of starch into L-LA. Vigorous aeration is needed while producing LA as Rhizopus is an obligate aerobe. In comparison to LAB, the rate of production is low (58). The co-culture technique was also studied for productivity. In a study, it was seen that when genetically engineered Enterococcus faecalis N4 was co-cultured with L. pentosus, productivity obtained 3.68 g L^{-1} h^{-1} after 12 hours of fermentation, proving that a combination of both may increase the productivity(58).

STRATEGIES APPLIED FOR LACTIC ACID ADVANCEMENTS

Metabolic engineering for lactic acid microbes

This advanced technology is used to design strains that can result in higher production of LA at low cost thereby reducing or removing the by-product formation. The basic problem of LA strains which led to the use and optimization of this technique is the utilization of limited substrates and low acid tolerance. In 2016, a study was done on the D-ldh gene, transferred from Leuconostoc mesenteroides into S. cerevisiae (63). CRISPR Cas9 system was used to metabolically engineer Schizosaccharomyces pombe strain, to produce D-lactic acid from cellobiose and glucose. ADH, GDP, and PDH genes were removed and gene encoding for D-ldh in Lactobacillus plantarum was introduced into the genome of fission yeast. Results showed that 35.5 g L^{-1} of glucose was consumed with a yield of 0.71 g D-LA/g of glucose (64). D-LDHA gene from Leuconostoc mesenteroides was expressed in S. cerevisiae strain JHY5610, whereas the genes involved in the production of the by-products such as glycerol and ethanol were deleted. A new strain named S. cerevisiae JHY5710 was formed as a result of adaptive laboratory evolution. PDCI gene was deleted from the strain JHY5710 and the L-DHA gene from Leuconostoc mesenteroides was added to the strain which was further labeled as S. cerevisiae JHY5730. The production yield of D-LA was found to be 0.83 g/g of glucose(65).

Immobilization of cells

The emerging demand for lactic acid globally results in the requirement of new techniques aiming a higher yield production is needed. Immobilization reduces the waste of biocatalyst activity thereby providing an advantage of reusing it. During, LA production it is important to produce higher yields to fill in the global demand thereby keeping the manufacturing cost low leading to the designing of metabolically engineered biocatalysts. These biocatalysts are expensive and hence the loss of their activity is a threat during production which leads us to think about how to recycle these biocatalysts. Hence, immobilization appeared as a new technique that can allow the reuse of these biocatalysts thereby maintaining a low cost. The basic principle behind the technique is to fix the biocatalyst at specific regions, physically or chemically for a specified reaction to being carried out. Productivity in this case is dependent on the immobilization method and the supporting material used (58). Calcium alginate is one of the most commonly used immobilization matrixes. The method is not used industrially for the production of LA due to the chances of reaction between citrate and phosphate ion which may hamper the process thereby disrupting the immobilized cells leaving the cells free in the fermenter reactor (66). Hence, the need for a new catalyst led to the formation of a mesoporous silica-based material, on which the living cells of Lactobacillus rhamnoses were immobilized. This showed higher efficiency experimentally as no dissolution of the matrix took place. In a study conducted in 2016, Rhizopus oryzae was immobilized on a fibrous matrix in a stirred bioreactor with cell-free fermentation broth. The fermenter design along with other maintained environmental conditions favored the immobilization and high production yield of lactic acid without substrate limitation (67). Immobilized Lactobacillus casei was used for L-lactic acid production from molasses as a substrate along with corn steep liquor as a nitrogen source. Several matrixes such as chitosan, PVA-alginate, sodium alginate, and others were tested. Double layer coated alginate beads immobilized with chitosan and Lactobacillus casei had high stability as well as entrapping efficiency (68).

Fermentation with cell recycling

Cell recycling systems improve process productivity by supporting production at high cell density. The insertion of the microfiltration membrane gives uniqueness to the system. Firstly, the basic systems and stirred tank reactors are joined, whereas, after completion of production, the medium reaches the cross-flow microfiltration module after transfer from the bioreactor (58). In a study, xylose was converted to L-lactic acid by using this method where 0.789 g g^{-1} of yield was obtained with 32.3 g L^{-1} concentration (4). Via the hollow fiber membrane cell recycles fermentation system, recombinant E.coli was used for D-lactic acid continuous production where gene activating pyruvate formate-lyase enzyme was deleted and heterologous β-glucosidase was expressed on the cell surface. The process was carried out in a jar fermenter under anaerobic conditions using cell recycle fermentation. 4.3-5.0 g L^{-1} of D-LA was produced from cellobiose directly for continuous production —(69).

