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HEALTH IMPACT OF FLY ASH DISPOSAL – A STUDY OF TWO POWER PLANTS IN TAMILNADU

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Introduction

Power development is the key to economic development in any nation, and more so in the case of developing countries like India. "Economic growth, energy demand and electricity are interconnected" (Russell, 1991). In India, ever since independence, there is a growing demand for electricity owing to the aspiration of rapid economic growth leading to rapid industrialisation, accelerated urbanisation and mechanisation of agriculture. In fact, the power sector has been receiving adequate priority ever since the process of planned development began in 1950. At the time of independence, in 1947, the installed capacity was 1,361 MW, which has increased to 3,14,642.33 MW as on31st January 2017[9]. Out of it, 1, 38, 915 MW (60%) is thermal (coal/lignite) based. Even after technological advancement, fossil fuel-fired power plants are the principal energy sources in electric power sector and are likely to be so in the immediate future, considering the present status of the projects and various constraints in development of hydro and nuclear power. In order to achieve economic growth of 8%–9%, total coal demand has increased from 730MT in 2010–2011 to 2,000 MT in 2031–2032. Of this approximately75 percent would go to thermal power plants TTPs(India Energy Book, 2012).

With this increasing demand, generation of coal combustion residuals (CCRs) are also increasing. Indian coal is of low-grade with 30%–45 % ash content in comparison to imported coals which have only 10%–15%low ash content of. Relatively lower calorific value, coupled with high ash content and inefficient combustion technologies aggravates emission of greenhouse gases and other pollutants from India's coal and lignite-based TTPs(CAT& UE., 2014). High ash coal results to more wear and tear of the plant and machinery, low thermal efficiency of the boiler, slogging, choking and scaling of furnace and most harmful of them all, generation of a large amount of fly ash. It has been cited in one study that thermal power plants, using about 70% of total coal in India, are among the large point sources (LPS) having significant contribution (47% each for CO2 and SO2) in the total LPS emissions in India(Mittal, et.al). However, with all this negative externalities, we cannot do away with this source. To achieve sustainable development, the nation may have to generate at least 2, 60,000 MW of power (i.e., 10% increase in the rate of annual electricity generation) by the year 2020 and as a consequence 273 MT of CCRs is expected to be released.

Of the total ash generated in India, 80% is fly ash. India ranks fourth in the world in the production of coal ash as by-product waste after USSR, USA and China. Nearly 90MT of fly ash is generated per annum at present in our country and is largely responsible for disposal problem and environmental pollution. In developed countries like Germany, 80% of the fly ash generated is being utilised, whereas, in India only 30% is being consumed and the remaining discharged into water bodies. Keeping in view the formidable future problems due to this for Environmentally Sound Management (ESM) of hazardous wastes, it is very crucial for confidence building on CCRs utilisation and increase in acceptability of CCR-based products among end users (Planning Commission, 2010). The present paper compares two thermal stations in Tamil Nadu – one with 100% utilisation of fly ash (Mettur) and the other with less than 100% (NorthChennai) utilisation – to make a comparative study on health impact.

Need for This Study

Worldwide electricity generation process in all (TPPs)is almost identical but, the quantity and quality of CCRs varies distinctly due to the quality of coal, temperature maintained in the boiler, efficiency of electrostatic precipitator, etc. In the case of Indian coal, -0.7kg of coal is required to produce 1kWelectricity. Because of the availability of cheap coal domestically, direct cost of production is low. But this leads to increased generation of fly ash. Thus, even though power plants involve social benefits, there are also social costs involved in the form of environmental degradation costs or external costs. Coal-based TTPs affect the air quality of the surrounding region more than other plants and the cost of health impairment forms an important chunk of the external costs of coal-based power plants National Environmental Engineering Research Institute(NEERI). Studies showed that the effective utilisation of this resource material would not only minimise the disposal problem but help in conservation of scarce minerals, reduce emission of greenhouse gases and enhance performance and durability of structure.

