PUNJAB POLLUTION CONTROL BOARD

Final Report

Effect of Effluent disposal on Water Quality and Human Health among people living in close proximity to major Wastewater Drains in Punjab.

Conducted by

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Abbreviations

Abbreviations	Full Name
As	Arsenic
Cd	Cadmium
Cr	Chromium
Ni	Nickel
Se	Selenium
Hg	Mercury
Cu	Copper
Pb	Lead
Fe	Iron
TA	Total Alkalinity
TH	Total hardness
P	Phosphorus
Cl	Chloride
Ca	Calcium
Mg	Magnesium
F	Flouride
NH_3	Ammonia
RCl	Residual Chlorine
DDT	Dichloro Diphenyl Trichloroethane
DDD	Dichloro Diphenyl Dichloroethane
DDE	Dichloro Diphenyl Dichloroethylene
HCH	Hexachloro Cyclo Hexane
MN	Micronuclei
ml	Millilitre
GI	Gastrointestinal
ppb	Parts per billion
ppm	Parts per million
OR	Odds Ratio
ND	Not Detected
BDL	Below Detectable Limit
BOD	Biochemical oxygen demand
COD	Chemical oxygen demand

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Contents

1. Executive Summary

Punjab, a prosperous state of India, pioneers in both agriculture and industrialization. However these two activities along with ever increasing urbanization are leading to pollution of its vast water resources. Despite being one of the richest states of the country in terms of per capita income, the health indices of the state are not the best with an infant mortality of 42 per 1000 live births, high prevalence of anemia among children between 6-35 months (80.2%) and pregnant women (41.6%) as per National Family Health Services-3 (NFHS-3). Only 34.7% children with diarrhea are treated with oral rehydration solution. Due to urbanization and industrialization in the state, a large amount of wastewater is generated and is drained mostly partially or untreated in the local drains, which had led to the pollution of these drains. The present study was conducted in Punjab to ascertain the effect of effluent water pollution on human health and water quality among the people living near five major effluent drains viz. Buddha drain, Hudiara drain, East Bein drain, Tung Dhab drain and Kala Singha drain of the area.

Mapping of area was done by a team of field investigators under supervision of medical officer and study investigators to prepare a village level profile in terms of exposure to industrial wastes, proximity of industry to the village and perception of local people regarding ground and tap water pollution. The villages were classified as reference and control areas, which were of high (mid and down stream) and low pollution (early stream) respectively.

A total of 5371 and 2018 study subjects were selected by systematic random sampling from reference and control area respectively and interviewed to elicit information on various morbidities. Samples of water, vegetable, fodder, urine and milk (human and bovine) were collected to ascertain effects of pollution on their quality. This included testing of physical and chemical quality besides contamination by heavy metals and pesticides. Blood samples were also collected to estimate pesticides concentrations. Buccal smears were scrapped to ascertain initiation of mutagenic activity in epithelial cells.

The study revealed a statistically significant association of occurrence of gastrointestinal problems (diarrhea, vomiting etc), water related vector borne diseases (malaria, dengue), skin, eye and bone problems among persons residing in reference area ($p<0.05$). Drain wise stratified analysis revealed a significantly higher association of gastrointestinal, skin, eye and bone problems among resident of reference area of Buddha drain. The numerous industrial units in Ludhiana, discharging inadequate or untreated effluent and municipal waste water could be a major reason for the morbidity profile of the study subjects in that area The study revealed that flourosis is a major problem in Punjab with significantly higher association of mottling and discoloration of teeth and more than permissible fluoride levels. Overall delayed milestones, gastrointestinal problems and blue line on gums were significantly higher among children of reference area as compared to control area. Average abortion rates among women were also significantly higher in reference area.

Mean biochemical and chemical oxygen demand (BOD and COD respectively) levels in excess of the permissible limits (MPL) are indicators of inadequate treatment of domestic sewage prior to discharge into water bodies. An analysis of the level of BOD and COD according to place of sampling in relation to the point of sewage disposal into the drain has further substantiated the claim that the untreated or partially treated sewage is discharged into these drains. Level of organic pollution as reflected by BOD and COD value was observed to be maximum at points which were just downstream from point of municipal sewage disposal. The possible point sources had been identified. The study also revealed Mercury, Cadmium, Chromium, Copper and Lead to be higher in samples of ground and tap water tested. Metal and electroplating industries found in abundance in these towns from which the drain pass are the most probable cause of higher levels of heavy metals in drain, tap and ground water. Cadmium and Selenium are found in higher concentrations due to effluent discharge from food, dying and leather industries. Similarly Copper, Lead and Chromium levels are attributed to leather, tanning and metal industries. The bacteriological quality of drinking tap water was found to be poor as shown by presence of higher total coliform and E. coli.

Heptachlor, β-Endosulphan and Chloripyriphos pesticides were observed in concentrations exceeding the maximum residue limit in 25%, 21.5% and 16.1% samples of ground and tap water. Pesticides were also detected in vegetables, fodder, bovine and human milk and blood samples. This shows that pesticides have entered into food chain. The possible reasons for detection of these pesticides may be due to agricultural run off and irrigation of fields with drains water. The health effects observed in the present study are a manifestation of higher levels of heavy metals and pesticides in drinking water, which is bioaccumulating in fodder, food, milk and blood. Majority of the morbidities observed are acute toxicities of these heavy metals and pesticides. Since the rapid industrialization has its onset, which can be traced to 1990s, it is very likely that the chronic effects of heavy metals and pesticides contamination may manifest in the coming years. Evidence of micronuclei in epithetical cells, reflecting evidence of genetic damage is observed to be higher in epithetical cells of buccal smear from persons in reference area of Hudiara Nallah. The DNA adducts study in limited blood samples has confirmed varying degree of mutations in 65% of the blood samples. This is an early indication of likely increased manifestation of cancerous lesions, which might be seen in subsequent time. Another evidence of likely chronic effects emerging in future is the significantly higher prevalence of general health effects like numbness of fingers and loss of finger nail/hair, which is an indicator of early neurotoxicity due to heavy metal concentration like mercury and lead.

It is concluded that inorganic and organic pollution is an important problem in all major drains as reflected by higher BOD, COD, heavy metals (Hg, Cu, Cd, Cr, Pb) and pesticides residue (Chlorpyriphos, Malathion, Dimethoate, Aldrin, Heptachlor, α-Endosulphan, β-Endosulphan) in reference as compared to control area. This is also reflected by higher level of heavy metals (Hg, Cu, Cd, Pb, Cr) besides pesticides residue (Chlorpyriphos, Malathion, Dimethoate, Aldrin, Heptachlor, α-Endosulphan, β-Endosulphan) in ground and tap water which has affected the food chain and human health as reflected by higher concentration of these heavy metals and pesticides seen in samples of vegetables, fodder, bovine and human milk, urine and blood in reference area as compared to control area. Mercury and fluoride levels have been found to be consistently more than permissible limits in reference and control areas. There is an evidence of genotoxicity as reflected by higher prevalence of occurrence of micronuclei and mutations in reference population as compared to control area, which is significant in subjects belonging to reference area of Hudiara Nallah. The health effects of water pollution is reflected by significantly higher association for occurrence of gastrointestinal problems, water related vector born diseases (Malaria, Dengue), skin problems, eye and bone problems in the reference population. Average abortion rates among women and delayed milestones among children are significantly higher in reference area. There is no evidence at present of higher chronic health problems due to genotoxicity since environmental pollution takes long time even in decades to reflect in chronic diseases.

Recommendations:

Since there is a high level of inorganic and organic pollution in major wastewater drains of Punjab, the Technical Review Committee of the project recommended that

1. There is a need for regular monitoring of water quality of drains, industry and municipal bodies for organic and inorganic pollution. The Municipal Committees and regulatory bodies need to strictly enforce the relevant rules for water pollution.
2. Water Supply and Sewage Board, Punjab should undertake steps for provision of safe drinking water and proper disposal of sewage. Rural development and Panchayati raj department should encourage panchayats in rural area to plan, construct, manage and maintain their own water supply and sanitation facilities as a model, which is successfully being implemented in Gujarat.
3. The local bodies department should support Municipal Corporations committees of major towns in Punjab to setup sewerage/solid waste treatment facilities. Similarly, industry should treat their effluent before discharging into water bodies and it should be strictly enforced by regulators.
4. Water Supply and Sewage Board should also do regular monitoring of drinking water quality. It should include monitoring of physical & chemical parameters, heavy metals, pesticides and bacteriological testing. Strict action should be initiated against defaulters. The board should also setup or identify regional laboratories in the state in public or private sector to undertake tests for water quality including heavy metals and pesticides.
5. The Health Department should establish a surveillance system to identify acute and chronic effects due to heavy metals and pesticides. Regional laboratories in government or private sector should be identified to monitor heavy metals and pesticides in urine and blood. Local health authority designated by health department should undertake

monitoring the level of heavy metals and pesticides in the food. Similarly Biomedical Waste Management rules should be strictly followed in all health institutions of the state to prevent possible contamination of drinking water with mercury.

6. Agriculture and dairy development department should undertake regular monitoring of pesticide and heavy metal levels in food grains, vegetables, fruits and milk.

7. Environment or Cooperative department should promote voluntary action for restoration of water quality of major drains as demonstrated by experience of eminent people working on Buddha Nallah and East Bein. Government should extend full support for people carrying out such voluntary activities.

8. Further studies for identification of DNA adduct are needed to identify the specific heavy metals and pesticides involved in genotoxicity. Similarly source identification for water pollution from industry and municipal committees should be undertaken.

2. Introduction

Punjab is one of the most prosperous states of India, pioneering in the green revolution and industrialization. Punjab has abundant water resources, but due to rapid migration of people from villages to cities, industrialization and use of fertilizers and pesticides, these resources are getting polluted. Large amount of effluent being generated by different kind of industries, which are responsible for formation of some big effluent drains.

The sources of water pollution are industries, municipal sewage, urban storm water and non-point pollution especially due to runoff from agriculture fields etc. which discharge fluid laced with various contaminants including heavy metals into the water bodies. Heavy metals are naturally occurring elements and are present in varying concentration in all ecosystems. There are huge numbers of heavy metals found in elemental form and in a variety of other chemical compounds. Human activities have drastically changed the biochemical cycles and balance of heavy metals[3].

Heavy metals are known to be potentially hazardous substances. They can be absorbed by green plants, which are the primary producers in the ecosystem. As they move up the food chain from producers to consumers, they tend to bioaccumulate in the plant and animal tissues and cause physiological and neurological disorders. In Punjab, various studies[5-8, 12] have already reported bioaccumulation of heavy metals like lead, mercury and zinc in aquatic fauna. Metals like Cadmium, Lead, Zinc and Chromium have also been found beyond permissible limits in green vegetables grown in fields irrigated with water from drains like Hudiara Nallah and Gandha Nallah in Amritsar and Buddha Nallah in Ludhiana. Studies by PPCB have also reported the presence of heavy metals in waters and sediments of major rivers[13].

A preliminary study done by PPCB show that main source of pollution in East Bein is untreated wastewater of the cities, industrial wastewater, agriculture and other related activities of the villages along the East Bein. Ground water quality has also been affected with respect to total dissolved solids. Accumulation of Chromium, Nickel, Zinc, and pesticides are high in the sediment of East Bein. Traces of metals like Chromium, Nickel, and Zinc were detected in soil samples of the fields irrigated by the effluents of East Bein[10]. Water quality of Hudiara Nallah has deteriorated due to discharge of untreated/treated effluents by industries, Municipal Corporation of Amritsar and Guru Nanak Dev University. This Nallah is not only affected by industrial and city sewage but also from agriculture and other activities of villages along it. It was found that concentration of Zinc was high in the sediment of the Nallah[11].

Another study show that gastroenterological and vector borne diseases, i.e. malaria, dengue, were higher in Ludhiana as compared to control area, i.e. Samrala. Estimation of metals in effluent water by atomic absorption spectroscopy shows presence of chromium, cadmium, arsenic and mercury. Out of this cadmium, arsenic and mercury are known carcinogens[4].

It had been reported in a study that people living in close proximity of Tung Dhab Drain, which is sub-drain of Hudiara Nallah, are having significantly higher genotoxicity as compared to the people not exposed to contaminated water living in control areas[9]. With the above background, it was decided to undertake an epidemiological study on the effects of effluents on human health and water quality among the people living in close proximity to major waste water drain in Punjab.

3. Aims & Objectives

1) To ascertain the status of chemical composition of effluent of five major effluent drains.

2) To assess the pattern and extent of chemical pollution of tap and ground water at adjoining to the study sites.

3) To assess health profile of people living near wastewater drains.

4) To find out any association between exposure to chemical pollution and health profile of study population

4. Methodology

4.1 Study Setting

Punjab is a prosperous, north Indian State, which has literacy rate of 74%. Access to sanitation in urban and rural area is 93.7% and 56% respectively while 54% of population has access to piped drinking water supply (79.4% urban, 38.4% rural). The health indicators of Punjab reveal a birth rate, death rate and infant mortality rate of 18.1 and 6.7 per 1000 population; and 40 per 1000 live births respectively. It is called the land of 5 rivers. Agriculture is the main source of living for people. Source of irrigation is mainly canal water and tube wells.

Figure-1: Mapping of Study Areas

The study includes five major drains of Punjab, which include Buddha Nallah, Hudiara Nallah, Tung Dhab Drain, East Bein Drain, and Kala Singha Drain. Buddha Nallah originates near the village Raipur (District. Ludhiana) passes through Ludhiana city and meets river Satluj near Khera Bet. East Bein or Chitti Bein is a natural storm water drain, which originates near village Bhairan Majra in District Nawan Shahar. Several sub-drain fall into

East Bein, of which Kala Singha drain is most important as it carries individual wastes of Kapurthala and Jalandhar and meets East Bein near Khanpur. Hudiara Nallah is basically a storm water drain with total length of 55 kms originating from the village Heir on Amritsar-Ajnala road up to village Daoke, after which it flows into Pakistan.Tung Dhab Drain is the tributary of Hudiara Nallah, which originates near village Shankarpura passes through Amritsar city carrying industrial and domestic sewage and falls into Hudiara Nallah near Khiala Kalan. A map showing the location of various drains is shown in figure 1.

4.2 Study Design

A cross sectional study was conducted in the areas covering each of the five selected drains in Punjab. A rapid survey for mapping of the area along the drains was done and a village level profile of the entire area was prepared in terms of exposure to industrial wastes, proximity of industry to the village, usage of pesticides in farming and perception of local people regarding ground and tap water pollution.

Table 1: Drain-wise distribution of study villages for epidemiological study

Drain	Study Villages	
	Reference area	Control area
Buddha Nallah	Khera Bet, Ghaunspur, Chandan Nagar, Malakpur, Partap Singh Wala	Raipur, Bahlolpur
East Bein Drain	Maheroo, Khun-Khun, Phul Guddowal, Heir, Haripur	Kulam, Barnala Kalan
Kala Singha Drain	Baler Khanpur, Bulandpur, Kesarpur, Fatehpur, Kala Singha	Nangal, Mahmudpur
Hudiara Nallah	Raja Tal, Lahori Mal, Mehwa, Bhajni Rajputan, Achintkot	Nangal Panuan, Bhoma
Tung Dhab Drain	Mahal, Gumtala, Boparai Baj Singh, Khiala Kalan, Guru Amardas colony	Bullowal, Shankarpura

These villages were categorized into high and low pollution villages. Two low pollution villages per drain were selected as control area. These include the village at the origin of the drain and another village 5 Km proximal to the origin. A total of five villages were selected as the reference area for each drain. These villages were the areas where effluent disposal into the drain was maximal. These villages were selected by stratified random sampling to include equal proportion of villages near the mid-point and end point of the drain.

Table 2: Drain-wise distribution of study villages for sample collection and laboratory testing

Drain	Study Villages	
	Reference area	Control area
Buddha Nallah	Khera Bet, Chandan Nagar.	Raipur
East Bein Drain	Khun-Khun, Phul Guddowal	Barnala Kalan
Kala Singha Drain	Fatehpur, Kala Singha	Nangal
Hudiara Nallah	Raja Tal, Lahori Mal	Bhoma
Tung Dhab Drain	Mahal, Boparai Baj Singh	Shankarpura

The study has two components firstly to ascertain health effects of effluent pollution on human health and secondly to ascertain the effect of effluent pollution on physical and chemical parameters and concentration of heavy metals, pesticides in water, vegetable and fodder.

4.2.1 Epidemiological study for health effects of effluent pollution

A cross sectional epidemiological survey was conducted to ascertain effect of effluent pollution on human health in selected villages along each drain.

4.2.1.1 Sample size

Sample size was calculated using Epi Info statistical program. Census 2001 population figures for Ludhiana, Amritsar and Jalandhar were 30.6 lakhs, 30.21 lakhs and 29.56 lakhs respectively. Assuming expected prevalence of gastric disorder caused by effluent exposure, as 10%, incidence of genetic disorders as 0.56%, desired precision of 2.5%, worst acceptable as 0.10% and confidence level of 95% a sample size of 1000 was worked out for reference area. For the cross-sectional household survey, it was estimated to select five thousand individuals from reference area and two thousand individuals from the control area of all the five selected drains.

