IMPETUS OF CIRCULAR ECONOMY: EMERGING TRANSFORMATIONAL TRENDS IN ELECTRIC ENERGY BUSINESS

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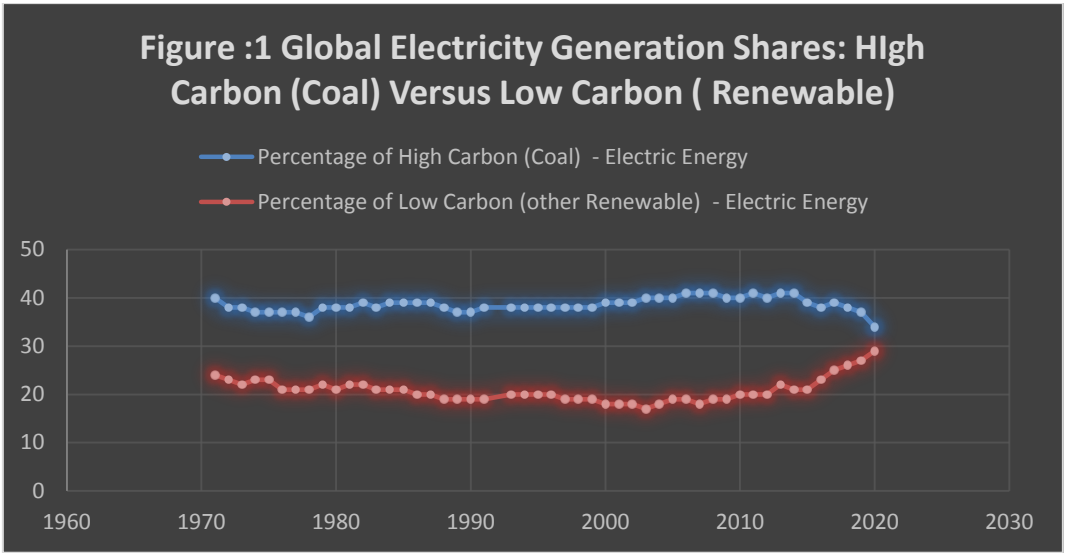
Abstract
The perseverance of this chapter is to present the vital haulers of Electric Energy transition through real-world seamless applications of circular economy explicitly connoting to Environmental Sustainability Effectiveness, Energy security with sensible deployment of resources and continuum long term pervading inflection on Green Electric Energy Business. A few illustrations and cases of selected thermal power plants on current prominent high-tech innovations of South Indian State in particular is presented as an exemplary.

1 Electric Energy Sector and Sustainable Development

Copious nations at the Intercontinental level are in the pivotal point of an Energy Metamorphosis that comes in to sight to have a preference for Electric Energy as the most ideal conclusive efficient energy carrier. Along with this, the most vital rudimentary conversant datum with universal truth underpinnings, from spells immemorial to contemporary times coal based energy feedstock's for electricity generation are a hub for emission of negative environmental externalities such as air pollution at an exorbitant levels especially in progressive economies like India. The deliberate and determined efforts of India as vibrant part of 2030 Agenda for sustainable energy have paved the pathway for a swift shift from Linear Economic Models to Circular Economy Models in its all-pervading economic activities through strictly imbibing high technological breakthroughs as a counteracting measure along with strict regulatory regimes and optimal resource utilization. But to a matter of a grave concern, these pertinent issues largely remain ignored to a desirable extent in certain states of the country, with a notable estimation of worrying statistics.

1.1 Coal Based Electric Energy and Air Pollution Emissions

India being the fourth largest consumer of electricity in the world has its reliance on dirty feedstock coal for base load electricity production and this will exponentially get bigger in next 30 years. The Green Energy Business initiatives of huge investments in renewable sources of energy such as solar and wind energy can only be benefactor of ascribing partial utility with a complementarity role but will not guarantee as a complete substitutability feedstock in relative comparison with coal. The long term measurement of trend analysis (1971 to 2020) in percentage terms of Global , power mix that constitutes high carbon emission of non-renewable energy and low carbon emission of other renewable (bio fuel, Geothermal , tidal, wind and solar PV and Thermal) clearly exhibits the highest demand for coal generation during pre- covid times (up till 2018) but during covid era there was an surge in demand for low carbon energy sources.



