Proceedings WAMIP-2010
M. S. Rao, et al. (eds)
N.I.H., 2010

Assessment of Impact of Intensive Agriculture on Groundwater Regime in Ludhiana & Muktsar Districts, Punjab

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Abstract : Groundwater Quality monitoring carried out in Ludhiana and Muktsar districts of Punjab under Information Technology for Sustainable Agriculture in Punjab through Technology Information Forecasting and Council of DST has provided valuable groundwater quality database. Water quality database includes major ion concentrations, pesticide residue concentrations. Groundwater monitoring has been covered in the industrial areas of Ludhiana and in the intensive agriculture areas of both districts. Groundwater quality database has been supported by geophysical investigations, groundwater flow and mass transport modeling studies. The predictions from groundwater flow & mass transport models indicate that the reversal of hydraulic gradient in Ludhiana district poses problem of likely migration of contaminants in groundwater towards Ludhiana city. Severe Nitrate as nitrate and pesticide contamination as well as water logging conditions have been reported in Muktsar district. Recent updates of groundwater quality information suggest that there is no let up in the situation and noticed further deterioration of groundwater level in Ludhiana and groundwater quality in Muktsar district.

INTRODUCTION

The concept of sustainable agriculture becomes pertinent and takes on a new dimension when viewed in the context of limits to resource availability and use. Degradation of water resources has been widely regarded as a major threat to sustainable agricultural production in the country. It has been projected that the land degradation problem may become even more severe if urgent steps are not taken to reverse the process. In the arid and semi-arid areas of country, the quality and quantity of water is also becoming a serious constraint to sustainable agricultural production. The Punjab state is intensively cultivated and is contributing large share to the grain basket of the country. However, thirty five years after the start of green revolution in 1968, the people have started realizing the limitation of intensive resource use without taking care of its long term sustainability. There has been a large-scale degradation of land resources due to erosion, salinization, water logging etc.. A concern has been expressed at different levels that the agricultural productivity in Punjab has been declining. Groundwater resources have been used extensively in the Punjab over the last four decades to meet the need for sufficient irrigation water and drinking water for the ever expanding population in a region with poor infrastructure facilities as well as green revolution. The uncontrolled and uncoordinated development of groundwater exacerbated the effects of deterioration of water quality and decline in water levels.

The ICAR committee recommended that it would be desirable if benchmark sites are established in major agro-climatic zones to continuously monitor natural resources, production system and socio-economic impact on long-term basis for evaluating sustainability indicators. Keeping this in view, UNDP-TIFAC sponsored a project entitled "Information Technology for Sustainable Agriculture in Punjab" (IT-SAP) is being implemented in five districts viz., Amritsar, Ludhiana, Muktsar, Patiala and Hoshiarpur representing five agro-ecological zones of Punjab. In order to understand the problem of water logging, changing hydrological regime, soil salinity, declining yield of crops particularly cotton, detailed investigations under the IT-SAP project were undertaken in Ludhiana and Muktsar districts of Punjab with a thrust on collection of available field data and generating primary data for assessment of present groundwater quality and preparation of groundwater forecasting models as regards groundwater level as well as water quality.

LUDHIANA DISTRICT

Ludhiana district is one of the industrialized districts in Punjab with a four decade background. The Budha nala is the surface water stream flowing in the Ludhiana city, choked with human waste and industrial effluents and soil charged with heavy metals. Electroplating industry is having large number of units in Ludhiana. The groundwater from various localities in the city have been reported to be containing toxic pollutants like hexavalent chromium and cyanide in excessive proportions. The present water supply in Ludhiana city is from 209 deep tube wells. There are about 3000 hand pumps and 500 shallow tube wells in the rest of the city. There are four well-marked potential granular zones 6-14 m thick, separated by thick clay beds. During last one decade a trough region of groundwater contours around Ludhiana has been developed due to over exploitation of groundwater. This has resulted in reversal hydraulic gradient from Budhanala (Fig. 1). Periodical water level measurements at 62 observation wells during July and November 2003 have shown that the maximum depth to water level exceed 25 m in Ludhiana city and environs and minimum water level has been found between Budhanala and Satluj River. Most of the drinking water supply wells in Ludhiana city and irrigation wells in agriculture fields are pumping at a rate > 1000 m^3/day.

