ISSN: 0975-833X

Available online at http://www.journalcra.com

International Journal of Current Research
Vol. 16, Issue, 01, pp.26831-26835, January, 2024
DOI: https://doi.org/10.24941/ijcr.46502.01.2024

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

RESEARCH ARTICLE

INVESTIGATION OF ENVIRONMENTAL KUZNETS CURVE FOR POLLUTANT EMISSION LEVELS IN DHANBAD, JHARKHAND

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ARTICLE INFO

Article History:
Received 25th October, 2023
Received in revised form
27th November, 2023
Accepted 15th December, 2023
Published online 19th January, 2024

Key words:
Environmental Kuznets Curve, Gross Domestic Products, Pollutant Emissions, Sequential Mann-Kendall Test.

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ABSTRACT

This study aims to explore the possible relationship between economic growth and pollutant emissions in Dhanbad, Jharkhand. Specifically, the focus will be on three pollutants: nitrogen dioxide (NO_2), particulate matter (PM10) and sulphur dioxide (SO_2). The results of Sequential Mann-Kendall test statistics indicate that per capita GDDP has been increasing since 2015, which is statistically insignificant. However, there is a significant SQ-MK change point for pollutant emission levels in this analysis. The study also shows that economic growth correlates with higher levels of pollutant emissions. According to the study, there is a significant negative relationship between per capita GDDP and nitrogen dioxide concentration, with a correlation coefficient of -0.72. The study also found a negative correlation between GDDP and particulate matter (PM10) concentration, with a correlation coefficient of -0.3. Furthermore, the study suggests a strong negative correlation between GDDP and sulphur dioxide concentration in the context of Dhanbad, with a correlation coefficient of -0.8. According to the EKC analysis, nitrogen dioxide concentration, particulate matter (PM10) concentration, and sulphur dioxide concentration exhibit a statistically significant U-shaped Environmental Kuznets Curve.

Citation: ***Amit Bara.*** **2024.** "Investigation of environmental kuznets curve for pollutant emission levels in dhanbad, Jharkhand". *International Journal of Current Research*, 16, (01), 26831-26835.

INTRODUCTION

Industrialization, which is often associated with economic growth, has been found to be a key contributor to environmental degradation, particularly air pollution. This is mainly due to the high levels of fossil fuel combustion and subsequent gas emissions such as carbon dioxide, nitrogen dioxides, particulate matter (PM10), carbon monoxide, and sulphur dioxide, resulting from industrialization in most developing countries. These pollutants have a direct impact on human health and the ecosystem, and their emission levels have continued to rise over time. Many researchers have explored the relationship between economic growth, energy consumption, and the release of pollutants (Soytas *et al.* (2007); Ghosh (2009); Zhang *et al.* (2009); Shahbaz *et al.* (2012); Ahmed *et al.* (2017); Bara *et al.* (2023a,b,c)). An analysis conducted by Fodha et al. (2010) in Tunisia has shown that there exists a long-run correlation between the per capita emissions of two pollutants and the per capita GDP. The study reveals an inverted U-shaped relationship between emissions (SO_2) and GDP. The findings indicate that income has a one-way causal relationship with pollution in Tunisia. Govindaraju et al. (2013) conducted an analysis in China and India. They found a long-term correlation between carbon emissions, economic growth, and coal consumption in China, but not in India. However, in the case of India, only a short-term causality is identified. A study conducted by Sinha et al. (2016 & 2017) examined the levels of NO_2 and SO_2 emissions in Indian cities. The study found that the non-rejection of the EKC hypothesis emphasizes the impact of economic policies that promote growth on the environment. This paper examines the relationship between economic growth and environmental degradation.

The paper is structured as follows: Section 2 describes the study area, Section 3 discusses the methodology and data collection, Section 4 presents the analysis's empirical results, and the final section concludes the study.