Thousand individuals were to be selected from reference area of each drain, which was further sub-divided into 200 individuals per village of the reference area. Similarly, four hundred individuals were selected from control area of each drain with further sub-divided into 200 individuals from each village of the control area of the selected drains. These individuals were selected by systematic random sampling after preparing a set of all households in the village. Overall 7856 study subjects were selected, of which 5567 and 2289 were from reference and control area respectively. In reference area 4317 subjects were adults while 1250 were children. Similarly in control area adults and children were 1777 and 512 respectively.

4.2.1.2 Study Tool

Household questionnaire: The individuals selected in the above mentioned manner were interviewed on a pretested structured schedule to elicit information on socio-demographic profile, source and quality of drinking water, perception of water pollution and system wise (gastrointestinal, skin, eye, bone, kidney, obstetrical and miscellaneous) morbidities. Individuals were also enquired about their health status over the last one-year. Separate schedules were used for adult and childhood morbidities. Survey was done by a team of two Junior research fellows and four Field investigators under supervision of a Medical officer, who elicited information on morbidities.

4.3 Laboratory Testing for Assessment of Effluent pollution

The samples were collected from the respective villages in reference and control areas of the five drains (Table 2). These samples included ground water (15), tap water (6) and effluent water (15) in each of the six rounds for sample collection. These samples were tested for physical-chemical parameters, heavy metals and pesticide residues. Vegetable (10), fodder (10) were analyzed for heavy metal and pesticides while urine (10) samples were analyzed for the presence of heavy metals. Bovine and Human milk (5 each) were analyzed for pesticide residue. Ground and tap drinking water samples (12) were also assessed for bacteriological quality. Besides this blood samples (25) were also analyzed for pesticides and DNA adducts.

For collection of ground water, the water (Hand pump) source was first sterilized with the burning flame using spirit lamp. Water was allowed to run off for first half an hour and thereafter samples were collected. Similarly in surface water collection, tap was sterilized using sprit lamp flame. After cooling tap was let on for 5 minutes and then mid-stream sample was collected. Effluent water samples were collected from approximately middle of the drain with the help of a container tied to a long bamboo stick with rope.

Representative samples of vegetable and fodder were taken from the field along the drains. Twenty-four hour urine sample was collected in sterilized containers. Water samples, which were collected, were staggered in different seasons over a period of one year (2006-2007).

Table 3: Season wise collection of water samples (2006-2007)

Sample	Summer (Mar, May)	Monsoon (July)	Winter (Oct, Dec, Feb)
Ground Water	30	15	45
Tap Water	12	6	18
Effluent Water	30	15	45

The physical-chemical parameters, which were analyzed, were pH, alkalinity, total hardness, calcium, magnesium, ammonia, phosphate, total iron, chloride, residual chlorine and fluoride. Water testing kit standardized by Central Pollution Control Board, New Delhi was used for the analysis. BOD (Bio-chemical Oxygen Demand) and COD (Chemical Oxygen Demand) were measured for effluent sample using BOD incubator and COD apparatus respectively. For BOD estimation, samples were incubated for 5 days at 20^{0} C and titrated to get the results. Similarly for COD analysis samples were condensated for 3 hours and titrated to get the value.

A total of twenty pesticides were tested which include organochloro pesticides (Dieldrin, Alpha-Endosulphan, Beta-Endosulphan, Endosulphan sulphate, alpha-HCH, beta-HCH, gamma-HCH, delta-HCH, 4, 4-DDT, 2, 4-DDT, DDE, DDD, Chlordane, Chlorpyriphos, Aldrin, Heptachlor) and organophosphorus pesticides (Malathion, Dimethoate, Monocrotophos).

Table 4: Drain-wise laboratory testing of samples.

Drain	Area	Parameters Tested			
		Phy/Chm. Parameter's	COD/BOD	Heavy Metals	Pesticides
Buddha Nallah	Reference	30	11	36	28
	Control	10	5	12	12
East Bein Drain	Reference	20	10	24	17
	Control	15	5	18	9
Kala S. Drain	Reference	25	10	30	20
	Control	10	5	12	6
Hudiara Nallah	Reference	25	10	30	27
	Control	10	5	12	6
Tung D. Drain	Reference	25	10	30	25
	Control	10	5	12	8

The samples were processed by extraction, clean up and concentrated by using Rotary Vaccum Evaporator to approximately 2 ml. For the identification and quantification of pesticide residues, Nucon 5765 gas chromatograph fitted with electron capture detector (for organo chlorines) and Nitrogen Phosphorus detector (for organo phosphorus) was used. For ECD 1.5% OV-17 and 1.95% OV-210 Pyrex glass column used and 3% OV 101 for NPD (100-120 mesh size). 2%Diethylene Glycol Succinate (DEGS) column was used as an alternate column for the confirmation of organochloro pesticides.

Heavy metals viz. Copper, Lead, Mercury, Cadmium, Chromium, Selenium, Nickel and Arsenic were analyzed using Atomic Absorption Spectrophotometer for the quantification of heavy metals.

4.3.1 Micronucleus assay for genotoxicity

Three hundred samples of buccal smears were collected in duplicate from the residents of the villages along each drain for the analysis of genotoxicity through micronucleus (MN) assay. These included 210 samples distributed uniformly in all villages of reference area and 90 from the control area. These individuals were selected by systematic random sampling within a village after preparing a list of all households. The samples were collected between February to December 2006. The individuals were made to rinse their mouth with water. The buccal mucosal cells were scrapped from inner side of cheek with a sterilized blunt spatula. Smear was made on albumin-coated slides. The slides were then fixed in 95% alcohol and stained by papanicolaou method (PAP staining).

Each slide was coded and scored blind. The micronucleus (MN) analysis was done with a light microscope, at 400X magnification. Five hundred cells were scored per slides and then MN per cell was calculated.

4.3.2 DNA Adducts

DNA was extracted from EDTA blood using QiAmp DNA blood mini kit (Qiagen, Germany) according to manufacturer's instructions. The extracted DNA was quantified spectrophotometrically and then subjected to polymerase chain reaction (PCR) to amplify a 10.4 kb HPRT fragment in order to detect the formation of DNA adducts.

Primers used

HPRT Forward: 5' TGGGATTACACGTGTGAACCAACC 3'

HPRT Reverse: 5' GCTCTACCCTCTCCTCTACCGTCC 3'

PCR Conditions

Denaturation	-	95° C 40 sec
Annealing	-	52° C 40 sec
Amplification	-	72° C 40 sec

34 Cycles

The amplified product was then subjected to a 1% agarose gel electrophoresis. A semi-quantitative densitometric assessment was done for the PCR products by comparing the pixel density of control bands with that of the test bands using Image Master Total Lab software. The intensity of the bands was inversely proportional to the DNA adduct formation and the pixel density of tests was expressed as percentage of pixel density of control.

4.3.3 Data Entry and Analysis

Epidemiological data was entered in SPSS version 10.0. Univariate analysis was done for categorical epidemiological survey data by chi-square test and estimate of risk for association of various adult and childhood morbidities with residence in reference area was calculated by odds ratio. Stratified analysis of health effects across all five drains was done. Role of possible confounding factors was evaluated by stratifying the results of epidemiological survey according to various socio-demographic variables like age, sex, education and occupation besides personal habits viz. smoking, drinking etc. Mental Haenzel combined odds ratios were computed combining the different strata.

Data of laboratory tests was entered in MS-Excel 5.0 spreadsheet and analyzed using SPSS 10:00. Separate drain wise mean levels of physical-chemical parameters, BOD-COD, heavy metals and pesticides in water samples and; pesticide and heavy metals in vegetable, fodder, bovine and human milk were computed. Drain-wise prevalence of samples with mean level of parameter tested more than the permissible limit was compared to draw association with place of origin of sample (reference versus control). Statistical significance of mean concentrations across areas, drains and seasons was assessed using t-test.

Mean micronuclei count per cell was compared among residents of reference and control area and statistical significance computed using t-test. Age and sex-wise analysis for micronuclei count was also done. Area-wise comparison of difference in prevalence of micronucelation in cells was done using chi-square test and odds ratio.

4.4 Quality Control

4.4.1 Epidemiological Survey

Quality of the survey was maintained by an internal quality control mechanism. Out of total (1415) forms, 20% and 10% forms were filled by JRF and Medical Officer respectively and compared with the form filled by the field staff.

4.4.2 Laboratory Testing

Testing of 10 samples of water (ground, effluent, tap) along with one sample each of vegetable and fodder was conducted at Punjab Horticultural Post harvest Technology Center, Punjab Agricultural University, Ludhiana for cross checking the results of testing laboratory. Quality control was done for heavy metal and pesticide residue analysis.

5. Results

5.1 Epidemiological Survey to determine the health effects of effluent water pollution

5.1.1 Baseline characteristics of study groups

Table 5: Baseline Characteristics of Study Population

Characteristics	Reference Area	Control Area
Households	1002	401
Total Population	5567	2289
Male	2875 (51.64)	1206 (52.68)
Female	2692 (48.35)	1083 (47.31)
Adult	4317	1777
Children	1250	512
Mean Age (in yrs)	27.93	28.4
Average Family Income		
Below 840	262 (26.14)	128 (32)
840-2499	499 (49.8)	184 (46)
2500-4199	210 (21)	75 (18.7)
4200-8399	21 (2.1)	12 (3)
8400-16,799	8 (0.8)	2 (0.5)
16,800 or above	2 (0.2)	0
Type of Locality		
Residential	901 (89.92)*	391 (97.5)*
Industrial	12 (1.19)	2 (0.5)
Commercial	2 (0.2)	0
Farm Land	85 (8.48)*	8 (1.99)
Other	2 (0.2)	0
Perception of chemical exposure		
Yes	537 (12.41)	183 (10.29)
No	3643 (84.21)	1595 (89.7)
N.A.	146 (3.37)	0
Smoking Habits	143 (3.31)	64 (3.6)
Alcohol Habits	297 (6.87)	98 (5.51)

* Figures in parenthesis indicates percentage

A total population of 5567 and 2289 persons was selected in reference and control area. An approximate proportion of equal males (~ 52%) and females (~ 48%) were observed in both areas. The mean age and average family income were also similar in the two groups with predominant families having an income range of 840-2499 in both reference (49.8%) and control area (46%). Significant difference was observed in the distribution of population in terms of type of locality ($p=0.001$) and perception of exposure to chemical ($p=0.02$), with higher percent population in reference areas (12.4%) having exposure. There is no significant difference among the population residing in reference and control areas according to smoking habits ($p>0.5$) or alcohol consumption ($p>0.05$) (Table 5).

Table 6: Assessment of Water Quality in study population

Characteristics	Number of Households (%)	
	Reference Area (N=1002)	Control Area (N=401)
Source of Drinking Water		
Shallow hand pump	91 (9.08)	58 (14.46)*
Deep hand pump	658 (65.66)	293 (73.06)
Tap	208 (20.75)	44 (10.97)
Deep well	4 (0.4)	1 (0.24)
Others	41 (4.1)	5 (1.24)
Perception of polluted drinking water	501 (50)	282 (70.32)
Duration of consumption (in yrs)	1.22	2
Treatment of drinking water	45 (4.5)	3 (0.75)
Industrial Water Pollution		
Industry close to drinking water source	79 (7.78)	1 (0.24)
Solid disposal in open space	78 (7.78)	1 (0.24)
Waste water in open drain	76 (7.58)	1 (0.24)
Industrial waste in fields	21 (2.1)	0
Solid Waste Pollution		
Type of Toilet Facility		
Septic tank	234 (23.24)	98 (24.43)
Dry pit	265 (26.44)	107 (26.68)
Open air defecation	408 (40.71)	176 (43.89)
Sanitary latrine	94 (9.38)	20 (4.98)
Others	1 (0.1)	0
Agricultural Practices		
Use of pesticides in field	320 (31.93)	90 (22.44)
Use of nallah water for irrigation	132 (13.17)	0
Use of vegetables grown in nallah water	79 (7.88)	4 (1)

*Figure in parenthesis indicates percentage

The most common source of drinking water is deep hand pump in both reference and control area. Half of the families perceive that they are drinking polluted water in study area and 70% of the families in control area (Table 6).

Industrial water pollution (7.8% in study area, 0.24% in control area), use of nallah water for irrigation (13.2% in study area and nil in control area) and practice of growing vegetables in nallah water (7.8% in study area and 1% in control area) was more in study area as compared to control area, which is all statistically significant ($p<0.001$).

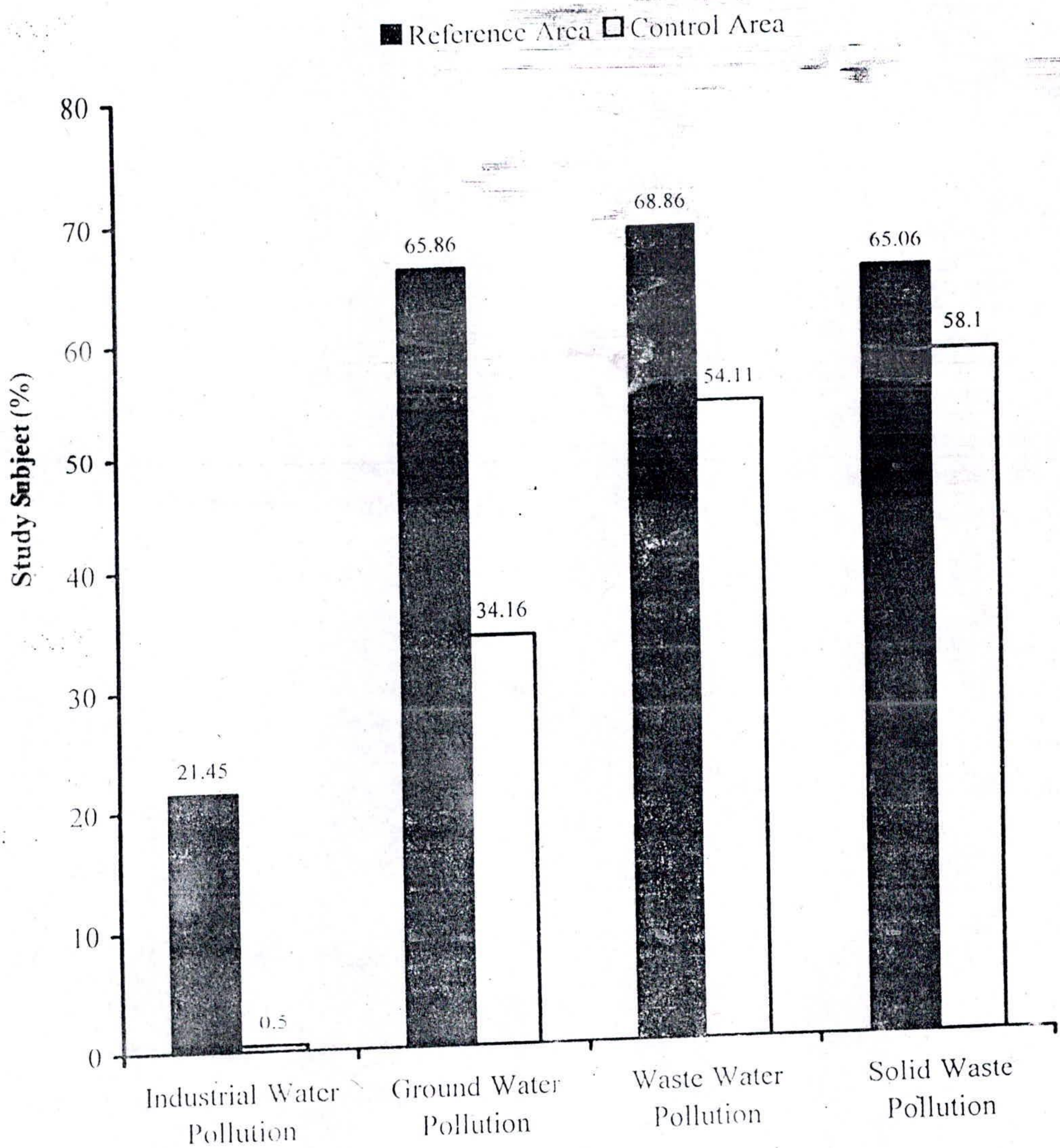
Table 7: Household perception of environment pollution in the locality

Characteristics	Number of Households (%)		OR (95% CI)
	Reference Area (N=1002)	Control Area (N=401)	
Industrial Water Pollution	215 (21.45)*	2 (0.5)*	54.5 (14.7-54.7)*
Ground Water Pollution	660 (65.86)	137 (34.2)	3.72 (2.89-4.78)
Waste Water Pollution	690 (68.86)	217 (54.1)	1.88 (1.47-2.4)
Solid Waste Pollution	652 (65.06)	233 (58.1)	1.34 (1.05-1.71)

*Figure in parenthesis indicates percentage

There is statistically significant association of household perception of environmental pollution with the location of residence in Nallah area. High association of industrial water pollution was observed in reference area (OR=54.5; 95% CI=14.7-54.7) (Table 7, Figure -2).