Geophysical investigations at 22 locations has been carried out to infer aquifer geometry of predominantly sandy clay formations of the Satluj alluvium. Positive correlations have been found between sodium with chloride and sulphate. Magnesium also shows positive correlation with sulphate and negative correlation with chloride (Table 1 & 2). The groundwater is falling under C_2S_1 and C_3S_1 category in the Wilcox Diagram. Groundwater in Ludhiana district is not effected by sodium hazard but with a medium to high with regard to Salinity hazard for irrigation water use. The intensive groundwater exploitation for

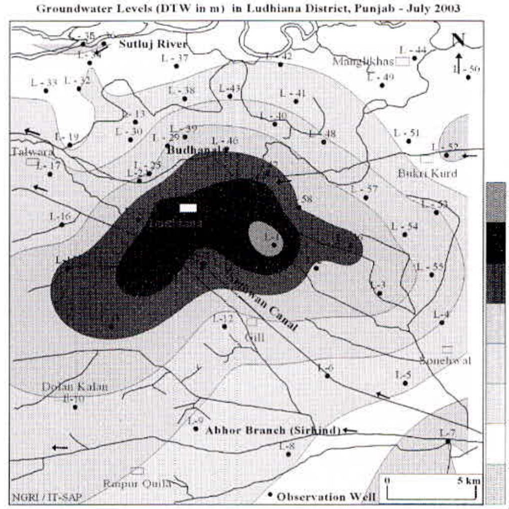


Fig. 1 : Depth to Water Level in m (bgl) in a Part of Ludhiana District during July 2003

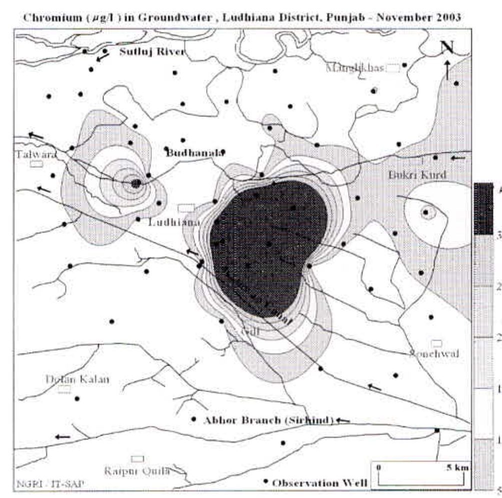


Fig. 2 : Chromium (mg/l) in Groundwater, November 2003

Table 1 : Statistical Analysis of Groundwater Quality in Ludhiana District – July 2003

Parameter	Unit	Min	Max	Q25	Q50	Q75
pH		7	8.6			
TDS	mg/l	180	6529	417	499	773.5
Na	mg/l	4	488	13.5	29	65
Mg	mg/l	19	122	34	49	65.5
Ca	mg/l	16	128	32	40	76
K	mg/l	3	130	7.5	9	12.5
Cl	mg/l	10	420	20	40	90
SO_4	mg/l	10	286	27	44	107
HCO_3	mg/l	50	680	200	270	310
NO_3 as NO_3	mg/l	0	207	0.8	19.2	39.0
F	mg/l	0.21	1.23	0.37	0.49	0.66
Total Hardness	mg/l	1.18	6.40	2.61	3.18	4.39
MH	mg/l	33.1	91.6	51.6	62.5	71.6
SAR	mg/l	0.1	16.8	0.35	0.71	1.32

Table 2 : Statistical Analysis of Groundwater Quality in Ludhiana District – November 2003