Concurrent fermentation and saccharification

Concurrent fermentation and saccharification have been recently investigated and involves microbial fermentation and one-step enzymatic hydrolysis. LA was produced using sugar bagasse as the substrate using this method. The average productivity was obtained of 0.78 g L^{-1} h^{-1} while 1.14 g L^{-1} h^{-1} was observed when sugar concentration was increased by solubilizing bagasse (70). The use of this process reduces the time of processing thereby decreasing the inhibition of glucose.

Lactic acid recovery

Fermented broth obtained post-fermentation contains LA with several impurities such as sugars, amino acids, proteins, and inorganic salts. To obtain the pure polymer, separation, and recovery from the fermentation broth are important. Solvent extraction, reactive distillation, membrane filtration, hybrid short path evaporation, ion exchange resins are some of the methods studied for purification (71). The methods used for separation and recovery are compared in Table 2.

Membrane separation is widely studied as an alternative for LA purification. Nanofiltration, electrodialysis, ultrafiltration, and microfiltration are membrane-based

Table 2: Comparative study of different separation processes used for lactic acid recovery.

Method	Advantages	Disadvantages
Precipitation	• Simple process. • High yield. • The composition of fermentation broth does not affect the yield.	• Several filtration steps are needed. • Expensive.
Liquid-liquid extraction	• The risk of thermal degradation is reduced. • Chemicals used can be recycled. • Energy consumption is less.	• Distillation needs to be done for recovery. • Chemicals used should have high distribution coefficients are needed.
Membrane process	• The purification level is high. • The rate of selectivity is high. • It can combine with conventional fermenters thereby lowering equipment costs. • Power consumption is low.	• The membrane may disrupt. • Scale-up is difficult. • Expensive.

Reactive distillation	• Lower down cost. • Chemical recycling. • No requirement of catalyst. • The purification rate is high.	• Complex process. • The homogenous catalyst can get corroded easily. • Used specifically in chemical reactions performed reversibly in the liquid phase.

techniques used often. The semi-permeable membrane acts as a physical hurdle for the transfer of solutes, which are further divided into two distinct phases blocking the mixing of the components of the two phases. For the separation of organic acids, electrodialysis is considered one of the efficient approaches. Selectively permeable anionic and cationic membranes are alternatively arranged between cathode and anode. The ions disperse to the cathode and anode based on charge when electricity is applied. This process is used to concentrate the ions in a solution or remove salts. Membranes are non-porous and have a diameter of 10-500 µm. Monopolar and bipolar electrodialysis has been mainly used for LA separation .

A monopolar or conventional electrodialysis system is a two-component system having two sets of anionic and cationic exchange membranes. The system is used for demineralizing or concentrating organic acids. Due to its function of counter ion competition, the system can efficiently separate the organic acid mixture. The bipolar membrane electrodialysis system has gained interest in the past 10 years because of its low effect on the environment . Water dialysis helps to complete the fulfilment of H+ required during the separation and hence no addition of inorganic acids is required. It also helps in the recovery of the base which is required for pH adjustment. An electrodialysis system was prepared using CMI7000 cation exchange membranes, to check the efficiency of separation of LA from fermented whey. Results showed that LA along with other organic acids was successfully separated using the above chose membranes . L-LA was produced by hydrolyzing the organic fraction of municipal solid waste. Monopolar electrodialysis was used for the pre-treatment, where LA was concentrated, and D-LA was removed thereby leaving only L-LA after separation. The optical purity of the enantiomer was observed to be 98% .

PLA processing: from monomer to polymer

Direct condensation polymerization

It is a difficult technique in the case of free solvent systems but is the cheapest route of polymer synthesis. PLA is then produced from high molecular weight LA is more abundant due to its high demand . Low molecular PLA is formed as a result of self-condensation where hydroxyl and carboxyl groups are present in equal concentrations. Various coupling agents are added to form high molecular weight PLA as they will react with the present hydroxyl or carboxyl groups thereby increasing the coupling rate . To acquire high thermal stability, PLA was produced from lactic acid by direct condensation polymerization in the presence of microperlite. Microperlite in the reaction increased the molecular weight of the resultant polymer and increased the rate of crystallinity. It was observed that perlite blocks the rate of degradation due to temperature increase in crystallinity caused by improved orientation of the side chain. FTIR, GPC, and DSC in combination with XRD were used to analyze the chemical structure, molecular weight, and crystallinity, whereas DSC in combination with TGA was used to explore the thermal stability of the polymer. As a result, the temperature for degradation and crystallinity of the polymer was found to be increased which consequently increased the thermal stability of the polymer .

