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Economic Impact of Fluoride Contamination on Land and its Averting Expenditure in Western Zone of Tamil Nadu

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Abstract

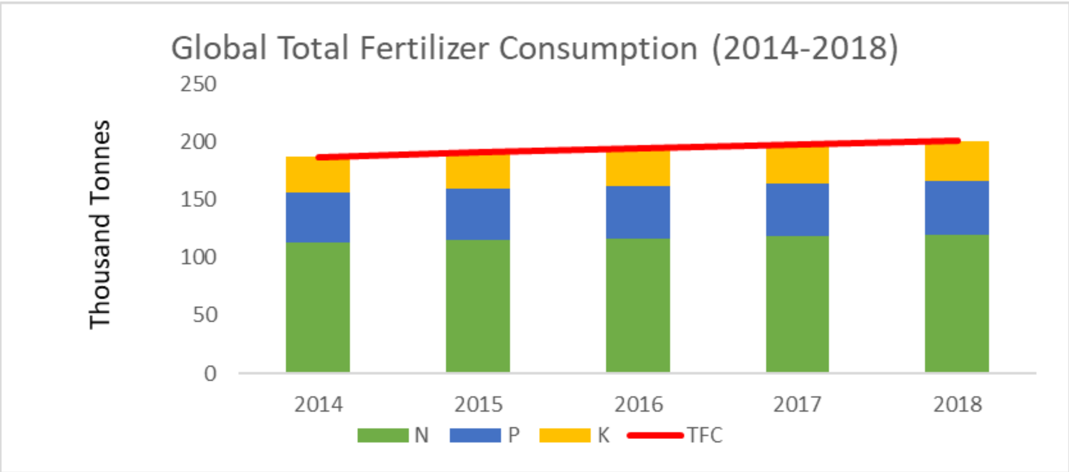
Groundwater is a prime source for human intake, agricultural and industrial uses in several regions around the globe. Continuous depletion of groundwater is a global threats that primarily affects agriculture sector through contamination in groundwater such as fluoride discharge in water. Fluoride is one of the critical ions that negatively influencing the groundwater quality. Anthropogenic interventions such as overuse of phosphatic fertilizers in the farmers field, brick manufacturing industries, over deepening of well are the lead sources for the release of fluoride in ground water as well as the environment and it is becoming worldwide problem. India annually extracts around 251 cubic kilometre of ground water which is 52 per cent of the total global annual extraction of groundwater and also 90 per cent of groundwater is used for irrigation that covers 60 per cent of the total irrigated area. The current study is to estimate economic losses such as land and crop productivity, averting expenditure due to use of fluoride contaminated groundwater. The primary data were collected by using multistage random sampling method of about 248 farmers of low fluoride affected, moderately fluoride affected, highly fluoride affected and non-fluoride affected locales in the proportion of sample size. Analysis employed for the study percentage analysis and the results revealed that fluoride contamination could increase the area under fallow, increase years of fallow and decline in yield was increased. Fluoride contamination in ground water was the major factor that influenced these effects in affected locales as opined by the respondents.

Introduction

The demand for quality water for irrigation of crops is ever increasing, whereas the availability of water remains comparatively constant in most parts of the world. Continuous depletion of groundwater increases global threats, including sudden decline in agriculture activities [Aeschbach-Hertig and Gleeson (2012) & Turner *et al.* (2019)]. Agricultural development and growth should increase if a growing population is to be fed. Pressures on the existing water supply are intense between industry and agriculture. Lower quality water is presently being employed to satisfy the requirements of agriculture. Such water might contain high concentrations of salts as well as contaminated substances such as fluoride, lead, arsenic and boron (Miller *et al.*, 1999).

Fluoride is one of the critical ions that influence the groundwater quality. Fluoride in groundwater occurs due to natural activities or anthropogenic activities. It is a chemical element belongs to halogen family and it ranks 13th element available in plenty of earth's crust [Greenwood and Earnshaw (1984); Gillespie *et al.* (1989); Brindha and Elango (2011); Mishra *et al.* (2014); Pradhan and Biswal (2018)]. Fluoride rich minerals such as apatite, biotite, fluorite and hornblende present in parent rocks are weathered and lead to fluoride discharge in groundwater (Rao 2009); Brindha *et al.* (2016)). Anthropogenic interventions such as overuse of phosphatic fertilizers in a farmers field, brick manufacturing industries, over deepening of well, coal based power station, smelting industries are lead to a release of fluoride to environment (Pickering (1985); Ozsvath (2009); Rawat *et al.* (2010); Dey *et al.* (2012); Mukherjee and Singh (2018)).

Figure 1.1 Global Total fertilizers (NPK) consumption



Source: *FAO- World Fertilizer trends and outlook, 2018*

Total fertilizer consumption is at an increasing trend at global level. In the year 2014, the total fertilizer consumption was 1,86,895 thousand tonnes and for the year 2018, it was about 2,00,522 thousand tonnes. Between these four years consumption of total fertilizer has been increased to 13,627 thousand tonnes. It clearly indicates that the application of over dosage of fertilizers leads to contamination in groundwater (Kundu and Mandal, 2009).