Parameter	Unit	Min	Max	Q25	Q50	Q75
pH		6.9	8.82			
TDS	mg/l	147	1553	352	435	646
Na	mg/l	10	258	17	28	48
Mg	mg/l	10	102	29	44	53
Ca	mg/l	16	128	24	40	64
K	mg/l	5	244	8	9	13
Cl	mg/l	10	410	20	30	70
SO_4	mg/l	8	386	34	68	124
HCO_3	mg/l	40	470	170	190	230
NO_3 as NO_3	mg/l	0.05	321.75	0.88	21.1	46.72
F	mg/l	0.05	1.26	0.19	0.27	0.33
Total Hardness	mg/l	0.81	7.39	2.21	2.78	3.58
MH	mg/l	20.49	90.07	56.79	63.66	73.20
SAR	mg/l	0.19	4.74	0.50	0.74	1.21

drinking water supply of Ludhiana has caused reversal of hydraulic gradient resulting in contaminant migration from Budhanala towards the city. The groundwater levels of July 2003 have been simulated in the groundwater flow model with an effective groundwater recharge of 55 mm/year using *Visual MODFLOW* (Fig. 3). The groundwater balance computed from the groundwater flow model indicates that Budhanala contributes about 11 mcm/yr of effluent flows to the groundwater regime through stream-aquifer interaction. The predicted contaminant migration from the Mass Transport in 3 Dimensions *(MT3D)* model for the year 2023 indicate migration of TDS plume from Budhanala towards city (Fig. 4). Significantly the migration of chromium in

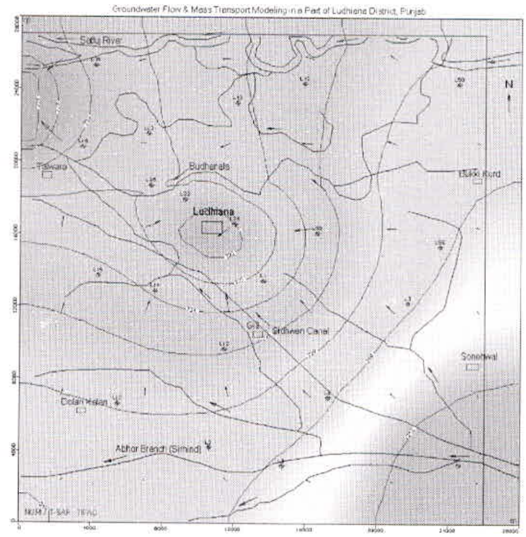


Fig. 3 : Computed Groundwater Water Level in m (amsl) - July 2003

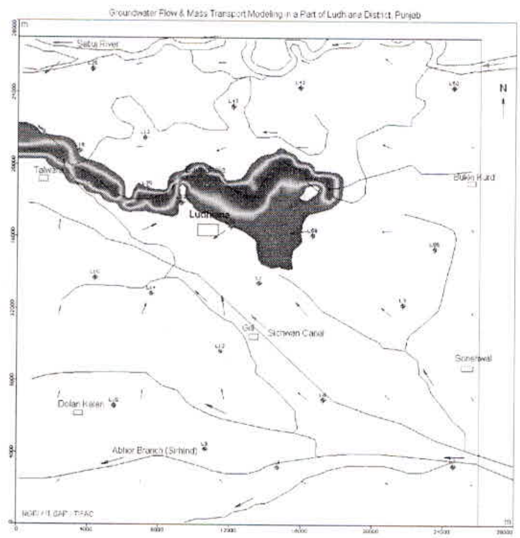


Fig. 4 : Computed TDS (mg/l) migration from Budhanala after 50 years (2023)

groundwater is very slow due to its adsorption to the clay porous matrix. Contamination of first aquifer in Ludhiana and adsorption of chromium in clay lenses may be saving the second aquifer containing leachate transport from first aquifer to the second aquifer.