1.2 Status of Pollution Control Norms: Indian Scenario

India's repeated catastrophe of compromising with non-adherence to pollution norms for a substantial portion coal based power plants as per Global standards have resulted in a mishap of omitting the unique deadline of 2017. Known with the conversant fact of India's coal reserves accounts for 205 GW of power production, i.e. nearly 56 percent of over-all installed electric energy generation volume in the country with 77 percent of its electricity supply. This kind of alarming situation triggering over time need to be taken in to precedence as the most time pressing need of hour by ensuring a cleaner environment. The Centre for Science and Environment appraised that at present power generation accounts 70 percent of fresh water withdrawals by industry, 60 percent of industrial Particulate matter (PM), 45 percent of sculpture di oxide and 30 percent of Nitric Oxide emissions and with 80 percent of mercury as pollutants. The deadline for meeting compliance benchmarks have taken a back seat by extending the duration for the year 2020. (Environment Pollution Agency). More than 300 power plants across the nation in Energy Business need to install Circular Economies Strategies. In an official proclamation , dated January 31st, 2020 the Finance Minister of Government of India staunchly recommended to shutdown few thermal utilities that have failed to meet the regulation standards with regard to emissions of PM, SO2 and NOx across the country. The central Pollution Control Board issued notices to thermal plants in Haryana, Punjab, Uttar Pradesh, Telangana, Andhra Pradesh, and Tamil Nadu under section 5 of Environmental Protection Act.

1.3 Spearman Rank Correlation Analysis: Trajectories Estimates

The various economic activities in Krishna District of Andhra Pradesh State are described by resource dependent manufacturing businesses comprising coal, crude oil, machinery and chemical production. For instance as an Electric Energy base and area of heavy industry, Krishna District plays an imperative role for a pecuniary progress of state. As a result, there is an imperative requirement to reconnoiter the various circular materialization contrivances, along with influencing factors and counteracting processes for extenuation of air pollution. This paper engrossed on the methods of Spearman's rank correlation coefficient to establishing mathematical

model. It analyzed the monthly data for the year 2018-2019, relating to the correlation between the content of PM and corresponding pollutants SO2 and NOx, thereby providing theoretical and experiential evidence for air pollution management work. This chapter aims to study whether there is specific association between two observed variables PM, SO2 and PM, NOx and to estimate the strength of relationships. The statistical experiential outcomes yields the succeeding spearman's association end result.

The following data comprises 18 pairs, 23 pairs, 10 pairs, 11 pairs and 11 pairs of PM, SO2 thermal pollutants of Stage I, II, III and IV samples that were collected from a selected thermal power plant of Andhra Pradesh. Similarly 18 pairs, 21 pairs, 10 pairs, 11 pairs and 11 pairs of PM, Nox thermal pollutants of Stage I to IV of power plant were also collected. Is it of concern to identify if the two environmental pollutant variables are interconnected?

Spearman Rank Correlation (rho) Empirical Results of Thermal Environmental Pollutants in selected power plant of Andhra Pradesh: 2018-2019

PM and SO2	Stage I (unit 1 and Unit2) - 2x210MW	Stage II (unit 1 and Unit 2) 2x 210 MW	Stage III (Unit 1) 210 MW	Stage III (Unit2) 210 MW	Stage V (Unit 1) 500 MW
N	18	21	10	11	11
Rho	0.677745	0.07073	0.490909	0.096558	-0.17432
t-stat	3.686916	0.30908	1.59376	0.291034	-0.53109
p-value	0.001997	0.760625	0.149656	0.777621	0.608212
P<0.05	P less than 0.05	P not less than 0.05	P not less than 0.05	P not less than 0.05	P not less than 0.05