Higher concentration of fluoride are associated with deep bore well water (Razdan *et al.*, 2017). Globally 29 countries have been affected by fluoride contamination groundwater table. India is one among them, groundwater is one of the major source for agricultural practices. Annual water availability is about 1,869 Billion Cubic Meter (BCM) per year, out of which surface water is of 690 BCM per year ground water is of 433 BCM per year respectively. However, groundwater is easily accessed almost everywhere through bore wells and thus, forms the largest share of agriculture and drinking water supply. Of the extracted groundwater around 89 per cent is used in the irrigation sector, 9 per cent is used for domestic purposes and the remainder 2 per cent goes into industrial use. In India, per cent of wells with water below ten years average (2007-16) shows that Tamil Nadu ranks first with having 87 per cent of digged wells (CGWB, 2018). Consumption of fertilizer has increased from 938.025 to 969.740 thousand tonnes from the year 2000-01 to 2017-18 (CMIE, 2019). It clearly shows that fertilizer consumption has been increased over the years. Tamil Nadu is one among fluoride affected states in India where 23 out of 33 districts are prone to fluoride contamination in water (CGWB, 2016). Since, last few decades, millions of people are affected due to fluoride contamination in groundwater. With this background, the present study attempts to estimate economic losses due to use of groundwater with fluoride contamination which includes influence on agricultural land which could be short term or long term.

Materials and Methods

Study area

Multistage random sampling method was used for the selection of study area. At first stage, District wise fluoride affected locales of Tamil Nadu with the permissible limit of above 1.5 mg/L collected from central ground water board, 2014-15. In second stage, district has been segregated into different agro climatic zones based on fluoride content and finally, western zone was selected. At third stage, it was classified into affected locale (highly, moderately and less fluoride affected locale) was shown in Table 1. From this two blocks from each of the locales, then three villages of each block were selected based on secondary data.

Table 1: Classification of Fluoride affected locales

Classification	Fluoride Affected Locales	Class Interval

Less	a) Andipatti, b) P.K. Palayam, c) Dindigul, d) Bangalapudur	1.59 – 1.69
Moderate	a) Kunnam, b) Natham	1.69 – 1.83
High	a) Thoppampati, b) Athani, c) Ammapet	1.83 - 1.97

Finally, 186 samples were selected based on sample size methodology given by Yamane (1967)

$$\text{Yamane Formula } (n) = \frac{N}{1+N(e^2)}$$

Where: n = sample size; N = total number of farmers population (6021618); e= error limit/ level of precision of 5 % (0.05).

From the above sampling formula, the arrived sampling size was 399. But taking up the time constraint in mind and for convenience, sampling size of about 46.5 per cent i.e. 186 samples were preferred for the study. List of selected villages and farmers is furnished in Table 2.

Table 2: Distribution of sample respondents in study area

S.No.	**Locale**	**District**	**Block**	**Villages**	**Proportionate no. of Sample Farmers**
1	Less Fluoride Affected Locale (LFAL)	Coimbatore	P.K. Palayam	1	21
				2	
				3	
		Theni	Andipatti	1	41
				2	
				3	
Sub Total (A)				6	**62**
2	Moderate Fluoride Affected	Dindugal	Natham	1	23
				2	

	Locale (MFAL)			3	
		Perambalur	Kunam	1	39
				2	
				3	
Sub Total (B)				6	**62**
3	High Fluoride Affected Locale (HFAL)	Erode	Athani	1	29
				2	
				3	
			Ammapettai	1	33
				2	
				3	
4.	Non Fluoride Affected Locale (NFAL)	Coimbatore	Madukkarai	1	29
			Thondamuthur	2	33
				3	
Sub Total (C)				6	**62**
Grand Total (A+B+C)				**24**	**248**

Impact of Fluoride Contamination on Land and its Averting Expenditure

In this section, impact of fluoride contamination on land, namely opinion of the farmers about land quality, fallow lands, decline in yield and decline in land value were analysed besides averting or defensive expenditure made on land.

Opinion of the Farmers about Land Quality

Land quality was assessed based on the visual observations as well as enquiry with farmers on yield reduction, the type, number of crops raised, etc. A three point land quality index was constructed as used by Palmquist and Danielson (1989), with one for poor, two for moderate and three for good quality land to study the impact of water pollution on land quality. The results of the land quality indices of the sample farmers are presented in Table 3.

