Evaluation of Best Management Practices in Nitrogen Management – A Study in Groundwater Nitrate Contaminated Area of Cuddalore District, Tamilnadu

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ABSTRACT

In many parts of the country there is growing concern about the degradation of water quality that draws the attention of professionals involved in this field. Groundwater contamination has many sources and evidences suggest that agriculture's relative contribution may be significant. The deleterious effects of groundwater contamination by agrochemicals particularly nitrogenous fertilizers pose serious socio economic and environment threat to many rural communities who subsist on this resource. The best way of managing the nitrate pollution is the promulgation and adoption of Best Management Practices (BMP) and this paper attempts to validate the BMP practices that will contain nitrate pollution. In the present study an attempt was made to construct BMP Index for calibrating the efficient nitrogen use. To assess the influence of the important factors that determine the adoption of Nitrogen Best Management Practices an empirical linear model was specified. The BMP attributes comparison of crops in affected block showed that among the crops, the actually applied nitrogen over the recommended dose was the highest in paddy crop, the scale on fertilizer application techniques was the lowest in sugarcane crop and the overall NBMP index was the lowest in paddy crop. In unaffected block among the crops the nitrogen application over the recommended dose, the scale on fertilizer application technique and the overall BMP index were all in unfavourable condition towards tapioca. The comparison of the two blocks reveals that among all the attributes that builds up the BMP index, the scale on fertilizer application techniques favourably contributed in the case of unaffected block. The source of technical guidance was found to be an important variable, which influenced the BMP index of both the affected and unaffected blocks to a considerable extent. Hence it was recommended to strengthen the awareness on groundwater nitrate contamination and impart technical knowledge on BMP through efficient institutional arrangements and the role of economic instruments for voluntary adoption of BMP is also suggested.

Key words: Groundwater, Nitrate Pollution, Best Management Practices, index, Adoption Determining Factors.

1. INTRODUCTION

It is increasingly recognized that water is a scarce resource and should be used judiciously. Much of the literature as well as projects and programs have focused on water quantity, with little or no attention to water quality. However, in many parts of the country there is growing concern about degradation of the water quality that draws the attention of policy makers, planners, engineers and other professionals involved in this field (Shiklamanov,2000).

The crucial role groundwater plays as a decentralized source of drinking water for millions rural and urban families cannot be overstated. According to some estimates, it accounts for nearly 80 per cent of the rural domestic water needs, and 50 per cent of the urban water needs in India But, a variety of land and water- based human activities is causing pollution to this precious resource(Central Groundwater Board, 2010) . Groundwater contamination has many sources and evidences suggest that agriculture's relative contribution may be significant. Agricultural chemicals are the major source of groundwater non-point pollution in different pockets of our country. Frequent incidents of groundwater contamination from agrochemicals have been documented in many parts of the nation. Groundwater pollution through agriculture, often dispersed over large areas, is a great threat to fresh groundwater ecosystems. Intensive use of chemical fertilizers in farms and indiscriminate disposal of human and animal waste on land result in leaching of the residual nitrate causing high nitrate concentrations in groundwater. (Dineshkumar and Shah, 2001)

One of the most important aspects of protecting groundwater from pollution is restricting the use of chemical fertilizers. Chemical fertilizers are highly water-soluble and they can easily become groundwater contaminants as the water they are dissolved is percolated into groundwater supplies (Jha,2000). One effect of this kind of contamination is nitrite poisoning which occurs when infants drink well water contaminated with the nitrate ion (NO_3^-) from artificial fertilizers. This affliction, which is called methemoglobinemia or blue baby syndrome, can reduce an infant's resistance to disease and cause retardation and death in extreme case. Studies have also suggested that elevated nitrate concentration in drinking water above the permissible level of 45 ppm may be associated with other health problems ranging from hypertension in children to gastric cancer in adult and fatal malformations (William Easter and Sathya, 1995) Suthar et al. (2009) found out that the average nitrate was 60.6± 33.6 (SD) mg/l in some agro-economy based rural habitations of northern Rajasthan. Balakrishnan et al. (2011) found approximately 74% of the wells in Gulbarga city have nitrate concentration above the permissible limits affecting a large part of 4,30,000 people living there.