Figure 2: Area wise Household Perception of environmental pollution.



5.1.4 Area wise morbidity profile

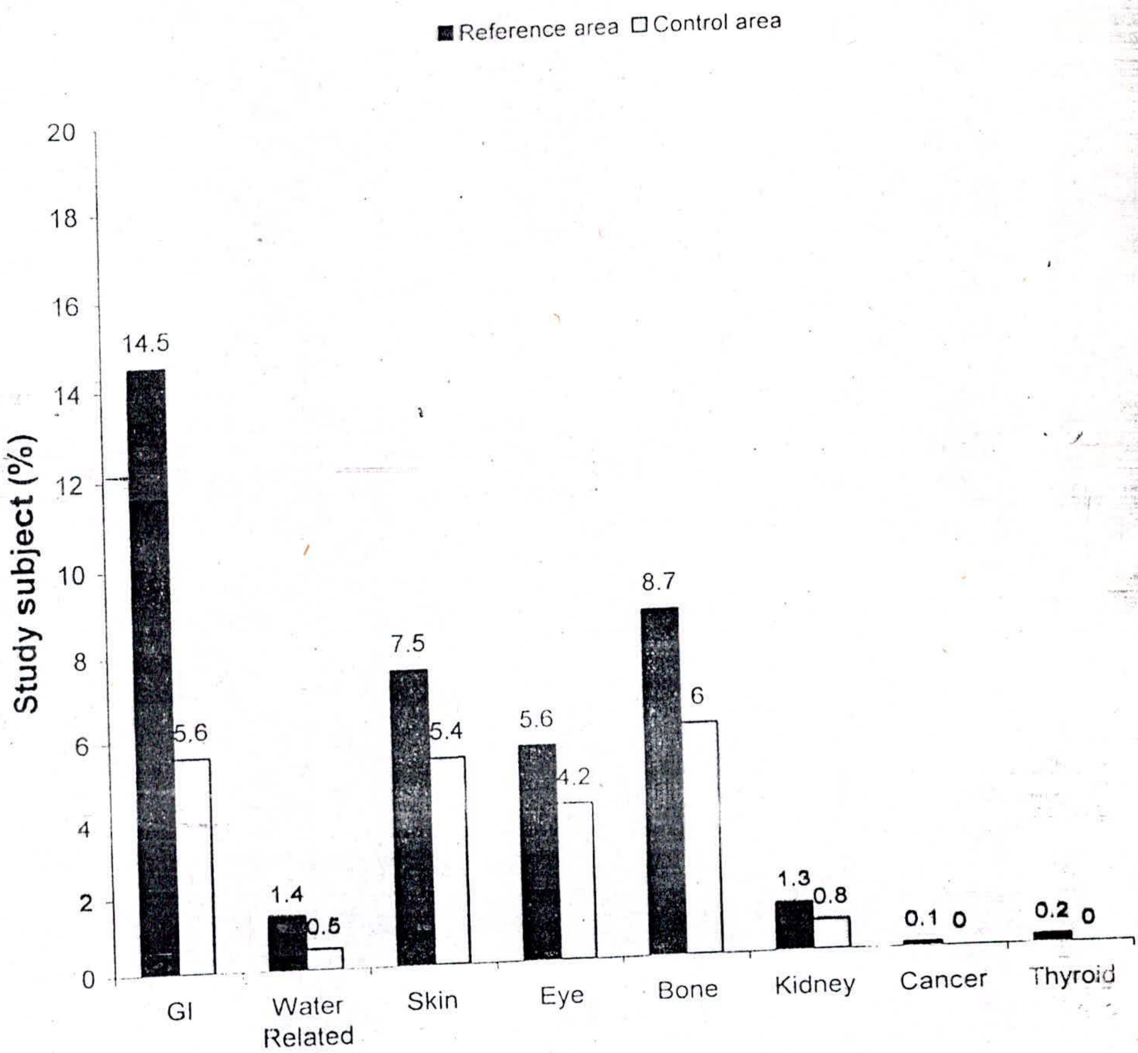
Table 8: Morbidity profile of adult study population

Characteristics	Reference Area (N=4317)	Control Area (N=1777)	p-Value	OR (95% C.I)
Gastrointestinal Problem	626 (14.5)	100 (5.63)	< 0.001	2.884(2.285 – 3.540)
Cramps	378 (8.75)	41 (2.3)	< 0.001	-
Nausea	293 (6.78)	28 (1.57)	< 0.001	-
Constipation	280 (6.48)	52 (2.92)	< 0.001	-
Loose stool	160 (3.7)	15 (0.84)	< 0.001	4.521 (2.655 – 7.698)
Watery Stools	159 (3.[illegible])	14 (0.78)	< 0.001	4.533 (2.614 – 7.861)
Stool with mucus	42 (0.97)	9 (0.5)	0.069	1.930 (0.937 – 3.973)
Stool with fever	88 (2.03)	7 (0.39)	< 0.001	5.262 (2.432 – 11.38)
Stool with blood	18 (0.41)	0	0.006	-
Jaundice	144 (3.33)	20 (1.12)	0.505	0.837 (0.495 – 1.413)
Loss of appetite	100 (2.31)	2T (1.18)	0.004	1.985 (1.236 – 3.188)
Any water related disease	59 (1.36)	8 (0.45)	0.002	3.064 (1.461 – 6.425)
Malaria	57 (1.32)	8 (0.45)	0.003	2.959 (1.409 – 6.214)
Dengue	3 (0.06)	0	0.266	-
Skin problem	326 (7.54)	96 (5.4)	0.003	1.430 (1.131 – 1.809)
Itching of skin	327 (7.57)	95 (5.34)	0.002	1.451 (1.147 – 1.836)
Lesion on skin	261 (6.04)	79 (4.44)	0.013	1.383 (1.069 – 1.790)
Eye problem	245 (5.67)	75 (4.22)	0.021	1.365 (1.048 – 1.779)
Irritation in eyes	211 (4.88)	65 (3.65)	0.036	1.353 (1.019 – 1.797)
With redness	160 (3.7)	51 (2.87)	0.105	1.303 (0.946 – 1.794)
Watery discharge	164 (3.8)	57 (3.2)	0.340	1.161 (0.854 – 1.589)
Bone problem	374 (8.66)	105 (5.91)	< 0.001	1.510 (1.207 – 1.889)
Pain in bones	370 (8.56)	104 (5.85)	< 0.001	1.508 (1.204 – 1.888)
Fractured	35 (0.81)	9 (0.5)	0.202	1.605 (0.770 – 3.347)
Kidney problem	55 (1.27)	15 (0.84)	0.152	1.516 (0.854 – 2.69)
General health problem	385 (8.91)	70 (3.94)	< 0.001	2.386 (1.838 – 3.097)
Mottling of teeth	349 (8.1)	61 (3.43)	< 0.001	2.472 (1.872 – 3.264)
Discoloration of teeth	262 (6.06)	79 (4.44)	0.012	1.388 (1.074 – 1.796)
Hair loss	153 (3.54)	43 (2.42)	0.024	0.753 (0.372 – 1.524)
Numbness	22 (0.5)	12 (0.67)	0.429	-
Mental retardation	5 (0.11)	0	0.521	-
Cancer	8 (0.18)	0	0.070	-
Thyroid				

*Figure in parenthesis indicates percentage

Statistically significant association of any GI problem, cramps, nausea, constipation, loose stool, watery stool, stool with fever, stool with blood, loss of appetite with reference (p<0.01) was observed in reference area as compared to control area (Table 8, figure-3).

Figure-3: Area wise adult morbidity profile



Overall gastrointestinal problems, water related diseases (malaria, dengue), skin problems eye problem (irritation in eyes, redness etc) and bone problems were significantly associate with residence in reference area of drain (p<0.05). Drain wise stratified analysis revealed tha residence in reference area of Buddha Nallah had a statistically significant association with occurrence of gastrointestinal diseases, skin, eye and bone problem each (p<0.05). On th other hand water related disease and skin problems were significantly associated with reference area of East Bein drain (0.004) and Tung Dhab drain (0.04) respectively whi gastrointestinal diseases were statistically significantly associated with reference are residence of all drains. Overall Kidney problems were higher in reference area (1.3%) th the control area (0.8%) which was however statistically insignificant (p=0.1) (Table 9).

Table 9: Area wise adult morbidity among study subjects in five drains

Morbidity	Number of person		OR	95% CI	p-Value
	Reference	Control			
Any G.I Problem	6[illegible]5 (14.5)	100(5.63)	2.884	2.3-3.54	<0.001
Hudiara Nallah	141 (16.8)	27 (7.06)	2.648	1.7-4.1	<0.001
Tung Dhab Drain	79 (9.66)	19 (5.42)	1.865	1.11-3.13	0.017
East Bein Drain	197 (22.1)	25 (6.8)	3.878	2.51-6.0	<0.001
Kala Singha Drain	117 (13)	18 (5.94)	2.377	1.42-4.0	0.001
Buddha Nallah	92 (10.6)	11 (2.94)	3.912	2.1-7.4	<0.001
Water Related Disease	59 (1.36)	8 (0.45)	3.064	1.5-6.43	0.002
Hudiara Nallah	15 (1.78)	5 (1.30)	1.369	0.5-3.8	0.544
Tung Dhab Drain	1 (0.12)	0	-	-	0.513
East Bein Drain	34 (3.81)	3 (0.81)	4.808	1.5-15.8	0.004
Kala Singha Drain	8 (0.88)	0	-	-	0.099
Buddha Nallah	1 (0.12)	0	-	-	0.511
Skin Problem	326 (7.54)	96 (5.4)	1.430	1.13-1.81	0.003
Hudiara Nallah	85 (10.1)	27 (7.06)	1.478	0.94-2.32	0.088
Tung Dhab Drain	6 (0.73)	17 (4.9)	1.778	1.03-3.1	0.037
East Bein Drain		27 (7.35)	0.924	0.60-1.5	0.743
Kala Singha Drain	48 (5.33)	16 (5.28)	1.015	0.57-1.8	0.959
Buddha Nallah	64 (7.37)	9 (2.4)	3.228	1.6-6.6	0.001
Eye Problem	245 (5.67)	75 (4.22)	1.365	1.05-21.7	0.021
Hudiara Nallah	43 (5.11)	20 ((5.23)	0.975	0.6-1.7	0.928
Tung Dhab Drain	50 (6.11)	12 (3.42)	1.836	0.96-3.5	0.060
East Bein Drain	64 (7.17)	20 (5.44)	1.341	0.8-2.25	0.265
Kala Singha Drain	48 (5.33)	16 (5.28)	1.015	0.6-1.2	0.959
Buddha Nallah	40 (4.6)	7 (1.87)	2.533	1.12-5.70	0.020
Bone Problem	374 (8.56)	105 (5.91)	1.510	1.21-1.9	<0.001
Hudiara Nallah	88 (10.46)	29 (7.59)	1.423	1.0-2.21	0.114
Tung Dhab Drain	63 (7.71)	20 (5.71)	1.379	0.82-2.32	0.224
East Bein Drain	96 (10.76)	20 (5.44)	2.092	1.3-3.44	0.003
Kala Singha Drain	63 (7)	23 (7.6)	0.921	0.56-1.51	0.744
Buddha Nallah	64 (7.37)	13 (3.47)	2.210	1.20-4.1	0.009
Kidney Problem	55 (1.27)	15 (0.84)	1.516	0.85-2.7	0.152
Hudiara Nallah	14 (1.66)	4 (1.04)	1.600	0.52-4.9	0.406
Tung Dhab Drain	7(0.86)	2 (0.57)	1.504	0.31-7.3	0.610
East Bein Drain	20 (2.24)	3 (0.81)	2.783	0.82-9.42	0.086
Kala Singha Drain	8 (0.88)	4 (1.32)	0.673	0.20-2.3	0.518
Buddha Nallah	6 (0.7)	2 (0.53)	1.295	0.3-0.44	0.752
Cancer	5 (0.11)	0	-	-	0.521
Hudiara Nallah	0	0	-	-	-
Tung Dhab Drain	0	0	-	-	-
East Bein Drain	1 (0.11)	0	-	-	0.521
Kala Singha Drain	0	0	-	-	-
Buddha Nallah	0	0	-	-	-
Thyroid Disease	8 (0.18)	0	-	-	0.070
Hudiara Nallah	1 (1.011)	0	-	-	0.500
Tung Dhab Drain	3 (0.37)	0	-	-	0.256
East Bein Drain	3 (0.33)	0	-	-	0.266
Kala Singha Drain	0	0	-	-	-
Buddha Nallah	1 (0.12)	0	-	-	0.511

*Figure in parenthesis indicates percentage

Table 10: Area wise general health problems among adults in five drains

Morbidity	Number of person		OR	95% CI	p-Value
	Reference	Control			
Mottling of Teeth	385 (8.91)	70 (3.94)	2.386	1.838-3.097	<0.001
Hudiara Nallah	100 (11.89)	26 (6.8)	1.848	1.179-2.897	0.007
Tung Dhab Drain	100 (12.23)	7 (2)	6.834	3.142-14.86	<0.001
East Bein Drain	107 (11.99)	14 (3.81)	3.437	1.942-0.083	<0.001
Kala Singha Drain	15 (1.67)	17 (5.61)	0.285	1.141-0.578	<0.001
Buddha Nallah	63 (7.25)	6 (1.6)	4.800	2.059-11.19	<0.001
Discoloration of Teeth	349 (8.1)	61 (3.43)	2.472	1.872-3.264	<0.001
Hudiara Nallah	86 (10.22)	9 (2.35)	4.721	2.350-9.485	<0.001
Tung Dhab Drain	97 (11.87)	5 (1.42)	9.296	3.749-23.05	<0.001
East Bein Drain	90 (10.08)	16 (4.35)	2.462	1.426-0.489	0.001
Kala Singha Drain	19 (2.11)	23 (7.6)	0.263	0.141-0.489	<0.001
Buddha Nallah	57 (6.56)	8 (21.3)	3.215	1.519-6.809	<0.001
Hair Loss	262 (6.06)	79 (4.44)	1.388	1.074-1.796	0.012
Hudiara Nallah	37 (4.39)	12 (3.14)	1.419	0.731-2.753	0.298
Tung Dhab Drain	47 (5.75)	24 (6.85)	0.829	0.499-1.379	0.470
East Bein Drain	78 (8.74)	16 (4.35)	2.102	1.210-3.652	0.007
Kala Singha Drain	61 (6.77)	15 (5.28)	1.396	0.781-2.494	0.258
Buddha Nallah	37 (4.5)	12 (3.2)	1.419	0.734-2.742	0.215
Numbness	153 (3.54)	43 (2.42)	-	-	0.024
Hudiara Nallah	28 (3.32)	8 (2.09)	1.610	0.727-3.566	0.236
Tung Dhab Drain	32 (3.91)	8 (2.3)	1.743	0.795-3.821	0.161
East Bein Drain	44 (4.93)	8 (2.17)	2.328	1.085-4.996	0.026
Kala Singha Drain	31(3.44)	11 (3.63)	0.947	0.470-1.908	0.879
Buddha Nallah	18 (2.1)	8 (2.13)	0.969	0.418-2.248	0.941
Mental Retardation	22 (0.5)	12 (0.67)	0.753	0.372-1.524	0.429
Hudiara Nallah	6 (0.71)	6 (1.57)	0.450	0.144-1.405	0.159
Tung Dhab Drain	4(0.49)	1 (0.26)	1.717	0.191-15.42	0.625
East Bein Drain	6 (0.67)	1 (0.27)	2.479	0.297-20.66	0.386
Kala Singha Drain	6 (0.66)	4 (1.32)	0.502	0.141-1.790	0.279
Buddha Nallah	0	0	-	-	-
Headache	264 (6.11)	71 (3.99)	1.559	1.193-2.039	0.001
Hudiara Nallah	58 (6.89)	8 (2.09)	3.463	1.637-7.327	0.001
Tung Dhab Drain	56 (6.85)	8 (2.3)	3.100	1.462-6.574	0.002
East Bein Drain	87 (9.75)	19 (5.17)	1.979	1.098-3.578	0.008
Kala Singha Drain	28 (3.14)	23 (7.6)	0.391	0.222-0.690	0.001
Buddha Nallah	35 (4)	13 (3.47)	1.167	0.610-2.232	0.641

*Figure in parenthesis indicates percentage

Overall area wise analysis of general health problems in five drains revealed that mottling and discoloration of teeth, hair loss, numbness and headache were statistically significantly associated with reference area ($p<0.05$) (Table 10, figure-4). Drain wise stratified analysis revealed that mottling and discoloration of teeth were both significantly associated with reference area of all five drains, with maximum association (OR=6.8 and 9.3 respectively for mottling and discoloration of teeth) recorded in Tung Dhab drain. Significant association of hair loss and numbness was found with reference area of East Bein drain ($p<0.05$). Headache was significantly associated with reference of all drains except Buddha Nallah ($p<0.005$).