Table 3. Opinion of farmers about land quality

(in Nos)

S. No.	Category	Farm categories				Total
		Less affected	Moderately affected	Highly affected	Non affected	
1	Poor	12 (19.35)	15 (24.19)	26 (41.94)	0 (0.00)	53 (21.37)
2	Medium	30 (48.39)	28 (45.16)	21 (33.87)	29 (46.77)	108 (43.55)
3	Good	20 (32.26)	19 (30.65)	15 (24.19)	33 (53.23)	87 (35.08)
Total		62 (100.00)	62 (100.00)	62 (100.00)	62 (100.00)	248 (100.00)

Note: Figures in parentheses represent per cent to total

The critical analysis of the results reported in Table 3, indicated that among the sample farmers of HFAL, 41.94 per cent rated the soil quality as poor. In moderately fluoride and LFAL, about 45.16 per cent and 48.39 per cent of farmers opined that the quality of the soil as medium quality. In NFAL, more than 50 per cent of the sample farmers rated the quality of the soil as good. In total, 21.37 per cent of the sample farmers were of the view that land quality was poor in the affected locale. About 43.55 per cent of the farmers had the opinion that the land quality was medium and 35.08 per cent of the farmers expressed that their cropland was good.

5.3.1.2. Fallow lands and yield decline

The details of cultivable lands turning to fallow lands and the yield decline of crops are presented in Table 4.

In the case of conversion of cultivable land into fallow lands, the higher effect was observed in HFAL with 1.15 hectares and 5.50 years of fallow lands. MFAL registered with

0.63 hectares and 4.65 years of fallow lands. In less fluoride affected farms with less fallow area (0.28 hectares) and the years of fallow were less with 3.45 years when compared to high and MFAL.

Table 4. Fallow lands and yield decline in fluoride affected locales

S. No.	Particulars	Farm Categories		
		Less affected	**Moderately affected**	**Highly affected**
I	**Fallow lands**			
a.	Area (in ha)	0.28	0.63	1.15
b.	Fallow land (in years)	3.45	4.65	5.50
II	**Yield decline**			
a.	Quantity			
	Paddy crop (T/ha)	0.78	1.06	2.11
	Maize crop (T/ha)	12.52	15.47	19.64
b.	Reasons (in %)			
	Fluoride contamination	95.00	100.00	100.00
	Drought	5.00	0.00	0.00
	Pest and diseases	0.00	0.00	0.00

Source: Primary survey (2017-18)

The highest yield decline was observed in paddy, HFAL with 2.11 tonnes per hectares followed by MFAL with 1.06 tonnes per hectares and less fluoride affected farms with 0.78 tonnes per hectares. Similarly, the decline in yield of maize was found in HFAL with 19.64 tonnes per hectares followed by MFAL with 15.47 tonnes per hectares and LFAL with 12.52 tonnes per hectares. Therefore it could be concluded that, fluoride contamination could increase the area under fallow, increase years of fallow and decline in yield was increased. Fluoride contamination in ground water was the major factor that influenced these effects in affected locales as opined by the respondents.

Averting or Defensive Expenditure for land

The particulars of land based averting or defensive expenditure of fluoride affected locales are shown in Table 5.

It could be understood from the table that these expenditures were higher in HFAL with Rs. 16312 per hectare, in MFAL with Rs. 14085 per hectare followed by LFAL with Rs. 10,937 per hectare.

The composition of these land based expenditure observed that for the item of expenditure on organic manure, the highly fluoride affected farmers incurred with highest expenditure was 74.79 per cent. In moderately fluoride affected farmers, the expenditure was 76.32 per cent and for less fluoride affected farmers expenditure was 76.80 per cent. Next, the highest expenditure was incurred on additional seed crop and it was 18.21 per cent, 17.18 per cent and 16.46 per cent to total in highly, moderately and LFAL, respectively. Though the quantum of gypsum application is marginal, it was directly proportional to the fluoride contamination intensity prevailed in these locales and organic manure application was the highest land based averting expenditure.

Table 5. Estimation of Land Damage Averting Expenditure in Fluoride affected locales

(in Rs/ha)

S. No.	Particulars	Less affected	Moderately affected	Highly affected
1	Additional seed used for crops	1800 (16.46)	2420 (17.18)	2970 (18.21)
2	Organic manure	8400 (76.80)	10750 (76.32)	12200 (74.79)
3	Gypsum	737 (6.74)	915 (6.50)	1142 (7.00)
4	Total	10937 (100.00)	14085 (100.00)	16312 (100.00)

Source: Field survey (2017-18)
Note: Figures in parenthesis represent per cent to total

Conclusion

The expenditures were higher in HFAL (Rs. 16312 per hectare) followed by moderately and LFALs (Rs. 16312 & Rs. 10,937 per hectare). The composition of these land based expenditure observed that highest expenditure incurred with organic manure in fluoride affected locales. The study found that usage of fluoride contaminated groundwater resulted in a decrease in cropped area, land value, the yield of crops and an increase of fallow lands. The same factor resulted in an increase of averting expenditure for land in fluoride affected locales. Hence, the state government should encourage the farmers to improve the water table through the usage of appropriate measures.

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