PM and NOx	I	II	III	IV	V
N	18	21	10	11	11
Rho	0.336278	0.518881	0.624242	0.059774	0.316527
t-stat	1.42829	2.645794	2.260055	0.179643	1.001052
p-value	0.172438	0.015944	0.053718	0.861412	0.342955
P<0.05	P not less than 0.05	P less than 0.05	P not less than 0.05	P not less than 0.05	P not less than 0.05

The stage I of power plant , 18 pairs of two observed variables PM,SO2 and Stage II 21 pairs of two variables PM, Nox appears to have significant spearman correlation coefficient with value of 0.6777 and 0.5188 that signposts a robust positive correlation concerning the two variables. However there is a warranted necessity to execute significance investigation to resolve whether based upon this sample, there is slightly or certainly not any confirmation and evidence to recommend undeviating correlation is existent in the population. To perform this, the chapter emphasizes upon testing the null hypothesis, Ho that there is no similarity of association in the population against the alternative hypothesis H1, that there is a monotonic

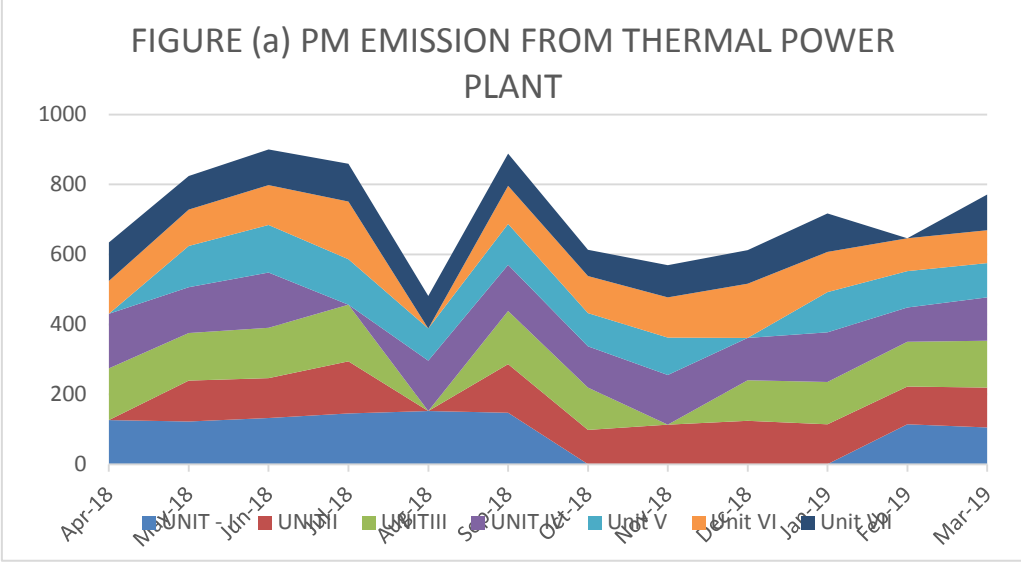
correlation. The statistics will specify which of this divergent hypothesis is utmost expected to be accurate. This can be articulated as

Ho: Ps=0

H1: Ps≠ 0

I.e. the null hypothesis connotes to no monotonic correlation existent in population in contradiction of the alternative, that there is monotonic correlation existent. This may possibly be described as follows: A spearman's correlation was run to govern the relationship between 18 pairs of PM, So2 values and 21 pairs of PM, Nox values. The test reports that the p value for this test recorded as being 0.001 and 0.015 i.e. less than 0.05. It can be mentioned experientially that there was a very strong evidence to believe H1i.e. PM, So2 and PM, Nox are monotonically correlated in the population. There was a strong positive monotonic correlation between PM, So2 and PM, Nox (rho=0.677, n=18, p<0.05) and (rho=0.5188, n=21, p<0.05) that are statistically significant. The remaining stages of thermal power plant exhibited a small positive responsiveness of these three pollutants (So2, Nox and PM), that are quite evidentially purported for a scientific claim that null hypothesis can be rejected and alternative hypothesis is accepted by a fact that, thermal air pollution contribution is through Nox and So2 to particulate matter by violating the standard norms of Pollution Control Board (See Exhibit 1). The stage IV of PM and So2 exhibited a small negative association correlation r= -0.17.