Figure-4: Area wise general health problems among adults

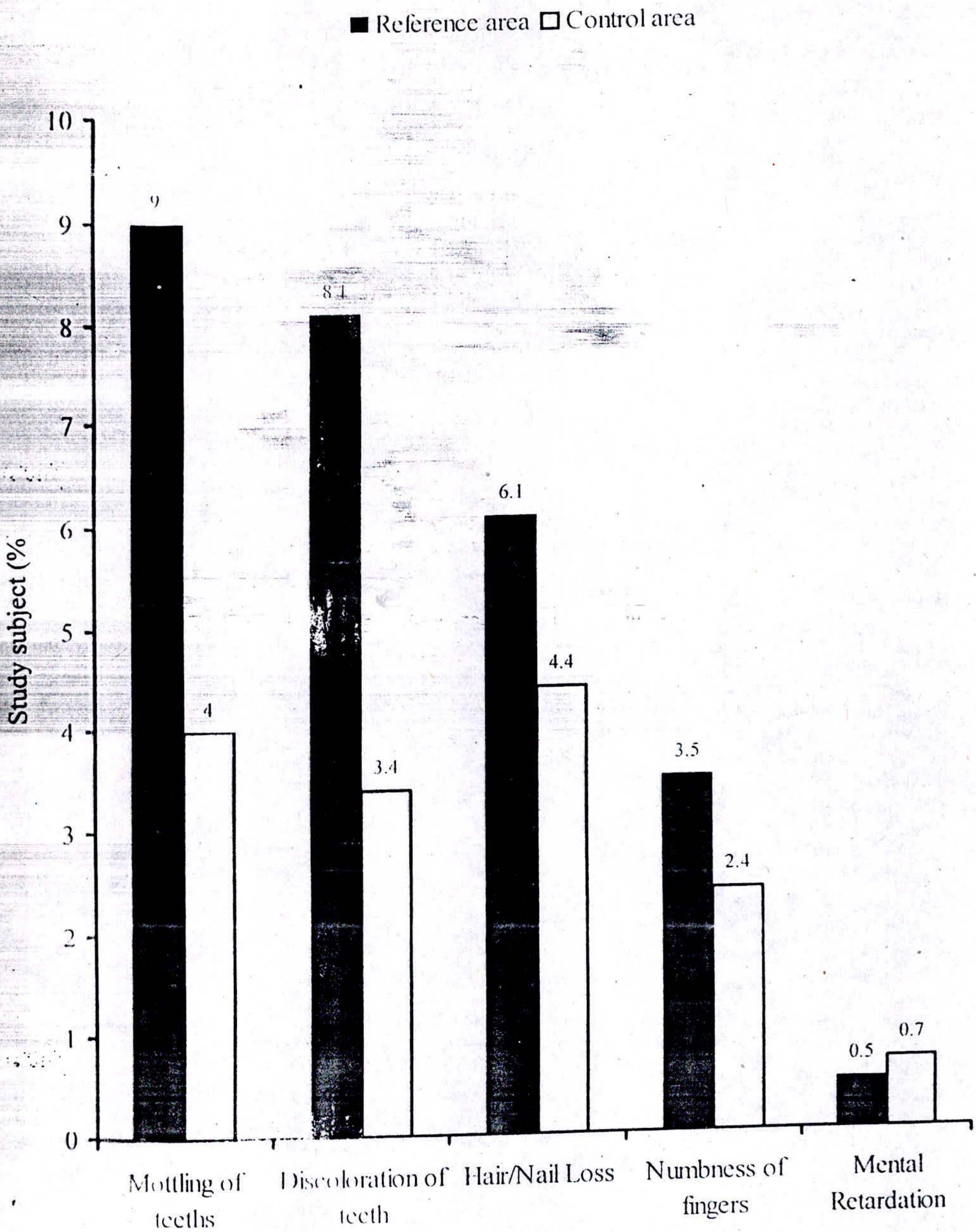


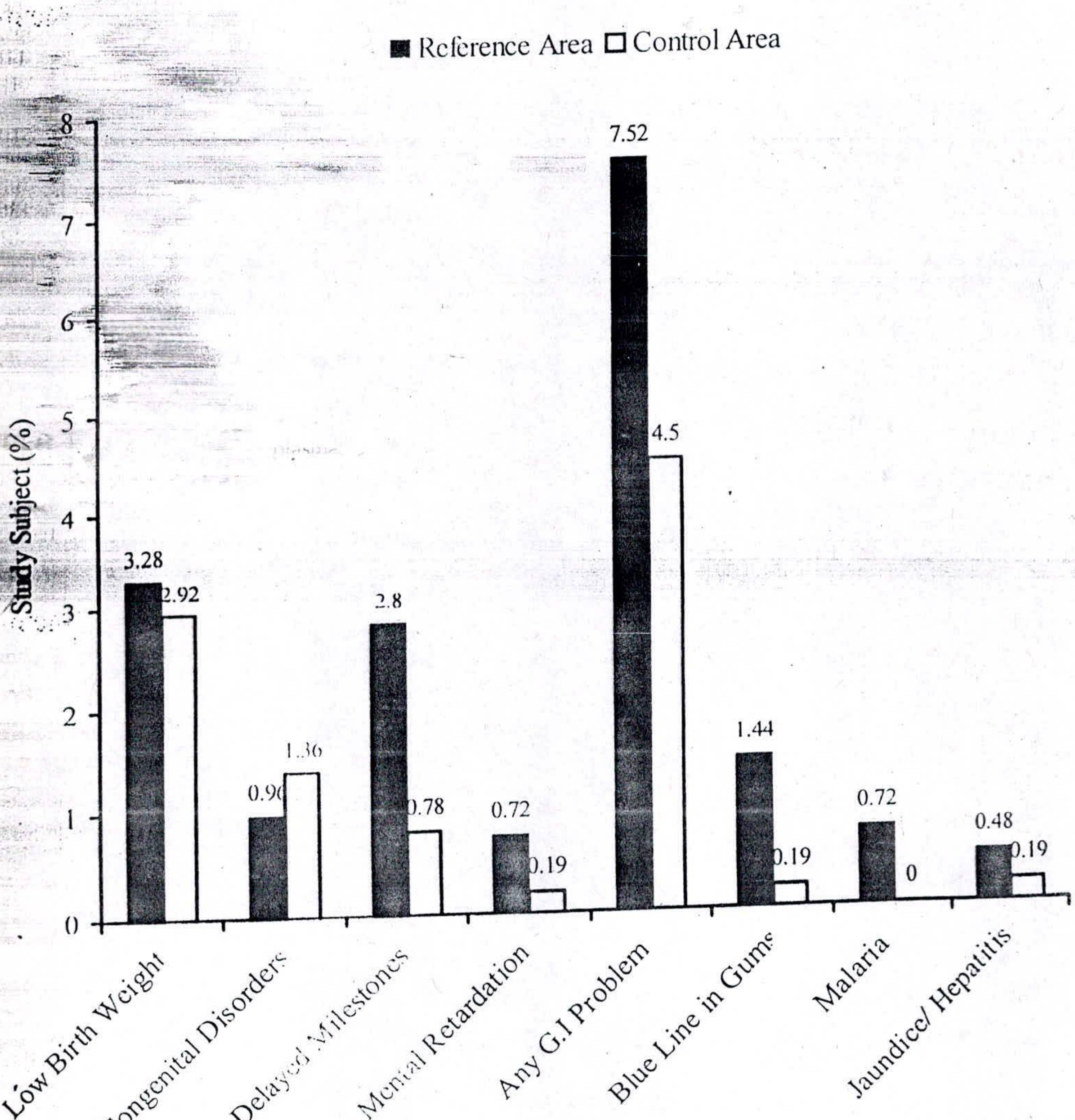
Table 11: Area wise childhood Morbidity among study subjects in five drains

Morbidity	Number of person		OR	95% CI	p-Value
	Reference	Control			
Low Birth Weight	41 (3.28)	15 (2.92)	1.1	0.6 -2.0	0.7
Hudiara Nallah	8 (2.81)	1 (0.8)	3.6	0.4 -29.0	0.3
Tung Dhab Drain	4 (1.5)	1 (0.96)	1.6	0.2 -14.2	0.1
East Bein Drain	11 (5.69)	7 (11.29)	0.5	0.2 -1.2	0.1
Kala Singha Drain	6 (2.64)	4 (3.22)	0.8	0.2 -2.9	0.7
Buddha Nallah	9 (4)	2 (2.1)	1.9	0.4 -9.2	0.5
Congenital Disorders	12 (0.96)	7 (1.36)	0.7	0.3 –1.8	0.5
Hudiara Nallah	1 (1.4)	2 (1.6)	0.9	0.2 –4.9	1.0
Tung Dhab Drain	2 (0.75)	1 (0.96)	0.8	0.07 –8.9	0.6
East Bein Drain	2 (0.81)	1 (1.61)	0.5	0.04 –5.6	0.5
Kala Singha Drain	3 (1.32)	3 (2.41)	0.5	0.1 2.7	0.7
Buddha Nallah	1 (0.44)	0	-	-	0.7
Delayed Milestones	35 (2.8)	4 (0.78)	3.6	1.3-10.3	0.007
Hudiara Nallah	5 (1.76)	0	-	-	0.3
Tung Dhab Drain	10 (3.75)	0	-	-	0.068
East Bein Drain	10 (4.06)	3 (4.83)	0.8	0.2-3.1	0.7
Kala Singha Drain	6 (2.64)	1 (0.8)	3.3	0.4-2.8	0.4
Buddha Nallah	4 (1.8)	0	-	-	0.3
Mental Retardation	9 (0.72)	1 (0.19)	3.7	0.5-29.3	0.183
Hudiara Nallah	1 (0.35)	0	-	-	0.507
Tung Dhab Drain	0	0	-	-	-
East Bein Drain	5 (2.03)	1 (1.61)	1.3	0.15-11.03	0.831
Kala Singha Drain	1 (0.44)	0	-	-	0.459
Buddha Nallah	2 (0.88)	0	-	-	0.354
Any G.I Problem	94 (7.52)	23 (4.5)	1.73	1.1-2.8	0.020
Hudiara Nallah	26 (9.15)	11 (8.8)	1.04	0.5-2.2	0.908
Tung Dhab Drain	11 (4.13)	3 (2.88)	1.45	0.4-5.31	0.571
East Bein Drain	11 (16.66)	6 (9.67)	1.87	0.75-4.62	0.171
Kala Singha Drain	8 (3.52)	1 (0.8)	4.49	0.55-36.35	0.124
Buddha Nallah	8 (3.5)	2 (2)	1.74	0.36-8.32	0.486
Blue Line in Gums	18 (1.44)	1 (0.19)	7.5	1.2-311.6	0.022
Hudiara Nallah	7 (2.46)	0	-	-	0.077
Tung Dhab Drain	0	0	-	-	-
East Bein Drain	9 (3.65)	0	-	-	0.126
Kala Singha Drain	0	1 (0.8)	-	-	0.175
Buddha Nallah	2 (0.88)	0	-	-	0.354
Malaria	9 (0.72)	0	-	-	0.054
Hudiara Nallah	2 (0.7)	0	-	-	0.347
Tung Dhab Drain	1 (0.37)	0	-	-	0.531
East Bein Drain	4 (1.62)	0	-	-	0.312
Kala Singha Drain	0	0	-	-	-
Buddha Nallah	2 (0.88)	0	-	-	0.354
Jaundice/ Hepatitis	6 (0.48)	1 (0.19)	2.5	0.3-20.52	0.388
Hudiara Nallah	2 (0.7)	1 (0.8)	0.9	0.08-9.8	0.917
Tung Dhab Drain	1 (0.37)	0	-	-	0.531
East Bein Drain	3 (1.21)	0	-	-	0.382
Kala Singha Drain	0	0	-	-	-
Buddha Nallah	0	0	-	-	-

*Figure in parenthesis indicates percentage

There were 1250 children from reference area, 512 children from control area. Overall, delayed milestones among children were observed to be significantly associated with reference area (OR 3.6; 95% CI 1.3-10.3). Children in reference area were having significantly higher prevalence of any gastrointestinal problem (p=0.02) and blue line in gums (p=0.02) Malaria, jaundice, low birth weight and mental retardation although found to be higher among children of reference area was statistically insignificant (Table 11, figure-5).

Figure-5: Area wise general health problems among children



5.1.4 Association of different morbidities with socio-demographic variables

Table 12: Prevalence of diseases among adults according to age.

Diseases	Age group (years)						
	10-20 (N 1640)	21-30 (N=1523)	31-40 (N=1110)	41-50 (N=752)	51-60 (N=517)	≥60 (N=552)	p-Value
Gastrointestinal	135(8.2)	168(11)	144(13)	117(16)	78(15)	84(15)	<0.001
Water-related	12(0.7)	20(1.3)	15(1.3)	10(1.3)	6(1.2)	4(0.7)	0.5
Malaria		-	-	-	-	-	-
Skin Problem	81(5)	75(5)	78(7)	80(11)	52(10.1)	56(10)	<0.001
Eye Problem	[illegible]	19(3.2)	52(4.7)	66(8.8)	50(9.7)	76(14)	<0.001
Bone	15(1)	45(3)	89(8)	109(14.5)	88(17)	133(24.1)	<0.001
Kidney	5(0.3)	11(0.7)	18(1.6)	15(2)	10(2)	11(2)	<0.001
Cancer		-	-	-	-	1(2)	0.1
Thyroid		-	2(0.2)	4(0.8)	2(0.4)		0.005
Mottling of teeth	81(5.12)	99(6.5)	87(7.8)	80(10.6)	54(10.4)	51(9.2)	<0.001
Discoloration of teeth	78(4.7)	92(6)	79(7.1)	70(9.3)	51(9.8)	40(7.3)	<0.001
Hair/Nail Loss	65(3.9)	91(5.9)	75(6.7)	59(7.8)	31(5.9)	20(3.6)	<0.001
Numbness in fingers	15(0.9)	47(3.1)	49(4.4)	44(5.8)	28(5.4)	13(2.4)	<0.001
Mental Retardation	5(0.3)	9(0.6)	7(0.6)	5(0.6)	4(0.7)	4(0.7)	0.7

*Figure in parenthesis indicates percentage

Higher prevalence for all the systemic and general health problems was observed among females with statistically significant association ($p<0.05$) being observed for eye, bone and kidney diseases besides general health problems viz. hair/nail loss and numbness finger among the females (Table 12-13).

Table 13: Prevalence of diseases among adults according to sex.

Diseases	Male (N=3122)	Female (N=2972)	OR (95% CI)
Gastrointestinal	338(11)*	338(11.4)*	0.8(0.7-1)
Water-related	31(1)	36(1.2)	0.8(0.5-1.3)
Malaria	30(1)	35(1.2)	0.8(0.5-1.3)
Skin Problem	205(6.6)	217(7.3)	0.9(0.7-1.1)
Eye Problem	133(4.3)	187(6.3)	0.6(0.5-0.8)
Bone	155(5)	324(11)	0.4(0.4-0.5)
Kidney	25(0.8)	45(1.5)	0.5(0.3-0.8)
Cancer	-	1(0.03)	-
Thyroid	-	8(0.3)	-
Mottling of teeth	203(6.5)	252(8.5)	0.7(0.6-1)
Discoloration of teeth	182(5.8)	228(7.6)	0.7(0.6-1)
Hair/Nail Loss	129(4.1)	212(7.1)	0.6(0.4-0.7)
Numbness in fingers	57(1.8)	139(4.7)	0.4(0.3-0.5)
Mental Retardation	15(0.5)	19(0.64)	0.7(0.4-1.5)

*Figure in parenthesis indicates percentage

A statistically significant difference ($p<0.001$) across decadal age groups among the study subjects for all the diseases except water related vector borne diseases, cancer and mental retardation. Higher prevalence for all diseases was observed at age more than 40 years for all diseases.

Table 14: Prevalence of diseases among adults according to education.