MUKTSAR DISTRICT

Groundwater quality and water level monitoring in Muktsar district has been carried out through establishment of 70 observation wells (Fig. 5). The aquifer geometry has been inferred by carrying out Vertical Electrical soundings and are correlated with available lithologs. The geo-electric sections and available lithologs indicate that the top formation is dominated by clayey sands, fine to medium sand underlain by thick clay hindering movement of recharge water to the deeper zones. Water quality analyses for major ions and trace elements analyses have been carried out. The minimum depth to water table has been < 1.5 m and maximum being about 6.0 m during post monsoon season indicate the water logging

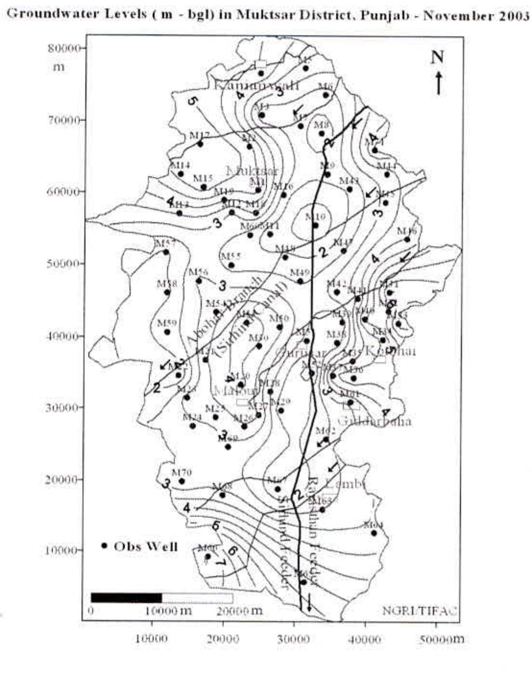


Fig. 5 : Depth to Groundwater Level Contours in m (bgl) - November 2003 & Location of Observation Wells in Muktsar District, Punjab

condition, whereas the water levels are slightly lower by 2-3 m during pre- monsoon. The water logging conditions are found around Lambi, Gurusur and Malout blocks around the Sirhind feeder canal command areas. Poor drainage conditions as well as Abhor branch canal network around Malout also contribute for water logging conditions.

TDS concentration of groundwater has been found > 2000 mg/l in Malout, Lambi, Gidarbaha and North eastern part of Muktsar district during July 2003 (Fig.6), whereas there has been slight reduction in the areal spread of TDS concentration during post monsoon period implying that there is severe problem of brackishness of groundwater (Tables 3 & 4). In general, violations of WHO drinking water standards in respect of TDS, Chloride, Sulphate, Nitrate as N and Fluoride have been evident over 60% of the study area. In the above regions where TDS has been maximum, Nitrate as N has been also found to be very high (>30 mg/l). The Nitrate as N contamination could be mainly attributed to intense agriculture and anthropogenic impact of fertilizers application (Fig. 7) Critical analysis of Nitrate as N concentration in groundwater reveals that its concentration is high during post monsoon compared with pre-monsoon suggesting that nitrates would have leached to shallow groundwater table through the recharge process. The water logging conditions and shallow water table also aids their horizontal movement. As regards fluoride concentrations, about 75% of the district falls under exceeding the WHO limit of 1.5 mg/l. The maximum values are found > 5 mg/l. The fluoride enrichment could be due to lot of phosphates fertilizer usage and associate fluoride