The graphical illustrations of the selected Power Plant of Krishna District, depicts fluctuating tendencies of three thermal pollutant



The Figure (a) of Particulate Matter Chart displays a stacked area exhibiting relationship of pollution parts to whole over 12 monthly period of year 2018-2019. The magnitude of change overtime draws the attention towards the total value across a trend. Unit VII of stage IV exhibited a declining trend in its pollution levels unlike other units.

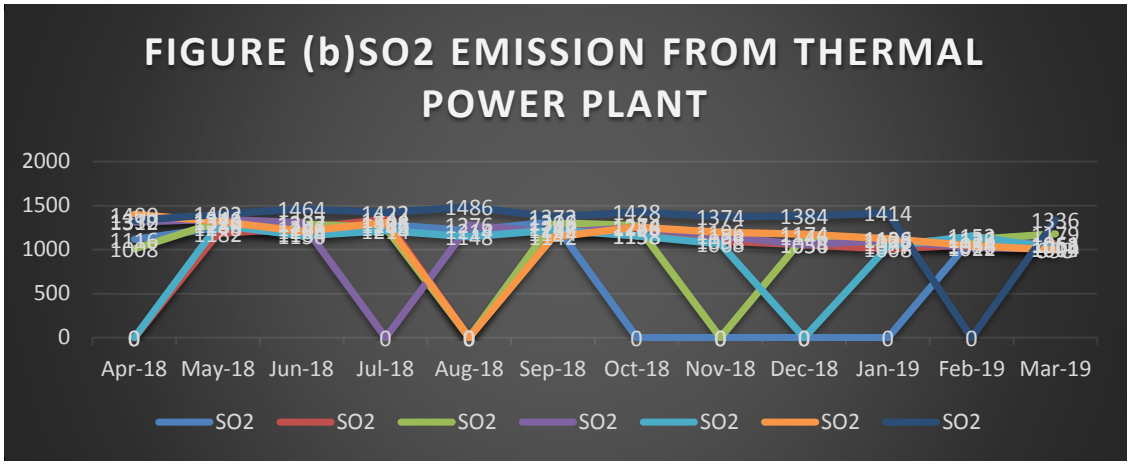
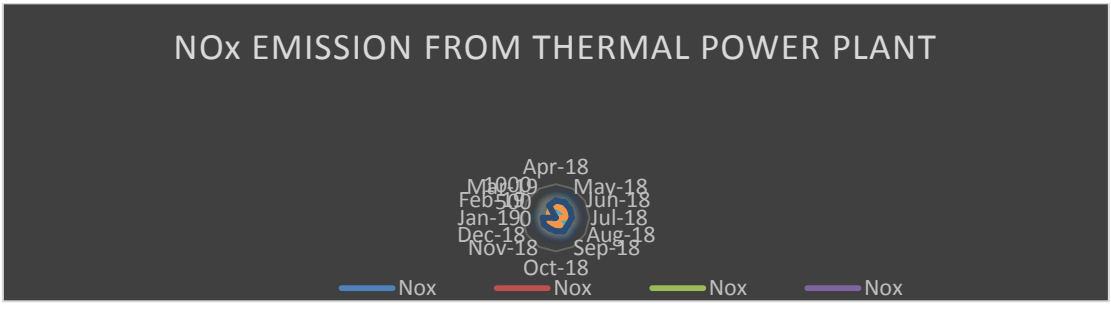


Figure (b) portrays an increasing trends throughout all the units of power station. The inverted V shaped strikingly denotes that the power station is not in service for certain duration of months. This kind of line chart, is used to display trend overtime. Figure (c) scrutinizes the radar representation of Nox emission with a centrifugal point spearing ahead with increasing trend over a period of time.



