Socio-Economic Impacts of Water Pollution: A Case Study of Delhi

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Abstract: Delhi is home to more than 20 million[1] people from all over the country. According to BIS, Delhi's tap water is most unsafe. People with different socioeconomic background gets exposed to this pollution differentially. This study of household specific water pollution exposure index in seven districts in Delhi manifests this and can be helpful in channelizing the policies in right direction and thus in efficient utilisation of resources.

Keywords- Water Pollution, BOD, Delhi pollution.

INTRODUCTION

Water and its quality plays an important role in healthy living life but with the advent of industrialisation in 18th century, came a package of secondary effects that has been posing serious threat to various aspects of human life. Water quality is deteriorating and its main cause are unconstrained discharge of effluents, untreated industrial water discharge and various domestic waste. As evidenced, deterioration of water quality is having deleterious effect on human health. Burden of this can be viewed clearly in increasing mortality and morbidity and decreasing cognitive ability. Contaminated water is one of the most significant factors which contribute to the high morbidity and mortality from infectious diseases in developing countries. Contaminated water supplies have the potential to cause large and explosive epidemics (e.g., cholera). The non-availability of specific treatment for viral diseases such as hepatitis and the increasing problem of antibiotic resistance. There is continuous ignorance on the part of government and various regulating agency and result of which is that 80% of world population is facing water supply and security threat. As per WHO reports, Globally, at least 2 billion people use a drinking water source contaminated with faeces and by 2025, half of the world's population will be living in water-stressed areas. Water often becomes contaminated during distribution or transport to the home, and during storage and handling within the home. Contaminated water can transmit diseases such diarrhea, cholera, dysentery, typhoid, and polio. Contaminated drinking water is estimated to cause 4,85,000 diarrhea deaths each year. (WHO, 2019).

India being a developing country has limited resource to cope with these kinds of problems. Rapid industrialisation, urbanisation and population explosion is exacerbating the problem in hand. According to reports, 70% of water in India is contaminated impacting every 3 in 4 Indians and contributing 20% of total disease burden. Typhoid, diarrhea and cholera are among the most prevalent water borne disease. India has 20 water basins and most of them are polluted. The Ganga and the Yamuna is the most polluted river of the country.

Now a days, Delhi is facing so many environmental issue, because of which it is posing serious threat to well being of city's and area's inhabitants as well as flora and fauna. It is also 9th most populated metropolis of the world. Because of such a large population it is creating pressure on the scarce resources such as water. The river Yamuna, which is the main reason for Delhi's existence is heavily polluted. Recently according to BIS, Delhi's tap water is most unsafe. People with different socioeconomic background resides here and gets exposed to this pollution differentially. According to studies, at its point of exit from city limits, DO(Dissolved Oxygen) is only 1.3mg/l and colliform counts jumps from 8500 per 100ml at entry to 329,312 per 100 ml at exit against the norm of 5mg/l(DO) and 500/100ml.In 2007, half of the cities raw sewage went to the river without treatment. Here we try to study household specific

[1] According to census 2012

water pollution exposure index for household in seven districts in Delhi.

It is said that, 55% of the cities population is connected to the sewer system and treatment plants but due to clogging and corrosion in the system many of the system do not work at its full capacity.19 drains flows into the river, contribute to 96% of the total pollutants. Only 5% of the sewer that is discharged is being treated posing serious health hazard to whoever is drinking that water. Now talking about the condition of tap water, whether it is potable or not, Delhi is at the bottom of list in ranking on water quality according to BIS standard. According to them, out of 28 parameters Delhi failed to meet criteria on 19 parameters. (Consider Figure 1)

Water samples were analysed for various physio-chemical parameters such as pH, total suspended solids (TSS), total dissolved solids (TDS), total hardness (TH), total alkalinity (TA), biological oxygen demand (BOD), chemical oxygen demand (COD), dissolved oxygen (DO), electrical conductivity (EC), chloride, sulphate, nitrate, toxic metals, and microbial population (MP) levels. For our analysis, we will use BOD to measure the level of water pollution. BOD is a measure of the amount of oxygen that require for the bacteria to degrade the organic components present in water. The BOD standards of a non-contaminated water must be below 3 mg/l. The farther the value of water sample from this standard, the more contaminated the water.

