Economic Burden of Multi-Morbidity of Households in the Ennore Peri-Urban Industrial Region, Tamil Nadu: A Prevalence-Based Retrospective Cost of Illness Approach

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Abstract: Peri-urban industrialization has been the cause behind intricate negative dynamics among land use change, environmental quality and health of local communities. Especially, the ill-health of local communities imposes a huge economic burden, which is influenced by a number of factors. So, this study estimates 'Economic Burden of Illness (EBD)', and studies the influence of social, economic and demographic variables/factors on the former. This research study is a prevalence-based cum retrospective household 'Cost of Illness (COI)' study, which was conducted in the year 2023, among local community households at the Ennore peri-urban industrial region area. The data regarding direct and indirect COI were collected and analysed using semi-structured interviews and STATA version 17 respectively. The results have revealed that mean annual household COI, direct and indirect COIs are Rs. 119871.63, Rs. 66422.66 and Rs. 53448.97 respectively. The mean proportion of 'Annual Household COI' in the Annual Household Income is 56.56%, which is a serious socio-economic concern. Further, the results of the multiple linear regression model, which was employed to examine the relationship between annual household COI and other social, economic and demographic variables, has revealed that a marginal increase in a male member with chronic illnesses impact the 'Annual Household COI' more than a marginal increase in a female. Especially, the working age population 15-64 have been affected the most. The findings indicate that the Ennore Peri-urban area needs a public health intervention program that maximises the utility gain of health benefits, and focuses on mainly males in the working age.

Keywords: Multimorbidity, Chronic Illness, Working Age Population, Cost of Illness

1. Introduction

Industrialization has propelled the economies of the world to next subsequent stages of economic development in the last five decades (Adelman, 2000). Such structural transformation has led to mass production and consumption at developed cum industrialized countries, especially since second world war (Akamatsu, 1961), but has imposed awful and environmental impacts on particular regions especially peri-urban zones (Hossain and Huggins, 2021), and social impacts on the local communities who reside there (Ngoc, 2014).

The catastrophe of such phenomenon is higher in especially underdeveloped countries in the global south (Simon, McGregor and Thompson, 2006; Yang et al., 2024). The series of environmental degradation, experienced by industrialized peri-urban areas, comprise air, water, soil and land pollution cum degradation (Liu and Bae, 2018; Mehta and Karpozouglou, 2015; Fernandez-Caliani, 2012). This has further imposed a spectrum of impacts on the health of local communities (Ngoc, 2014). This kind of a colossal impact on the health imposes a humongous economic burden on illness-affected local community households (LCHs) at especially peri-urban areas (Ali et al., 2021). Such environmentally

and socioeconomically vulnerable peri-urban areas are defined as those zones of transition in terms of land use and livelihoods, that impact the peripherals of major urban regions (Simon, 2008; Simon, 2023).

2. Literature Review

2.1 Global Impact of Pollution on Morbidity and Mortality

The three major types of industrial/environmental pollution are air, ground water and surface water pollution. The two major typologies of illnesses caused by pollution from industries and other anthropogenic sources, are air-borne and water-borne illnesses. Within each major typologies, two different sub-types are seen. They are,

- Acute and Chronic Illnesses (ACIs).

2.1.1 Impact of Air Pollution

Air pollution has been the most important risk factor that has been in a causal relationship with, 33% of mortalities reported in the South Asia, and the global mortality of about 8.1 million annually, out of which 6.7 million were attributed to outdoor air pollution (2.1 million were from India) (IHME, 2024; HEI, 2024; HEI, 2020).

Coming to exposure and vulnerability to air pollution, poverty and proximity to industrial sites, stand out as prominent factors at the global scenario (Rentschler and Leonova, 2023; World Health Organization, 2015). Rentschler and Leonova (2023) opines that poverty plays the most prominent role, as approximately 7.3 billion people are being exposed to higher than the WHO's recommended limit of $PM_{2.5}$ emissions. Further, Siddique and Kiani (2020) has empirically proved that the impact of industrial pollution on health is relatively higher in lower-middle income countries than the upper-middle income countries, by studying the nexus between the two in the both, using panel data for a period of 30 years.

Apart from proximity and poverty, the other factors that increase the vulnerability are age, gender, caste and occupation. Those vulnerable groups are, the foetus in-utero especially males (Yi et al., 2022), infants (Fu et al., 2019), children (Mathiarasan and Huls, 2021) and elderly people (Bell, Zanobetti and Dominici, 2013); women, especially pregnant women (Liu et al., 2020); and lower caste groups (Subramanian et al., 2006) respectively.

2.1.1.1 Morbidity due to Age, Gender, Caste and Occupation

The exposure of foetuses to air pollution during the mother's pregnancy affects the neurological cognition and development in the childhood (Yi et al., 2022). The exposure during childhood leads to wheezing, snoring, asthma, lung cancer, cardiovascular diseases and other chronic illnesses (Sánchez et al., 2019; Sim et al., 2020; CEHC, 2024). The elderly population generally suffer from chronic illnesses such as lung [especially Chronic Obstructive Pulmonary Disease (COPD)], and heart-related issues (Bateson and Schwartz, 2004; Goldberg et al., 2013). The occupational exposure to industrial pollutants leads to rhinosinusitis, asthma (Velasquez et al., 2020; Nishida and Yatera, 2022) etc.

