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Advances in Applied Science Research, 2013, 4(3):5-9

ISSN: 0976-8610
CODEN (USA): AASRFC

Groundwater contamination from agro-chemicals in irrigated environment: Field trials

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ABSTRACT

This paper highlights on the increasing fears that chemicals in agriculture have found their way into drinking water causing health complications. In fact many chemicals have not had these effects but waiting to do so by moving into groundwater sinking slowly and finally going into taps. Nitrate fertilizer is largely blamed for these fears. Use of fertilizers obviously would increase manifold to meet the food needs arising out of population explosion and it would further aggravate the situation. Therefore the use of chemicals in agriculture presents global alarm particularly for Andhra Pradesh where environmental degradation is rampant and unfortunately least groundwater contamination resulting from application of agricultural chemicals especially the fertilizer.

Key words: Water Pollution, Nitrates, Fertilizers, Agrochemicals, Anantapur, Andhra Pradesh.

INTRODUCTION

Among all the agricultural concerns agro-chemicals have given rise to grave environmental contamination. An unthoughtful use of chemicals may render agricultural land, water and air inefficient for supporting life. It is unfortunate that most of the public environmental protection programs are urban-oriented; whereas the pollution and its direct effects in the local sectors are ignored as much as 50 to 70% of the water resources are polluted due to contamination from agricultural activities (Lal and Stewart, 1994). Groundwater pollution due to nitrates is increasing in India. The water quality assessment studies carried out in 17 Indian states by National Environmental Engineering Research Institute (NEERI) showed that out of 4,696 water samples, 1,290 samples (27%) have nitrate exceeding the drinking water standard (Bulusu and Pande, 1990). The nitrate concentration of well water has shown rising trends in many countries with in the last 30 years (Guarda et al., 2004). Application of nitrogen based fertilizers such as NPK (Nitrogen, Phosphorous, Potassium), urea together with organic manure like cow dung, decomposed vegetative waste, in more than required quantities, could lead to the percolation of nitrate in to sub-surface water bodies. Improper disposal of the human and animal waste, unlined drainage and sewerage lines may also add to the nitrate contamination of groundwater (Jack and Sharma, 1983). This paper presents an attempt to discus agriculture oriented environmental problems and highlights the experiments conducted to realize the best management practices BMP's to mitigate ground water contamination.

Agro-Chemicals:-
The agro-chemicals can be grouped into brand a category that is biocides and fertilizers. Biocides, herbicides, fungicides, rodenticides etc. they are poisonous substances deliberately disseminated to exploit their toxic properties. They cause pollution when they reach wrong targets. After a continuous use, these toxic chemicals are

found in waters, air and soil in the bodies of fish, birds, worms and eggs in many human beings, mother's milk and possibly tissues of unborn child. Some pesticides destroy enzymes, and block energy generating oxidation processes and initiate malignancy in the cells.

Dichloro-diphenyl-trichlroethylene (DDT) is perhaps the most notorious chemical. It was used to kill both medical and agricultural pest saving millions of human lives as well as many from starvation. However, its indiscriminate over-use has caused worldwide environmental contamination and death of non target organisms. Almost everybody in the world has a measurable amount of DDT and its breakdown products. Toxic effects of DDT have migrated from areas of application to remote places. However, use of DDT has been bounced and risk of its hazard is reducing. The level of global contamination resulting from the use of biocides needs no further emphasis. Some of the remedial measures to eliminate / reduce the hazards are as under:

- A better control over the disposal and dispersal of the chemical.
- Use of carefully designed and calibrated spraying and dusting machines with possibly electrostatic spraying to magnetize spray drops and reduce drift losses
- Field applications supervised by trained / qualified personnel. Use of protective devices e.g. mask, gloves, long boots etc.
- Avoid long exposures of field workers to active material.
- Scientific research to dig up new substances that may replace poisonous synthetic biocides.