In this paper, we would like to see if there is any distributional aspect of water pollution on socioeconomic attribute of population residing in different district of Delhi. For this, first of all we construct household exposure index and will try to establish if there is any relation between exposure index and different socioeconomic attributes like age, gender, religion, education, income etc. Based on result, we are going to conclude if there is any distributional aspect within city. The objective of our study is to examine the cross-sectional relationship between exposure and various socioeconomic and other characteristics of the population across the districts of Delhi. This study is important because Delhi, in recent times, has experienced very high contamination in water coupled with an ever-bursting population through immigration from different parts of the country. There have been consistent measures taken to counter water pollution and its impact on health of the residents but the policies are not targeted differently and such common policies for the whole population who are exposed to different level of threats is not going to reap efficiently out of applied resources. Therefore, our study can be helpful in channelizing the policies in right direction and thus in efficient utilisation of resources.

Samples were collected from 11 different places out of which every samples fails the test. However, according to other two studies, one by Jal Shakti Ministry and other by Delhi government, water supplied is fit for drinking and in fact better than most of the European countries.

LITERATURE REVIEW

Water Pollution is a rising global crisis over the years. Multiple economic approaches have been devised for the quantification of health damage caused by environmental pollution. Several studies have examined the impacts of water pollution on life of different beings. Dasgupta (2004) studies the health damages from water pollution in Delhi through production function approach by focusing the utility maximizing behavior of the consumers. The paper examines the valuation of water as a resource in relation to the low income, infrastructurally disadvantaged urban household, by exploring the links between water quality, waterborne disease, and the preference patterns of households in urban Delhi. Thus measuring the total cost of illness due to water contamination in drinking water in Delhi. The consequences faced due to water pollution in Delhi can be easily studied from their work and their results can be taken as an implication to our model.

Sayal et al.(2016) in their study quantifies the environmental impact of lead (Pb) contamination in household drinking water in Dingi village of Pakistan. They collected the water samples from village categorised in three different zones on the basis of distance from wastewater channel. To calculate the impact of contaminated water on household, a exposure index was formulated. With the help of health production function approach, they estimated the marginal willingness to pay of the household for water contamination to estimate the cost of illness and welfare loss. However, a probit model was applied to estimate the probability of sickness, plus medical and aversive costs.

While, Majumdar and Gupta (2009) uses household production function approach to formulate a structural model of averting behaviour and illness to empirically estimate the total losses borne by households of Kolkata on averting activities and waterborne illness. For this, they estimate out-of-pocket expenditure and opportunity cost of illness. They found that the undesirable quality of water results in huge spending every month by households. We are trying to study extra expenses borne by people from pollution which leads to burden on household's budget and are reflected in cutting short of education or nutritional food. Our results are expected to be similar to that of Majumdar and Gupta (2009).

To study the air pollution impact on household, Kathuria and Khan (2007) tries to find evidence of environmental inequity through the relationship between socio-economic characteristics and air pollution exposure by computing a household-specific air pollution exposure index for Delhi. They found that exposure is differently impacted by socio-economic characteristics depending upon the location of households. A higher value of the coefficient in industrial areas suggests that location of such households plays an important factor to exposure level. Also, the vulnerability of older people and children indicates that irrespective of location these are exposed more to pollution. In our framework, we are trying to apply Kathuria and Khan (2007) approach but in the light of water pollution by constructing a household exposure index and will tried to find relation between exposure index and different socioeconomic attributes.

In another study by Zivin and Neidell we studied that Pollution exposure not only cause diseases but also impact the earning ability of people. To prove this, Zivin and Neidell (2012) used dataset on the productivity of agricultural workers in analysing the impact of ozone pollution on productivity. They argued that pollution also have productivity impacts on the intensive margin of workers and attempt to assess this environmental productivity effect. They find that the labor supply of agricultural workers is insensitive to ozone levels in their research. Agricultural workers face considerably higher levels of exposure to pollution than individuals who work indoors. On the parallel lines, takeaways for us from their research is that agricultural workers face considerably higher levels of exposure to contaminated water levels since water used in irrigation are not well treated.