Tamil Nadu, which is the fourth largest GDP contributor to the country, has four major state-owned coal-based TTPs with a capacity of around 2,970 MW(CEA Report, 2013). In Tamil Nadu75% of the total energy production is met by thermal sources. The TPPsin Tamil Nadu generates about 100 lakh tonnes (10 million tonnes) of fly ash every year. There are

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differences in fly ash utilisation between state-owned, central government owned and privately owned TTPs. State-owned units are utilising out of compulsion, because Ministry of Environment and Forests (MoEF) wants it to be done in a phased manner. Tamil Nadu Electricity Board has arrived at an action plan for all four thermal stations to achieve 100% ash utilisation before 2015 as directed in the GOI notification 1999. Among state-owned units differences exist. CEA report shows that two TTPs have achieved more than 100% utilisation (Mettur andNorth Chennai Thermal Power Station), the third (Ennore TPS) achieved 80% utilisation and the fourth(Tuticorin) below 75% utilisation. In this context, the present study proposes to look into this contradiction and aims at comparing the difference in health impact without 100% utilisation and with 100% utilisation of fly ash among 2 TPPS of Tamil Nadu–Mettur TPP and NorthChennai TPP.

Objectives

- To assess the unit-wise generation-utilisation gap in fly ash utilisation between the TPPs under study.
- To describe the environmental damage caused by fly ash.
- To estimate the health impact of fly ash disposal.

Methodology

The datasets for this study is gathered from primary and secondary sources. Health impacts due to air pollution was given emphasis and this was ascertained among residents who were residing within 50km radius of respective TPPs by administering questionnaire, which contained many questions related to impact of fly ash on health indicators. Further, the data relating to economic status of the residents have also been gathered to examine how fly ash negatively affects both economic and health status of the residents.

For the purpose of study, two TTPs have been selected based on the utilisation of fly ash –viz., less than 100% utilisation (North Chennai TPP) and more than 100% utilisation(Mettur TPP) of fly ash. The study assumed that with higher installed capacity, there will be more generation of fly ash and with more generation, the impact on health is more. With higher utilisation of fly ash this impact can be reduced. Out of the two plants where primary survey is undertaken, the study intended to show that where there is higher utilisation the impact on health is less. The secondary data for this study was collected from the reports published by Central Electricity Authority (CEA) and Tamil Nadu Generation and Distribution Corporation (TANGEDCO). Additionally, theoretical foundations for this study are gathered from textbooks, journals and websites. The study has made use of simple statistical tool of t-test to evaluate the objective.

Literature Review

The World Health Organization (WHO) and other sources attribute about one million deaths/year to coal air pollution. According to the reports issued by WHO in 2008 and by environmental groups in 2004, coal particulates pollution is estimated to shorten approximately 1,000,000 lives annually worldwide.(Energy Source, 2011).

Chabraet al(2001) conducted a cross-sectional study among residents of Delhi to determine the role of ambient air pollution in chronic respiratory morbidity. The authors selected random stratified sample (N = 4,171) of permanent residents who were 18-year-olds and above who lived near one of the nine permanent air quality monitoring stations in the city. Air quality data for the past 10 years were obtained, data were based on the differences in total suspended particulates and the study areas were categorised into lower- and higher-pollution zones. A standardised questionnaire was administered, clinical examination was carried out and spirometry followed. The authors assessed chronic respiratory morbidity. A multiple logistic regression identified the determinants of chronic symptoms.