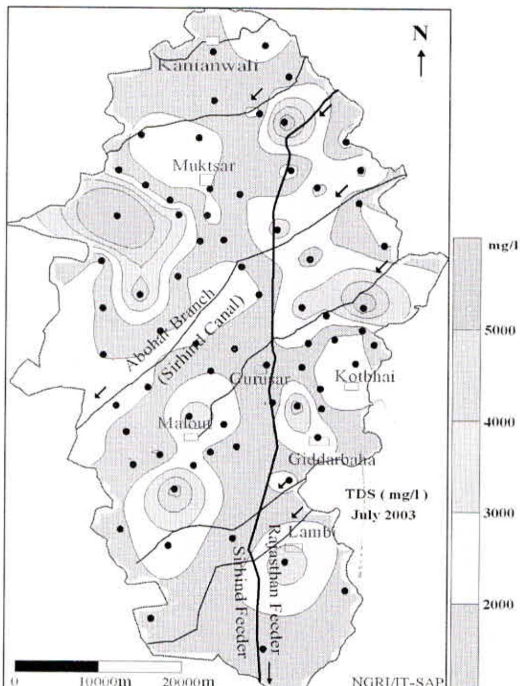


Fig. 6 : TDS (mg/l) in Groundwater of Muktsar District – July 2003

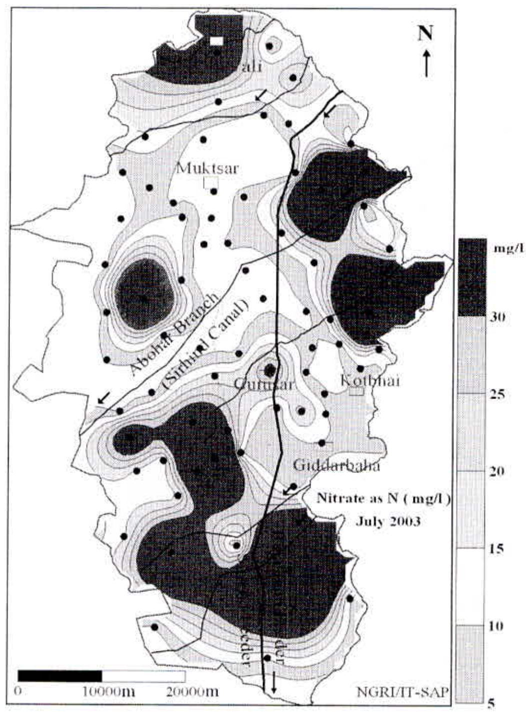


Fig. 7 : Nitrate as N (mg/l) in Groundwater of Muktsar District – July 2003

Table 3 : Statistical Analysis of Groundwater Quality in Muktsar District – July 2003

Parameter	Unit	Min	Max	Q25	Q50	Q75
pH		7.2	8.9			
TDS	mg/l	192	10530	874	1440	2429
Na	mg/l	10	2124	122	290	558
Mg	mg/l	0.2	856	49	83	136
Ca	mg/l	8	240	32	40	64
K	mg/l	7	341	9	11	22
Cl	mg/l	30	3530	90	160	430
SO_4	mg/l	40	1300	152	360	790
HCO_3	mg/l	30	2200	220	340	530
NO_3 as NO_3	mg/l	2.0	643	19.1	44.2	73.2
F	mg/l	0.25	16.8	0.76	1.5	2.9
Total Hardness	mg/l	0.81	37.2	2.4	4.4	7.2
MH	mg/l	0	94.6	59.9	72.8	81.9
SAR	mg/l	0	31	1.9	5.7	13.1

Table 4 : Statistical Analysis of Groundwater Quality in Muktsar District – November 2003

Parameter	Unit	Min	Max	Q25	Q50	Q75
pH		7.5	8.6			
TDS	mg/l	227	10496	787	1206	2293
Na	mg/l	12	3050	95.7	239	528.7
Mg	mg/l	5	253	44	66	114.5
Ca	mg/l	8	320	24	40	72
K	mg/l	8	345	12	16	28.2
Cl	mg/l	20	3020	60	205	442
SO_4	mg/l	22	3600	130	359	628
HCO_3	mg/l	20	1070	157	245	420
NO_3 as NO_3	mg/l	0.28	915	19.4	40.5	70.4
F	mg/l	0.03	14.5	0.69	1.36	2.56
Total Hardness	mg/l	0.6	15.9	2.7	4.0	6.4
MH	mg/l	0	93.3	63.6	69.5	77.8
SAR	mg/l	0	33.2	2.0	5.3	12.3

minerals. The presence of heavy metals may also be attributed to fertilizer use only in the absence of any potential industrial sources.

Wilcox diagram of groundwater quality indicate problems of salinity and sodium hazards with majority of groundwater samples falling under C_3S_2, C_3S_3, C_4S_3 classes. Groundwater salinity could be attributed to excessive use of fertilizers leaching to groundwater through irrigation return flows as well as due to presence of brackish water underneath. Thus the applied rejected fertilizers/ salts are only contained in the top zone resulting in soil and shallow groundwater salinity.