DATA AND METHODOLOGY

In our study, we have utilised the NSSO Household data from 68th and 71stround for household demographic, social and economic factors in Delhi. From there, we have taken data of 948 household living in eight district of Delhi regarding various demographic and socioeconomic factors like education, age distribution, income, religion occupation etc. We have taken dummy for occupation, caste and RTWQMS. If any member of the household works in industry we take it as 1 otherwise its 0.Similarly for the presence of lower caste we have taken 1 and 0 for upper caste. If any RTWQMS is located in that area we have taken it as 1 otherwise its 0. We have appropriated the water pollution data for year 2011 from CPCB. We have considered eight districts (North West, North, North East, East, New Delhi, West, South West and South) and chosen the nearest Real Time Water Quality Monitoring Stations (RTWQMS) for each of these districts. Since water in Delhi comes from Ganga and Yamuna, and there are four places where RTWQMS is located for the respective rivers, we have taken mean BOD of water as a measure of water pollution. Then we find from which barrage which district is served which will help in finding the extent of water pollution exposure. Yamuna at Nizamuddin has the highest BOD with 15.5mg/l while Yamuna at Wazirabad has the lowest one with 2.2mg/l. In order to find how people are exposed to water pollution, an ideal index of exposure is necessary. But people in the same region will have different levels of exposure depending on various socioeconomic and demographic characteristics. We, therefore, calculate a household specific exposure index.

LOCATION OF RTWQMS

River Ganga

- Haridwar Upper Ganga Barrage (BhimGoda) by CPCB River Yamuna
- Delhi Upstream, Wazirabad by CPCB
- Delhi Downstream Okhla by CPCB
- Delhi upstream Okhla at Kalindi Kunj
- Nizamuddin Bridge

For this purpose, we first calculate an household index (HHi). We segregate each household i, based on their age and occupation type (hh_type) which are as below:
nam = Number of Adult Males
naf = Number of Adult Females
nom = Number of Old Males
nof = Number of Old Females
nc = Number of Children

NSSO data categorizes occupation type under the name hh_type, given by
hh_type = 1 for Self employed in agriculture
hh_type = 2 for Self employed in non-agriculture
hh_type = 3 for Regular wage/salaried
hh_type = 4 for Casual labour in agriculture
hh_type = 5 for Casual labour in non-agriculture
hh_type = 9 for others
Now, based on the hh_type, we assume the litre of water exposed to water pollution for adult male and female (nam & naf) as well as for old male (nom), old female (nof) and children (nc)

Water pollution Exposure for adult male and female	
Hh_type	Exposure(in unit)
1	80
2	60
3	50
4	100
5	50
9	50
Exposure of Non-working Group	
Nom	30
Nof	40
Nc	60

Here, 1 unit=5ltr. Of water.
Based on the above assumptions of exposure(in litre), we calculate the household index (HHi) given by:-

$$HHi = \frac{(nam \times Litre)+(naf \times Litre)+(nom \times 40)+(nof \times 40)+(nc \times 50)}{100 \times hh\_size}$$

where, hh_size is size of the household and 100 is assumed to be maximum amount of water used by each person[2]

We further calculate Xj, which is the BOD of water supplied by corresponding river in the jth district for j = 1,....,8. we have used mean value of BOD for the analysis.
Then, we arrive at the household specific exposure index, given by;

$$HHX_{ij} = X_j \times HH_i$$

where, HHX_{ij} is the BOD exposure of the i^{th} household in the j^{th} district.
To assess the effect of various socio-economic factors on the household exposure to water pollution, we regress the household exposure index (HHX_{ij}) on variables such as income, education, caste, religion, proportion of females, old and children in the household, etc. The relevant determinants of exposure are:
INCOME: Income represents economic vulnerability of the households. Many studies have shown and stated that household act differentially when it comes to averting expenditures. Averting expenditures means expenditure on item or practices that might reduce exposure to water pollution. People might use RO, filter or other water purifying methods so that water could be usable. Studies have shown that rich people averting expenditures are generally higher and less exposure to water pollution while poor have limited resource to spent on these methods and they simply boil water so that it could be usable and hence exposure could be larger.

EDUCATION: Education plays important role in exposure to water pollution. A priori, it could be expected that more educated will be less exposed because generally they put more emphasis on health and hence try to maintain water quality at best. Illiterate people are generally ignorant about these things and hence are more exposed. So, in the study, we incorporate education by creating an education index based on age(>14) and years of schooling.