Apart from viewing illnesses through the lens of disproportionate impacts based on age, gender, occupation and poverty etc, pollutant specific illnesses are also observed, as each pollutant has its own impact on health.

2.1.1.2 Pollutant/Greenhouse Gas (GHG) Specific Illnesses

The industrial pollution leads to emission of GHGs/pollutants such as carbon dioxide (CO_2), nitrous oxide (N_2O), sulphur dioxide (SO_2), methane (CH_4), ozone (O_3), nitrogen dioxide (NO_2), nitrogen oxide (NO), $PM_{2.5}$ and PM_{10}. Each pollutant/GHG has a specific nature and impact on the human health profile. The emissions of CO_2 cause COPD, asthma, endothelial dysfunction, decrease in cognition, headache and impaired lung function (Jacobson et al., 2019; Sims et al., 2020; Duan et al., 2020). Exposure to N_2O cause skin cancer (Lee et al., 2013). The emissions of SO_2 cause asthma (Sims et al., 2020; Zheng et al., 2021). The emissions of CH_4 lead to inclination of oxidative stress, vascular dysfunction and cardio-vascular diseases (Olufunmilayo et al., 2023; Bezerra et al., 2023). The emissions of O_3 cause asthma, migraine (Zheng et al., 2021; Lee et al., 2018; Garg et al., 2022). The emissions of NO_2 cause asthma, idiopathic pulmonary fibrosis, COPD and migraine (Zheng et al., 2021; Ko and Kyung, 2022; Saki et al., 2020; Lee et al., 2018; Garg et al., 2022). The emissions of NO, cause irritation of throat and nose, asthma in children, lung inflammation, increases melanoma and induces spike in tumour (Krzeszowiak et al., 2016; Sim et al., 2020; Peel et al., 2013; Yarlagadda et al., 2017).

The $PM_{2.5}$ emissions causes asthma, acute respiratory distress, COPD, lung cancer, lower and upper respiratory infections (LURIs), myocardial infarction, heart failure, atherosclerosis, migraine and mental illnesses like anxiety and schizophrenia (Weber et al., 2016; Hopke et al., 2019; Huang et al., 2017;

Farhadi et al., 2020; Gordon et al., 2014; Li et al., 2018; Künzli et al., 2005; Lee et al., 2018; Garg et al., 2022; Yue et al., 2020; Gao et al., 2017).

The PM_{10} emissions leads to spike in lung macrophages, systemic inflammation, vascular endothelial dysfunction, COPD, myocardial infarction in adults, lung cancer, migraine, blood markers, and increase in white blood cells and fibrinogen (Tamagawa et al., 2008; Lee et al., 2020; Strobl et al., 2024; Kang et al., 2020; Lee et al., 2018; Garg et al., 2022; Schwartz, 2001; Pekkanen et al., 2000).

From the above list of pollutants and GHGs, particulate matter pollution is the largest source of heavy metals in air, which have varied 'Metallurgically-Related' effects on the 'Health of the Population' living in these areas.

2.1.2 Impact of Water Pollution

The primary sources of water such as ground and surface water, are globally polluted by industrial land use and anthropogenic activities. Even though there is only a limited source of freshwater, almost $1/7^{th}$ of rivers in the Africa, Asia and Latin America, have already been exposed to detrimental pollution levels that are largely organic in nature, due to urbanization and industrialization (UNEP, 2016).

The illnesses caused by the consumption of polluted freshwater either directly (as drinking water) or indirectly (through food chain) are diarrhoea, typhoid, hookworm disease etc (Prüss et al., 2002; Krishna et al., 2017). Especially, freshwater polluted with industrial wastes containing heavy metals such as iron, arsenic, cadmium, copper, nickel, lead and zinc etc, leads to different forms of cancer, which is a serious public health concern (Yang et al., 2024).

All these ACIs imply a high level of 'Economic Burden of Illness (EBD)' as explained in the introduction and literature part. The quantification of such a comprehensive economic burden would contribute much to the literature.

2.2 EBD/Cost of Illness (COI)

EBD (or) COI is the expenditure foregone to cure ACIs, estimated for a specific time period, concerning a nation, region, group of person and even a single person. The cost categories under COI are stratified into three major parts, namely direct, indirect and intangible costs.

The direct costs, consist of two components namely, health care cost and non-health care costs (Brown et al., 2001). Health care costs are costs incurred for the supply of medical goods and services, in order to manage or regain a person's health from illness (Neri and Ornaghi, 2014).

Whereas, indirect costs are the cost incurred due to declined/lost productivity due to morbidity and mortality of patients at work, which is attributable to illnesses (Brown et al., 2001). In order to estimate it, the following three methods are used,

1. Human capital
2. Friction cost
3. Willingness to pay

Intangible costs are those ascribable to the pain borne by the patients, which is onerous to estimate (ibid). In order to estimate the above COI, two different approaches are used. They are,

1. Prevalence-based: This approach is the measurement of COI based on a specific time period (most probably over a year).
2. Incidence-based: This approach computes the COI over the lifetime of the patients, from the period of contraction of the illness, till either cure/rehabilitation or demise.