(NEERI2006) conducted a study to assess the environmental impacts caused by power plants and has tried to monetise those impacts in order to facilitate a better understanding of the same. The study included three types of power plants: thermal, gas and hydroelectric projects. The study very clearly enumerated the external impacts pertaining to air, water, noise, land, biological and socioeconomic components of environment caused by the power plants. The study found that coal based thermal power plants affect the air quality of the surrounding region more than other two varieties of plants. Around the coal based plants a variation in the ambient sulphur dioxide (SO_2), NO_x and suspended particulate matter (SPM) concentration was noticed. From the epidemiological data of the area surrounding the coal based plant, it is inferred that population living within a 5 km radius of the plant suffered from respiratory ailments. For the purpose of evaluation, the study has differentiated external costs into three major categories, namely ecosystem, agriculture and health costs. The cost of health impairments form an important chunk of the external costs of coal based power plants but such costs are absent in hydroelectric project and negligible in the case of natural gas power plants. The study also found that the high external cost of coal generation is mostly because of health impacts and global warming caused by the flue gases from such plants. Another major factor of uncertainty in the case of thermal power plants is the installed capacity of the plant. Since the cost of impacts such as effects on health depend on the concentration of the various pollutants in the ambient air, the costs will increase

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proportionately with installed capacity. This is because higher capacity power plants will discharge larger amounts of pollutants into the ambient air and therefore, the associated external costs will also increase.

Debi Goenka(2012) in her study estimated the annual health impact costs due to PM pollution from coal-fired power plants in India. The study took into account 111 coal-fired plants in India representing a generation capacity of 121GW. The data for study was compiled by "Urban Emissions" based on the methodology of concentration-response functions established from epidemiological studies.

Guttikunda and Jawahar(2014) estimated the total emissions by different states of India based on the boiler size, coal consumption rates and control equipment efficiencies, which is collected from thermal power plant performance reports. The authors concluded that, under the current emission regulations, the emission rates are the highest in Russia and India. China, the United States, the European Union (EU) and Australia have stronger regulations, whereas, in India, even with 55% of the installed coal-based generation capacity, there is a conspicuous lack of regulations for SO_2, NO_x and mercury emissions. There is also no continuous and open emission monitoring data available at the plant level, which makes enforcement of standards nearly non-existent.

Mittal etal(2016) conducted emission estimates of carbon dioxide (CO_2), SO_2 and NO_x from thermal power plants in India for a period of nine years from 2001–2002 to 2009–2010. Eighty six power plants with total installed capacity of 77,682 MW were considered for this analysis which required input data from Central Electricity Authority of India (CEA). These plants represent about 76% of the total installed capacity of thermal power plants in India. These estimates were based on a model in which the mass emission factors are theoretically calculated using the basic principles of combustion and operating conditions. Future emission scenarios for the period 2020–2021 were generated based on the estimates of the nine years from 2001–2002 to 2009–2010. The authors opined that power plants in India use different qualities of coal, different combustion technologies and operating conditions. As a result, these plants have differences in achieved efficiencies (coal usage per unit of electricity). The estimates show region wise differences in total emissions as well as differences in emissions per unit of electricity. Computed estimates show the total CO_2 emissions from thermal power plants have increased from 3,23,474.85 Gg for the year 2001–2002 to 49,8655.78 Gg in 2009–2010. SO_2 emissions increased from 2,519.93 Gg in 2001–2002 to 3,840.44 Gg in 2009–2010, while NO_x emissions increased from 1,502.07 Gg to 2314.95 Gg during the same period. The emissions per unit of electricity are estimated to be in the range of 0.91 to 0.95 kg/kWh for CO_2, 6.94 to 7.20 g/kWh for SO_2 and 4.22 to 4.38 g/kWh for NO_x during the period 2001–2002 to 2009–2010. The study concluded that increase in coal use efficiencies in electricity generation by thermal power plants can significantly reduce the emissions from greenhouse and polluting gases. From this brief review it is clear that TPPs do cause health impacts. As mitigation measure, fly ash utilisation is recommended by environmentalists and policymakers.

Environmental Degradation and Fly Ash Disposal

TTPs have been found to affect environmental segments of the surrounding region very badly. Fly ash can be disposed-off in a dry or wet state. In dry disposal, the environmental deterioration is attributed to emission of large amount of SOx, NOx and Suspended Particulate Matter (SPM) and Respirable Suspended Particulate Matter (RSPM) which disperses over 25 km radius and causes respiratory and related ailments to human beings and other animals. Since the cost of impacts on health depends upon the concentration of various pollutants in the ambient air, the costs will increase proportionately with the installed capacity. This is because higher capacity power plants will discharge larger amounts of pollutants into the ambient air and therefore, the associated external costs will also increase.