Once an aquifer is contaminated with nitrate, it will cost a large amount of money to use that aquifer as a source of drinking water. Hence the curative measures are economically non- viable and practically not feasible and so the preventive measures have to be resorted to so as to conserve the groundwater resource from pollution. Nitrogen is one of the major components of all the fertilizers. Over application and improper timing of applying the fertilizers, cause the nitrates to leach into the groundwater (Gupta, 1992; CGWB, 2014).

In this context the best way of managing the nitrate pollution is the promulgation and adoption of Best Management Practices (BMP) and this paper attempts to validate the BMP practices that will contain nitrate pollution. In this direction a study has been conducted in the problem area of Tamilnadu with the objective of validating the extent of adoption of BMP practices that will contain nitrate pollution and the factors constraining the adoption.

2. MATERIAL AND METHODS

Based on groundwater quality analysis by central groundwater board,(CGWB year book,Tamilnadu and Puducherry,2015) the nitrate polluted areas were identified.The Mangalore block in Tittakudi taluk of Cuddalore district was purposively selected where the groundwater concentration of observation wells ranged from 68mg/lit to 180 mg/lit while permissible limit for drinking water is only 45 mg/lit. The area is characterized with the cultivation of higher percentage of heavy fertilizer consuming crops like paddy, sugarcane, and tapioca and higher rate of groundwater recharge facilitating soil properties, which favor active groundwater contamination. These factors attribute the selected block as a relevant domain of this research. The nearby Nallur block which was unaffected by nitrate pollution in Tittakudi Taluk of Cuddalore district was selected for comparison purpose. From the selected two blocks two villages from each block were selected purposively.

For field level investigation a sample size of 100 farmers was selected from two blocks allocating a quota of 50 each to the nitrate polluted and unpolluted blocks viz., Mangalore (nitrate polluted – affected block) and Nallur blocks(nitrate unpolluted – unaffected block). The 50 farmers in each block were distributed between the two villages as probability proportion to the number of households.

2.1 Methods of Analysis

2.1.1 Best Management Practices for Nitrogen Fertilization

Nitrogen (N) is the essential plant element that most frequently limits irrigated crop production. Commercial N fertilizers are cost effective means of supplementing soil supplied N for plant growth and are necessary for sustaining high crop yields. However, it has been documented that improper or excessive use of N fertilizer can lead to nitrate pollution of ground or surface water. In addition to increased fertilizer consumption, changes in types of fertilizer applied may mean a greater likelihood of contamination particularly when recharge rates are high. The likelihood that a chemical move into groundwater depends on method, timing, placement of fertilizer application and irrigation practices. Accumulated evidences indicate that there is a positive correlation of higher intensity of agrochemical contamination with higher irrigation intensity (Schrder, 1997). Regulations that require major reductions in groundwater pollution may result in significant adverse changes in economics of crop production and increasing food costs for consumers (Hanley et al, 1995). On the other hand, elimination of agrochemical pollution may be possible with relatively little effect on farm profit and consumers costs if producers have a range of alternative management practices and crops from which to choose. Hence the fertilizer applicators should minimize this problem by implementing Best Management Practice (BMPs) in nitrogen fertilizer use (Waskom, 1994).

Best management practices (BMPs) are individual or combinations of management, cultural and structural practices that researchers (academic or governmental), have identified as the most effective and economical way of reducing damage to the environment. The BMP’s manage nitrogen applications to maximize crop growth and economic return while protecting water quality (Cestri et al,2003).

2.1.2 Construction of Nitrogen Best Management Practices Index(NBMP)

In the present study an attempt was made to construct BMP Index for nitrogen use. The NBMP’s which are relevant to the selected area and crops are taken for analysis. They are soil test based recommended dose of ‘N’ application, recommended dose of FYM application, optimum number of irrigation, and season and soil type based ‘N’ fertilizer application use techniques viz., specific form of ‘N’ fertilizer recommended for crop, spilt application, placement, timing of 'N' application and use of Nitrification inhibitors.