Out of the two, most widely utilized one is the prevalence-based approach, as it has relatively lower time consumption to estimate long-run health costs. Apart from methods and approaches, the perspective of estimating COI is also an important aspect. In that sense, different perspectives have been implemented in the COI literature. Those perspectives are societal, system of health care, insurance corporations, private business, government, and individuals and households (Luce et al., 1996).

3. Need for a Peri-Urban Assessment of Economic Burden of Multimorbidity

The impacts of pollution and the disproportionate vulnerability to ACIs, impose a highly regressive EBD on the LCHs who reside there for a long time. Especially, the peri-urban areas and their local communities are highly vulnerable due to their geographical attributes, manifestation of large-scale industrialization, vacancy of humongous parcels of low-priced lands (Hossain and Huggins, 2021), and feeble land and environmental governance mechanisms etc.

At the first stage, it is imperative to examine the socio-demographic profile of peri-urban LCHs, and ACIs that affect their health. Then, at the second stage, estimate the annual household economic burden

using the COI methodology. Then at the final stage, examine the influence of age, gender (with chronic illnesses) and annual household income, on the COI.

4.0 Research Design and Methods

This research is a prevalence-based retrospective COI study that was conducted in the year 2023, among the LCHs. The data on ACIs, and their COI were collected from 203 households using semi-structured interviews. The four sampled villages such as Kattukuppam, Sivanpadaiveethi Kuppam, Seppakkam and Ooranambedu, were purposively selected based on the proximity and impact of pollution. Kattukuppam and Sivanpadaiveethi Kuppam are fishing villages that are located 2.3 and 2.6 Kms far away respectively from North Chennai Thermal Power station (NCTPS), which is the most polluting industry in the Ennore peri-urban industrial region. Seppakkam and Ooranambedu are agricultural villages that are located 50 metres and 2.3 kms far away respectively from the NCTPS- fly ash pond.

The proportional random sampling technique was utilized to select the households. The primary data pertaining to the COI were analysed using descriptive statistics, and the influence of socio-demographic and economic variables on it, through multiple linear regression model (MLRM). The MLRM is a widely used method in COI research (Jo, 2014). This model facilitates the analysis of complex interrelationships among different social, demographic and economic variables, with the COI. Further, the research on COI highlights this method to be highly efficacious in distinct healthcare executions (Trunfio et al., 2022). These analyses were performed using the STATA version 17.

The following table 1, depicts the socio-demographic profile of the total number of household members.

Table 1. Socio-Demographic Profile of Household Members

Sl. No.	Variable	Category			Number (n= 697)	Percentage
1.	Age Composition	≤ 20			155	22.24
		21-40			256	36.73
		41-60			248	35.58
		61-80			38	5.45
		Total			697	100
	-	-			-	-
2.	Gender/Sex	Male			365	52.37
		Female			332	47.63
		Total			697	100
	-	-			-	-
3.	Education	Uneducated			89	12.77
		Schooling (Primary)			105	15.07
		Schooling (Secondary)			239	34.29
		Schooling (Higher Secondary)			85	12.20
		Tertiary			171	24.53
		N/A (Attributed to Age Factor)			8	1.15
		Total			697	100
	-	-			-	-
4.	Employment	Employed			484	69.44
		Unemployed			55	7.89
		N/A	Student		150	21.52
			Attributed to Age Factor		8	1.15
			Total (N/A)		158	22.67
		Total (Employment)			697	100
	-	-			-	-
5.	Occupation	Fishing			97	13.92
		Agriculture			36	5.17
		Industry			60	8.61
		Others			291	41.75
		No Occupation	Unemployed		55	7.89
			Student		150	21.52
			Attributed to Age Factor		8	1.15
		Total			697	100

Source: Author's Estimation

From the above table 1, it is possible to decipher that the total number of household members is 697. The 21-40 age category holds the maximum number of members. The category which holds the second highest position, is 41-60. This indicates that 72.31% of members fall in the working age population 20-

59, as mentioned in the Economic Survey of India (2019). The number of male and female members are 365 (52.37%) and 332 (47.63%) respectively.

Almost, 89 (12.77%) out of 697 members have no education/exposure to education. Out of schooling education categories, secondary schooling holds the maximum numbers. Out of 697 members, 239 (34.29%) have completed/are pursuing secondary schooling. Whereas, primary and higher secondary schooling categories have member counts of 105/15.07% and 85/12.20% respectively. Out of 697, 171/24.53% have completed/are pursuing tertiary education like diploma, undergraduate, post graduate and doctoral education. Almost, 8 members are found to be below the age of 3, with neither exposure to education nor occupation.

Next, is the employment status of members of households. Out of 697, 484 members are employed with household chores, fishing, agricultural and industrial activities, service sector, informal jobs, own small businesses, and the 'Mahatma Gandhi National Rural Employment Guarantee Scheme'. These employed people are more than 2/3rd/69.44% of the total members. Whereas, the unemployed members are just 55/7.89%, as the remaining do not either have an eligible employment age or exist as a student. The category of N/A holds 158 members. Out of which, 150 are students.