The main emissions from coal-fired and lignite-based TTPsare CO2, NOx, SOx, and air-borne inorganic particles such as fly ash, carbonaceous material (soot), SPM and other trace gas specific (Mittal, et.al2016). For SO2 and NOx, there are no mandatory requirements to operate emission control equipment, except for specifications of stack heights, assuming that the emissions will be dispersed to farther distances and thus, diluting the ambient concentrations. For example, MoEF requires all TPPs with generation capacity more than 500 MW to build a stack of 275m; those between 210 MW and 500 MW to build a stack of 220 m; and those with less than 210 MW to build a stack based on the estimated SO2 emissions rate (Q in kg/hr) and a thumb rule of height = 14×(Q) 0.3. The stack heights for old TPPs ranged between 150 m and 220 m. Particulate Matter (PM) is the only pollutant for which controls are widely applied. The standard for PM pollution was revised in 2013 to 50 mg/Nm3, which was 150 mg/Nm3 for the plants commissioned prior to 2013. (CAT & UE 2014).Being cheaper than any other manner of fly ash removal, it is widely used in India at present. The environmental aspect of fly ash disposal aims at minimising air and water pollution. The fly ash produced by TTPs can cause all three environmental risks– air, surface water and ground water pollution. The pathways of pollutant movement through all these modes are schematically represented in Figure 1.

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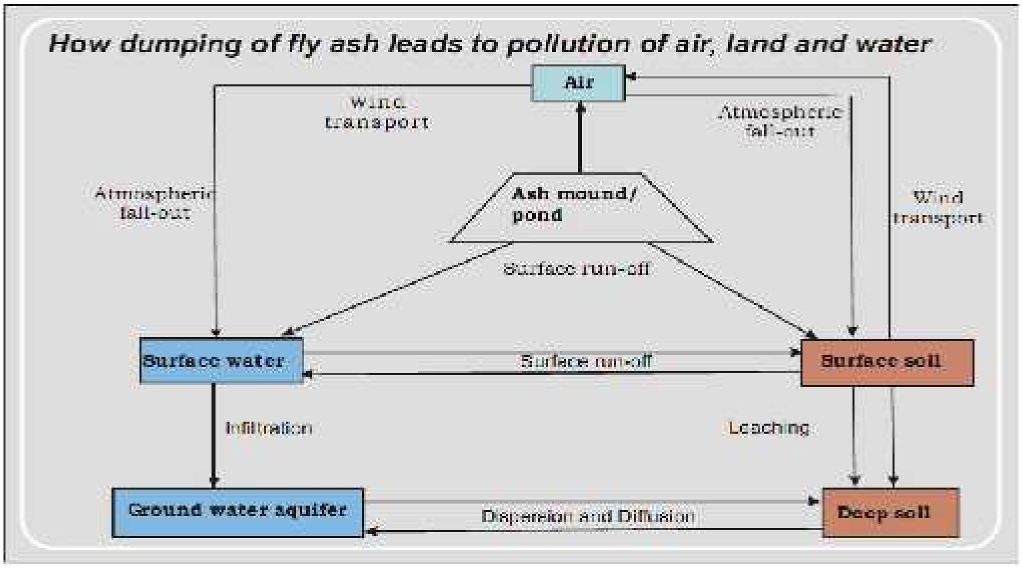
Figure.1: Schematic Pathways of Pollutant Movement around Fly Ash Disposal



Air Pollution

Coal-fired electric power plants comprise of the single biggest source of CO2 emissions in the world. Burning fossil fuels such as coal releases carbon dioxide pollution, making energy use the single largest source of greenhouse gases in the world. Dry fly ash is readily lifted by mild wind during transportation, dumping and spreading due to lack of cohesive forces in the fine solid particles takes place. The climatic conditions throughout major parts of India can be classified as dry tropical with temperatures ranging from 30°C– 45 $^{\circ}$C, almost for eight to ten months of a year. At such temperature variations, the rates of evaporation losses from ash ponds are quite high rendering it completely dry in upper surface layers if full ponding of water is not done in the ash pond. Air pollution from such disposal ash ponds affect the people living adjacent to ash ponds, particularly in summer season.