Disease	Education							p-Value
	Illiterate (N=1855)	Literate (N=180)	Primary (N=990)	Middle (N=1040)	Metric (N=1201)	Secondary (N=570)	Degree (N=248)	
Gastrointestinal	266(14.3)	25(14)	119(14)	105(10)	113(9.4)	59(10.3)	37(1.5)	<0.001
Water-related	18(0.9)	3(2.0)	9(0.9)	13(1.3)	15(1.2)	5(0.8)	4(1.6)	1.0
Skin Problem	177(9.5)	10(5.5)	66(6.6)	68(6.5)	57(4.7)	30(5.3)	14(5.6)	<0.001
Eye Problem	144(7.7)	13(7.2)	40(4.0)	36(3.5)	49(4.1)	20(3.5)	15(6)	<0.001
Bone	270(14)	17(9.4)	69(7)	41(4.0)	48(4.0)	16(2.8)	15(6)	<0.001
Kidney	27(1.4)	3(1.6)	16(1.6)	10(1.0)	10(0.8)	3(0.5)	1(0.4)	0.2
Cancer	1(0.05)		-	-	-	-	-	0.9
Thyroid	4(0.2)		-	1(0.1)	1(0.1)	-	2(0.8)	0.06
Mottling of teeth	182(1)	14(7.7)	84(8.4)	65(6.3)	71(6)	26(4.6)	12(5)	<0.001
Discoloration of teeth	154(8.3)	16(9.0)	79(8.0)	62(6)	66(5.5)	21(3.7)	12(5)	<0.001
Hair/Nail Loss	85(4.6)	11(6.1)	58(6)	49(5)	70(6)	37(6.5)	29(12)	0.001
Numbness in fingers	78(4.2)	10(5.5)	42(4.2)	24(2.3)	25(2.1)	9(1.6)	7(3)	<0.001
Mental Retardation	24(1.3)	1(1.6)	3(0.3)	2(0.2)	2(0.2)	1(0.2)	1(0.4)	<0.001

Figure in parenthesis indicates percentage

A statistically significant different ($p<0.001$) was observed for diseases like skin diseases, eye problem, mental retardation, kidney diseases, mottling of teeth, discoloration of teeth and numbness of fingers among stud subjects according to educational status with highest prevalence for the former four diseases found among illiterates while latter four among just literate respectively. Generally the lesser educated and illiterate had higher prevalence of diseases (Table 14).

Table 15: Prevalence of diseases among adults according to occupation.

Disease	Occupation									p-Value
	Prof. (N=77)	Semi-Prof (N=277)	Owner (N=57)	Farmer (N=587)	Farm Lab (N=201)	Skilled (N=89)	Semi-Skilled (N=276)	Unskilled (N=643)	Unemployed (N=3886)	
Gastrointestinal	12(16)	29(11)	11(19.3)	63(11)	34(17)	6(6.7)	44(16)	64(10)	463(12)	0.02
Water-related	-	3(1.1)	1(1.7)	9(1.5)	1(0.5)	-	1(0.4)	7(1.1)	45(1.1)	0.7
Skin Problem	5(6.5)	17(6)	6(10)	35(6)	15(8)	4(4.5)	14(5.1)	51(8)	275(7.1)	0.7
Eye Problem	7(9.1)	15(5.4)	5(8.7)	31(5.3)	8(4)	5(5.6)	7(2.5)	31(5)	211(5.4)	0.3
Bone	6(7.8)	15(5.4)	9(16)	51(9)	11(5.5)	4(4.5)	10(3.6)	34(5.3)	339(8.7)	0.001
Kidney	-	6(2.2)	1(1.7)	6(1.0)	-	-	4(1.4)	3(0.5)	50(1.3)	0.2
Cancer	-	-			-	-	-	1(0.3)	-	1.0
Thyroid	-	-			-	-	-	8(0.21)	-	0.8
Mottling of teeth	5(6.5)	16(6)	9(16)	14(8)	17(8.5)	4(4.5)	14(5.1)	44(7)	302(7.7)	0.2
Discoloration of teeth	7(9.1)	17(6)	6(10.5)	36(6)	11(5.5)	3(3.4)	16(5.8)	39(6.1)	275(7.1)	0.6
Hair/Nail Loss	10(13)	27(10)	6(10)	23(4)	6(3)	-	13(4.7)	23	233(3.6)	0.001
Numbness in fingers	1(1.3)	7(2.5)	5(8.7)	14(2.4)	2(1.0)	4(4.5)	4(1.4)	17(2.6)	142(3.6)	0.02
Mental Retardation	-	1(0.4)		4(0.7)	-	-	-	2(0.3)	27(0.7)	0.6

•Figure in parenthesis indicates percentage

Farm owners reported having significantly higher prevalence of gastrointestinal ($p=0.02$) and bone diseases ($p=0.001$) and numbness of fingers ($p<0.001$) (Table 15). Additionally, farm owners reported highest prevalence of water related vector borne diseases and skin diseases besides general health problem like mottling and discoloration of teeth.

Skilled workers reported having lowest prevalence for gastrointestinal, water related and skin disorders besides general health problems like mottling and discoloration of teeth.

Table 16: Prevalence of diseases among adults according to smoking and drinking habits

Disease	Smokers				Drinkers			
	Yes (N=207)	No (N=5887)	OR (95% CI)	p-Value	Yes (N=395)	No (N=5699)	OR (95% CI)	p-Value
Gastrointestinal	37(18)	689(12)	1.6(1.1-2.4)	0.007	68(17)	658(12)	1.6(1.2-2.1)	0.001
Water-related	4(2.0)	63(1.1)	1.8(0.6-5.1)	0.2	9(2.3)	58(1)	2.3(1.1-4.6)	0.02
Skin Problem	18(8.7)	401(6.8)	1.3(0.8-2.1)	0.3	36(9.1)	386(6.7)	1.4(1.0-2.6)	0.1
Eye Problem	20(9.6)	300(5.1)	2.0(1.2-3.2)	0.004	27(6.8)	293(5.1)	1.4(1.0-2.0)	0.14
Bone	26(12.6)	453(7.7)	1.7(1.1-2.6)	0.011	44(11)	435(7.6)	1.5(1.1-2.1)	0.01
Kidney	2(1.0)	68(1.2)	0.8(0.2-3.4)	0.8	8(2.0)	62(1.1)	2.1(1.0-4.0)	0.10
Cancer	-		-	0.8	-	-	-	0.8
Thyroid	-		-	0.6	-	-	-	0.5
Mottling of teeth	26(13)	429(8)	1.8(1.2-3.0)	0.004	39(9.8)	416(7.3)	1.4(1.0-2.0)	0.06
Discoloration of teeth	23(11.2)	387(6.6)	1.8(1.1-3.0)	0.010	38(9.6)	372(6.5)	1.5(1.1-2.1)	0.02
Hair/Nail Loss	7(3.4)	334(5.6)	0.6(0.3-1.3)	0.163	14(3.5)	327(5.7)	0.6(0.4-1.0)	0.07
Numbness in fingers	9 (4.4)	187(3.2)	1.4(0.7-2.7)	0.340	12(3.0)	184(3.2)	1.0(0.5-1.7)	1.0
Mental Retardation	2(1.0)	32(.51)	1.8(0.4-7.5)	0.4	2(0.5)	32(0.6)	1.0(0.2-4.0)	1.0

Figure in parenthesis indicates percentage

Smokers were observed to have statistically significant association with gastrointestinal, eye and bone diseases besides mottling and discoloration of teeth ($p<0.05$) (Table 16). Smokers had a greater association for all the diseases observed in the study except kidney disorders and hair/nail loss. Similarly, alcohol drinkers reported to have higher association for all diseases observed in the study except hair/nail loss. Significantly, higher association among alcohol drinkers was observed for gastrointestinal, water related and bone diseases apart from general health problem's viz. mottling and discoloration of teeth ($p<0.05$).

5.1.4 Area wise stratified analysis of adult morbidities according to socio-demographic variables

Area wise analysis of adulthood morbidities according to socio-demographic variables revealed that none of the variables individually viz. age, sex, occupation, education, smoking habits and perception of chemical exposure to self had any confounding effect on gastrointestinal and water-related health problems (Table 17).

Table 17: Area wise Gastrointestinal and Water Related diseases stratified across socio demographic variables

Variables	Gastrointestinal			Water Related Diseases		
	Number of Subjects		*Adjusted OR (95% CI)*	Number of Subjects		*Adjusted OR (95% CI)*
	Reference (N=4317)	Control (N=1777)		Reference (N=4317)	Control (N=1777)	
Age			2.9 (2.3-3.6)			2.9 (1.4-6.2)
10-20	116 (10)*	19 (4)*		11 (1)*	1 (0.2)*	
20-30	148 (14)	20 (4.6)		16 (1.4)	4 (1)	
30-40	130 (2)	14 (4)		15 (2)	0	
40-50	97 (18)	20 (10)		9 (1.6)	1 (0.5)	
50-60	67 (17)	11 (8.8)		4 (1.0)	2 (1.6)	
≥60	68 (19)	16 (8.1)		4 (1.1)	0	
Sex			2.8 (2.3-3.5)			3.0 (1.5-6.4)
Male	294 (13.3)	44 (4.8)		28 (1.3)	3 (0.3)	
Female	332 (15.7)	56 (6.5)		31 (1.5)	5 (0.6)	
Education			2.8 (2.2-3.5)			3.1 (1.5-6.4)
Illiterate	229 (16.4)	37 (8.1)		17 (1.2)	1(0.2)	
Literate	25 (20.5)	0		2 (1.6)	1 (1.7)	
Primary	100 (14)	19(6.7)		9 (1.3)	0	
Middle	89 (13)	16 (4.5)		12 (1.7)	1 (0.3)	
Metric	95 (12)	18 (4.6)		14 (1.7)	1 (0.3)	
Secondary	51 (13.2)	8(4.3)		3(0.7)	2 (1.1)	
Degree	36 (18.3)	1 (2)		2 (1)	2 (4)	
Occupation			2.8 (2.3-3.6)			3.1 (1.4-6.5)
Professional	9 (8.3)	3 (10.3)		0	0	
Semi-professional	25 (13)	1 (1.7)		3 (1.5)	0	
Farm owner	8 (16)	3 (1.3)		1 (2)	0	
Farmer	61 (13.3)	2 (1.5)		9 (2)	0	
Farm Labour	31 (24)	3 (4.5)		0	1 (1.4)	
Skilled worker	6 (8.4)	0		0	0	
Semi Skilled	36 (18)	8 (11)		1 (0.5)	0	
Unskilled	50 (11)	14 (7.4)		6 (1.3)	1 (0.5)	
Unemployed	400 (15)	63 (5.4)		39 (1.4)	6 (0.5)	
Chemical Exposure			2.8 (2.3-3.5)			3.0 (1.4-6.3)
Yes	86 (16)	5 (3)		12 (2.2)	1 (0.5)	
No	540 (14.3)	95 (6)		47 (1.2)	7(0.44)	
Smoking			2.8 (2.3-3.6)			3.1 (1.5-6.5)
Yes	31 (22)	6 (9.4)		3 (2.1)	1 (1.5)	
No	595 (14)	94 (5.5)		56 (1.34)	7 (0.4)	

***Figure in parenthesis indicates percentage**

Any gastrointestinal disorder was observed to be significantly higher ($p<0.05$) among study subjects of reference area across all decadal age groups and sexes. The association of gastrointestinal disease was higher among those who perceived exposure to chemical pollution (OR=2.8) as against those who did not perceive.

Table 18: Area wise Eye and Skin diseases stratified across socio-demographic variables

Variables	Eye Problem: Number of Subjects: Reference (N=4317)	Eye Problem: Number of Subjects: Control (N=1777)	Eye Problem: Adjusted OR (95% CI)	Skin Problem: Number of Subjects: Reference (N=4317)	Skin Problem: Number of Subjects: Control (N=1777)	Skin Problem: Adjusted OR (95% CI)
Age			1.4 (1.1-1.8)			1.4 (1.1-1.8)
10-20	20 (1.7)*	7 (1.5)*		61 (5.2)*	20 (4.2)*	
20-30	44 (4)	5 (1.1)		62 (5.7)	13 (3)	
30-40	37 (4.8)	15(4.6)		58 (7.5)	20 (6)	
40-50	49 (9)	17 (8.2)		57 (10.5)	23 (11)	
50-60	13 (11)	7 (5.6)		49 (12.5)	3 (2.4)	
≥60	[illegible]	[illegible]		39 (11)	17 (8.6)	
Sex			1.4 (1.1-1.7)			1.4 (1.1-1.8)
Male	98 (4.4)	35 (4)		155 (7)	50 (5.4)	
Female	147 (7)	40 (4.6)		171 (8.1)	46 (5.3)	
Education			1.3 (0.9-1.6)			1.4 (1.1-1.7)
Illiterate	104 (7.4)	40 (8.7)		140 (10)	37 (8.1)	
Literate	11 (9)	2 (3.4)		8 (6.5)	2 (3.4)	
Primary	33 (4.6)	7 (2.5)		54 (7.6)	12 (4.2)	
Middle	26 (3.8)	10 (3)		48 (7)	20 (5.6)	
Metric	35 (4.3)	11 (3.6)		40 (5)	17 (4.4)	
Secondary	20 (5.2)	0		23 (6)	7 (4)	
Degree	13 (6.6)	2 (4)		13 (6.6)	1 (2)	
Occupation			1.4 (1.0-2.0)			1.4 (1.1-1.8)
Professional	6 (12.5)	1 (3.4)		3 (6.3)	2 (7)	
Semi-professional	13 (6.7)	2 (2.3)		15 (8)	2 (2.3)	
Farm owner	3(6)	2 (28)		6 (12)	0	
Farmer	25 (5.1)	6 (4.7)		31 (7)	4 (3.1)	
Farm Labour	4 (3)	4 (5.7)		11 (8.4)	4 (6)	
Skilled worker	4 (5.6)	1 (5.5)		3 (4.2)	1 (5.5)	
Semi Skilled	7 (3.5)	0		11 (6)	3 (4)	
Unskilled	19 (4.2)	12 (6.3)		38 (8.4)	13 (7)	
Unemployed	164 (6)	47 (4)		208 (7.6)	67 (5.7)	
Chemical Exposure			1.3 (1.0-1.7)			1.4 (1.1-1.8)
Yes	28 (5.2)	12 (6.5)		45 (8.3)	4 (2.2)	
No	201 (5.5)	63 (4)		272 (7.4)	92 (5.7)	
Smoking			1.4 (1.1-1.8)			1.4 (1.1-1.8)
Yes	15 (10.5)	5 (8)		14 (10)	4 (6.3)	
No	230 (5.5)	70 (4.1)		312 (7.5)	92 (5.4)	

*Figure in parenthesis indicates percentage

Association of eye problems among reference area study subjects (as compared to control area) was observed to be highest for 20-30 years, female sex, just literate by education and professionals. No significant association with respect to area was observed for eye diseases among those who perceived exposure to pollution and cigarette smokers (Table 18).

Significantly higher association (p < 0.05) for skin problems among residents of reference area as compared to control area was observed for 50-60 year olds, females, non-smokers and those not perceiving exposure to chemical pollution.

Table 19: Area wise Bone and Kidney diseases stratified across socio-demographic variables

Variables	Bone Problem			Kidney Problem		
	Number of Subjects		Adjusted OR (95% CI)	Number of Subjects		Adjusted OR (95% CI)
	Reference (N=4317)	Control (N=1777)		Reference (N=4317)	Control (N=1777)	
Age			1.6 (1.3-2.0)			1.5 (0.9-2.7)
10-20	11 (1)*	[illegible] (0.[illegible])*		4 (0.3)*	1 (0.2)*	
20-30	34 (3.1)	11 (2.5)		9 (0.8)	2 (0.5)	
30-40	67 (8.6)	22 (6.5)		14 (2)	4 (1.2)	
40-50	87 (16)	[illegible] (10)		12 (2.2)	3 (1.4)	
50-60	[illegible] (19.1)	[illegible] (10.5)		8 (2)	2 (1.6)	
≥60	100 ([illegible])	[illegible] (1[illegible])		8 (2.3)	3 (1.5)	
Sex			1.5 (1.2-1.9)			1.5 (0.8-2.7)
Male	121 (5.5)	31 (3.7)		20 (1)	5 (0.54)	
Female	253 (1[illegible])	[illegible] (8.[illegible])		35 (1.6)	10 (1.2)	
Education			1.4 (1.1-1.7)			1.5 (0.8-2.6)
Illiterate	217 (15.5)	[illegible] (11.5)		21 (1.5)	6 (1.3)	
Literate	14 (11.5)	3 (5.2)		3 (2.4)	0	
Primary	57 (8)	[illegible] (4.2)		13 (1.8)	3 (1)	
Middle	28 (4.1)	13 (3.6)		7 (1)	3 (1.1)	
Metric	33 (4)	15 (4)		7 (1)	3 (1)	
Secondary	10 (2.5)	6 (3.3)		3 (1)	0	
Degree	13 (6.6)	2 (4)		1 (0.51)	0	
Occupation			1.5 (1.2-1.9)			1.5 (0.8-2.7)
Professional	6 (12.5)	0		0	0	
Semi-professional	12 (6.3)	3 (3.5)		5 (2.6)	1 (1.2)	
Farm owner	7 (11)	[illegible] (28.5)		0	1 (14.3)	
Farmer	40 (8.7)	11 (8.6)		6 (1.3)	0	
Farm Labour	8 (6.1)	3 (4.3)		0	0	
Skilled worker	4 (5.6)	0		0	0	
Semi Skilled	7 (3.5)	3 (4)		3 (1.5)	1 (1.3)	
Unskilled	24 (5.3)	10 (5.3)		2 (0.4)	1 (0.52)	
Unemployed	266 (10)	[illegible] (6.2)		39 (1.4)	11 (1)	
Chemical Exposure			1.5 (1.2-1.9)			1.5 (0.8-2.7)
Yes	53 (10)	12 (6.5)		11 (2)	1 (0.55)	
No	306 (8.4)	93 (5.8)		43 (1.2)	14 (1)	
Smoking			1.5 (1.2-1.9)			1.5 (0.8-2.7)
Yes	21 (15)	5 (8)		2 (1.4)	0	
No	353 (8.1)	100 (6)		53 (1.3)	15 (1)	

*Figure in parenthesis indicates percentage

Significantly higher association for bone problems (reference area versus control area) was observed for older age groups (> 50 years), both sexes illiterate and primary grade educated, professionals and semi skilled workers, non smokers and those not perceiving any exposure to chemical pollution. Kidney problems were higher across all age and sex specific stratum although insignificant ($p>0.05$) (Table 19).