From the analyses and interpretation of the socio-demographic profile, it is clear that most of them are in the working age but their education and occupation are primitive in nature. The majority have not completed even their schooling, and are dependent on the traditional economic activities such as fishing and agriculture. Even if other members have completed tertiary levels of education, they lack good job and income opportunities. So, it could be hypothesized their annual household income is very less. In order to explore this, the mean and distribution of annual income of 203 households have been analysed and are shown in the following tables 2 and 3 respectively.

Table 2. Mean Annual Household Income

Sl. No.	Variable	Mean	Std. dev
1.	Annual Household Income	338948.3	323386.1

Source: Author's Estimation

Table 3. Annual Household Income

Sl. No.	Category	Number	Percentage
1.	Less than 1 lakh	38	18.72
2.	1 lakh - 2 lakhs	56	27.59
3.	2 lakhs - 3 lakhs	33	16.26
4.	3 lakhs - 4 lakhs	22	10.84
5.	4 lakhs - 5 lakhs	19	9.36
6.	Higher than 5 lakhs	35	17.24
	Total	203	100

Source: Author's Estimation

From the above tables 2 and 3, it is clear that though the mean household income is Rs. 338948.3, only 76 (37.44%) households have an income above Rs. 3 lakhs. 127 households (62.56%) fall below the mean. Further, 56 households fall in the category of Rs. 1-2 lakhs. That too, 38 households (18.72%) have their household incomes below Rs. 1 lakh or India's average household income of Rs. 1.4 lakh (PRICE, 2021). This indicates that almost 1/5th households, fall under poorest 20% of the Indian households (ibid).

From all the categories, it is evident that 168 (82.77%) households are either destitutes or aspirers. Those are not even middle-income households (MIHs). Only 35 households (17.24%) are MIHs, who earn in the range of Rs. 5-30 lakhs. Since 82.77% of 203 households are low-income households (LIHs), it could be hypothesized that their conditions of housing cannot be good.

After studying the social, demographic and economic profiles of households, the following table 4, illustrates the major typologies of COI, their sub-components, and respective evaluation approaches made in the study.

Table 4. Types of COI and their Evaluation Approaches

Sl. No.	Category	Sub-Component	Approach of Evaluation
1.	Direct cost of illness (DCOI)	Health Care Cost	Physician Services: Cost incurred for consultation of the general practitioners and specialists and appointment registration (Jo, 2014)
			Medication:

			Cost Incurred to procure prescribed drugs for the treatment of illness (ibid)
			Diagnosis Tests: Cost incurred for imaging and laboratory testing to diagnose specific illnesses (ibid)
			Institutional Inpatient Care and Treatment Services: • Institutional Inpatient Care: Cost incurred for the hospitalization of patients affected by illness. It includes the inpatient care in specialized units like Intensive Care Unit, Critical Care Unit and Nursing home facilities (ibid) • Treatment Services: Cost incurred for surgery, consumables, time spent by the personnel, equipment/apparatus, good and services related to blood and oxygen facilities (ibid).
		Non-Health Care Cost	Transportation: Cost incurred for travel/transportation (to and fro) of illness affected patients and their care-givers (ibid)
2.	Indirect cost of illness (IDCOI)	Other Productivity Losses	Income Loss of Patients: Morbidity, Impairment, Job absenteeism (ibid)
			Income Loss of Care-Givers: Job absenteeism (Ganapathy et al., 2015)

Source: Jo (2014)

5. Results and Discussion

This section presents the results of the descriptive analysis of the airborne and waterborne ACIs, COI and its components, and the MLRM.

5.1 ACIs

The following table 5, shows the list of ACIs caused by the industrial air and water pollution, and the number of sampled households suffering from each and every illness.

Table 5. ACIs

Sl. No.	Type	Name			Number	%
1.	Acute	Cold			203	100
		Cough			203	100
		Fever			203	100
		Headache			37	18.23
		Breathlessness/Dyspnea			107	52.71
		Skin Allergies			200	98.52
		Eye Irritation			48	23.65
		Nose Irritation			50	24.6
		Loss of Consciousness			16	7.88
		Emesis	Due to Fishing in Polluted Water		58	28.57
			Others		29	14.29
			Total		87	42.86
		Typhoid			109	53.69
		Swelling	Due to Fishing in Polluted Waters	Upper Half of the Body	35	17.24
				Lower Half of the Body	22	10.84
				Total	57	28.08
		Eye Irritation	Due to Fishing in Polluted Waters		31	15.27
		Diarrhoea			38	18.72
2.	Chronic	Skin Allergies			155	76.35
		Skin Allergies	Due to Fishing in Polluted Water		81	39.90
			Due to Farming in Polluted Water		28	13.79
			Total		109	53.69
		Breathlessness/Dyspnea			181	89.16
		Wheezing			65	32.02
		Rhinorrhoea			139	68.47
		Headache			68	33.50
		Stomach ache			66	32.51
		Discolouration of Teeth			129	63.55