Fertilizers pollution:
Use of fertilizers in agriculture is recognized as a potential source of water pollution. High Nitrate-Nitrogen (NO_3-N) concentrations found in surface and ground water is currently receiving attention. A certain portion of (NO_3-N) pollution comes from the use of agricultural fertilizers which can enter directly from the fields into the streams or underground sources. Report on water quality deterioration in Lake Biwa (Japan) showed that the drainage from agricultural land contributed to 47% and 23% of the total nitrogen and phosphorous respectively (Misawa and Kondoh, 1992). Pollution of drinking water supplies is being reported frequently.

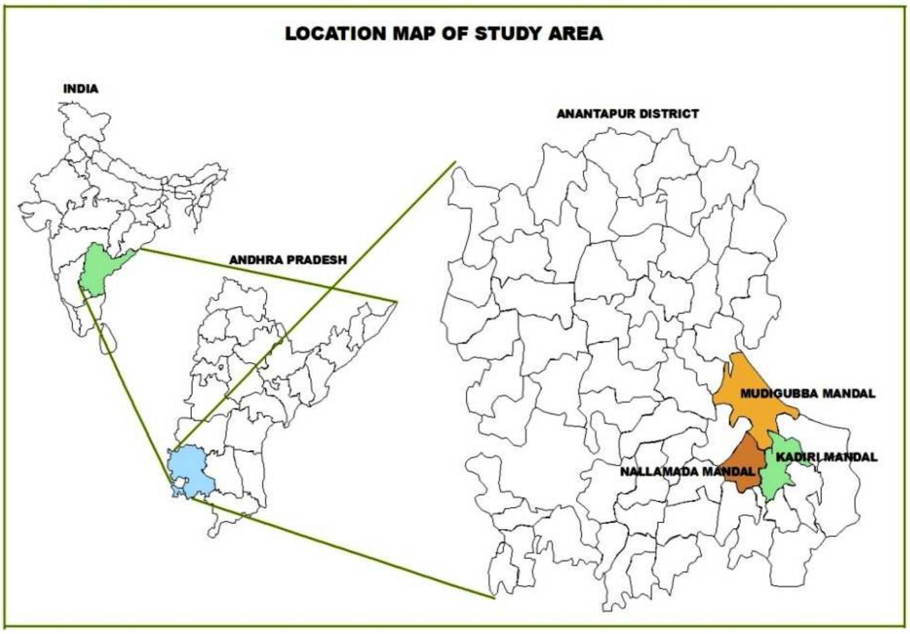

Figure 1: Location Map of Study Area

Study area:
A study was conducted by taking 150 samples of drinking water from different parts of villages in south eastern part of Anantapur District, Andhra Pradesh (Fig. 1). The results indicated higher nitrate contents in water of localities fed from agricultural fields, whereas areas with better drainage contained lower nitrate contents Similar were the results

from WASA tube-wells in the urban area (Yaqoob, 1990). No study, however, was available for the agricultural fields under the conditions of this region for understanding the leaching behavior of nitrates. Thus studies were planned to investigate the effect of varying amount of tillage, nature of implements doses of fertilizers, depth of irrigation and time of sampling after the fertilizers, depth of irrigation, and time of sampling after the fertilizer application. The nitrogenous fertilizers were applied under varying soil and crop conditions at different places were collected using porous cups and soil/water samples were analyzed for (NO_3-N) contents.

RESULTS AND DISCUSSION

In one of the experiments five tillage treatments namely tine cultivator, sweep cultivator, disk harrow, M.B plow and chisel plow were selected for comparing their effects on nitrate leaching. Fifteen plots, each measuring 57X10 M2 in sizes were used for making three replications of each treatment. All the plots were prepared once with their designated implements. At the time of wheat planting, 125 kg/ha of Diammonium Phosphate (DAP) was applied after seed-bed preparation with two sweep cultivations to all the plots. First, water sampling was carried out two weeks after DAP application at 0-30, 30-60, 60-90, 90-120 and 120-150 cm depths. Secondly water samples were taken one month after the application of area (125 kg/ha) and a surface irrigation of 10cm. the samples were analyzed for (NO_3-N) contents using Disulphonic acid method. The data on (NO_3-N) contents were analyzed statistically.