DESCRIPTION OF THE STUDY AREA: Dhanbad is a district located in the Indian state of Jharkhand. It covers an area of 2,040 square kilometer's and is located at $23.7998^{\circ}N$, $86.4305^{\circ}E$ with an elevation of 728 feet above sea level. The district has a population of 2,846,954 people and is divided into 1 sub-division, 10 blocks, and 1209 villages. Dhanbad is known for having one of the oldest and largest markets in the region, as well as being a center for large-scale industries such as mining, utilities, retail, IT, and cement. It is also referred to as the coal capital of India. However, it is important to note that Dhanbad is the second most polluted city in the state of Jharkhand, after Jamshedpur (Fig. 1.)

MATERIAL AND METHODS

To investigate the correlation between economic growth and pollutant emission levels in Dhanbad, Jharkhand, this study has selected the following variables: per capita Gross District Domestic Product (GDDP), Nitrogen Dioxide (NO_2), Particulate matter (PM10), and Sulphur Dioxide(SO_2). The data for GDDP was obtained from the International Crops Research Institute for Semi-Arid Tropics, District level Data (DLD) for India, while the population data was sourced from the Dhanbad Census of 2011.

Fig. 1. Location map of Dhanbad, Jharkhand

For this research, nitrogen dioxide, PM10, and sulphur dioxide concentration levels were collected from the Central Pollution Control Board of the Ministry of Environment, Forest, and Climate Change of the Government of India.

PEARSON'S CORRELATION COEFFICIENT

Bivariate correlation is a statistical technique that helps to gauge the strength of the linear relationship between two variables. It is calculated by dividing the covariance of two variables by the product of their standard deviation. The correlation coefficient can range between -1 and 1, with values closer to -1 indicating a negative correlation, values closer to 1 indicating a positive correlation, and a value of 0 indicating no correlation between the variables.

Pearson's correlation between the variables p and q is defined as follows:

$$\text{Correlation}(p,q) = \frac{\text{Cov}(p,q)}{\lambda_p \lambda_q} \quad (1)$$

Where $\text{Cov}(p,q)$ is the covariance of p, and q and is given by

$$\text{Cov}(p,q) = \frac{1}{(n-1)} \sum_{j=1}^{n} (p_j - \bar{p})(q_j - \bar{q}) \quad (2)$$

Where $\bar{p}$ and $\bar{q}$ are the mean of the variables p and q, respectively and n is the sample size. And, λ_p and λ_q are standard deviations of p and q, respectively (Gupta (2017)).

SEQUENTIAL MANN-KENDALL TEST

The Sequential Mann-Kendall (SQ-MK) (Sneyers (1990)) test is a statistical method used to identify abrupt changes in significant trends. The test creates two series, a progressive series u(t)and a retrograde series $u'(t)$. When the two series cross and diverge beyond a certain threshold value, it indicates a statistically significant trend. The intersection point of the two series gives an estimate of the year when the trend begins. In this study, the threshold values are ±1.96 ($p \leq 0.05$), and the crossing point estimates the year when the trend starts.

The procedure of the SQ-MK test is as follows:

- For every comparison, we count the number of cases where $x_i > x_j$ and denote it as n_i. Here, x_i and x_j; $i, j = 1,2,\ldots,n$ are sequential values in a series.
- The test statistic t_i is calculated by
- $t_i = \sum_{j=1}^{i} n_j$ (3)
- The mean $E(t_i)$ and the variance $\text{var}(t_i)$ of the test are calculated by
- $E(t_i) = \frac{n(n-1)}{4}$ and $\text{var}(t_i) = \frac{i(i-1)(2i+5)}{72}$ (4)
- Sequential progressive value can be calculated as
- $u(t_i) = \frac{t_i - E(t_i)}{\sqrt{\text{var}(t_i)}}$(5)
- Similarly, $u'(t_i)$ is calculated in reverse order from the end of the sequence.

ENVIRONMENTAL KUZNETS CURVE HYPOTHESIS

The Environmental Kuznets Curve (EKC) (Kaika *et al.* (2013)) is a theory that describes how environmental degradation and GDP per capita are related. According to this theory, in the early stages of economic growth, the release of pollutants increases, leading to more environmental pressure. However, after a certain point of GDP per capita, economic growth can lead to environmental improvement. This suggests that the amount of pollutant emissions typically follows an inverted U-shaped curve in relation to GDP per capita.