		Migraine		10	4.93
		Asthma		46	22.66
		Pneumoconiosis		13	6.40
		Arthritis	Rheumatoid	9	4.43
			Others	33	16.26
			Total	42	20.69
		Sinusitis		85	41.87
		Tuberculosis		45	22.17
		Bronchitis		50	24.63
		Heart-Related		38	18.72
		Kidney-Related		24	11.82
		Cancer	Lung Cancer	8	3.94
			Other Types	17	8.37
			Total	25	12.31
		Chronic Fatigue		43	21.18
		Ear Infections	Due to Fishing in Polluted Waters	50	24.63
			Others	0	0
			Total	50	24.63
		Eye Infection	Due to Fishing in Polluted Waters	36	17.73
			Others	0	0
			Total	36	17.73
3.	Disability	Leg Amputation	Due to Fishing in Polluted Waters	1	0.49
			Others	0	0
			Total	1	0.49

Source: Author's Estimation

From table 5, it is clear that acute cold, cough and fever, have affected all the 203 households. The respondents opine that these illnesses are a result of other LURIs caused by industrial pollution. The respondents say that another major reason for fever, is the consumption of contaminated drinking water and especially fishing activities of fisherfolk in the river. Almost, 109 households have been affected by typhoid, which brings symptoms like fever, emesis, stomach ache and diarrhoea (Masuet-Aumatell and Atouguia, 2021). This indicates the increased level of contamination of water. Though emesis has affected 87 households, 29 and 58 have been affected by air pollution and the above-mentioned fishing activity, in polluted waters. These 29 households have been affected with emesis, due to occupational exposure to coal in Ennore industries. The individuals who deal with coal, due to their informal occupation, suffer from chest pain as coal gets stuck in their chest due to inhalation. Nausea becomes an unavoidable one too. The members who experience occupational exposures to coal, need to swallow large pieces of banana, to remove coal from their food pipe.

Diarrhoea has affected 38 households, and occurred due to the above causal factor. In this aspect, adaptation strategy performed by all households to prevent waterborne illnesses is the consumption of canned potable water, instead of ground and surface water. This measure has prevented occurrence of diarrhoea and emesis in the households that do not perform fishing. Further, fishing activity (occupational exposure) have led to acute swelling on the upper and lower halves of the body in 57 fisherfolk households. The discolouration of teeth (usually yellowish) has affected 129 households. This could be mainly attributed to causes other than fishing in polluted waters, namely usage of groundwater for brushing the teeth, and to suffice other purposes.

Chronic stomach ache has impacted 66 households, due to intake of polluted water during fishing activity. Chronic ear and eye infections have been experienced by 50 and 36 households, due to fishing in polluted waters alone. Further, a single household has an individual male who has undergone amputation of his leg, due to the infection caused by some deep cut in the leg, during fishing in polluted water.

Further, acute and chronic skin allergies prevail among LCHs. Among two sources, the first source is air pollution from industries. This airborne source has caused acute and chronic skin allergies in almost 200 and 155 households respectively. The respondents opine that the incidence of such acute skin allergies has been due to the emissions of fly ash, coal and pollutants and GHGs from NCTPS and other proximal industries. The skin allergies include reddish, whitish and blackish patches and inflammations on the skin. The second source is the water pollution caused by industries in the Kosasthalaiyar river and Ennore creek. Due to occupational exposure of fisherfolk to polluted waters, the same chronic skin

allergy issues are faced by them, in almost 81 households. Also, farmers in 28 households have been affected, through exposure to polluted agricultural fields.

Acute eye irritation due to air pollution, has affected 48 households. Almost, fisherfolk in 31 households have been observed to have such irritation, due to occupational exposure. Acute nose irritation has affected almost 50 households. Acute and chronic headache caused by air pollution, have affected 37 and 68 households respectively.

Chronic breathlessness/dyspnea has made 181 households (89.16%) suffer with ill-health. It seems to be the most widespread disease among the sampled households. Whereas, acute breathlessness/dyspnea has affected 107 households (52.71%). Since breathlessness is the co-morbidity of LURIs, it is possible to decipher that majority suffer from respiratory ACIs. Acute loss of consciousness has affected 16 households. This could be attributed to the sudden inhalation of violated levels of noxious pollutant and gases. Chronic wheezing, which is one of the main factors behind acute and chronic breathlessness, has affected 65 households. Chronic rhinorrhoea has impacted 139 households. It is a symptom of asthma, sinusitis and other respiratory illnesses. Chronic asthma has affected 46 households. A significant portion of those patients suffer from co-morbidities such as dyspnea, rhinorrhoea etc.

Chronic sinusitis, which is associated with rhinorrhoea, has relatively more incidence than asthma. Almost, 85 households suffer from sinusitis.

Chronic tuberculosis has affected 45 households (22.17%), and associated rarely with asthma, but often with wheezing. Chronic bronchitis has impacted 50 households, and has been associated mainly with wheezing, cough and tuberculosis among households.

Chronic heart-related illnesses have impacted 38 households. These illnesses are associated with LURIs caused by air pollution, especially particulate matter pollution. The chronic kidney-related illnesses such as kidney stones, kidney damage and kidney failure have affected more than 11.82% of households. These illnesses as discussed in the literature, affect the most vulnerable groups in each household.