Direct polycondensation in an azeotropic solution

The polymer produced with direct polycondensation has problems such as low molecular weight and is of low quality due to the problems associated with the elimination of the by-products. Several new methods have been developed to overcome this disadvantage where azeotropic and solid-state polymerization are the two main methods used . In azeotropic polymerization, azeotropic solvents are used for the elimination of water. In organic solvents, the equilibrium between monomers and polymers is controlled to produce high molecular weights. The impurities caused by depolymerization and racemization are kept away by lowering down the applied temperature than the polymer melting point .

In an experimental setup microwave system, PLA was synthesized by direct melt condensation polymerization. Microwave power and temperature were kept constant throughout the experiment by applying to cool externally, and for the Microwave transparent liquid, o-xylene was used. PLLA synthesis by L-lactide via ROP method and DMP method was studied to check for the properties of the products obtained and the energy efficiency of both the systems. It was concluded, that 73% of energy-saving was successfully achieved in MW-DMP whereas the production rate also increased by 37.7% .

Ring-opening polymerization

Ring-opening polymerization (ROP) synthesizes functionalized polylactides and polylactides having high molecular weight. The formation of these polymers takes place when the cyclic monomers of ester react with a catalyst and a co-initiator. The initiator or the catalyst is responsible for initiating the reaction. Depending on the type of catalyst ROP is classified into three major reactions: anionic, cationic, and co-ordination insertion . Cyclic dimers of LA formed are referred to as polylactide. The process involves the removal of water from aqueous LA kept in continuous condensation to form prepolymers or oligomers. By transesterification, the obtained prepolymer is catalyzed to form a cyclic dimer which is further purified. The PLA formed is present in three forms- D, L, or Meso lactide, where the first two forms are optically active. At the industrial scale, the lactide's ROP leads to the formation of a family of Lactide co-polymers .

PLA based composites

To address the drawbacks of PLA, reinforcing fibers, MP, NP, and selective additives are added within the PLA matrix to achieve improvements in properties and specific characteristics. The different materials used for reinforcement of PLA are shown in Table 3.

PLA reinforced with fibers

PLA-flax

PLA-flax and PLA composites were manufactured via a film stacking technique, resulting in higher Young's modulus and tensile strength when differed to similar Polypropylene (PP)-flax composites and quite similar to glass fiber polyester composites counterparts. Hence, it was concluded to be a good alternative for glass fiber reinforced unsaturated polyester resins. Sheets produced from both standard and modified PLA-flax mat composites had improved stiffness and impact resistance for PLA . It has been observed that flax fiber content is a vital element in the determination of physical and mechanical characteristics of the composite and increasing flax fiber content results in improved mechanical properties. PLA-flax is a promising material for the automotive industry and can be used as an alternative to PP-flax composites which are utilized currently in several automotive panels. Modified PLA-flax composites with improved toughness and matrix-fiber interactions were obtained through the treatment of Flax fiber surface with corona discharge, aminopropyltriethoxysilane treatment, alkali treatment, and maleic anhydride (MA) grafting.

PLA-kenaf

Kenaf fiber was found to be a good reinforcement fiber for high-performance biopolymers after observing the improvements in properties in PLLA-kenaf composite as compared to kenaf and PLA sheets by themselves . Lee et al. (2009) produced a PLA-kenaf composite with improved mechanical properties, higher heat deflection temperatures (HDT), and reduced water swelling than the standard PLA polymer. Even low (1-5%) Kenaf loadings displayed good matrix-fiber adhesion and improved mechanical properties in PLLA-kenaf composites .