Nitrate-nitrogen contents present at drift soil depths two weeks after application of Diammonium phosphate (DAP) are given in Table 1. The data show higher contents of (NO_3-N) in the top soil layers. This was obvious as neither irrigation was applied nor any precipitation occurred during this time interval to transport the fertilizer downward. Mean (NO_3-N) contents in various soil layers after the application of area with first irrigation are given in table 2.

Analysis of variance of the data after irrigation indicated that the effect of depth of soil on (NO_3-N) contents tested statistically significant. A comparison of the values of (NO_3-N) contents before and after irrigation suggests that maximum concentration of (NO_3-N) was present in upper 0-60 cm layer. A noticeable leaching appears to have occurred up to 90 cm, traces of nitrates were however, found upto 150 cm soil depth just with a conventional dose of fertilizer and a single 10cm irrigation. The exponential nature of data with increasing depth of soil further released that (NO_3-N) would even leach beyond 150 cm. this downward movement of nitrates would perhaps continue in the irrigations to follow. In case, this trend persists in our agricultural fields year after year, then the day is not too far when ground water reservoir would be badly polluted.

The effect of tillage implement tested statistically non-significant. This was expected as there was little evidence for the nitrate concentration in each treatment to differ. The main focus was to study nitrate leaching behavior for view print of implement-depth interaction. A significant implement-depth interaction suggested that various tillage practices managed nitrates differently at each soil depth however, sweep and tine cultivators showed better results compared with other implements. Sweep tilled plots were better than tine cultivation in retaining NO_3-N in the top (0-60cm) soil layer. It is apparent that sweep cultivation can be considered as an appropriate tillage practice among the treatment included in this experiment. In short the following conclusions were drawn from this study.

Table 1: Nitrate-Nitrogen (PPM) for various tillage treatments (before irrigation)

Tillage Treatment	0-30 cm	30-60 cm	60-90 cm	90-120 cm	120-150 cm
Narrow time cultivator	11.0	3.5	2.1	1.1	0.72
Sweep cultivator	8.1	4.6	2.0	0.8	0.73
Disk narrow	7.6	2.3	2.0	0.7	0.51
Mold board (M.B) plough	6.9	2.6	1.2	0.6	0.1
Chisel Plough	7.8	6.1	0.7	0.4	0.2

Table 2: Nitrate -Nitrogen (PPM) for various tillage treatments (after irrigation)

Tillage Treatment	0-30 cm	30-60 cm	60-90 cm	90-120 cm	120-150 cm
Narrow time cultivator	8.4	5.4	2.5	1.4	0.76
Sweep cultivator	9.0	7.6	2.4	1.6	0.51
Disk narrow	5.7	4.5	2.80	1.43	0.6
Mold board (M.B) plough	4.4	3.0	1.45	1.60	0.34
Chisel Plough	5.13	4.4	2.0	0.52	0.43

1. A normal 10cm irrigation played a significant role in the downward movement of nitrates
2. Sweep cultivators and narrow tine were considered relatively appropriate for retaining nitrates in the 0-60 cm soil layer compared with other implements.
3. A noticeable leaching of nitrates was observed. The nitrate contents exponentially decreased with the depth of soil. An extrapolation of this trend suggests nitrates would certainly move too far from soil depths considered here.

Table 3 gives details about the crops under cultivation, average and fertilizer dosage to the crop in southeastern part of Anantapur District, A.P. Maximum amount of farm yard manure and chemical fertilizers is used for Paddy when compared to other crops. The quantity of fertilizer used for Paddy is more than 10 times that used for other crops. This fact substantiates the conclusion that Paddy cultivation is responsible for the high nitrate content of surrounding ground water sources. The nitrogen based fertilizers or manure used on a sandy soil are more vulnerable to leaching into groundwater than the nitrogen fertilizers used on a clay soil; as water moves rapidly through sandy or coarse textured soils (Bhumbla, 2006; Voudouris et al., 2004).