Based on this information, the index was constructed as shown below.

$$NBMP= \left[\left(\frac{1}{4}\right)\left[\left(1-\left(\frac{NAi}{NRi}\right)\right)+\left(1-\left(\frac{FAi}{FRi}\right)\right)+\left(1-\left(\frac{IAi}{IRi}\right)\right)+\left(1-\frac{TAi}{TCi}\right)\right]\right]\times 100$$

Where

NBMPI = Nitrogen Best Management Practice Index.

i= Number of farmers, (1,2,3, …..n).

NA_i = Absolute difference in quantity of nitrogen applied to recommended quantity of nitrogen for crop

NR_i = Recommended quantity of nitrogen to the crop (Kg / ha)

FA_i = Absolute difference in applied FYM to recommended FYM for crop(t/ha)

FR_i = Recommended quantity of FYM to the crop (t/ha)

IA_i = Absolute difference in number of irrigation to optimal number of irrigation.

IC_i = Optimum number of irrigations.

TA_i= Number of fertilizer application technologies adopted in the selected technologies.

TC_i= Number of selected fertilizer application technologies (i.e., 5).

The absolute difference was taken because both overuse as well as under use with reference to the recommend dose will affect the yield.

Here $\left[\left(1-\left(\frac{NAi}{NRi}\right)\right)\right]=1$, if the applied quantity of nitrogen fertilizer is equal to recommended dose ,

$\left[\left(1-\left(\frac{FAi}{FRi}\right)\right)\right]$ = 1, if the applied quantity of FYM is equal to recommended dose of FYM,

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$\left[\left(1-\left(\frac{IAi}{IRi}\right)\right)\right]$ = 1, if applied number of irrigation is equal to optimal number of irrigation.

$\left[\left(1-\left(\frac{TAi}{TCi}\right)\right)\right]$ =1, if all the five identified N' fertilizer use techniques were adopted

NBMPI= 100, if all the practices are optimal.

The index was calculated for all the selected crops and for all the growers, which ranged between 0 to 100. The index will increase towards 100 with the higher level of adoption and will decrease towards zero with the lesser level of adoption in the BMP's.

2.1.3 Determinants of NBMP Adoption Index

To assess the influence of the important factors determining the adoption of Nitrogen Best Management Practices (NBMP) of farm household members the following model was framed. The calculated NBMP index was regressed against explanatory variables like the level of education, farm size, farming experience, age and source of technical guidance (D'Souza, Cyphers, and Phipps, 1993). The empirical form of the linear model specified was as below.

NBMPI = f (AGE, EDUC, FASI, FAEX, COGU)

Where

AGE = Age of the family head (in years)

EDUC = Education of head of household dummy at two point continuum (0= illiterate, 1 = schooling, 2- collegiate)

FASI = Farm size in ha

FAEX = Farming experience of the family head (in years)

COGU = Crop production technical guidance (Dummy =1, if guidance exist, 0 otherwise).

3. RESULTS And DISCUSSION

Managing the amount, form, placement and timing of 'N' application is the most practical and acceptable approach to minimize the ground and surface water contamination resulting from improper fertilizer use. The Nitrate Best Management Practices Index (NBMPI) was constructed incorporating the relevant variables as specified in the design. The results are presented and discussed below.

3.1 Nitrogen Best Management Practices (NBMP) Indices for Selected Crops

3.1.1 Paddy

The NBMP index for paddy is presented in table2. It could be observed from the table that the applied nitrogen was well above the recommended dose in the affected block but in unaffected block the recommended level of N use was higher compared to affected block despite this the application level was lower. The averages of all other variables were all below the recommended level in both the blocks. The comparison of the adoption of BMP variables between the blocks showed that the number of irrigation and farmyard manure were in higher level of use in affected block compared to unaffected. But, as far as the number of 'N' fertilizer application techniques was concerned, out of five important practices the number of practices followed was lesser in affected block (2.04) compared to the unaffected block (3.67). Hence, the overall NBMP index for paddy showed that the index value was lower in affected block (66.05 %) compared to unaffected block (84.46%) indicating that the extent of adoption of BMP in nitrogen use for paddy crop was not up to a considerable mark in affected block and this has to be improved further.