1.4 Circular Economy Strategies of Thermal Power Plant

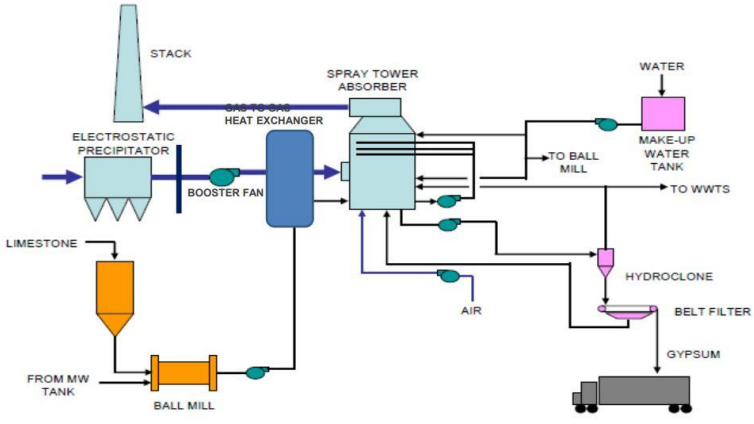
The voluminous production of coal combustion residues are having undeviating linkage with combustion process in thermal power stations. The enumeration of mineral compositions comprises of arsenic, cadmium, beryllium, boron, chromium, cobalt, lead, mercury, manganese, molybdenum, selenium, fly ash and dioxides. The reprocessing of these produces aids to alleviate the environmental harmful constituents and re-claim the industry by products as another industry raw materials. The procedure involves importance of handling scraps as efficient means in a padlocked circlet. For this tenacity, the fundamental worth of each material for recycle is taken in to account by means of scientific reusing availability, economic pragmatism and ecological requirements. Reuse potential indicator by Park and chertow in contemporary times enables for managing wastes as resources. This kind of circular material economies involves sustainable material management that is established on resource paradigm. This indicator enables to have a replication of varied technological innovations and commercial application of actual reuse for prospective Energy Businesses.

2.0 Green Technology Practices and Cost Effective Concerns

It is very much enchanting and appreciable to document the pertinent circular business model strategies replicated by Thermal power Station of Krishna District by taking a staunch stance to imbibe Green Technology in all the stages of power plant by adhering to strict norms of Central Pollution Control Board, by 31.12.2020.

Flue Gas Desulphurization (*FGD*)

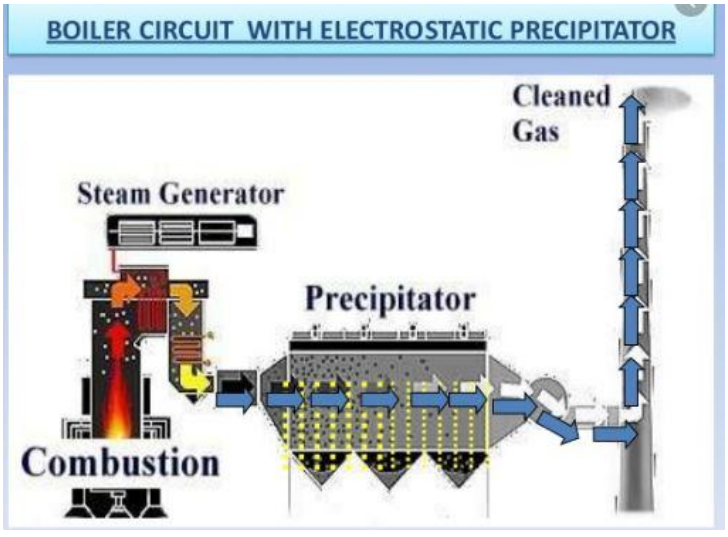
As a part of putting in to practice the application of green technological breakthroughs prepared by Central Electricity Authority (CEA), the prevailing Thermal Power Plants (TPPS) are obligatory to act in accordance with the new emission standards by the year 2022. These technologies thereby restrains the sulphur content to a maximum of 0.49 per cent and accomplish 90.6 per cent of SOx (sulphur oxide) removal efficiency.