PLA fibers: glass, carbon

RTP Company is a manufacturer of custom thermoplastic compounds and produces PLA-GF compounds with improved mechanical properties such as higher stiffness, tensile strength, flexibility, and HDT . Wang et al. (2019) used silane-modified GF (m-GF) for reinforcement of PLA which achieved greater rigidity, strength, and toughness, and was concluded to be a good candidate for use in automotive and aircraft industries. Ferreira et al. (2017) highlighted the difference in characteristics of PLA-CF and PLA concerning 3D printing. It was reported that short carbon fibers resulted in an increment of the tensile strength of about 2.2 times in the case of PLA-CF composites, as compared to the neat PLA . Li et al. (2016) created a modified CF reinforced PLA composite through a 3D printing approach known as rapid prototyping. It had 13.8% and 164% higher tensile and flexural strength respectively when compared to original PLA-CF composites. PLA-CF composite with enhanced toughness, interfacial capabilities, and good electrical properties was made using styrene-ethylene-butylene-styrene block grafted with maleic anhydride copolymer .

PLA-cellulose

PLA-cellulose nanocomposites resulted in higher storage modulus and yield strength. PLA-Lyocell composite achieved higher tensile strength, the greater value of Young's modulus and hardness, when compared to similar PP and PP-based composites . PLA-Cellulose sphere obtained through the Emulsion-Solvent Evaporation Method was compressed and molded to achieve a biocomposite film. The films had improved toughness, elongation at break, and strength.

PLA-Wood

PLA-wood composite strengths improve due to the wood's inherent strength . Some commercially available PLA-wood composites are Timberfill by Filamentum (70% PLA-30% Wood), corkFill/woodFill by ColorFabb, EasyWood by FormFutra etc .

PLA composites with fillers

Talc

One of the most commonly utilized fillers due to its ability to improve PLA performance at varying loadings. It improves heat resistance, stiffness, molding capacity and reduces production costs for PLA-based composites. The addition of 2% talc resulted in a 65-fold reduction in Isothermal crystallization halftimes, which helps achieve higher crystallinity (an essential parameter for determining heat resistance) and faster processing (101, 102). It was concluded to be effective as an agent of nucleation for the enhancement of the rate of crystallization (102).

Table 3: Materials utilized for PLA reinforcement **(82).**

PLA reinforcement	Type
Fiber-reinforced PLA	Flax
	Kenaf
	Carbon and glass
	Cellulose
	Wood
Filler reinforced PLA	Talc
	Carbonaceous fillers
	Hydroxyapatite
	Barium Sulphate
	Calcium Carbonate

Carbon filler

Carbon fillers are utilized for improving PLA properties like mechanical, nucleating, electrical, etc. PLA-Carbon black composites with higher electromagnetic shielding effectiveness were obtained for use in the electronics industry (103). The conductivity and flexibility of PLA-based composites have also been enhanced using such fillers (104). PL-graphite also provided enhanced mechanical and electrical properties for application in the electrical and aerospace industries(105).

Hydroxyapatite

Hydroxyapatite is a preferred candidate for creating PLA composites to be used in the biomedical field due to its bone-bonding capabilities, biocompatibility, and osteoconductivity. PLA-hydroxyapatite composites achieved enhanced bending strength and interfacial adhesion (106). Mechanical properties such as the tensile strength of PLA- hydroxyapatite were further improved using surface-modified hydroxyapatite (107).

Barium Sulphate

Radiopaque pancreatic stents were created using PLA-Barium Sulphate ($BaSO_4$) (108). $BaSO_4$ was also used for reinforcing PLA-based composites and increased the toughness, with the elastic modulus increasing along with increasing amounts of $BaSO_4$(109).

Calcium carbonate

PDLLA and Calcium carbonate were utilized in PLA composite production for utilization in biomedical applications such as bone replacements (110). Cranial reconstruction implants were made using PLA- $CaCO_3$ with enhanced bioactivity and biocompatibility (111).

CURRENT PROSPECTIVE

This study provides an overview of the various aspects of Poly-lactic acid such as production, improvements, and the application along with changes in trend at present. Though PLA has several advantages over conventional plastics and other biopolymers such as its biocompatibility, renewability, and increased processability, however, it also suffers from limitations such as its higher price compared to its counterparts, use of food crops which damages not only the availability of food but also deals in the destruction of natural habitats. It does not compost fast enough making it unsuitable for industrial composters and the compost itself does not improve the quality of soil, it has lower toughness and higher permeability leading to food spoilage in the case of its application on food packaging –(112). One solution currently implemented to deal with such limitations has been the ability to improve its properties according to the use, via blending different substances to create unique blends of PLA/PLA-based composites (113). Furthermore, it is one of the major reasons for the increased interest in its research. Further research and improvements need to be conducted on novel strains, higher yields, and innovative strategies to promote lower energy utilization without compromising the yield and quality of the PLA produced (114).