Table 20: Area wise Mottling and Discoloration of teeth stratified across socio-demographic variables

Variables	Mottling of Teeth			Discoloration of Teeth		
	Number of Subjects		Adjusted OR (95% CI)	Number of Subjects		Adjusted OR (95% CI)
	Reference (N=4317)	Control (N=1777)		Reference (N=4317)	Control (N=1777)	
Age			2.4 (1.8-3.1)			2.5 (1.9-3.3)
10-20	70 (6)*	14 (3)*		70 (6)*	8 (1.7)*	
20-30	87 (8)	12 (3)		77 (7.1)	15 (3.4)	
30-40	70 (9)	17 (5)		66 (8.5)	13 (3.8)	
40-50	72 (14)	8 (4)		63 (11.6)	7 (3.4)	
50-60	47 (12)	7 (5.6)		44 (11.2)	7 (5.6)	
≥60	39 (11)	12 (6.1)		29 (8.2)	11 (5.6)	
Sex			2.4 (1.3-3.1)			2.5 (1.9-3.3)
Male	176 (8)	27 (3)		160 (7.3)	22 (2.4)	
Female	209 (10)	43 (5)		189 (9)	39 (4.5)	
Education			2.4 (1.8-3.1)			2.4 (1.8-3.2)
Illiterate	156 (11)	26 (5.6)		130 (9.3)	24 (5.2)	
Literate	14 (11.4)	0		12 (9.7)	4 (7)	
Primary	71 (10)	13 (5)		66 (9.3)	13 (4.6)	
Middle	53 (7.7)	12 (3.4)		52 (7.6)	10 (3)	
Metric	60 (7.3)	11 (3)		58 (7.1)	8 (2)	
Secondary	20 (5.2)	6 (3.3)		19 (5)	2 (1.1)	
Degree	11 (5.6)	1 (2)		12 (6.1)	0	
Occupation			2.4 (1.8-3.1)			2.5 (1.9-3.3)
Professional	5 (10.4)	-		7 (14.6)	0	
Semi-professional	14 (7.3)	2 (2.4)		15 (8)	2 (2.4)	
Farm owner	9 (18)	0		6 (12)	0	
Farmer	44 (10)	0		34 (7.4)	2 (1.6)	
Farm Labour	17 (13)	0		11 (8.3)	0	
Skilled worker	4 (6)	0		3 (4.2)	0	
Semi Skilled	12 (6)	2 (3)		15 (7.5)	1 (1.3)	
Unskilled	32 (1.1)	12 (6.3)		27 (6)	12 (6.3)	
Unemployed	218 (9.1)	54 (4.5)		231 (8.5)	44 (3.7)	
Chemical Exposure			2.3 (1.7-2.9)			2.4 (1.8-3.1)
Yes	60 (11.2)	2 (1.1)		48 (9)	4 (2.2)	
No	298 (8.2)	68 (4.3)		275 (7.6)	57 (3.5)	
Smoking			2.4 (1.8-3.1)			2.5 (1.9-3.3)
Yes	21 (15)	5 (8)		18 (12.6)	5(8)	
No	364 (8.7)	65 (4)		331 (8)	56 (3.3)	

*Figure in parenthesis are percentage

5.2 Laboratory Results

5.2.1 Physical and Chemical Parameters

5.2.1.1 Area wise analysis

5.2.1.1.1 Effluent water

Table 21: Area-wise Physical-Chemical parameters in Effluent Water

Parameter**	Buddha Nallah		Hudiara Nallah		East Bein Drain		Kala S Drain		Tung Dhab Drain		Overall Mean		MPL***
	Ref (N=10)	Ctrl (N=5)	Ref (N=10)	Ctrl (N=5)	Ref (N=10)	Ctrl (N=5)	Ref (N=10)	Ctrl (N=5)	Ref (N=10)	Ctrl (N=5)	Ref (N=50)	Ctrl (N=25)	
Ph	6.75	6.6	6.6	6.9	6.2	6.4	6.2	6.7	6.5	6.5	6.44	6.62	9.0
Alkalinity	425	311	153	106.8	196.1	189.4	609.3*	538	476.1	273.6	492	404	600
Hardness	251	228	310	314.8	371.2	352.4	423.3	324	394.1	255	350	295	600
Calcium	157	138	163	183.3	216.2	215.6	216.6	203	221.1	159.8	194.7	180	200
Magnesium	93.9	90	147	131.5	155	156.8	206.7	120	171.4	96.2	154.8*	119*	100
Ammonia	1.64	0.5	2.3	2.6	2.23	0.54	2.05	0.5	2.25	0.5	2.08	0.92	5.0
Phosphate	0.57	0.14	0.5	0.62	0.26	0.68	0.7	0.72	0.5	0.16	0.61	0.46	5.0
Total Iron	0.64	0	0.2	0.04	[illegible]	0	0.3	0	0.4	0	0.35	0.01	1
Chlorides	242	30.9	80	181.6	95.3	124.6	182.1	95.5	106.2	69.59	141.1	100	1000
Residual Cl	0.1	0	0	0	0.02	0	0.03	0	0.03	0	0.018	0	1.0
Flourides	2.5*	1.5	2.3*	3*	2.5*	3*	2.5*	3*	2*	3*	2.35*	2.7*	2.0

* Concentration more than MPL **All values (except pH) are in mg/L *** MPL Standards-BIS

The area wise physical-chemical parameters in effluent water are given in Table-21, figure-6. The study revealed that overall pH in effluent water of reference (6.44) and control (6.62) area was observed to be acidic and the difference was found to be statistically significant (p=0.02). Overall alkalinity and hardness was found to be below maximum permissible limit in both reference and control area. However, statistically significant difference for both alkalinity (p=0.006) and hardness (p=0.02) was observed between reference and control area. Mean concentration of calcium and magnesium in reference area was higher than control area, the results were however found to be statistically significant for magnesium (p=0.02) and insignificant for calcium (p=0.3). Mean concentration of ammonia, phosphate, iron, chlorides and residual chlorides in reference and control area were observed to be below maximum permissible limit. Also overall concentration of all these parameter were found to be more in reference area as compared to control area. However, results were found to be statistically significant for all ($p<0.05$), except phosphate ($p=0.08$) between reference and control area (Table-21, figure-6).

Figure 6: Area wise Physical-Chemical Parameters in Effluent water

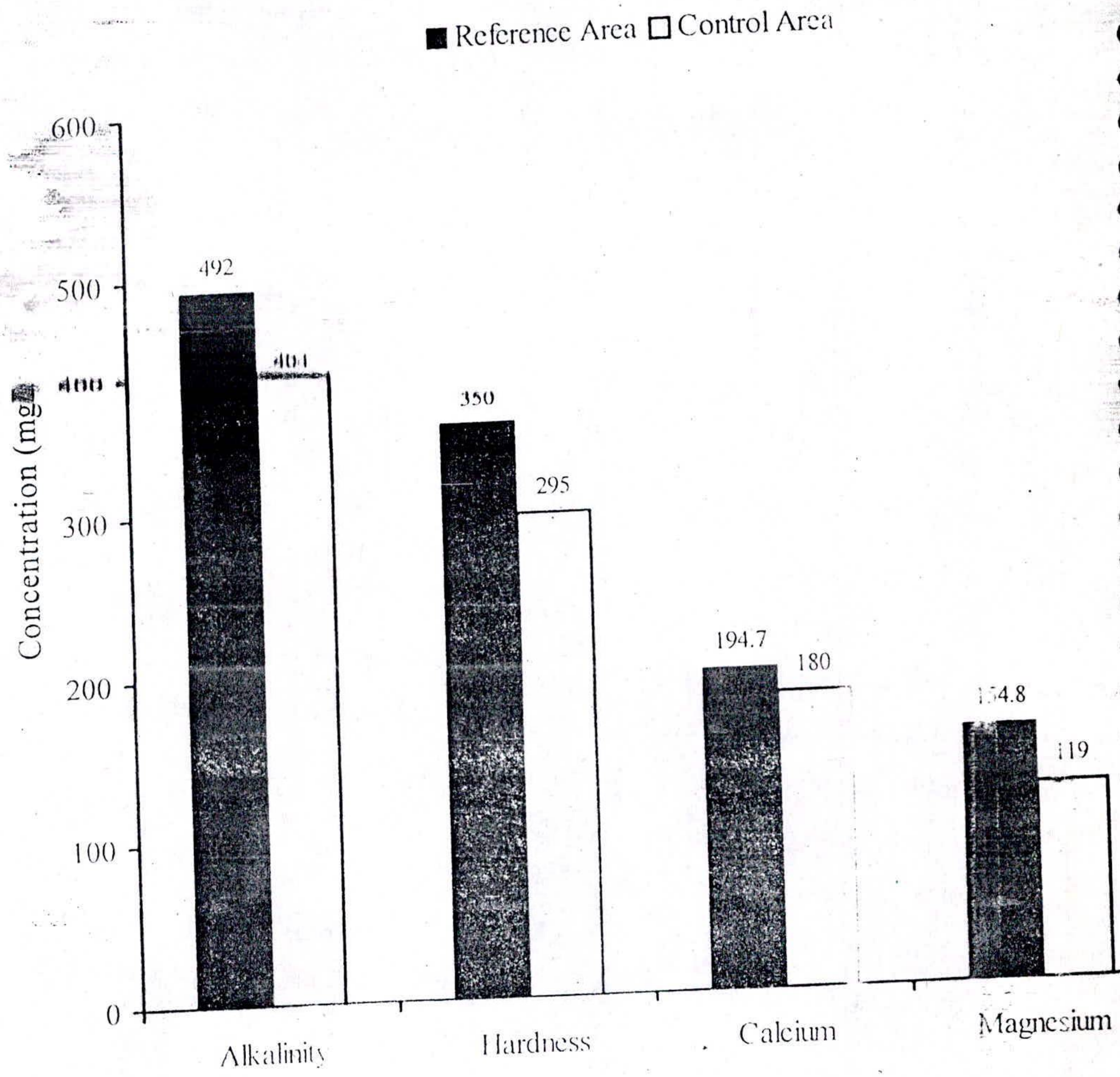


Table 22: Area-wise Physical-Chemical parameters in Ground Water

Parameter**	Buddha Nallah		Hudiara Nallah		East Bein Drain		Kala Singha		Tung Dhab Drain		Overall Mean		MPL***
	Ref (N=10)	Ctrl (N=5)	Ref (N=10)	Ctrl (N=5)	(N=10)	Ctrl (N=5)	Ref (N=10)	Ctrl (N=5)	Ref (N=10)	Ctrl (N=5)	Ref (N=10)	Ctrl (N=5)	Ref (N=10)
pH	7	7	7	7	7.15	7	7	6.1	7	7	7.03	6.96	7
Alkalinity	298.2	178.6	374.1	271.2	513	322	473	323	470	256.2	426	270	600
Hardness	327.9	249.2	387.8	429	376	346	374	339	336	276	360	328	600
Calcium	154.7	134.8	212.5*	237*	212*	194	237*	165	186	155.3	201*	177	200
Magnesium	163.2*	114.4*	176*	193*	164*	153*	135*	174*	150*	119*	157*	150*	100
Ammonia	0.45	0.5	0.5	0.3	0.35	0.5	0.29	0.3	0.3	0.6	0.41	0.44	1.8
Phosphate	0.18	0.1	0.07	0.06	0.98	0.04	0.04	0.06	0.07	0.08	0.08	0.07	5.0
Total Iron	0.1	0	0	0	0.15	0	0.02	0.04	0.04	0.02	0.06	0.08	1
Chlorides	36.62	12.57	73.5	81.4	70	80	76.8	79.2	71.5	31.3	65.6	56.8	1000
Residual Cl	0	0	0	0	0	0	0	0	0	0	0	0	0.2
Fluorides	2.45*	2*	1.75*	1.5*	1.5*	1.5*	2.5*	2*	2.25*	3*	2.3*	2*	1.5

* Concentration more than MPL ** All values (except pH) are in mg/L *** MPL Standards-IS: 10500-1991

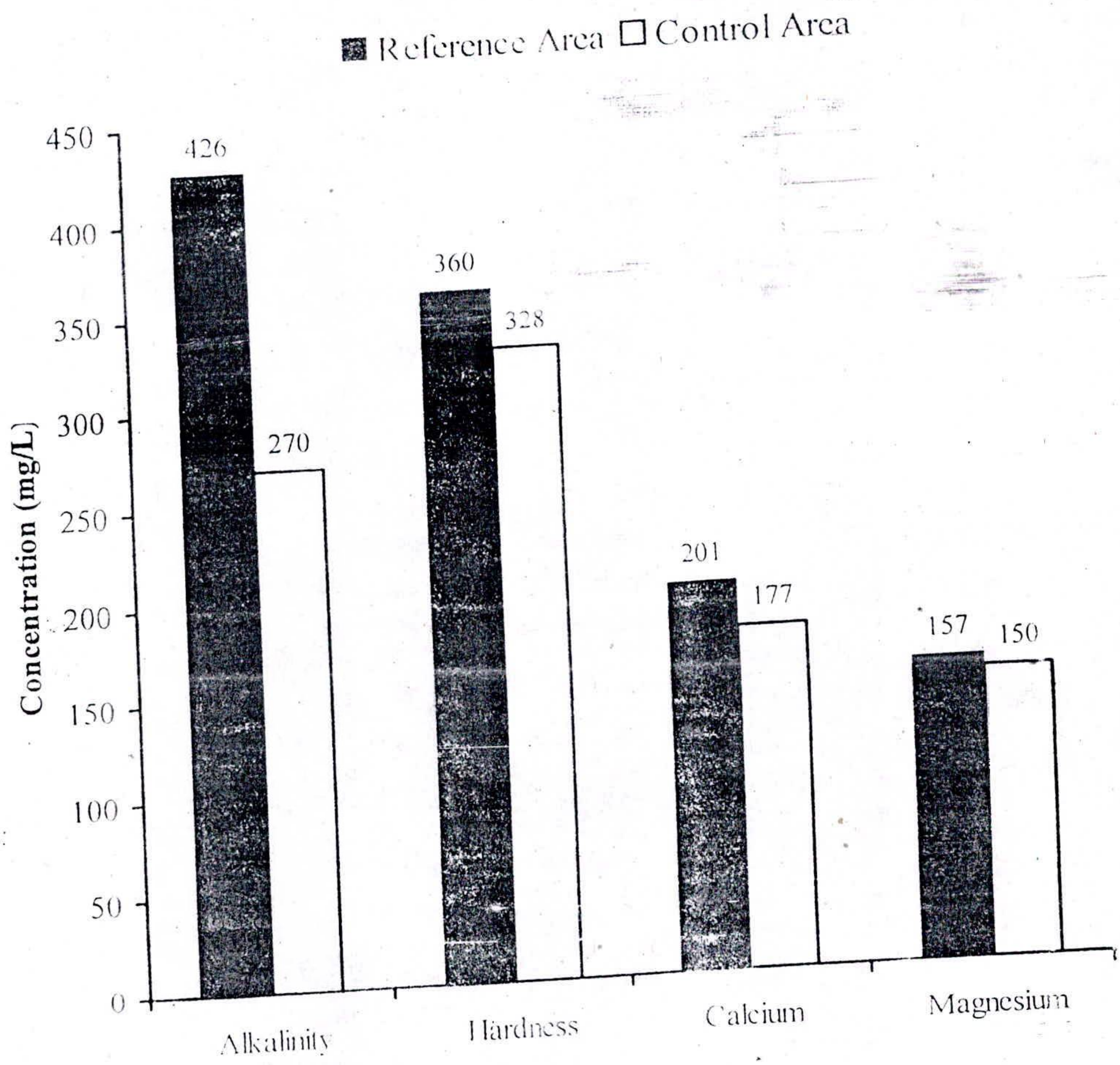
5.2.1.1.2 Ground water

Overall prevalence of samples with more than permissible limit for pH was found to be higher in reference area (81.11%) as compared to control area (77.8%). However, results were found to be statistically insignificant (OR=1.227; 95% CI=0.5-3.2) (Table-22, figure-7). Overall Alkalinity and Hardness were found to be more in reference area as compared to control area. The area wise mean concentration was statistically significant for Alkalinity ($p<0.001$), while insignificant for hardness ($p=0.3$).

Mean concentration of Calcium, Magnesium and Fluoride in reference area was found to be higher than control area. However, the results were found to be statistically insignificant ($p>0.05$). These parameters were consistently higher than permissible limit in both reference and control areas. Overall prevalence of samples with more than permissible limit for calcium was found to be more in case area (40%) as compared to control area (33.3%)which was however statistically insignificant (OR=1.3; 95% CI=0.06-3.0).