The groundwater modeling study has helped to simulate the groundwater conditions of July 2003 in the Muktsar district using *Visual MODFLOW (Gurunadha Rao et al, 2004.* The groundwater balance computed from the model indicates that there is some outflows toward western part of the district. All the feeder canals including the Bikaner canal contribute about 10-15% of additional recharge to the groundwater system. Transient state simulation has shown a rising trend of well hydrographs all over the district (Fig. 8), which has been causing water logging conditions with negative draw down around feeder canals.

PERSISTENCE OF PESTICIDE RESIDUES IN GROUNDWATER

Groundwater analyses carried out for pesticide residues in Ludhiana and Muktsar districts of Punjab have shown persistence of Organo-Chlorine pesticides of BHC (Lindane), Heptachlor, Heptachlor Epoxide, Endosulfan I, 4,4 - DDT, Methoxychlor and Organo-Phosphorous pesticides of Methyl Parathion, Dimethoate and Malathion during July, November 2003 and May 2004. It has been found that generally the presence

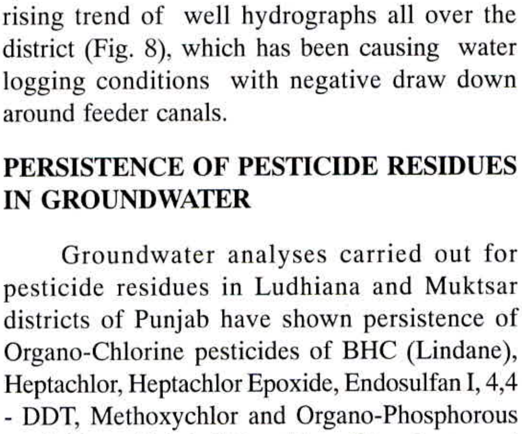


Fig. 8 Rising trend of well Hydrographs at well Nos. M48 & M51 for 5 years In Muktsar district

of organo-chlorine pesticide residues in groundwater of Muktsar district are about 6-8 times higher than Ludhiana district. The use of pesticides depends on corps grown in the area. Cotton crop grown over large areas in Muktsar district is contributing higher levels of pesticide residues in groundwater as compared with predominantly paddy grown areas in Ludhiana district. As all are aware that cotton crops requires more pesticide application than paddy. Further shallow water table condition in the Muktsar district also escalating the problem as pesticides may leach fast to the shallow water table compared to the deep water table conditions in Ludhiana as illustrated by the concentration of isomers of BHC in groundwater (Figs. 9 & 10). Compared to cotton crop, paddy crop requires more irrigation water and thereby more dilution of pesticide residues could be possible while leaching to the groundwater table.

CONCLUSIONS

Generating data at micro level will require still greater efforts in these districts. Distinct possibilities of more efficient and judicious use of inputs like fertilizers, pesticides and irrigation water have been suggested whereby agricultural production system in Muktsar and Ludhiana districts can be reset on a sustainable manner. Similar investigations have to be covered horizontally in other districts and vertically down to help percolate the new capabilities of information technology to the block and village levels. The industrial waste disposal facilities like Common Effluent Treatment Plant (CETP) and Treatment, Storage and Disposal Facility (TSDF) for disposal of hazardous wastes from industries have been suggested in industrialized Ludhiana district. Conjunctive use of groundwater and canal water utilization is strongly recommended for reducing the sodium and salinity hazard from groundwater irrigation. The ultimate goal of establishing precision farming technology will be founded on the successes of present experiment