Let us assume that y is the indicator of pollution and that x is the indicator of economic development. Then, a standard U-shaped or an inverted U-shaped EKC takes the following mathematical form

$$y = a_0 + a_1 x + a_2 x^2 + \varepsilon \quad (6)$$

Now, differentiate above equation 2-times w. r. to G, then, we have

$$\frac{dy}{dx} = a_1 + 2a_2 x$$

$$\frac{d^2P}{dP^2} = 2a_2$$

From above equation, the stationary point is given by setting $\frac{dy}{dx} = 0$.

$$\text{Thus, } a_1 + 2a_2 x = 0, \text{or } x = \frac{-a_1}{2a_2} \quad (7)$$

As $a_2 < 0$, the equation (6) exhibits local maxima, indicating evidence of an inverted U-shaped environmental Kuznets curve (EKC). Conversely,$a_2 > 0$, the equation (6) also displays local minima, indicating evidence of a U-shaped EKC.

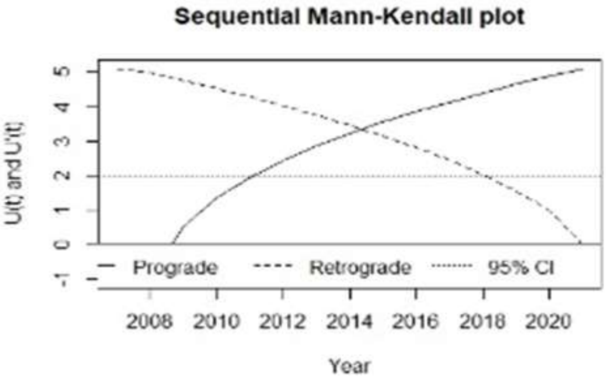
RESULT AND DISCUSSION

ECONOMIC GROWTH AND POLLUTANT EMISSIONS: SQ-MK TREND

The result of Sequential Mann-Kendall test statistics for per capita GDDP, nitrogen dioxide concentration, PM10 concentration and sulphur dioxide concentration clearly detects the statistically significant change point in yearly trend of pollutant emission levels in Dhanbad over the period 2007-2021. Yearly plots of $u(t_i)$ and $u'(t_i)$ values for each of the variables have been shown in figure 2. From 2015 onwards, there is a significant increase in per capita GDDP, with the two curves intersecting in that year before diverging, but this change point is statistically insignificant at a value of 3.54 as it fell beyond the level of significance. On the other hand, Sequential Mann-Kendall test statistics for the pollutant emission levels indicates that the two curves $u(t_i)$ and $u'(t_i)$ for nitrogen dioxide concentration intersect in 2010, but this change point is statistically significant with a value of -2.03. For PM10 concentration, there is a detectable change point is present in 2008, but this change point is statistically significant at the chosen level of significance. The reduced value of intersection point is -1. Finally, the two curves $u(t_i)$ and $u'(t_i)$ for SO2 concentration, $u(t_i)$ and $u'(t_i)$, gradually converge and intersect in 2009 before diverging. However, this change point at 2009 is statistically significant with a value of -1.57. (Table 1)

PER CAPITA GDDP AND POLLUTION: CORRELATION

Figure 3 illustrates the potential correlation between the per capita GDDP and the pollutant emission levels in Dhanbad, Jharkhand.



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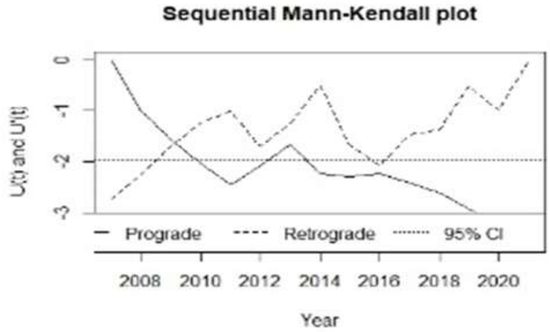

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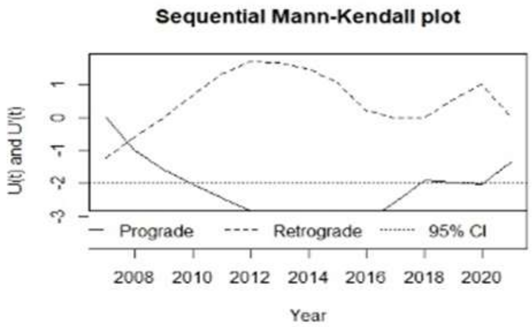