Samples with more than permissible limit of Magnesium associated more in control area (66.66%) as compared to reference area (62.22%) however the difference was statistically insignificant (OR 0.8; 95% CI 0.4-1.8). Overall Concentration of Phosphate and Chlorides were found to be higher in reference area as compared to control area. However the difference were found to be statistically insignificant for both ($p>0.05$). Samples with more than MPL was associated more in control area (83.3%) as compared to reference area (77.8%) for fluoride and no statistical difference was observed (OR=0.7; 95% CI=0.3-2.0).

Figure 7: Area wise Physical-Chemical Parameters in Ground water



5.2.1.2 Seasonal variation

5.2.1.2.1 Effluent water

Seasonal trend of effluent water for physical and chemical parameters was observed as winter followed by summer and monsoon. Overall pH in Effluent water was found to be almost similar (i.e. acidic) in all the three seasons, Alkalinity was found to be higher in summer (466.10 mg/L) followed by winter (465.1 mg/L) and monsoon (451 mg/L) which was however statistically insignificant ($p=1.0$). Overall concentration of Hardness, Magnesium, Phosphate, Chlorides and Residual Chlorides was found to be higher in winter followed by summer and monsoon. However, results were found to be statistically insignificant for these parameters ($p>0.05$) except Phosphate, which was statistically significant ($p=0.012$).

Overall concentration of Calcium, Ammonia and Iron was found to be statistically insignificant for calcium ($p=0.34$), iron ($p=0.8$) and difference was observed to be statistically significant for Ammonia ($p=0.0002$). No seasonal trend was observed for Fluoride and difference was found to be statistically insignificant ($p=1.0$).

Table 23: Seasonal Pattern of Physical-Chemical parameters in Effluent Water

Parameters**	Summer (N=30)	Monsoon (N=15)	Winter (N=30)	Mean (N=75)	MPL*
P_H	6.5	6.47	6.52	6.5	9.0
Total Alkalinity	466.11	450.8	465.07	460.66	600
Total Hardness	317.93	309.13	355.4	327.49	600
Calcium	177.24	197.47	198.5	191.07	200
Magnesium	144.02	112.4	156.9	137.8	100
Ammonia	1.17	1.68	2.23	1.7	5.0
Phosphate	0.5	0.40	0.71	0.54	5.0
Total Iron	0.21	0.25	0.256	0.24	1
Chlorides	120.22	116.34	140.47	127.55	1000
Residual Cl	0.013	0	0.016	0.012	1.0
Fluorides	2.47	2.47	2.47	2.47	2.0

** All values (except pH) are in mg/L * MPL Standards-BIS

5.2.1.2.2 Ground water

Seasonal trend of ground water for physical and chemical parameters was observed to be monsoon followed by summers and winter. The study revealed that ground water shows no seasonal variation for overall pH. Overall alkalinity and chloride concentration was observed to be maximum during monsoon followed by winters and summer. However, results were found to be statistically insignificant for alkalinity (p=0.4) and chloride (p=0.7). Overall hardness, calcium, magnesium, phosphate and iron concentration was found to be higher in winters followed by summer and monsoon. However, no statistical difference was observed for these parameters (p>0.05). Overall ammonia concentration was found to be maximum in case of monsoon (0.53 mg/L) followed by summer (0.4 mg/L) and winter (0.4 mg/L) and difference was found to be statistically significant (p=0.04). No seasonal variation was observed for residual chlorides, moreover its concentration was found to be negligible in each drain. Overall fluoride concentration shows no seasonal variation and results were found to be statistically insignificant (p=. 993)

Table 24: Seasonal Pattern of Physical-Chemical parameters in Ground Water

Parameters**	Summer (N=30)	Monsoon (N=15)	Winter (N=30)	Mean (n=75)	MPL*
P_H	7.00	7.07	6.98	7.02	7
Total Alkalinity	355.86	409.43	374.37	379.89	600
Total Hardness	342.53	328.67	366.83	346.01	600
Calcium	193.23	189.47	193.70	192.13	200
Magnesium	149.30	139.20	168.67	152.39	100
Ammonia	0.41	0.53	0.38	0.44	1.8
Phosphate	0.08	0.05	0.08	0.07	5.0
Total Iron	0.03	0.00	0.07	0.04	1
Chlorides	58.87	65.97	64.91	63.25	1000
Residual Cl	0.00	0.00	0.00	0.00	0.2
Fluorides	2.19	2.19	2.18	2.18	1.5

**All values (except pH) are in mg/L * MPL Standards-IS: 10500-1991

3.1.2.3 Tap water

Seasonal trend of tap water for physical and chemical parameters was observed to be monsoon followed by summers and winter. Overall pH in tap water was observed to be neutral in all the three seasons and results were however found to be statistically significant ($p=0.04$). Overall alkalinity, hardness, calcium, phosphate and chloride concentration was found to be higher in monsoons followed by summer and winters. The difference in concentration was found to be statistically insignificant for all the parameters ($p>0.05$) while statistically significant for phosphate ($p=0.008$). Overall magnesium and ammonia concentration was found to be maximum in monsoon followed by winters and summer. However, results were found to be statistically insignificant for both ($p>0.05$). Concentration of magnesium was found to be above MPL in each drain. Overall iron and residual chloride concentration was negligible and result were however insignificant.

Overall fluoride concentration in each season was similar and results were found to be statistically insignificant ($p=1.0$). No seasonal variation was observed, but fluoride concentration in each drain is higher than MPL.

Table 25: Seasonal Pattern of Physical-Chemical parameters in Tap Water

Parameters**	Summer (N=12)	Monsoon (N=6)	Winter (N=12)	Mean (N=30)	MPL*
P_H	6.98	7.15	6.98	7.04	7
Total Alkalinity	417.95	450	422.55	430.17	600
Total Hardness	287.7	351.2	281	306.63	600
Calcium	179.1	184	156.88	173.33	200
Magnesium	130.2	167.4	129.07	142.22	100
Ammonia	0.324	0.35	0.324	0.337	1.8
Phosphate	0.05	0	0.074	0.041	5.0
Total Iron	0	0	0	0	1
Chlorides	51.12	61.004	34.72	48.95	1000
Residual Cl	0	0	0	0	0.2
Fluorides	2.3	2.3	2.3	2.3	1.5

*MPL Standards-IS: 10500-1991 **All values (except pH) are in mg/L

5.2.1.3 Drain wise analysis

5.2.1.3.1 Effluent Water

Drain wise analysis shows that in Kala Singha drain alkalinity, hardness, and magnesium and fluoride concentration were observed to be higher. The difference of concentration among drains was observed to be statistically significant for alkalinity, hardness, magnesium ($p<0.001$) while insignificant for fluoride ($p=0.087$). In East Bein drain concentration of pH, calcium and phosphate were observed to be higher. However the results were found to be statistically significant for all these parameters. Buddha Nallah has higher concentration of chlorides (171.25 mg/L), which was statistically significant ($p=0.025$).

5.2.1.3.2 Ground Water

Hudiara Nallah has maximum concentration of hardness, calcium and magnesium among all the drains. The drain wise difference in concentration was found to be statistically significant for calcium ($p=0.03$) while insignificant for hardness and magnesium. In East Bein drain alkalinity, iron and fluoride concentration was found to be higher. The drain wise difference in concentration was found to be statistically significant for alkalinity and fluoride ($p>0.05$) while statistically insignificant for iron ($p=0.727$). Kala Singha drain has higher concentration of chloride, which was statistically significant ($p<0.001$).

5.2.1.3.3 Tap Water

Buddha Nallah has maximum concentration of pH, hardness and calcium among all the drains. The drain wise difference in concentration was found to be statistically significant for hardness and calcium ($p=0.004$; $p<0.001$) respectively while insignificant for pH ($p=0.010$). In Tung Dhab drain alkalinity, ammonia and fluoride has highest concentration, which was statistically significant for alkalinity and fluoride ($p<0.001$) while insignificant for ammonia ($p=0.285$).

5.2.2 Chemical Oxygen Demand

5.2.2.1 Drain wise analysis

The present study reported that mean COD concentration was found to be maximum during summer (508.87 mg/L) followed by monsoon (479.37 mg/L) and winter (448.25 mg/L) respectively (Table-26, figure-8). This result was observed to be statistically significant ($p<0.001$).

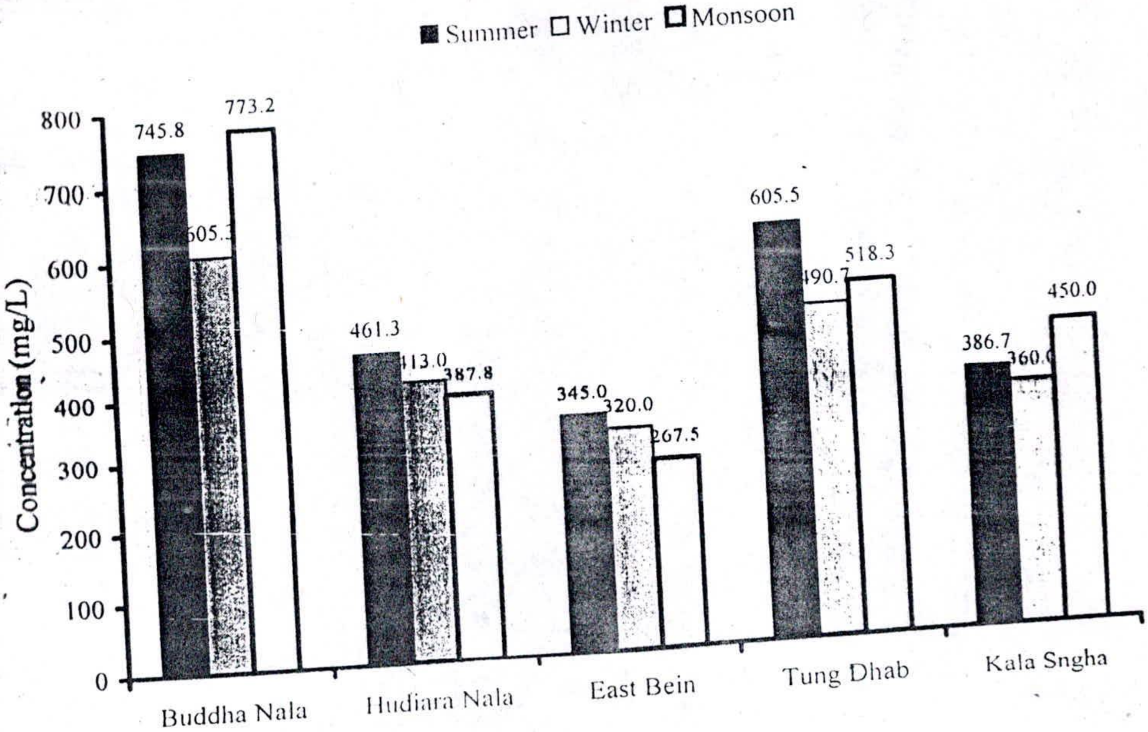
Table 26: Drain-wise seasonal pattern of COD

Drain	Summer (N=30)	Winter (N=30)	Monsoon (N=16)	Total (n=76)
Buddha Nallah	745.83	605.25	773.17	720.94
Hudiara Nallah	461.33	413	387.83	422.27
East Bein	345	320	267.5	309
Tung Dhab	605.5	490.67	518.33	547.67
Kala Sngha	386.67	360	450	406.67
Total	508.87	448.25*	479.37*	484.46

All values are in mg/L

*p<0.001 MPL= 500mg/L (BIS Standard)

Figure 8: Drain wise Analysis of COD



5.2.2.2 Area wise analysis

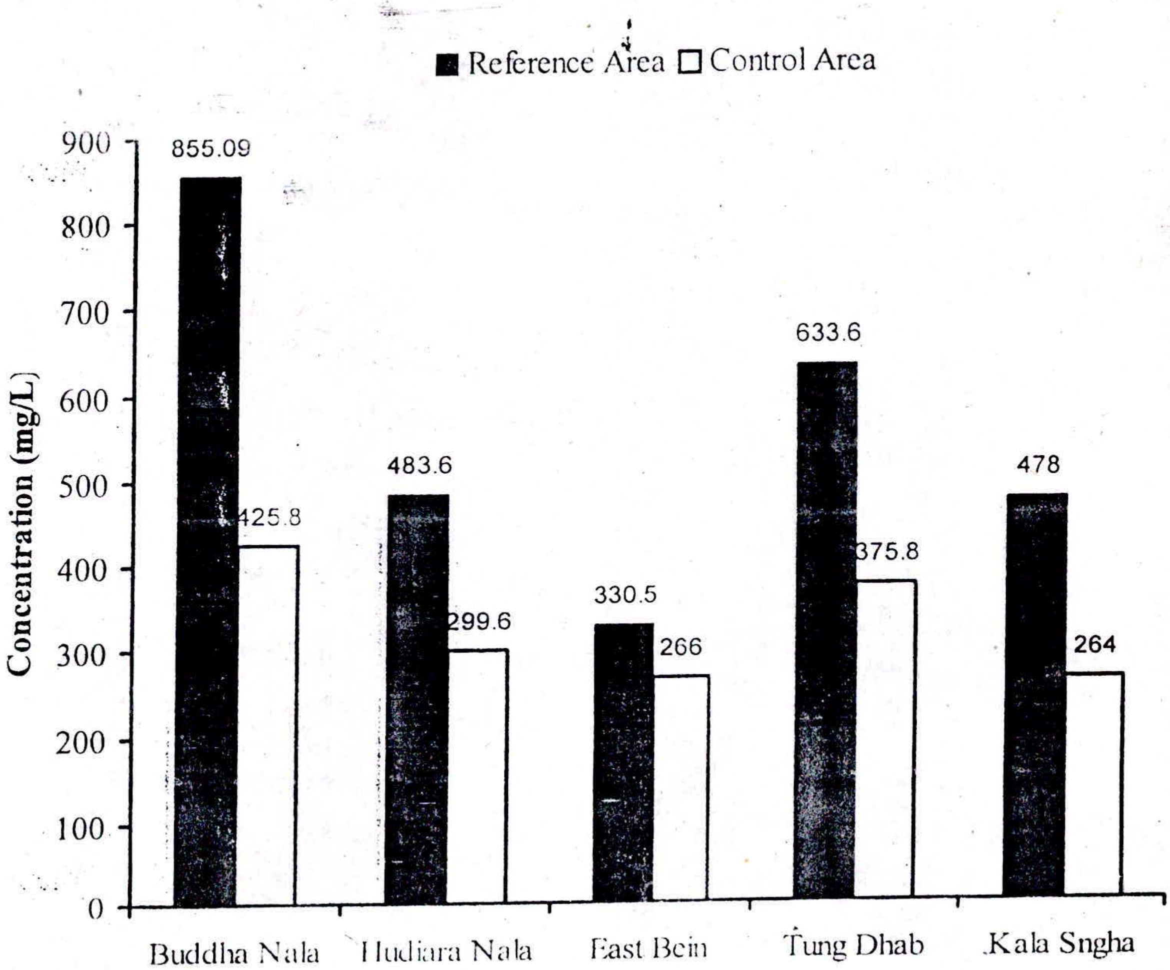
Table 27: Area-wise COD in Reference and control area

Drain	Reference (N=51)	Control (N=25)	Total (N=76)
Buddha Nallah	855.09	425.8	720.94**
Hudiara Nallah	483.6	299.6	422.27**
East Bein	330.5	266	309**
Tung Dhab	633.6	375.8	547.67**
Kala Sngha	478	264	406.67**
Total	562.02*	326.24*	484.46

*p<0.001. **p<0.001 MPL=500mg/L. (BIS Standard)