Surface Water Pollution and Ground Water Pollution

Inadequate sedimentation of ash particles in the ash ponds due to low storage time causes the fine ash particles to reach the adjacent surface water bodies influencing aquatic plants and animals. In ash mounds, adjacent water bodies are contaminated through suspended ash particles in surface run off during rainy seasons, if sedimentation chambers of adequate capacity are not provided. Likewise, leachates from improperly sited and designed ash ponds present potential threat of contamination to ground water beneath the base of the pond.

Soil Pollution

Studies on geo-accumulation of heavy metals around thermal power stations indicate that Cr and Zn top the ranking followed by Mn (all with geo-accumulation index of greater than unity). It has been claimed that many plant species can grow on fly ash disposal lands. The chemical analysis of some plants on old ash ponds have revealed that inorganic constituents of fly ash were present in elevated concentrations in the shoots of plants as compared to plants growing on natural soils (Thakre, 1996). Seepage of slurry water into the soil can cause water logging around the ash ponds, which in the meantime can have a negative impact on the crop production around an ash pond.

Analysis

Fly Ash Generation and Utilisation Details of TPPs analysed:

The table below gives details about the coal generation and utilisation of TTPs in TamilNadu.

Table:1. Fly Ash Generation and Utilisation among four TPPsduring the Year 2014–2015 in Tamil Nadu.

S.No.	Name of Power Utility	Installed Capacity (MW)	Coal Consumed (mtpa)*	Ash Content (%)	Fly Ash Generation (mtpa)	Fly Ash Utilisation(mtpa)	Percentage Utilisation (%)
1.	Ennore	340	0.072120	28.879645	0.020828	0.023668	113.635491

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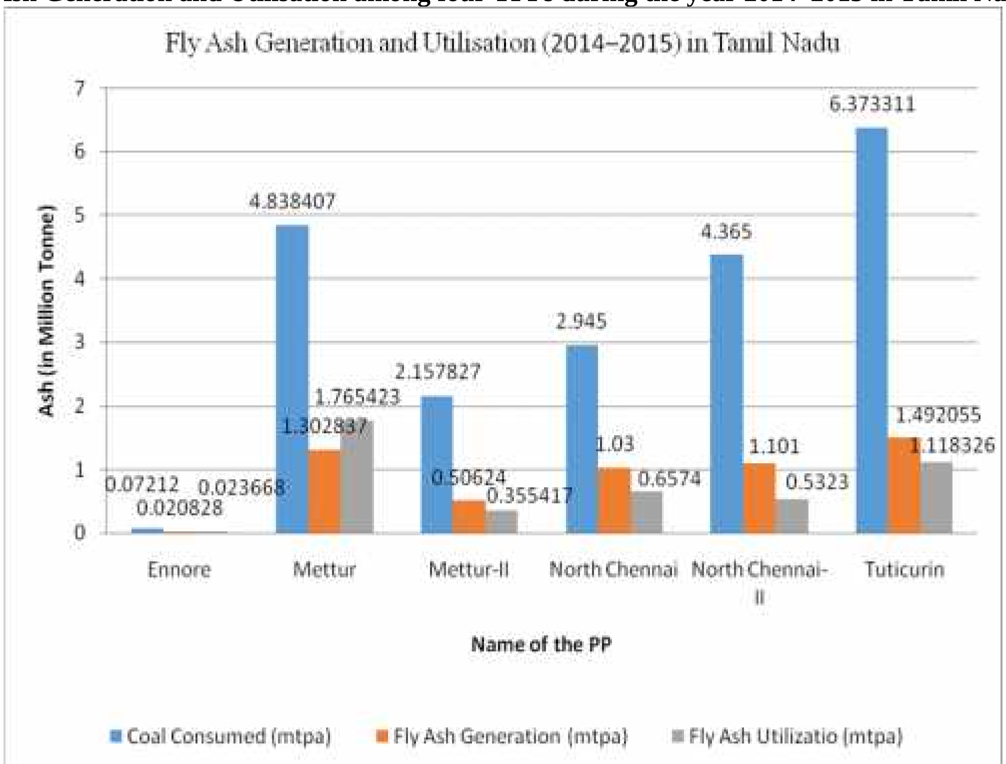
2.	Mettur	840	4.838407	26.926982	1.302837	1.765423	135.506053
3.	Mettur-II	600	2.157827	23.460639	0.506240	0.355417	70.201214
4.	North Chennai	630	2.945000	34.974533	1.030000	0.657400	63.825243
5.	North Chennai-II	1200	4.365000	25.223368	1.101000	0.532300	48.346957
6.	Tuticorin	1050	6.373311	23.410987	1.492055	1.118326	74.952063