3.1.2 Sugarcane

It could be observed from the table 2 that the recommended dose of nitrogen was lesser in affected block compared to unaffected block. However the usage of N in affected block exceeded the level that was recommended for this block and it was also quite higher than that of the un affected block's N use.. The average use of all other variables were all below the recommended level in both the blocks except irrigation which was marginally higher than that of the recommended number of irrigation in the affected block .As far as the number of nitrogen fertilizer application techniques were concerned out of the total 5 important practices the number of practices followed were higher in unaffected block (4.06) compared to the affected block (1.81). This might be the prime reason for groundwater nitrate contamination of the affected block.

The overall nitrogen Best Management Practices index for sugarcane showed that the index was lesser in affected compared to unaffected block indicating the extent of adoption of BMP in Nitrogen use for sugarcane was at satisfactory level in the unaffected block whereas in the affected block it was very poor. This clearly indicated that the technical guidance under the institutional sugar factory setup was well availed by the farmers of unaffected block than the affected block.

3.1.3 Tapioca.

It could be observed from table 2, that all the BMP index variables except the nitrogen application practices were higher than that of the recommended level in the affected block, whereas in unaffected block there was a marginal increase in nitrogen, irrigation and a marginal decrease in FYM usages. However it was found that the increase in the applied level of N over the recommended dose was not substantial in both the blocks. In the case of N application practices the scale was far below (1.88) than the required level in the affected block whereas in unaffected block it was comparatively higher (3.28). The index of N BMP was 70 per cent in affected and 75 per cent in unaffected block. Hence further efforts in improving BMP should be concentrated on the application practices rather than the quantity of inputs used. This involves the adoption of technically sound application practices, which warrants skill that should be imparted by the extension agencies.

The BMP attributes comparison of crops in affected block showed that among the crops, the actually applied nitrogen over the recommended dose was the highest in paddy crop, the scale on fertilizer application techniques was the lowest in sugarcane crop and the overall NBMP index was the lowest in paddy crop. In unaffected block among the crops the nitrogen application over the recommended dose, the scale on fertilizer application technique and the overall BMP index were all unfavourable towards tapioca. The comparison of the two blocks reveals that among all the attributes that builds up the BMP index, the scale on fertilizer application techniques favouably contributed in the case of unaffected block.

3.2 Distribution of NBMP Indices for Selected Crops

3.2.1 Paddy

The distribution of "N" BMP index for paddy crop is presented in table3. It could be observed from the table that around 58 per cent of the farmers in the affected block lay in the BMP index range of 60-70 whereas in unaffected block they constituted only 10 per cent. The category of 80-90 BMP index range was absent in affected block whereas in unaffected block they constituted about 53 per cent. In the affected category the farmers lying in the extreme range categories (<50 and >90) was very meager but in unaffected category the percentage of farmers in maximum range (>90) was considerable (10 per cent) and the minimum range was negligible.

3.2.2 Sugarcane

From the table3 it could be observed that in affected block around 52 per cent of the farmers come in the category of 60-70 NBMP index range, whereas in unaffected block around 53 percent of the farmers in fell in the category of 70-80 NBMP index range, whereas in affected block the farmers lay in this category range was less (about 29 per cent). It could be summarized that the percentage of farmers with higher BMP index (above70 per cent) was higher in the unaffected block compared to the affected block (43 per cent) the important point to be noticed was that the percentage of farmers in maximum and minimum range of NBMP index was absent in both the blocks.

3.2.3 Tapioca

The distribution of NBMP index for Tapioca crop in table 3 revealed that around 63 per cent of the farmers in the affected block lay in the category of 70-80 NBMP index range, followed by 25 per cent of the farmers in the range of 80-90 category, whereas in the unaffected block nearly 73 per cent of the farmers lay in higher NBMP Index categories (>80).

The comparison of BMP index distribution of farmers in various crops shows that in the case of affected block the farmers falling in the greater BMP index range was the highest in Tapioca and lowest in Paddy. In the case of unaffected block the NBMP index range was the highest in sugarcane and lowest in paddy. The comparison of BMP indices of affected and unaffected blocks showed that the difference was wide in paddy crop whereas in sugarcane and tapioca the difference was very close. Hence it might be construed that paddy might be the major contributor for groundwater nitrate contamination in the affected block.