CASTE: Caste system is very evident in Indian society and it could impact extent of exposure to water pollution. In general, lower caste people live in places that are unhygienic, shabby and quality of public services are worse. They generally get water with poor

[2] Approximately 50 litres of water per person per day are needed to ensure that most basic needs are met. (WHO, 2017). Assumption of 100 litres has been taken to accommodate other activities.

quality and since also don't have resources to purify they could be highly exposed. We have constructed a dummy variable for caste identification. 1 indicates lower caste and 0 for upper caste.

RELIGION: Different religion has different way of ablution because of which they could exposed differentially. According to a study among various religions, Muslims are more prone to water borne disease and highly exposed to water pollution. The reason is that members of the Muslim community offer prayer five times a day along with obligatory ablution (a ritualistic cleaning of parts of the body, including rinsing the mouth with available water). Again for Religion indication, we have constructed a dummy variable.

PROPORTION OF FEMALE: In most cases, females of the household are engaged in domestic works like cooking, cleaning etc. because of which they frequently comes in contact of water in comparison to male counterpart. So there might be differential impact on exposure index if we consider proportion of females in the household.

PROPORTION OF OLD AGE : Old person of the household comes in contact of water only when bathing or drinking. Other than that they are not exposed to any kind of water contamination. So household with high proportion of old age people, ex-ante expected to have negative impact on exposure index.

OTHER CONTROLLING VARIABLES

WEALTH: Ex-ante we expect wealth to have some effect on household exposure as wealth can add to the spending capacity of households in combating pollution. In this model total land possessed have been taken as a proxy for wealth.

OCCUPATION: This variable measure how different occupation affects an individual's exposure towards water pollution. Depending on type of occupation different individuals are exposed differently as approximated in above table. People involved in agricultural activities are affected more intensely.

Further we use a multivariate OLS regression to see the effect of the above mentioned variables on household exposure index (HHXij).

Preliminary Analysis:

Our study is centred on finding whether pollution exposure has any discriminatory effect for households based on their socio-economic characteristics. For the study we have defined the household pollution exposure index as explained above. This is our dependent variable which we regress on the attributes explained above. We use a multivariate OLS regression to see the effect of the above mentioned variables on household exposure index (HHXij).

The model is log-linear in exposure index and income while other variables are in normal or dummy forms as given below:

$$\ln HHXij = \beta 0 + \beta 1 income_{ij} + \beta 2 Educationindex_{ij} + \beta 3 occupation_{ij} + \beta 4 Total\ land\ possessed_{ij} + \beta 5 C_{ij} + \beta 6 R_{ij} + \beta 7 proportion\ of\ female_{ij} + \beta 8 proportion\ of\ old + \mu_{ij}$$

Where the subscript j refers to the BOD, μ_{ij} is the error term associated with BOD j, and the X_i are observations of the explanatory variables.

The log-linear form of model has been used to make the data approximately normally distributed because of the skewed distribution of some of the variables. Also, the log-linear formulations can take care of the problems of unequal variation and outliers. Moreover, it is easier to interpret the regression coefficients meaningfully in terms of growth in the dependent variable where a change of 1 per cent in the explanatory variable xi corresponds to a percentage change in the dependent variable. Our interest is beta coefficients which will determine the magnitude of effects of different attributes on household exposure.

Preliminary analysis have shown that, only 2 out of 8 variables are significant in nature. Income which was expected to have negative impact on household exposure is not significant and positive in nature.

RESULTS

We have used three types of the specification for the analysis, results of which are given in the table 1. From table 1, we can see that in specification 1 & 2 only 3 out of 8 variables are significant. Let's concentrate on specification 1 which is a log lin specification. So when we increase income by 1 unit exposure index would get affected by 26.7% but it is not significant. We have expected, ex-ante that income might have significant negative impact on exposure index but it is not in ours simple specification. This could be because given the location of a household, income cannot make much difference on the exposure caused by fulfilment of daily household activities. Coefficient of prop_occu is positive and significant indicating that presence people working outside has positive impact on exposure and hence are more prone water pollution. It means if there is a person working outside, then exposure might increase by 19%. Also, prop_old has negative significant coefficient as expected ex-ante. It means that presence of more old people have negative impact on exposure since apart from daily needs they rarely comes in contact of water and hence are less prone. Presence of old person decrease the exposure by 15.4%.Besides all other variables are not significant. So we have regressed another formulation which is log linear in nature. Now let's concentrate on specification 2. Again only 3 variables are significant. Income in this specification is also insignificant which was ex-ante expected to have negative significant impact.