Source: CEA Report
Note: *(mtpa-million tonne per annum).

Table 1 clearly shows, that, out of the four TPPs,Ennore and Mettur achieved 100% utilisation, where as,North Chennai and Tuticorin are lacking behind. The figure below clarifies this fact with one more variable added to it viz.,coal consumption.

Figure: 2. Fly Ash Generation and Utilisation among four TPPs during the year 2014–2015 in Tamil Nadu



Source: CEA Report (2014-15), Databased

Health Impact

Table: 2. Rank of Health Problems

S.No.	Health Problems	Tiruvallur	Rank	Salem	Rank
1.	Asthma	45	4	47	2
2.	Emphysema	1	16	1	16
3.	Lung Cancer	1	17	0	17
4.	Throat Cancer	2	15	6	12
5.	Heart Attack	6	13	11	9
6.	Heart Disease	30	7	37	8
7.	Headache	23	9	42	5
8.	Skin Problem	50	2	42	6
9.	Eye Irritation	49	3	49	1
10.	Breathing Problem	50	1	45	4
11.	Chronic [?? Incomplete]	4	14	6	13

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12.	Cough	10	11	3	14
13.	Vertigo	10	12	0	18
14.	Minor Respiratory Disease	24	8	8	11
15.	Inflammation	1	18	11	10
16.	SoreThroatStuffyNose	12	10	46	3
17.	RespiratoryDisease	38	5	40	7
18.	Nausea	36	6	2	15
19.	Others (specify)	1	19	0	19

Source: Primary Data

Table:2 clearly shows the rank of each health problem in the two TPPs. It is evident that in North Chennai TPP the foremost health issue is breathing problem, whereas, in Mettur TPP the main problem is eye irritation. Likewise, there is similarity in the list of health issues pointed out by respondents.

Table:3. Man-days lost due to Thermal Power Pollution(Per Year)

Man-days lost	Salem	Tiruvallur	Total
Below 5	12	14	26
6–10	28	22	50
11–15	7	14	21
Above 15 days	3	2	5
Total	50	50	100

Source: Primary Data

From Table:3 it is evident that in terms of man-days lost, the average days lost by the respondents near Mettur TPP is less than those nearNorth Chennai TPP.

Table: 4. Medical Expenditure(Per Year)

Expenditure (in Rs.)	Salem	Tiruvallur	Total
Below 2000	14	5	19
2001–4000	21	29	50
4001– 6000	13	11	24
Above 6000	2	5	7
Total	50	50	100

Source: Primary Data

Table:4 clearly shows that respondents in Salem spend less than respondents in Tiruvallur.

Table: 5. Income Loss Due to Health Problem(Per Year)

Income (in Rs.)	Salem	Tiruvallur	Total
Below 2000	14	13	27
2001–4000	22	21	43
4001– 6000	10	14	24
Above 6000	4	2	6
Total	50	50	100

Source: Primary Data

Table:5 shows that the average income foregone by the respondents near Mettur TPP in Salem is less than that of North Chennai TPP in Tiruvallur. The below table(Table:6)projects that those who do not have any awareness of pollution are also affected by illness.