3.3 Factors Determining the Adoption of NBMP in Selected Crops.

The farm specific factors responsible for adoption of NBMP were analyzed using linear regression model as specified in the design of the study. The results of empirical linear regression model is presented and discussed below.

3.3.1 Paddy

It is observed from table4 that in affected block the variables such as age of the farmers, farming experience, farm size, and source of technical guidance were found to be significantly influencing the adoption of NBMP index. In the case of unaffected block the variables such as educational level and farming experience of the farmers were only found to be statistically significant.

The coefficient of multiple determination (R^2) indicates that about 89 percent of the variation in affected block and 76 per cent of the variation in the unaffected block on the NBMP index adoption that was explained by the variables included in the model.

3.3.2 Sugarcane

It could be observed from the table 4, that in affected block the variables such as education level of the family head, farming experience and crop technical guidance were found to be significantly influencing the NBMP adoption index. Every increase in these variables increased the NBMP index. In the unaffected block the source of technical guidance alone found to be statistically significant. Among the explanatory variables the crop technical guidance influence was much profound and between the two blocks its influence was at higher magnitude in unaffected block.

3.3.3 Tapioca

It could be observed from the table4, that age and source of technical guidance were the variables significantly influencing the NBMP index in affected block. In the case of unaffected block the variables such as education and crop technical guidance were the significant variable influencing the NBMP index.

It could be inferred from the table that the source of technical guidance was the important variable, which influenced the NBMP index of both the blocks to a considerable extent and apart from technical guidance the education level of the farmers influenced the NBMP index adoption to a considerable extent in the affected block.

4. CONCLUSIONS

The results can provide a useful framework for decision-making as producers and policy makers confront growing environmental problems caused by, and affecting, agriculture. Implications can be derived for producers for whom local environmental quality is closely linked to production practices. In addition, the results can facilitate the policy formulation process as policy makers, responding to societal pressures, attempt to move agriculture in a more sustainable direction while trying to improve environmental quality in general.

Since the over use of nitrogen was observed in the study area, the farmers may be made aware of the optimum use. To achieve this, the efforts of the extension agencies have to be geared up regarding this issue in the target area. The notion regarding higher yield with higher doses of fertilizers has to be allayed and proper training regarding INM (Integrated Nutrient Management) practices should be inculcated. The curative measures are not giving easy solution and technologies that exist to remove nitrate from groundwater were complicated, expensive, and may take years or decades, the preventive measure viz., BMP in crop production should be widely promulgated by effective means.

The BMP analysis on nitrogen use revealed that the adoption of NBMP index was lesser in the problem area. Among the components of the index the fertilizer application techniques and the level of use of N fertilizer over the recommended dose gained much importance. Hence the best way to lessen the risks of nonpoint source pollution is to annually conduct soil tests and develop nutrient budgets to determine the amounts of nitrogen and phosphorus crops actually need. If too little nutrients are applied, crop yields will suffer, on the other hand, excess application of nutrients may cause environmental damage. Hence while formulating steps in developing crop budgets, soil testing of nutrient levels, determining the amount of nutrients individual crops require for target yield goals, and analyzing the costs and benefits of varying nutrient levels, spilt applications and use of slow-release nitrogen fertilizers should be given adequate attention.

Since the source of crop technical guidance played a major decisive role in NBMP adoption, the ways and means of effective channels of technical guidance has to be identified and all the extension activities formulated to solve these problems should be channelized through this source. The control on agriculture non-point sources pollution depends on how targeted the programs are at promoting inexpensive changes in existing agricultural practices that are already familiar to the farmers, and on the tangibility (visibility and immediacy) of derived environmental benefits (Ribaudo et al, 2001). However, it has also been found in literatures that introducing economic incentives has increased the numbers of farmers adopting environmentally friendly BMPs voluntarily.. Incentives offset the initial incremental costs involved in introducing the BMPs. When the benefits of the BMPs have been realized an incentive program may be phased out.