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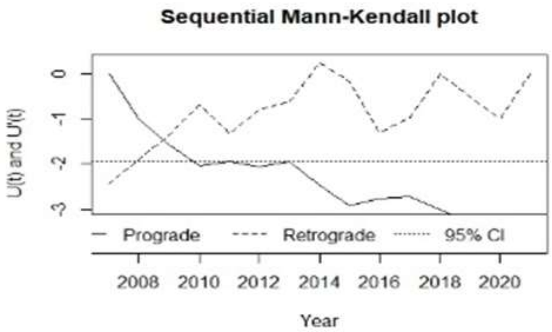
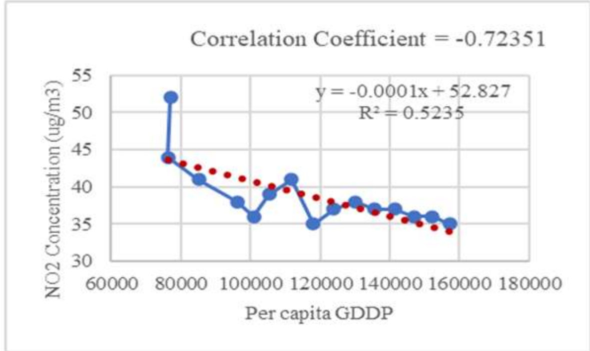


(d)

Fig. 2. SQ-MK trend of (a) Per capita GDDP, (b) Nitrogen dioxide concentration, (c) PM10 concentration, and (d) Sulphur dioxide concentration

A negative linear correlation exists between per capita GDDP and nitrogen concentration (See Fig.- 3.a). This indicates that a decrease in per capita GDDP results in a proportional decrease in nitrogen concentration. The correlation coefficient between per capita GDDP and PM10 concentration is -0.3, indicating there is weak negative linear correlation between these two variables (See Fig.- 3.b).



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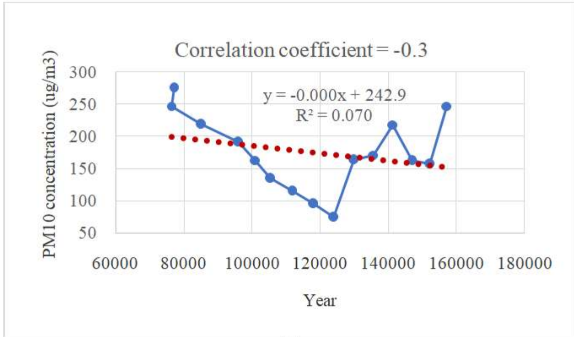

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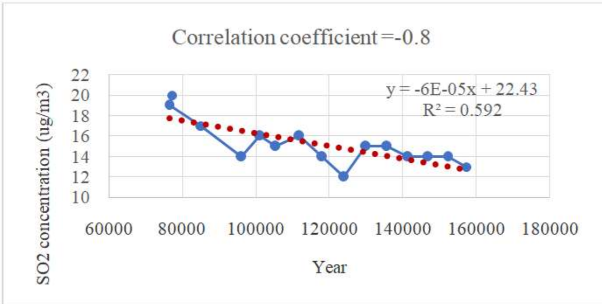


(c)

Fig. 3. Correlation between (a) Nitrogen dioxide concentration, (b) PM10 concentration, and (c) Sulphur dioxide concentration

There is a strong negative correlation (-0.8) between per capita GDDP and sulphur dioxide concentration, indicating that a decrease in GDDP results in a decrease in sulphur dioxide concentration (See Fig.-3.c).