In specification 3, since demographic data tells that there is a correlation between income and caste so we have dropped the variables c and r and prop_occu and we can see that income has become highly significant and positive. Now it can be said that income has played a positive role in exposure to water pollution. In this specification also, prop_old is significant and negative.

Now lets look at the constant in all three specification. It is positive and significant. It could be said that even if all the variables are taken to be 0, exposure to water pollution is still significant and positive.

In the analysis which was done by Dasgupta, she said that there is no straightforward relationship between household reporting cases of illness due to water borne disease and income quintile to which belong. Now if you take a look at column 1, we also don't have any significant relationship between household exposure index and income. She also concluded that educational attainment is not really a factor that contribute in incidence of diarrhea. It is not significant. In our case, also education doesn't contribute in household exposure to water pollution.

Majumdar and Gupta mainly worked through cost of averting expenditure and concluded that religion is not a significant factor in contributing to expenditure borne due to illness. In our regression also religion is not affecting household exposure to water pollution. In short, religion might be a factor but is not significant indicating ablution doesn't have any bite in reality. They also said that presence of young children doesn't have any impact on COI and household with more number of people is expected to have more burden of expenditure. Here in our study also presence of children don't have significant impact on exposure index. But proportion of old is significant which indicates that old people are more likely to fell sick due to impurities in water. It might be because of weak immunity or low count of WBC which aid in fighting with diseases.

So in conclusion we can say that more or less our results are in line with various studies which was done independently at different locations.

Tables and Figures:-

Table 1

Dependent variable:-ln_HHX $_{ij}$			
	(1)	(2)	(3)
Income	2.67 (3.21)		8.3432 (3.3415)*
ln_income		0.11 (0.02)	
edu_indx	-0.0005879 (0.0035609)	-0.000338 (0.004)	-0.0020 (0.0035)
prop_occu	0.193 (0.195)*	0.193 (0.0196)*	
land_total	16.67 (24.33)	15.25 (24.35)	-25.71 (25.63)
prop_female	-0.027 (0.047)	-0.0269 (0.0474)	0.0385 (0.0490)
Prop_old	-0.154 (0.035)*	-0.1545 (0.0364)*	-0.1466 (0.0368)*
C	-0.041 (0.023)	-0.0412 (0.0232)	

R	-0.024 (0.028)	-0.0234 (0.0282)	
constant	2.48 (0.0374)*	2.3921 (0.1625)*	2.5014 (0.0307*)

*significant at 5%

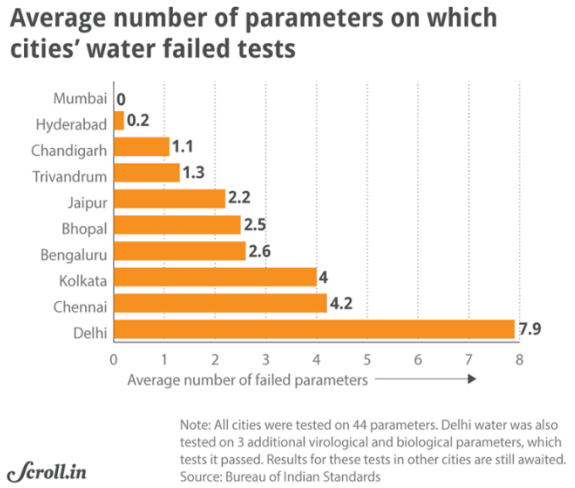

Figure 1- Cities failing pollution parameters

CONCLUSION

Residents of Delhi generally perceives water sources as of undesirable quality. There are frequent media reports about undesirable quality of water in Delhi. Apart from chemical contamination, water in Delhi contains pathogenic bacteria which causes different water borne diseases. The undesirable quality of water results in huge expenditures every month by household. These expenditures consist of out of pocket health expenditure and averting expenditures. Improvement in quality of water could drastically reduce these expenditures.

A good quality provision of services requires huge amount of investment but given the nature of bureaucracy and political hurdles this sector attract very low quantity of investment by private investors. Given the limited budget of the government, if the provision identify and target based there might be some improvisation in quality of water. Government should identify the most vulnerable section of the society and then provide them with the basic facilities. Poor people spend so much on these disease, if govt. could take pro active steps these people might not suffer that much.

DATA SOURCES

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