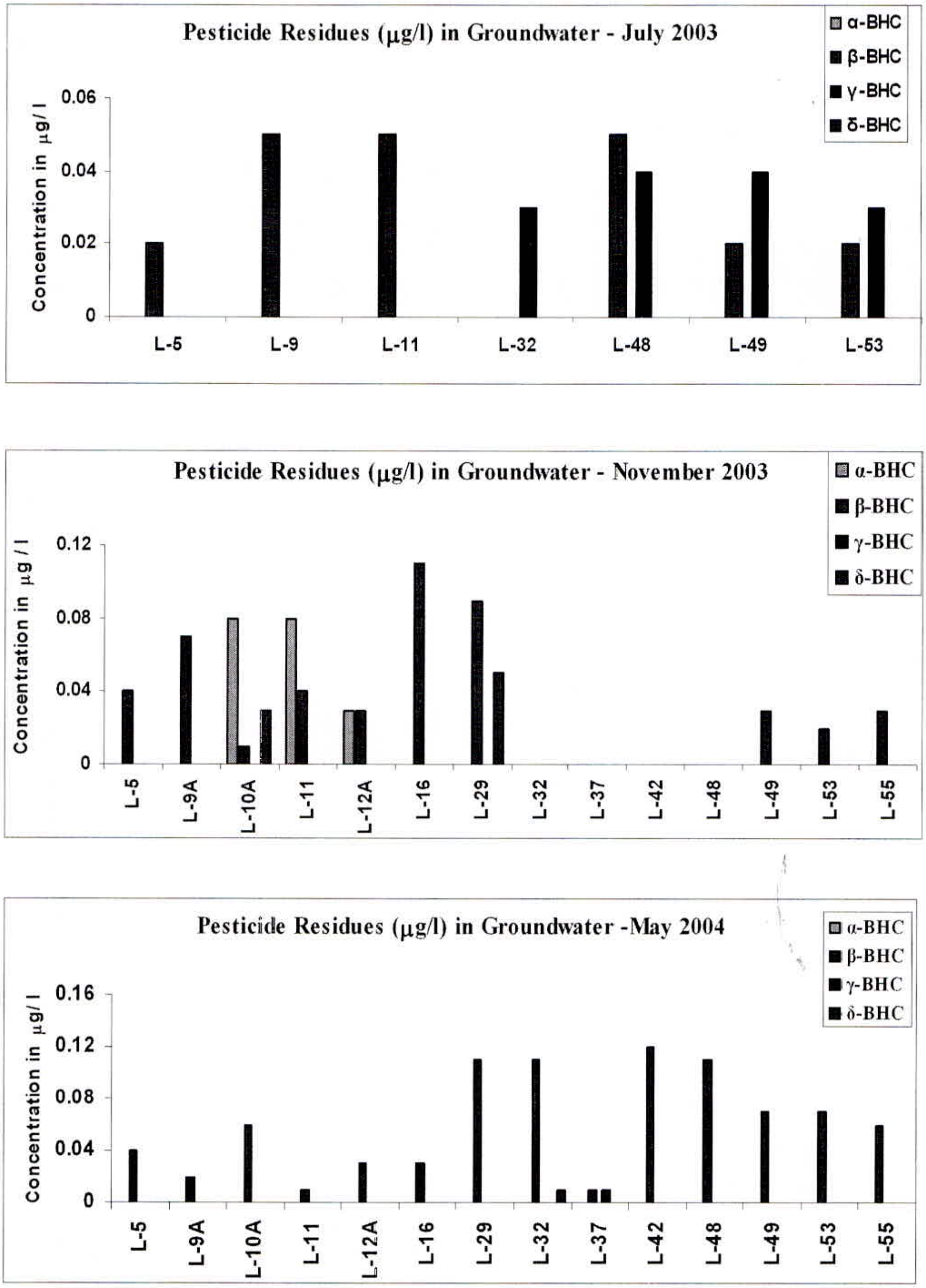
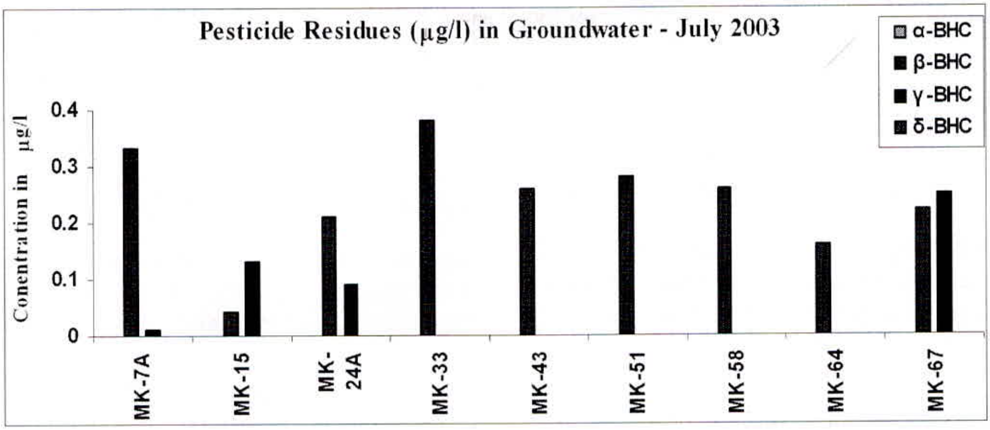
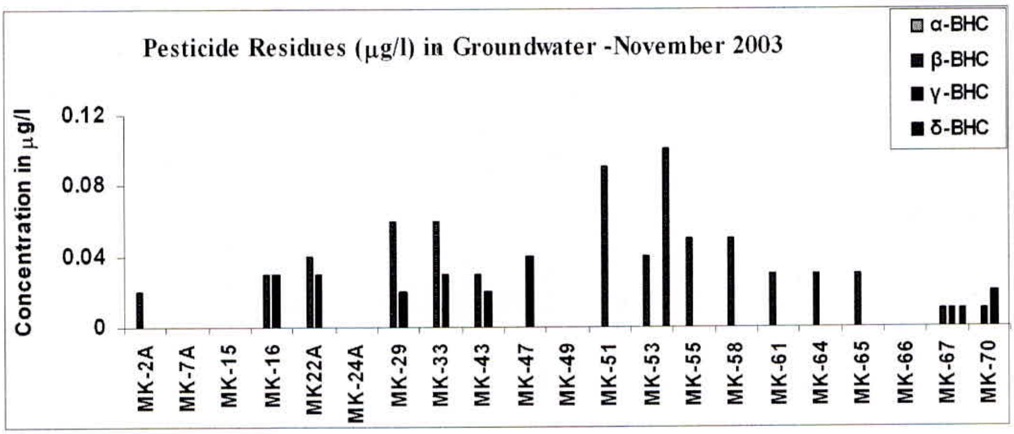