As per a contemporary Centre for Science, Technology and Policy (C-STEP) , FGD in TPPs necessitates an estimated disbursement of Rs 50–60 lakh per MW. The study has anticipated that, to meet the supplementary expenses and innovative emissions standards, the electricity charges may need to skyrocket by 25-75 paise per kWh. In that way, the government informed that investments for emission control technologies such as FGD would be well thought-out for license authorization through tariffs.

Electro Static Precipitators (ESP)

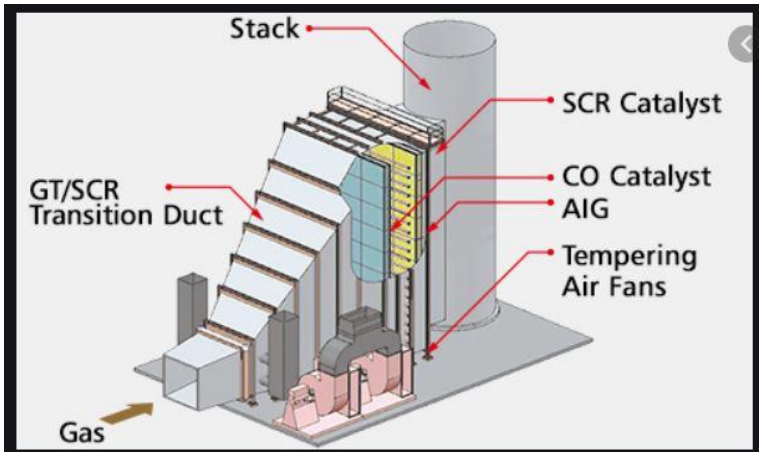
The derivative of coal ignition frequently called ash powder so formed cascades under two groups *viz*. Bottom ash and Fly ash. Lowermost slag is composed at the lowest of the boiler units while fly ash is poised in electrostatic precipitators and economizer hoppers. Customarily in a coal fired boiler, twenty percent of the whole ash is bottommost ash and balance eighty percent is fly ash. Air pollution regulatory apparatus for today's prerequisite are Electrostatic Precipitator (ESP) are in grander use.



They are extensively used all over the world for enhanced performance and improved dust assemblage competence. It is a consistent and confirmed technology which knows how to effectually handle enormous masses of coarse type fly ash without any operational problems. Energy saving facet on this controlling measures is certainly stimulating. For improvement of ESP performance, advancement of new technology and improvement of electronics & materials are in incessant method of enhancement.

De-Nox System

When coal is charred in a boiler, fragment of the nitrogen contained in the coal and air retorts with oxygen and NOx is produced. With well-nigh applied a new-fangled perception called “NOx lessening in flame”—namely, breaking down NOx resourcefully by directing combustion conditions in a blaze.



Furthermore, a technology for dipping the attentiveness of NOx emitted from a boiler is plausible to a firm level without the usage of a catalyst. Nevertheless, to decrease NOx concentration underneath that level, a catalyst and ammonia which is utilized as a reducing agent are compulsory. The thermal power plants need to employ selective catalytic reduction (SCR) knowhow for left-over detonation and other engineering processes.