S. No	Particulars	Paddy		Sugarcane		Tapioca	
		Affected	Unaffected	Affected	Unaffected	Affected	Unaffected
1.	Nitrogen (kgs)	152.95 (105.00)	98.53 (115.00)	253.01 (236.25)	195.19 (258.75)	56.54 (50)	52.62 (50)
2.	Irrigation (Numbers)	24.69 (25)	20.76 (25)	42.12 (42)	34.47 (42)	31.14 (30)	30.16 (30)
3.	FYM(Tonnes)	11.25 (12.50)	10.36 (12.50)	9.32 (12.5)	10.31 (12.5)	13.70 (12.50)	11.95 (12.50)
4.	Fertilizer Application Techniques (5 scale)	2.04 (5)	3.67 (5)	1.81 (5)	4.06 (5)	1.88 (5)	3.28 (5)
	'N' BMP Index	66.05 (100)	84.46 (100)	70.12 (100)	75.52 (100)	70.38 (100)	75.52 (100)

TABLE 1 NITROGEN BEST MANAGEMENT PRACTICE INDICES OF SELECTED CROPS.

Figures in parentheses are recommended and outside the parentheses are actually applied doses of inputs

TABLE 2 DISTRIBUTION OF NBMP INDICES FOR SELECTED CROPS

S. No	NBMP Index Range	Paddy		Sugarcane		Tapioca	
		Affected	Unaffected	Affected	Unaffected	Affected	Unaffected
1.	< 50	1 (3.85)	0 (0.00)	0 (0.00)	1 (3.33)	0 (0.00)	0 (0.00)
2.	50-60	4 (15.38)	1 (4.76)	1 (5.88)	0 (0.00)	2 (12.50)	1 (6.67)
3.	60-70	15 (57.69)	11 (52.38)	2 (11.76)	3 (10.00)	0 (0.00)	1 (6.67)
4.	70-80	5(19.23)	6 (28.57)	9 (52.94)	7 (23.33)	10 (62.50)	2 (13.33)
5.	80-90	0 (0.00)	3 (14.29)	5 (29.41)	16 (53.34)	4 (25.00)	9 (60.00)
6.	>90	1 (3.85)	0 (0.00)	0 (0.00)	3 (10.00)	0 (0.00)	2 (13.33)
Number of farms		26 (100.00)	30 (100.00)	21 (100.00)	17 (100.00)	16 (100.00)	15 (100.00)
Maximum (%)		91	98	89	89	88	96
Minimum (%)		46	49	55	58	54	58
Mean (%)		66.05	84.46	70.12	75.52	75.38	82.46

Figures in parentheses are percentages to total number of farms

TABLE 3 FACTORS DETERMINING THE ADOPTION OF BMP IN SELECTED CROPS

S. No.	Variables	Paddy		Sugarcane		Tapioca	
		Affected	Unaffected	Affected	Unaffected	Affected	Unaffected
1.	Constant	28.38 (7.14)	51.30*** (6.37)	52.94*** (5.74)	44.42*** (6.30)	30.95*** (2.50)	42.13*** (7.06)
2.	Age (in Years)	0.89*** (0.20)	0.21 (0.26)	0.06 (1.93)	0.19 (0.19)	0.99*** (0.10)	0.82 (0.78)
3.	Education (3 point scale dummy, 0=illiterate,1=schooling, 2=collegiate)	0.86 (0.86)	3.21* (1.89)	4.35** (1.63)	-1. 85 (2.53)	0.41 (0.49)	0.43*** (0.09)
4.	Farming exp (in Years)	0.41** (0.18)	1.76*** (0.54)	1.65*** (0.36)	1.99 (0.79)	-0.06 (0.10)	0.05 (0.29)
5.	Farm Size (in Years)	0.90* (0.48)	0.01 (0.56)	0.21 (0.55)	-0.11 (0.83)	-0.07 (0.11)	0.18 (0.43)
6.	Source of technical guidance (dummy, 0=no, 1=yes)	5.02** (2.14)	0.56 (2.18)	3.21* (1.81)	14.18*** (4.46)	10.34*** (0.53)	8.43*** (0.99)
7.	R^2	0.90	0.76	0.89	0.88	0.90	0.78

*** Significant at 1% level ,** Significant at 5% level,* Significant at 10% level .
Figures in parentheses are Standard Errors

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