EKC RELATIONSHIP BETWEEN GDDP AND POLLUTANTS

Linear correlation can give us insights into how per capita GDDP (Gross District Domestic Product) and levels of pollutant emissions are related. Figure 4 shows the EKC relationship between per capita GDDP and the pollutant emission levels in Dhanbad, Jharkhand. The results of the EKC model for nitrogen dioxide concentration indicate that all the coefficients in the regression model are statistically significant at 5% level of significance. The expected sign of square of per capita GDDP is positive and statistically significant. This shows that there is a U-shaped association between economic growth and nitrogen dioxide emissions level in Dhanbad (Table 2). The regression line represented in the chart with the regression equation and their coefficient values (See Fig.-4. a). The EKC model for PM10 concentration shows a statistically significant U-shaped curve in Dhanbad (See Fig.-4. b). As per the result of PM10 EKC regression model indicates that the expected sign of square of per capita GDDP is positive and significant. This implies that there is also a U-shaped curve (Table 3).

Table 1. Sequential Mann-Kendall Analysis

	GDDP			NO2			PM10			SO2		
Year	u(t)	u'(t)	Intersection	u(t)	u'(t)	Intersection	u(t)	u'(t)	Intersection	u(t)	u'(t)	Intersection
2007	0.00	5.10	FALSE	0.00	-2.72	FALSE	0.00	-1.24	FALSE	0.00	-2.42	FALSE
2008	-1.00	4.98	FALSE	-1.00	-2.24	FALSE	**-1.00**	**-0.60**	**TRUE**	-1.00	-1.92	FALSE
2009	0.52	4.76	FALSE	-1.57	-1.71	FALSE	-1.57	0.00	FALSE	**-1.57**	**-1.34**	**TRUE**
2010	1.36	4.53	FALSE	**-2.04**	**-1.23**	**TRUE**	-2.04	0.69	FALSE	-2.04	-0.69	FALSE
2011	1.96	4.28	FALSE	-2.45	-1.01	FALSE	-2.45	1.32	FALSE	-1.96	-1.32	FALSE
2012	2.44	4.02	FALSE	-2.07	-1.70	FALSE	-2.82	1.70	FALSE	-2.07	-0.80	FALSE
2013	2.85	3.75	FALSE	-1.65	-1.25	FALSE	-3.15	1.67	FALSE	-1.95	-0.63	FALSE
2014	3.22	3.46	FALSE	-2.23	-0.49	FALSE	-3.46	1.48	FALSE	-2.47	0.25	FALSE
2015	**3.54**	**3.15**	**TRUE**	-2.29	-1.65	FALSE	-3.75	1.05	FALSE	-2.92	-0.15	FALSE
2016	3.85	2.82	FALSE	-2.24	-2.07	FALSE	-3.13	0.19	FALSE	-2.77	-1.32	FALSE
2017	4.13	2.45	FALSE	-2.41	-1.47	FALSE	-2.57	0.00	FALSE	-2.72	-0.98	FALSE
2018	4.39	2.04	FALSE	-2.61	-1.36	FALSE	-1.92	0.00	FALSE	-3.02	0.00	FALSE
2019	4.64	1.57	FALSE	-2.93	-0.52	FALSE	-1.95	0.52	FALSE	-3.29	-0.52	FALSE
2020	4.87	1.00	FALSE	-3.23	-1.00	FALSE	-2.03	1.00	FALSE	-3.56	-1.00	FALSE
2021	5.10	0.00	FALSE	-3.61	0.00	FALSE	-1.34	0.00	FALSE	-3.81	0.00	FALSE

Table 2. EKC Model for NO2 concentration

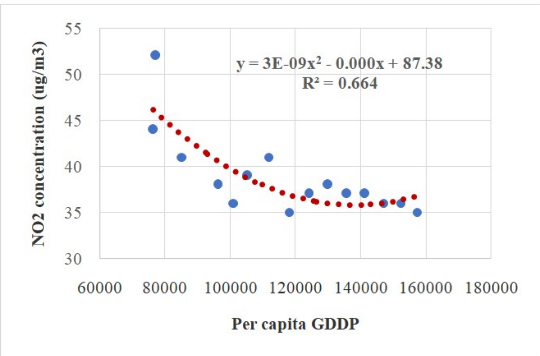
Dependent Variable: NO2				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
PCGDDP	-0.000747	0.000281	-2.661494	**0.0207**
SQPCGDDP	2.71E-09	1.20E-09	2.24608	**0.0443**
C	87.38688	15.7408	5.551617	**0.0001**
R-squared	**0.664506**			
Adjusted R-squared	**0.60859**			
F-statistic	**11.88408**			
Prob(F-statistic)	**0.001426**			