All the above ACIs have seemed to impose a greater impact on health, and increase the economic burden of multimorbidity, as illnesses are interlinked with each other. So, this study computes the COI of multimorbidity due to these illnesses.

5.2 Annual Household COI

The following table 6, shows the details of the ‘Annual Household COI’ and its major cost categories.

Table 6. Annual Household COI

Sl. No.	Variable	Mean	Std. dev
1.	COI	119871.63	104680.9
2.	DCOI	66422.66	60161.08
3.	IDCOI	53448.97	67495.68

Source: Author’s Estimation

The above table 6, shows that mean household COI is Rs. 119871.63. The maximum COI value that has been spent/foregone by a particular family is Rs. 6,38,600, which is a huge one. The mean DCOI is relatively higher than the mean IDCOI, as the majority of households are LIHs with lower productivity losses/marginal level of income loss of patients and care-givers, due to low level of education and occupation. The following table 7, shows the distribution of the ‘Annual Household COI,

Table 7. Distribution of Annual Household COI

Sl. No.	Category	Number	Percentage
1.	Less than 1 lakh	118	58.13
2.	1 lakh - 2 lakhs	51	25.12
3.	2 lakhs – 3 lakhs	22	10.84
4.	3 lakhs – 4 lakhs	8	3.94
5.	Higher than 4 lakhs	4	1.97
	Total	203	100

Source: Author’s Estimation

From the above table 7, it is clear that the annual household COI of 169 (83.25%) households is less than Rs. 2 lakhs. Almost, 118 (58.13%) households have spent even less than Rs. 1 lakh. Though 118 households’ COI seems to be less than Rs. 1 lakh, if compared with 38 households with annual income of less than Rs. 1 lakh, this much of COI seems to be a regressive one for those 38 households.

The following table 8, presents the details of the annual household DCOI and IDCOI, which are the components of annual household COI.

Table 8. Annual Household DCOI and IDCOI

Sl. No.	Category	Mean (Rupees)	Std. dev
1.	DCOI	66422.66	60161.08
	1. Health Care Costs	63559.6	-
	(a) Physician Services	8773.399	4063.61
	(b) Medication	41801.97	44075.77
	(c) Diagnosis Tests	6624.38	8874.798
	(d) Institutional Inpatient Care and Treatment Services	6359.85	9798.98
	Total (Health Care)	63559.6	-
	2. Non-Health Care Costs	2863.054	-
	(a) Transportation	2863.054	2679.703
	Total (Non-Health Care)	2863.054	-
	Total DCOI (Health Care +Non-Health Care)	66422.66	-
	-	-	-
2.	IDCOI	53448.97	67495.68
	1. Other Productivity Losses	53448.97	-
	(a) Income Loss of Patients	36190.84	48066.9
	(b) Income Loss of Care-Givers	17258.13	48402.45
	Total (IDCOI)	53448.97	
	-	-	-
3.	Total COI (DCOI + IDCOI)	119871.63	104680.9

Source: Author's Estimation

The following table 9, presents the details of the proportion of direct and indirect cost components in the Mean COI.

Table 9. Proportion of Direct and Indirect Cost Components in the Mean COI

Sl. No.	Cost Variable	Percentage
1.	Physician Services	7.32
2.	Medication	34.87
3.	Diagnosis Tests	5.53
4.	Institutional Inpatient Care and Treatment Services	5.31
5.	Transportation	2.39
6.	Income Loss of Patients	30.19
7.	Income Loss of Caregivers	14.41
	Total	100

Source: Author's Estimation

The table 8, illustrates that direct costs have been divided into two major costs/strata, namely health care and non-health care costs. Further, health care costs have been divided into four types. Out of these, the mean medication cost, which is Rs. 41801.97, is the cost category on which almost 2/3rd of health care cost (65.77%) is spent. In case of proportions in the mean COI, mean medication cost occupies a huge 34.87%. This means that the households spend more on the drugs required for treatment. From all these, it is clear that the dominance of DCOI could shoot up the economic burden of each household to a large level.

The following tables 10 and 11, show the descriptive statistics of the proportion of annual household COI in the annual income of each household.

Table 10. Proportion of Annual Household COI in the Annual Household Income (COI/Y)

Sl. No.	Variable	Mean	Std. dev	Min	Max
1.	COI/Y	56.56%	63.01%	0	506.79%

Source: Author's Estimation

Table 11. Distribution of COI/Y

Sl. No.	Category	Number	Percentage
1.	Less than 25.00%	67	33.01
2.	25.00% - 50.00%	48	23.65
3.	50.00% -75.00%	43	21.18
4.	75.00% -100.00%	21	10.35

5.	Higher than 100.00%	24	11.81
	Total	203	100

Source: Author's Estimation

From table 10, it is clear that the mean COI/Y of 56.56%, is a serious socioeconomic concern for households with lower socioeconomic conditions. This indicates that more than half of the annual household income is spent for maintenance and cure/rehabilitation of the health of members in each household, by LCHs, due to their mere living and occupation in the Ennore peri-urban industrial region and its industries respectively. Especially, a maximum COI/Y of 506.79% could be seen as a humongous level of burden imposed on that particular household. From table 11, it is clear that 85 households have COI/Y of more than 50%. Almost, 24 households have COI/Y higher than their whole income.