Up to the previous decade, PLA was majorly applied in packaging and biomedical applications. However, with newer emerging technologies such as 3D printing becoming mainstream, its range of implementations has further increased. Never avenues for the growth of lactic acid and PLA have emerged with an increment in its usage in cosmetic products like shampoos, creams, etc. due to its ability to lighten skin color, improving elastin and collagen synthesis, improving cell renewability, etc. Currently, 46% of all PLA consumed is for its implementation in the packaging industry with countries like India, China, Russia, and Brazil holding 30% of the market share as global leaders in the PLA industry (115). Several governments and companies have now taken several steps and put in place new policies to reduce/restrict the use of petrochemical-based synthetic plastics and have allocated funds along with providing immense aid to researchers and R&D departments for the development of inventive and innovative approaches to keep up with the ever-increasing and necessary demand for its production. The provided in-depth assessment of the various methods and techniques, both traditional and emerging ones, that are implemented in the PLA production processes can be utilized in aiding further research and improvements shortly.

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CONFLICT OF INTEREST

The authors do not have any conflict of interest.

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OBESITY, EATING BEHAVIOR AND PHYSICAL ACTIVITY DURING COVID-19 LOCKDOWN: A STUDY OF INDIAN TEENAGERS

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Abstract
Lockdowns measures including closure of educational institutions due to COVID-19 may affect youth's activity patterns, psychological stress and obesity status. This is the first kind of study in India on the basis of a large number of teenage subjects from the COVID-19 Impact on Lifestyle Changes. Through an online questionnaire, 144 participants from high schools, aged 10-19 years, voluntarily reported their lifestyles and weight, basal metabolic rate (BMI) status in between 19th July to 12th August 2020 (before and after lockdown). Our data suggest that teenagers having prevalence of significant weight (49.6±15.5 to 52.1±15.2 Kgs p <0.001) and BMI (21.0± 1.2 to 22.7±.1.7 p<0.01) gain. Data further showed that this weight gain was for 71.1 % teenagers and BMI 67.2% subjects. Also, significant decreases were seen in the frequency of engaging in active physical activity, and leisure-time walking, while significant increases were observed in the average sedentary time during weekdays and weekends. Our findings would serve as important evidence for making strategies to counteract or reverse the lockdown effects on youths' obesity.

Keywords
Exercise, Junk food, Obesity, teenagers, Lifestyle, Diet, Exercise, Sleep, COVID-19.

Introduction

The COVID-19 pandemic has compelled nearly everyone to redefine their daily lifestyle-related habits (1). In April 2020, more than 430000 people perished due to the coronavirus in India. (2). On March 21st, the Indian government imposed strict lockdown measures to curb the spread of the virus (3). World Obesity federation reported that countries where more than half the population is obese, have had ten times higher death rates from COVID-19 than the countries where the obese population is lesser relatively (4). These findings emphasize on the need to address the rising obesity epidemic also, alongside the COVID-19 pandemic. Obesity in India has reached epidemic proportions in the 21st century, with morbid obesity affecting 5% of the country's population (5). As unhealthy processed junk food is becoming more accessible, the average caloric intake per individual among more middle class and high-income individuals are skyrocketing (6). The intakes have further skyrocketed during the lockdown due to a sudden and radical shift in lifestyle of the population (7). Physical distancing and self-isolation has caused less socialization and has strongly impacted citizens' lives, affecting in particular eating habits and everyday behaviors (7).