The findings were compiled with a tabular illustration as follows:

Timelines given by CPCB for compliance

Stage	**Compliance**	**Time schedule/ Target date for compliance**
PM	**ESP up gradation plan**	
Stage – I	Measured PM levels are in the range of 100-150mg/Nm3 and higher than the new MOEF limit. M/s. BHEL suggested ESP up-gradation plan to meet the new limit.	31.12.2020.
Stage-II		31.12.2020
Stage-III		31.12.2020
Stage-IV		31.12.2020
SO2	**FGD Implementation plan**	
Stage-I	FGD is to be implemented. M/s. BHEL suggested FGD scheme	31.12.2020
Stage-II		31.12.2020
Stage-III		31.12.2020
Stage-IV		31.12.2020
NOx		
Stage-I	**Installation of De-NOx system**	31.12.2020
Stage-II	Complied	
Stage-III		
Stage-IV	BHEL suggested By-pass over fire air (BOFA) system and in-furnace NOx mitigation measures.	31.12.2020

TABLE 1ENVIRONMENTAL THERMAL POLLUTION EMISSIONS : POWER PLANT OF ANDHRA PRADESH (2018-2019)

Month	**UNIT - I**			**UNIT - II**			**UNIT - III**			**UNIT - IV**		
	PM	**SO_2**	**NO_x**	**PM**	**SO_2**	**NO_x**	**PM**	**SO_2**	**NO_x**	**PM**	**So2**	**NOx**
Apr-18	126	1116	221	NS	NS	NS	148	1008	374	156	1312	328
May-18	122	1248	296	117	1182	258	136	1314	322	131	1346	304
Jun-18	132	1184	240	114	1246	212	144	1292	293	158	1307	274
Jul-18	145	1286	284	149	1344	312	162	1248	256	NS	NS	NS
Aug-18	152	1214	223	NS	NS	NS	NS	NS	NS	144	1312	278
Sep-18	147	1316	318	139	1244	296	152	1008	324	132	1346	284
Oct-18	NS	NS	NS	98	1158	246	121	1314	212	118	1307	254
Nov-18	NS	NS	NS	113	1098	218	NS	1292	NS	142	1154	236
Dec-18	NS	NS	NS	124	1054	194	116	1248	237	121	1056	218
Jan-19	NS	NS	NS	114	1008	204	121	1072	268	142	1108	192
Feb-19	114	1126	232	108	1054	202	128	1112	193	98	1022	212
Mar-19	105	1053	276	114	1061	319	134	1179	284	124	1009	276

Month	UNIT - V			UNIT - VI			UNIT - VII		
	PM	SO_2	NO_X	PM	SO_2	NO_X	PM	SO_2	NO_X
Apr-18	NS	NS	NS	94	1400	344	110	1330	509
May-18	118	1280	353	104	1322	316	96	1402	528
Jun-18	136	1156	312	114	1208	334	102	1464	492
Jul-18	130	1214	346	165	1308	384	108	1422	476
Aug-18	92	1148	256	NS	NS	NS	93	1486	422
Sep-18	117	1222	300	109	1142	252	92	1372	454
Oct-18	95	1158	218	106	1256	224	75	1428	408
Nov-18	107	1068	222	115	1196	244	92	1374	374
Dec-18	NS	NS	NS	155	1174	248	96	1384	412
Jan-19	115	1037	208	115	1126	236	110	1414	396
Feb-19	104	1152	246	94	1046	230	NS	NS	NS
Mar-19	98	1014	292	94	998	324	102	1336	410

Stage	**Designed/ / monitored** **mg/Nm3**	**New MoEF limit** **(2020) mg/Nm3**
PM	Design levels	Limit
Stage – I	50	100
Stage-II	150	100
Stage-III	100	100
Stage-IV	100	50
SO2	Monitored levels	Limit
Stage-I	1200-1500	600
Stage-II	1200-1500	600
Stage-III	1200-1500	600
Stage-IV	1200-1500	200
NOx	Monitored levels	Limit
Stage-I	300-450	600
Stage-II	300-450	600
Stage-III	300-450	600
Stage-IV	300-450	300

References

1. Ellen MacArthur Foundation, SUN, and McKinsey Center for Business and Environment, Growth Within: a circular economy vision for a competitive Europe (2015)
2. IEA, CO2 emissions statistics (2019); World Economic Forum, The number of cars worldwide is set to double by 2040 (2016)
3. Field Work Documentation of Research Results of Thermal Power Plant of Andhra Pradesh, 2020