Further, the MLRM is used to study the influence of social, demographic and economic variables on the annual household COI.

5.3 MLRM

The following table 12, shows the variables used in the MLRM.

Table 12. Variables for the MLRM

Sl. No.	Type of Variable	Label	Description
1.	Gender	IDV-1	Number of males with chronic illnesses in the household
		IDV-2	Number of females with chronic illnesses in the household
2.	Age	IDV-3	Number of members in the working age 15-64 in the household (OECD, 2024).
		IDV-4	Number of members in the non-working age 0-14 and ≥65 in the Household (OECD, 2024).
3.	Income	IDV-5	Annual Household Income (In lakhs)
4.	Cost	Dependent Variable (DV)	Annual Household COI (In lakhs)

Source: Author's Estimation.

The number of males and females with chronic illnesses in the household have been taken as gender variables, in order to find out whether the chronic condition of which gender influences the COI more. Since the main factor that determines COI is the presence of chronic illnesses (Okediji et al., 2017), it is taken into account. Further, the number of working and non-working age members in the households have been taken as two age variables to find out which age (associated with occupation) group influence the cost more. Though age, gender and chronic illnesses influence the COI, it is the income that stands as a main factor that influences the COI. So, annual household income is taken into the analysis. The following tables 13, 14 and 15, show the results of MLRM.

Table 13. Model Summary

Model	R^2	Adjusted R^2
1	0.751	0.745
Predictors: IDV-1, IDV-2, IDV-3, IDV-4, and IDV-5.		

Source: Author's Estimation

Table 14. ANOVA

Model	Source	SS	df	MS	F	Sig.
1	Regression	389.27	5	77.85	119.43	0.0000
	Residual	129.08	198	.65		
	Total	518.34	203	2.55		
a. DV: Annual Household COI						

Source: Author's Estimation

Table 15. Coefficients

Sl. No.	Model	Coefficients		t	Sig.
		B	Std. Error		
1.	IDV-1	0.827	0.110	7.53	0.000
2.	IDV-2	0.686	0.088	7.76	0.000
3.	IDV-3	0.016	0.041	0.41	0.686
4.	IDV-4	0.009	0.076	0.12	0.907
5.	IDV-5	0.082	0.019	4.36	0.000

Source: Author's Estimation

From table 13, it is clear that the MLRM employed in this study is fit, with a good level of R2 value '0.751'. Further, the adjusted R2 of 0.745 indicates that the model's five IDVs explain 74.5% of the variation in the DV 'Annual Household COI'. This clearly states that there is a large/significant influence of gender, age and income on the annual household COI. Especially, the p-value of 0.0000, clearly indicates that the MLRM used here is highly significant. This implies that at least one IDV out of the five, has a significant influence on the annual household COI.

The number of males with chronic illnesses in the household, impacts the annual household COI at the maximum. The coefficient of 0.827 indicates that if there is an increase in a male member in the household, the annual household COI will increase by Rs. 82,700. Such an increase could be seen a catastrophic one for especially households with an annual household income of less than Rs. 1 lakh, who constitute around 18.71% of the households. It imposes a highly regressive burden, except on a few high-income households. Further, IDV-1 is the variable with highest predictive power among other IDVs, as the standard error of this variable/predictor is relatively very low than its coefficient.

Further, the coefficient of IDV-2 is 0.686. This IDV-2 is the second most strong predictor of annual household COI as the coefficient is high and at the same time, the difference between the standard error and coefficient is very high. A coefficient of 0.686, clearly means that an increase of one female with chronic illness in the household will increase the annual COI of Rs. 68,600. Comparing the coefficients of both IDV-1 and IDV-2, makes it clear that the number of males with chronic illnesses in the household have relatively higher impact on the annual household cost illness, than that of the females. The reason behind this is the males' occupational exposure to pollution through fishing, farming and industrial employment. The respondents in the four sampled villages opine to this fact. Further, a p-value of 0.0000, implies that the annual household income has a high level of significance in impacting the annual household COI. Especially, the coefficient of 0.082 states that an increase of Rs. 1 lakh in annual household income leads to an increase of approximately Rs. 8200 in annual household COI. So, it is possible to decipher that though annual household income is highly significant with annual household COI, the increase in annual household COI is just marginal. This could be mainly due to influence of the gender variables that are associated with the chronic illnesses. Especially, the effect of chronic illnesses could be the factor behind it.

The coefficients of the IDV-1 and IDV-2 are just 0.016 and 0.009 respectively. The coefficient of 0.016, clearly depicts that an increase in a single member in the working age in the household leads to an increase of approximately just Rs. 1600 in the annual household COI. Further, the standard error is above the coefficient. So, the particular age variable is a poor predictor of the COI. Above all, the p-value is greater 0.05 (0.686). It implies that the working age 15-64 is insignificant with COI. The same case is observed in case of non-working age population, where its p-value is greater than 0.05 (0.907). It is also a poor predictor of the COI. So, the results conclude that males with chronic illnesses impact the COI more than the females. Further, the annual household income has a significant positive relationship with the COI. Then, the age variables have been found to be insignificant with COI, when chronic illness and household income are taken in account. That is, the strength of chronic illness is relatively very high in terms of impacting the COI than the age and income. Though the model summary is able to convey this, the scenario seems to be little different when further introspection is undergone.