Drastic lifestyle changes have occurred due to two major influences: (a) staying at home [due to digital-education, smart working, limitation of outdoors and in-gym physical activity] and (b) stockpiling food, due to the restriction in grocery shopping. As a result, the lack of physical contact and disruption of work routine produced by the quarantine may result in boredom, which is linked to a higher energy intake (8). In addition to boredom, hearing or reading about the pandemic's bleak state via the media can be upsetting. When compared to general adults, the youth population has been shown to be more vulnerable to changes in lifestyle and eating patterns, which could be seen during the COVID-19 epidemic. Despite the fact that India's lockdown has been removed, state

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institutions continue to encourage preserving social distance, limiting outside activities, and limiting population mobility. For fear of a third wave epidemic, some Indian institutions remained closed until May, and others even required students not to return for the semester. When compared to general adults, the youth population has been shown to be more vulnerable to changes in lifestyle and eating patterns, which could be seen during the COVID-19 epidemic. Despite the fact that India's lockdown has been removed, state institutions continue to encourage preserving social distance, limiting outside activities, and limiting population mobility. For fear of a third wave pandemic, some Indian institutions remained closed until May, and others even required students not to return for the semester (9). Many kids were obliged to stay at home for extended periods of time as a result of these circumstances. (10-11). These foods, which are mostly high in simple carbs, can help to relieve stress by promoting serotonin production, which has a good influence on mood. Beyond a chronic state of inflammation that has been shown to increase the risk for more severe COVID-19 complications, this food craving effect of carbohydrates is proportional to the glycemic index of foods, which is associated with an increased risk of developing obesity and cardiovascular diseases.

Maintaining a healthy and diverse diet, as well as regular physical activity, may be hampered by this new condition. For example, limited access to daily grocery shopping may lead to reduce the consumption of fresh foods, especially fruit, vegetables and fish, in favor of highly processed ones, such as convenience foods, junk foods, snacks, and ready-to-eat cereals, which tend to be high in fats, sugars, and salt. Moreover, psychological and emotional responses to the COVID-19 outbreak may increase the risk of developing dysfunctional eating behaviors (12-13). It is well known how the experience of negative emotions can lead to overeating, the so-called “emotional eating” (14-15). Several studies related to obesity in lockdown have already been conducted in some countries.

A study of 41 children and adolescents with obesity in Italy found that compared to data collected in 2019, three weeks into social lockdown participants reported less time exercising and increased consumption of 'unhealthy' junk foods (16). In a UK study, adults with obesity were more likely to report that they believed that a limited number of behaviors typically protective against weight gain (e.g., physical activity) had declined compared to before lockdown (17), although neither of these studies included validated or widely used measures of physical activity, diet quality or overeating collected during social lockdown. Moreover, the importance of studying weight-related behaviors and understanding barriers to weight management during the COVID-19 crisis is highlighted by higher BMI being associated with an increased risk of hospitalization and death from coronavirus (18-19).

The aim of this study was to examine perceived changes in a variety of weight-related behaviors in a large sample of Indian teenagers during social lockdown (before vs. after), to examine if there were any common barriers to weight management as a result of the COVID-19 crisis. Furthermore, we investigated characteristics linked with and potentially contributing to reduced levels of physical activity and less healthy eating during the COVID-19 crisis by evaluating physical activity levels, diet quality, and problematic overeating during lockdown. Because people with obesity may be disproportionately affected by lockdown measures (for example, due to risk-based shielding measures and limited access to weight management services), the goal of this study was to see how much higher BMI is linked to weight management-related barriers and behaviours during COVID-19 lockdown. We hypothesized that greater BMI would be linked to unfavorable changes in weight-related behaviors and additional weight-management hurdles as a result of the COVID-19 crisis.

METHODOLOGY

Study design and data collection

A total of 144 eligible teenagers were included in this study. Teenagers (ages 10 – 19 years). The average age of the participants was 19·8±2·3 years old (Table 1). The majority of them were female (52·7 %), from Uttar Pradesh (36.1 %), a nuclear family (62.5 %) and from the western region (87·9 %). The most common annual household income category is below Rs. 12,000. None of the high school students from the northeastern and central regions participated in the survey. Between males and girls, there were no significant variations in age or ethnicity.

There remain significant changes of youths' weekly frequency of major food intake after lockdown, with differences between sex and across educational levels in some dietary types.

A Google forms survey was carried out in India from 19th July to 12th August 2020. The subjects were recruited using a snowball sampling method by distributing the survey among several social media groups such as Instagram, Facebook and WhatsApp. All recruited participants have voluntarily reported their basic socio-demographic information and routine lifestyles in the month immediately before the COVID-19 lockdown in India (March 2020, hereafter referred to as before lockdown), during lockdown (July 2020, hereafter referred to as during lockdown) and after the lockdown was lifted (July 2021 hereafter referred to as after lockdown). An informed consent notice was highlighted on the bottom page of the questionnaire, and only those teenagers who consented to have their data used and clicked the 'submit' button were taken into consideration while doing the analysis. The questionnaire was designed to be completed online anonymously.