Fig. 9 : Pesticide residues of BHC in Groundwater of Ludhiana district





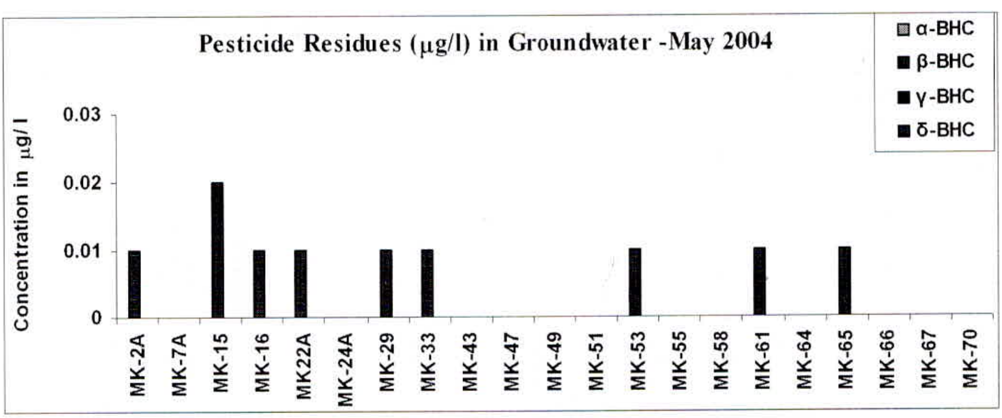


Fig. 10 : Pesticide residues of BHC in Groundwater of Muktsar district

making Punjab a trend setter for other states. The persistence of pesticide residues in groundwater in both districts warrant periodical assessment to check the levels due to intensive agriculture production.

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