When the age variables were regressed separately with COI, the age variables were found to be significant. The following tables 16, 17, 18 and 19, show the variables for the second MLRM and the results of that MLRM i.e., age variables with COI.

Table 16. Variables for Second MLRM

Sl. No.	Type of Variable	Label	Description
1.	Age	IDV-I	Number of members in the working age 15-64 in the household
		IDV-II	Number of members in the non-working age 0-14 and ≥65 in the Household
2.	Cost	DV	Annual Household COI (In lakhs)

Source: Author's Estimation

Table 17. Model Summary

"Model"	R^2	Adjusted R^2
1	0.602	0.598
Predictors: IDV-I, IDV-II.		

Source: Author's Estimation

Table 18. ANOVA

Model	Source	SS	Df	MS	F	Sig.
1	Regression	312.12	2	156.06	152.10	.0000
	Residual	206.23	201	1.03		
	Total	518.34	203	2.55		
a. DV: Annual Household COI						

Source: Author's Estimation

Table 19. Coefficients

Sl. No.	Model	Coefficients		t	Sig.
		B	Std. Error		
1.	IDV-I	0.377	0.026	14.72	0.0000
2.	IDV-II	0.158	0.093	1.69	0.092

Source: Author's Estimation

From the table 16, it is clear that number of members in the working age 15-64 in the household is taken as the first IDV i.e., IDV-I. In order to differentiate from the IDV-1 in the first MLRM, roman numeral has been used for this first IDV. The same is applied to the second IDV.

Further, from table 17, it is clear that the second MLRM employed in this study is fit, with good levels of R2 and adjusted R2 values of 0.602 and 0.598 respectively. This indicates that the model's two age-related IDVs explain 60.2% of the variation in the 'Annual Household COI'. Especially, the p-value which is 0.0000, clearly indicates that the second MLRM used here is highly significant. This implies that at least one IDV out of the two, has a significant influence on the annual household COI. From table 18, it is possible to decipher that the above premise is true. The IDV-I, number of members in the working age 15-64 in the household, impacts the annual household COI relatively higher than the number of members in the non-working age group in the household. The IDV 'Number of members in the working age 15-64 in the household' is highly significant with the 'COI', with a p-value of 0.0000. The coefficient of 0.377 indicates that an increase of one member in the working age 15-64 in the household will increase the annual COI by approximately Rs. 37,700. This seems to be a huge impact. Further, its coefficient is relatively very larger than the value of its standard error. This indicates that 'Number of members in the working age 15-64 in the household' is a very good predictor of the 'Annual Household COI'.

Further, the coefficient of 0.158 of IDV-II, denotes that an increase of one member in the non-working age 0-14 and ≥65 in the household, increases the annual household COI by approximately Rs. 15,800. This is not even a half of the impact of IDV-I. Further, the coefficient of IDV-II is just slightly higher than its standard error. This denotes that IDV-II is a medium level predictor of annual household COI, with a p-value of 0.092. IDV-II is significant with 10% level of significance. So, it is clear that the number of members in the working age group 15-64 has a relatively higher impact on the annual household COI, than the non-working age group. That is, the working age population 15-64 account for higher costs of illness in the study area 'Ennore Peri-Urban Industrial Region'.

6. Conclusion

The ACIs caused by the Ennore's industrial pollution has imposed an interlinked structure of multi-morbidity in all sampled households. Especially, the impact of chronic illnesses is found to have imposed a large economic burden of multi-morbidity on the LCHs. The mean annual household COI has been found to be Rs. 119871.63. Further, the DCOI has been found to be relatively higher than the IDCOI. Especially, the mean COI/Y of 56.56%, seems to be a catastrophic cum regressive burden on the LCHs, especially among those with lower socioeconomic status and disadvantaged groups in their households. Since households with lower socioeconomic status form the majority in the Ennore peri-urban area, higher COI is not only a catastrophe in terms of economic burden but also socioeconomic welfare of the LCHs.

Further, from regression analyses, it is clear that males have experienced a relatively more impact than females, as they are associated with occupational exposure to pollution. That is, through fishing and agriculture in polluted waters and occupational exposure of industrial labourers. Further, a significant positive relationship of annual household income but annual household income has a significant positive relationship with the COI. Then, the insignificance of age variables reveals that chronic conditions and income have higher influence than the age variables. Further, discovery of significance of age variables through separate regression exercises depicts the real impact on the age-related disparities of the COI. Especially, an increase in number of members in the working age 15-64 has found have higher impact on COI, than that of the non-working age population. This study concludes that the Ennore Peri-urban area needs a public health intervention program that maximises the utility gain of health benefits, as it lacks an optimum health care system that provides service at lesser costs. Especially, the males with chronic illness in the working age population 15-64 must be prioritized in terms of public health services. These programs must be provided at subsidized rates to the working age population.

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