Table 1: Questionnaires' and responses N=144.

Variable	Number	percentage
Age		
10-15	82	56.9
16-19	62	43.1
Gender		
Male	68	47.3
Female	76	52.7
Which state are you from?		
Uttar Pradesh	52	36.1
West Bengal	44	30.6
Others	48	33.3
Family status		
Nuclear	90	62.5
Extended	54	37.5
Family income (in month)		
<20	44	30.6
20-60k	19	13.2
60-100k	36	25.0
>100K	37	25.7
Weight:		
What was your weight pre lockdown?	49	48.7
What was your weight post lockdown	52.1	51.2
BMI		
Pre lockdown	21.4	49.65
Post lockdown	21.7	50.35
Roughly how many hours are you sleeping at night?		
3-5	12	8.3
6-8	103	71.5
9-11	29	20.1
Do you have any health problems/ existing disease related to obesity		
None	89	61.8
Respiratory	10	6.9
NCD	19	13.2
Other	26	18.1
I have eaten a healthy and balanced diet during lockdown		
1-2 times per week	29	20.1
3-4 times per week	31	21.5
>4 times per week	44	30.6
Not at all	40	27.8
During lockdown, I have eaten junk food		
1-2 times per week	59	41.0
3-4 times per week	35	24.3
>4 times per week	13	9.0
Not at all	37	25.7
During lockdown, I have exercised		
1-2 times per week	23	16.0
3-4 times per week	33	22.9
>4 times per week	76	52.8
Not at all	12	8.3
How many hours approximately a day have you exercised during lockdown?		
< 1 hr	42	29.2
1-2 hrs	75	52.1
3-4 hrs	10	6.9
>4 hrs	7	4.9
Not at all	10	6.9

Inclusion and exclusion criterion

The participants having any pre-existing medical condition (Diabetes, anemia, cancer or any other life threatening diseases are excluded from the study.

Statistical analysis

Continuous data are presented as means and standard deviations (SD) categorical data are presented as absolute and relative (%) frequencies. Chi-squared, t-tests were used to determine differences between groups. A p-value < 0.05 was considered as significant. All analysis was carried out using SPSS version 25.

RESULTS

Socio-demographic profile of study participants

144 teenagers ranging from 10 - 19 years participated in the study. The majority of participants were in the age group of 10-15 (56.9%). 68 males (47.3%) and 78 females (52.7%) participated in the survey. Demographically, 52 participants (36.1%) were from Uttar Pradesh, 44 (30.6%) from West Bengal, and 48 (33.3%) from other states of India. Noticeably, 90 participants (62.3%) belong to the nuclear family compared to 54 participants who belong to the extended family (37.5%). In terms of financial wellbeing, 44 participants (30.6%) of the participants had a monthly income of less than 20000 INR

Table 2: Profile of study participants (n=144)

S. No.	Socio-demographic variable	Frequency (N=144)	Percentage (%)
1.	**Age (in years)**		
	10-15	82	56.9
	16-19	62	43.1
2.	**Gender**		
	Male	68	47.3
	Female	76	52.7
3.	**Indian State**		
	Uttar Pradesh	52	36.1
	West Bengal	44	30.6
	Others	48	33.3
4.	**Family status**		
	Nuclear	90	62.5
	Extended	65	37.5
5.	**Family income/month (INR)**		
	<20k	44	30.6
	20-60k	19	13.2
	60-100k	36	25.0
	>100K	37	25.7
	Not known	08	5.6

COVID-19 lockdown affects the Weight and BMI of the teenagers

A study conducted in the Chinese adult population (22) shows an increasing trend of weight and BMI due to lockdown. Similarly, Chopra et al's study on Indian adults found that their eating patterns changed adversely during lockdown leading to weight gain (23).

However, our data in Indian teenagers showed that lockdown significantly improved the weight gain as well as BMI of both male and female teenagers (Table 3). Our data also showed a similar trend as found by others. Our data father suggest that 71.1% of the subject gained weight in comparison to 67.2% of the subjects' increased BMI.
(Table 3).

Table 3: Weight and BMI changes in Indian teenagers (n= 144).