Table 3. EKC Model for PM10 concentration

Dependent Variable: PM10				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
PCGDDP	-0.018209	0.003347	-5.441157	**0.0001**
SQPCGDDP	7.60E-08	1.44E-08	5.295015	**0.0002**
C	1214.329	187.6697	6.470566	**0**
R-squared	**0.721456**			
Adjusted R-squared	**0.675032**			
F-statistic	**15.54061**			
Prob(F-statistic)	**0.000467**			

Table 4. EKC Model for SO2 concentration

Dependent Variable: SO2				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
PCGDDP	-0.00037	0.00012	-3.079892	**0.0095**
SQPCGDDP	1.33E-09	5.16E-10	2.578986	**0.0241**
C	39.41911	6.738421	5.849904	**0.0001**
R-squared	**0.738034**			
Adjusted R-squared	**0.694372**			
F-statistic	**16.90369**			
Prob(F-statistic)	**0.000323**			



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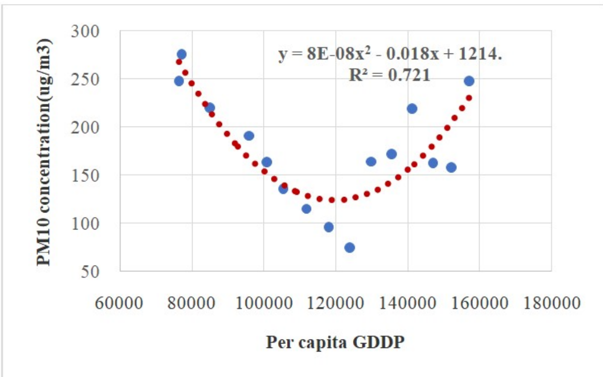

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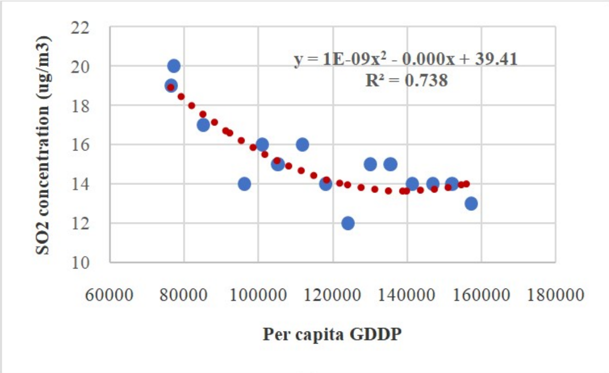

(c)

Fig.4. The EKC model for (a) nitrogen dioxide concentration (b) PM10 concentration, and (c) sulphur dioxide concentration

The results of the EKC hypothesis suggest that SO2 concentration in Dhanbad follows a U-shaped curve, which is statistically significant (Table 4). The regression line represented in the chart with the regression line with their coefficient values (See Fig.-4.c).

CONCLUSION

In this study, an analysis was conducted to determine the relationship between economic development and pollutant emissions, specifically nitrogen dioxide, PM10 particulate matter, and sulphur dioxide. The result of Sequential Mann-Kendall test statistics indicates that per capita GDDP has an increasing trend from 2015, which is statistically insignificant but for the pollutant emission levels there is a significant SQ-MK change points, respectively in this analysis. The study shows that economic growth correlates with higher levels of pollutant emissions. The study found a strong negative correlation between per capita GDDP and nitrogen dioxide concentration, with a correlation coefficient of -0.72. Similarly, a negative correlation was observed between GDDP and particulate matter (PM10) concentration, with a correlation coefficient of -0.3. Additionally, the study suggests a strong negative correlation between GDDP and sulphur dioxide concentration, with a correlation coefficient of -0.8 in the context of Dhanbad. According to the EKC analysis, nitrogen dioxide concentration, particulate matter (PM10) concentration, and sulphur dioxide concentration exhibit a statistically significant U-shaped Environmental Kuznets Curve. This study can be used by government agencies to improve district energy efficiency and reduce pollutant emissions.

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