Table: 6.Awareness of Pollution

Awareness of Pollution	Health problem		Total
	Yes	No	
Yes	75(A)	17(B)	92
No	5(C)	3(D)	8
Total	80	20	`100

Source: Primary Data

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$$\emptyset = \frac{AD - BC}{\sqrt{(A+B)(C+D)(B+D)(A+C)}}$$

$$\emptyset = \frac{(75x3)\,(17x5)}{\sqrt{(92)\,(8)\,(80)\,(20)}}$$

$$\emptyset = \frac{225 - 85}{\sqrt{1177600}}$$

$$\emptyset = \frac{225 - 85}{1085.17}$$

$$\emptyset = 0.129$$

To examine the relationship between awareness of pollution and health problem, the study has applied phi-coefficient as both the variables are natural dichotomies. The computed phi-coefficient: phi value 0.129, reveals that there is very less relationship between the two. It implies that those who are aware of pollution are also affected by same health issues as the unaware.

T- test

H_0: There is no significant difference in the average medical expenditure, man-days lost and foregone income with respect to utilisation of fly ash.

In order to validate the hypothesis, unpaired t-test has been administered and test results are produced in the below table.

Table: 7. T-test Result

Response Variable	Indicator Variable	Sample Size	Mean	Standard Deviation	Standard Error	T-value
Medical Expenditure	Salem	50	3924.00	1969.62	278.54	2.153** (0.034)
	Tiruvallur	50	4718.00	1709.83	241.80	
Man-days lost	Salem	50	7.32	3.51	0.496	3.172*** (0.002)
	Tiruvallur	50	9.82	4.32	0.611	
Income loss	Salem	50	3592.00	1935.15	273.67	2.610*** (0.010)
	Tiruvallur	50	4550.00	1729.84	244.63	

Source: Computed.
Note: ***sig at 1% level; **sig at 5% level; * sig at 10% level

From table: 7, it is noticed that the average medical expenditure incurred by the respondents residing nearby the high fly ash utilisation is computed to be Rs.3,924 and low fly ash utilisation power plant is Rs.4,718. It is obvious that respondents in Salem spend less than respondents in Tiruvallur. The t-test value (2.153) is also significant; therefore, the study rejects the null hypothesis and concludes that there is significant difference in the average medical expenditure incurred by respondents belonging to Salem and Tiruvallur.

In terms of man-days lost, the average days lost by the respondents in Salem is computed to be seven day per month while it is nine days for Tirvallur. Therefore, the study accepts that there is significant difference in the average man-days lost for respondents belonging to Salem and Tiruvallur District.

When a person does not go for work, his economic life is affected which is even more severe for daily wage earners. As large number of residents of this area are daily wage earners and salaried people could hardly be seen, the effect is definitely so. In the above table, it is computed that the average income foregone by respondents in Salem is Rs.3,592 and those of Tiruvallur is Rs.4,550. It clearly shows that respondents in Tiruvallur had to forego about Rs.1,000 greater than the respondents in Salem. The t-test also confirms that there is significant difference in the average income foregone by respondents belonging to Salem and Tiruvallur.

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Conclusion

Coal-fired power plants and the pollution they release every day are a major threat to human health and environment. We need to reduce our dependence on dirty coal by replacing these plants with clean energy alternatives like wind, solar and improvements in energy efficiency. As these alternatives are not possible in the immediate future, environmentalists and policymakers have come up with two options. i.e., limiting fly ash generation and enhancing utilisation. Limiting generation can be done through beneficiation and selective mining. When compared to this option, the second one is considered the best with respect to mitigating ill effects. The present study highlights the role of utilisation of fly ash in reducing its impact on health. Apart from cement production, where its utilisation has reached a plateau in the last decade(about 67%), new avenues have to be found and promoted. The use of fly ash in other areas has been tried in many countries but to suit the Indian conditions extensive laboratory and fieldwork is required for achieving desired results.

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