Table 3: Agricultural practices in study area

S. No	Crops under Cultivation	Area in Hectares	Fertilizer dosage recommended Kg/Hectare			Farm yard Manure
			N	P	K	
1	Paddy irrigated	3988	100-120	75	30	500
2	Jowar	1407	80-100	40	40	500
3	Bajra	577	100	50	30	-
4	Red gram	191	20	40	-	-
5	Castor	448	40	20-30	20	-
6	Ragi	381	40	40	40	-
7	Vegetables & others	600	25	50	-	-

Another experiment was conducted on an area of 0.87 ha divided into blocks and 24 plots. Begin text of second succeeding pages here. Do not leave additional margins inside the frame. Two tillage techniques (Sweep cultivator, chisel Plow), two levels of surface irrigation (5cm deep six irrigation and 10 cm deep four irrigation and two doses of fertilizer (Split dose and normal dose) were compared to study their effects on NO_3-N leaching. Soil water samples were collected to determine the NO_3-N from the porous cups installed at 30, 60 and 120 cm depths at both head and tail ends of the plot. Nitrate-nitrogen concentration of soil water samples were then detected adopting Hydrazine Reduction Method. Field studies indicated that tillage treatment had significant effect on NO_3-N leaching. At 30 cm depth mean NO_3-N concentration in sweep cultivated plots were higher than those of the chisel plowed plots. However, higher NO_3-N concentration detected at 60 and 120 cm depths in chisel plowed plots illustrated migration of nitrates to lower depths. This is due to low density of deep soil layer and more pore space available for water and solute movement. Whereas, sweep cultivator generated low soil densities only near the surface and high soil densities underneath. Hence, sweep cultivator offered a better tillage option to reduce NO_3-N leaching away from the root zone.

Heavy irrigations produced loss of water through deep percolation and enhanced nitrate leaching whereas, light but frequent irrigations confined the nitrates in only upper soil layers. Similar to the pattern observed in sweep cultivation, light irrigations showed more nitrates at 30cm depth, while at 60 and 120 cm depths higher NO_3-N concentration was observed for heavily irrigated plots. Light irrigations settled about 9.2% less NO_3-N concentration upto 120 cm depth. Results revealed that light but frequent irrigations held more nutrients within the root zone of the soils and thus proved to be a preferable alternative.

Comparatively more nitrate concentration were detected to upper soil layers even after the last irrigation in the split fertilized plots. About 19.4% less nitrate leaching was observed for split application compared with normal or conventional application. Split application checked fertilizer leaching by providing less amount of fertilizer exposed to the leaching agents. Hence, split fertilization proved useful by keeping most of the nitrates in the root zone for a longer period of time. In surface irrigation, the advancing sheet of water transported nitrates towards tail end of the plots. Tail end showed 4.9% more nitrates than the head ends of the plots. This effect might be due to high solubility of nitrates in water. Therefore, medium lengths of plots with low grade are advisable to reduce transport of nutrients to tail ends. Results provided the following conclusions.

CONCLUSION

1. Sweep cultivation proved a better tillage option to minimize NO_3-N leaching from the root zoom.
2. Light but frequent irrigations checked nitrate movement to the deeper soil strata.
3. Split application of fertilizer reduced NO_3-N leaching and nitrate redistribution to deep seated soil mantle.

The results of the present studies evidenced leaching of nitrogenous fertilizer in the form of NO_3 - N upto 150cm soil depth. Measures need to be taken to reduce the irreversible pollution of subsurface water. Unfortunately most of our anti-pollution programs are either urban or industry oriented and agricultural sectors absolutely neglected. Drainage, tillage, irrigation, crop rotation and fertilizer practices need to be managed in order to reduce threat of fertilizer on subsurface water pollution. In particular, the present investigation suggests that improved practices of soil, water and fertilizer management may effectively reduce NO_3-N leaching and safeguard our soil and water environment.

If the present trend in modernization of agriculture continues, pollution issues will become increasingly complicated in the future. What general model be adopted to minimize the pollution is rather more important than identification of problems. The following submissions provide a guideline to plan environmental strategies.

1. Environmental protection is more of necessity than luxury. Good environment is key to sustainable development.
2. Availability of trained specialists is necessary for the successful execution and assessment of environmental projects. Thus, initiation of formal educational programs will be needed.

Acknowledgments
The work was funded by the Department of Science and Technology (DST), New Delhi under the Fast track Young Scientist scheme (Project no: SR/FTP/ES-50/2007). The financial support from DST for carrying out this study is gratefully acknowledged.

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