	Female			**Male**			**Overall**			
	pre lockdown weight	pre lockdown weight	P value	pre lockdown weight	pre lockdown weight	P value	pre lockdown weight	pre lockdown weight	P value	% Change
Weight	45.1±11.8	47.1±11.4	<0.001	54.6±17.5	57.7±17.0	<0.001	49.6±15.5	52.1±15.2	<0.001	71.1
BMI	19.1± 5.1	20.9±1.6	<0.01	23.0±2.0	24.5 ±2.7	<0.01	21.0±1.2	22.7±.1.7	<0.01	67.2

DISCUSSION

The COVID-19 pandemic has severely affected people's everyday routines in India. Initially, the country's lockdown had ramifications in terms of food availability and use, putting a strain on normal food-related behaviour (13). Furthermore, in order to combat the spread of COVID-19, gyms, fitness facilities, and limitations on visiting parks, playgrounds, and other public places have been closed, limiting access to numerous forms of physical activity (14-15). Furthermore, confinement could have influenced sleeping patterns (5). Deviation from a healthy lifestyle can increase the chance of developing obesity and aggravate the condition of individuals who already have it (6). In light of the aforementioned concerns, it is crucial to determine the extent to which this pandemic and its associated restrictions have affected people's lifestyle-related behaviour, such as food habits, physical activity, and sleep patterns, particularly among teenagers.

This study assessed weight gain and BMI variations among Indian teenagers as a result of lockdown, as well as changes in eating patterns and physical activity. The questionnaire's diet-related questions look at how often people eat main meals, how often they snack, how much they eat healthy foods like whole grains, fruits and vegetables, eggs, and nuts, as well as how much they eat unhealthy foods like fried food, junk food, and sugar-sweetened products.

In addition, there are only a few elements dedicated to analysing immunity-boosting food intake. In addition, some physical activity questions examine the participants' participation in aerobic exercise, household-related tasks, sitting time, and screen time. Throughout the pandemic, experts from all around the world have shown a significant interest in assessing people's lifestyle-related behaviour. The self-developed questionnaire utilised on the Polish population, on the other hand, examines solely people's dietary choices and habits during the COVID-19 epidemic (16). Furthermore, the tool's reliability and validity are dubious. The questionnaire employed in another study was not well-designed and applicable to Indian citizens.

Increased screen time was connected with alcohol and sweets during the COVID-19 pandemic, depending on the screen device. Increased television and cell phone time were linked to higher sweetened food intake and a desire to consume alcoholic drinks, whereas increased computer time was linked to lower alcohol and sweetened food consumption. For further examination of hazardous behaviours caused by the epidemic, increasing screen time spent on the television and cell phone must be taken into account.

The crucial findings of the survey divulge certain trends in eating habits and physical activity behavior among teenagers. Our survey further showed the increasing trend of weight gain and BMI during the lockdown. This might be due to less physical activity and a sedentary lifestyle. Obviously, psychological behavior and mindset are also other important factors that make teenagers more inclined towards a sedentary lifestyle, leading to weight gain.

This is the first pan-India study of teenagers, with the goal of recruiting a representative sample for data collection via a pre-validated questionnaire to investigate the impact of COVID-19 on lifestyle-related behaviors. Some of the study's shortcomings include the possibility of reporting bias owing to the e-survey, and the validity of responses, which is a common concern with online surveys.

CONCLUSION

In conclusion, the preventative measures enacted/adopted to control COVID - 19 had a mixed influence on lifestyle-related behavior, with considerable improvements in regular meal consumption patterns and healthy eating behavior, as well as a reduction in unhealthy food intake, as positive indicators. Therefore, this study delineated the fact that continuous inaction among teenagers also improves weight gain which leads to a sedentary lifestyle and cardiovascular diseases in the future. Therefore, physical activities are the main factor to keep the teenage population healthy.

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SAVE THE ENVIRONMENT (STE) was founded and registered on 19th November 1990. In 1992 with the collaboration of WWF (India), the organization started working to combat arsenic poisoning problem of water in the arsenic prone areas of West Bengal. Since then STE has been involved in various projects related to combat arsenic problem in India.

Our Vision

To protect present and future generations from various environmental hazards.

Our Mission

To create awareness and motivation among rural communities & provide cost effective, energy efficient & environment friendly technologies.

Our Activities

Conducting interactive sessions, workshops/ seminars, awareness programs, field operations through projects, science fairs, posters & quiz competitions.

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