All values are in mg/L

Figure 9: Area wise COD pattern

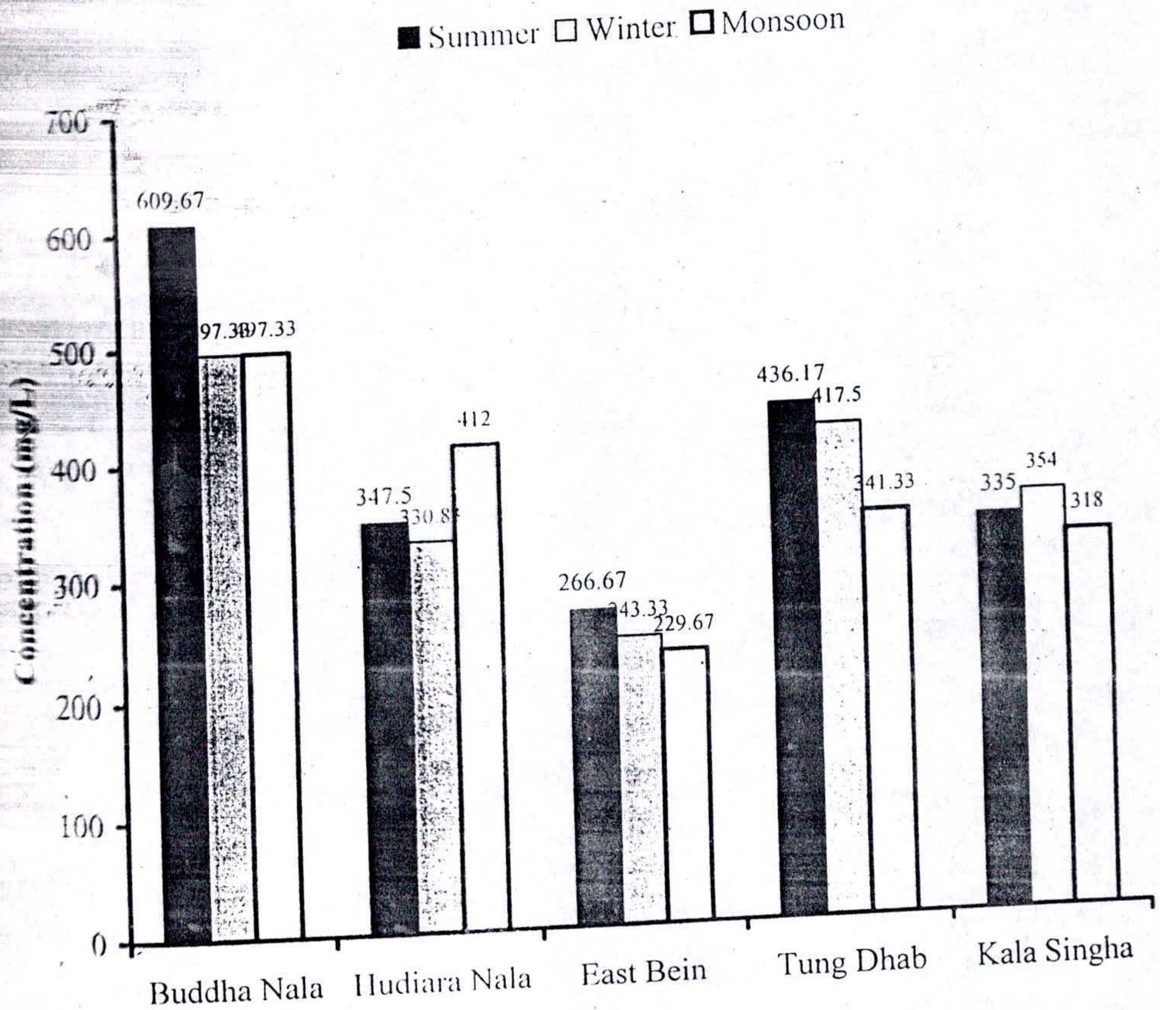


The present study revealed that COD was observed to be higher in reference area as compared to control area in all the five drains (Table-27, Figure-9). In Buddha Nallah mean value of COD for reference area (855.09mg/L) was found to be higher than control area (425.80mg/L), which was found to be statistically significant ($p<0.001$). Total COD value was observed to be maximum in Buddha Nallah (720.94mg/L) followed by Tung Dhab Drain (547.67mg/L) and found to be statistically significant ($p<0.001$).

5.2.3 Biochemical Oxygen Demand

5.2.3.1 Drain wise analysis

Figure 10: Drain wise seasonal pattern of BOD



The present study revealed that the mean BOD value was found to be maximum during summer (399mg/L) followed by winter (395.29mg/L) than monsoon (359.67mg/L) and it was found to be statistically significant ($p<0.001$) (Table-28, Figure-10).

Table 28: Drain-wise seasonal pattern of BOD

Drain	Summer (N=30)	Winter (N=30)	Monsoon (N=16)	Total (n=76)
Buddha Nallah	609.67	497.33	497.33	583.13
Hudiara Nallah	347.5	330.83	412	353.53
East Bein	266.67	243.33	229.67	249.93
Tung Dhab	436.17	417.5	341.33	409.72
Kala Singha	335	354	318	339.4
Total	399*	395.29*	359.67*	389.72

*p<0.001 MPL=400mg/L (BIS Standard)

All values are in mg/

2.3.2 Area wise analysis

Table 29: Area-wise BOD in reference and control area

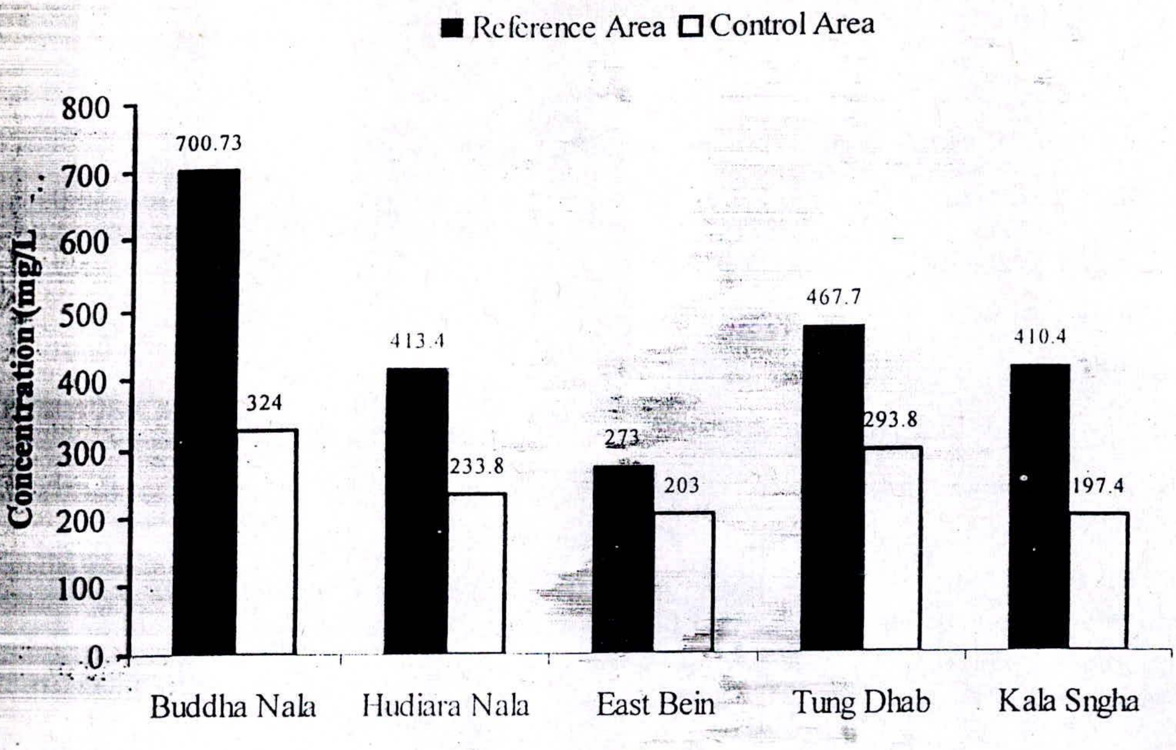
Drain	Reference (N=51)	Control (N=25)	Total (N=76)
Buddha Nallah	700.73	324	583.13**
Hudiara Nallah	413.4	233.8	353.53**
East Bein	273	203	249.93**
Tung Dhab	467.7	293.8	409.73**
Kala Sngha	410.4	197.4	339.40**
Total	457.90*	250.64*	389.72

*p<0.001, **p<0.001 MPL 400mg/L (BIS Standard)

All values are in mg/

The present study reported that BOD value was observed to be higher in reference are compared to control area in all the five drains (Table-29, Figure-11). Buddha Nallah n value of BOD for reference area (700.73mg/L) was fund to be higher than control (324mg/L), which was found to be statistically significant ($p<0.001$). Total BOD value v found to be maximum in Buddha Nallah (583.13) followed by Tung Dhab Drain (40 and was found to be statistically significant ($p<0.001$).

Figure 11: Area wise BOD in reference and control area



5.2.4 Heavy Metal Analysis

5.2.4.1 Area wise analysis

5.2.4.1.1 Effluent water

Table 30: Area-wise Heavy Metals in Effluent Water

Parameter**	Buddha Nallah		Hudiara Nallah		Tung Dhab Drain		East Bein Drain		Kala Singha Drain		Overall Mean		MPL ***
	Ref (N=12)	Ctrl (N=6)	Ref (N=12)	Ctrl (N=6)	Ref (N=12)	Ctrl (N=6)	Ref (N=12)	Ctrl (N=6)	Ref (N=12)	Ctrl (N=6)	Ref (N=60)	Ctrl (N=30)	
Cu	0.0185	0.0058	0.0035	0.0005	0.0005	0.0006	0.0225	0.0030	0.0029	0.0208	0.0096	0.0071	3.0
Cd	0.0015	0.0011	0.0085	0.0002	0.0018	0.0006	0.0020	0.0024	0.0003	0.0002	0.0028	0.0009	2.0
Cr	0.0012	0.0097	0.0081	0.0021	0.0037	0.0036	0.1450	0.0019	0.0054	0.0029	0.0349	0.0040	0.1
Hg	0.0242*	0.0063	0.0277*	0.0171*	0.0[illegible]14*	0.0201*	0.0397*	0.1921*	0.0320*	0.0327*	0.0310*	0.0537*	0.01
Pb	0.0122	0.0073	0.0038	0.0069	0.0084	0.0126	0.0142	0.0007	0.0340	0.0029	0.0084	0.0061	0.1
Zn	0.0029	0.0029	0.0009	0.0011	0.0018	0.0001	0.0024	0.0005	0.0013	0.0003	0.0018	0.0009	0.05
As	0.0020	0.0030	0.0031	0.0143	0.0050	0.0043	0.0026	0.0017	0.0018	0.0026	0.0029	0.0052	0.2
Ni	0.0224	0.0018	0.0113	0.0044	0.0103	0.0000	0.0076	0.0122	0.0150	0.0082	0.0133	0.0053	2.0

*Concentration more than MPL
**All values are in mg/L
***MPL Standards: BIS

Overall Copper, Cadmium and Chromium concentration in effluent water of reference area was found to be higher as compared to control area, which was however found to be statistically insignificant (p=0.7; p=0.1; p=0.4) respectively (Table-31, Figure-12). Overall concentration of Mercury was more than permissible limit in both reference and control area and was found to be higher in control area (0.054 mg/L) than reference area (0.03 mg/L), which was however found to be statistically insignificant (p=0.4). Overall concentration of Lead, Selenium and Nickel was observed to be higher in reference area as compared to control area. The area wise difference in concentration was found to be statistically significant for nickel (p=0.006) while insignificant for lead and selenium (p=0.4 and p=0.2) respectively. Overall Arsenic concentration in control (0.005 mg/L) was found to be higher than reference (0.003 mg/L) area, however results were found to be statistically insignificant (p=0.16). Out of 90 samples of effluent water, Arsenic was detected in 63 (70%) of samples, but within the permissible limit.

Figure 12: Area wise Heavy Metals in Tap and Ground Water.

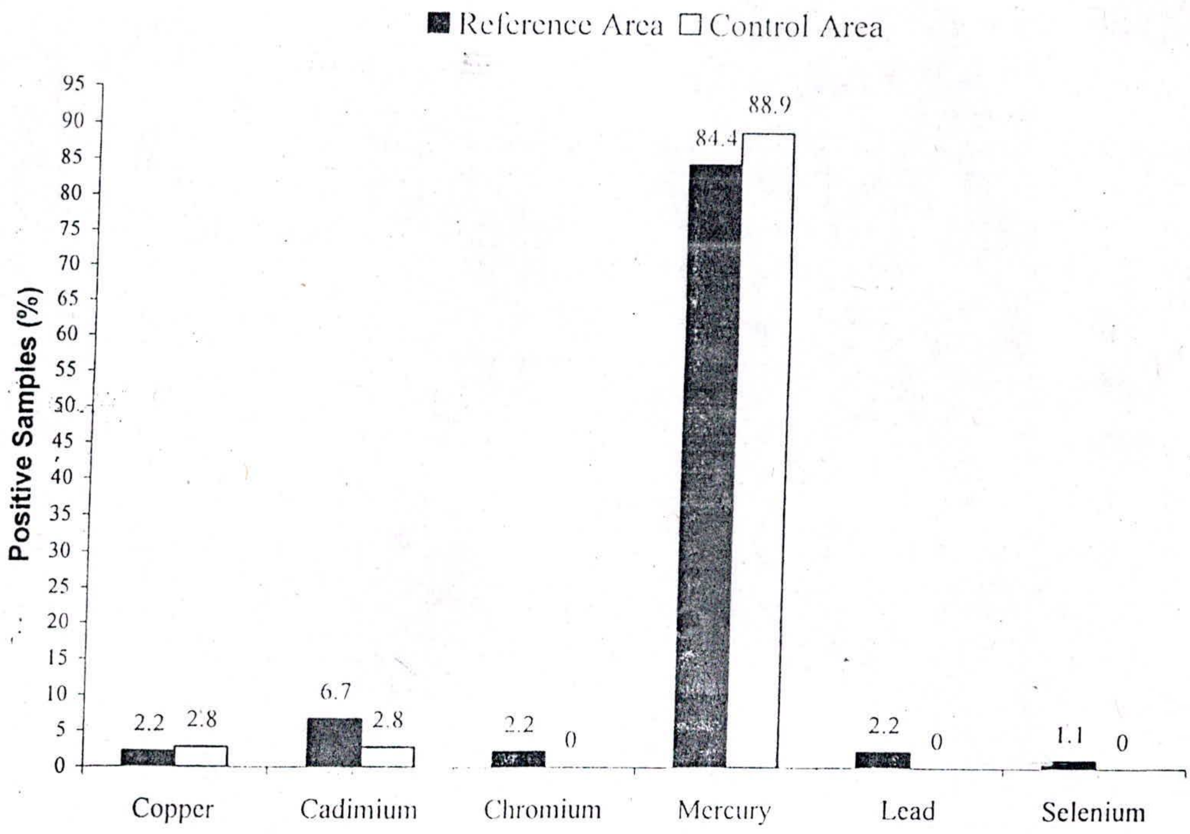


Table 31: Area wise Heavy Metals in Tap and Ground Water

Parameter**	Reference Area (N=90)	Control Area (N=36)	OR (95%CI)	MPL
Copper	2 (2.22)*	1(2.77)*	0.8 (0.07-9.06)	0.05
Cadimium	6(6.66)	1(2.77)	2.5 (0.3-21.5)	0.01
Chromium	2(2.22)	0	-	0.05
Mercury	76(84.44)	32(88.88)	0.7 (0.21-2.2)	0.001
Lead	2(2.22)	0	-	0.05
Selenium	1(1.11)	0	-	0.01

*Figure in parenthesis indicates percentage **All values are in mg/L

5.2.4.1.2 Ground water

Overall Copper, Cadmium and Chromium concentration in ground water of reference area was found to be higher as compared to control area, which was statistically insignificant ($p>0.05$). Overall prevalence of samples with concentration of Copper more than permissible limit was higher in control area (2.8%) as compared to reference area (2.2%). However, results show no significant difference (OR=0.8; 95% CI=0.07-9.0) between reference and control area.

Table 32: Area-wise Heavy Metals in Ground Water

Metals**	Buddha Nallah		Hudiara Nallah		Tung Dhab Drain		East Bein Drain		Kala Singha Drain		Overall Mean		MPL ***
	Ref (N=12)	Ctrl (N=6)	Ref (N=12)	Ctrl (N=6)	Ref (N=12)	Ctrl (N=6)	Ref (N=12)	Ctrl (N=6)	Ref (N=12)	Ctrl (N=6)	Ref (N=60)	Ctrl (N=30)	
Cu	0.0023	0.0032	0.0044	0.0002	0.0039	0.0131	0.0193	0.0019	0.0011	0.0050	0.0062	0.0040	0.05
Cd	0.0006	0.0000	0.0024	0.0023	0.0013	0.0002	0.0006	0.0017	0.0062	0.0017	0.0016	0.0012	0.01
Cr	0.0026	0.0058	0.0041	0.0018	0.0061	0.0043	0.0081	0.0029	0.0031	0.0013	0.0048	0.0320	0.05
Hg	0.0401*	0.0045*	0.1951*	0.2595*	0.0332*	0.0246*	0.0284*	0.0876*	0.0754*	0.0423*	0.0744*	0.0837*	0.001
Pb	0.0017	0.0008	0.0040	0.0059	0.0054	0.0075	0.0016	0.0000	0.0123	0.0050	0.0050	0.0038	0.05
Se	0.0045	0.0011	0.0016	0.0023	0.0008	0.0018	0.0021	0.0012	0.0007	0.0009	0.0019	0.0015	0.01
As	0.0005	0.0005	0.0015	0.0017	0.0018	0.0006	0.0008	0.0006	0.0047	0.0017	0.0018	0.0010	0.01
Ni	0.0022	0.0062	0.0030	0.0020	0.0001	0.0033	0.0101	0.0087	0.0043	0.0010	0.0040	0.0041	0.005

* Concentration more than MPL, **All values are in mg/l . ***MPL Standards USEPA (except Cu, As, Ni), Cu, As, Ni -- WHO

Overall prevalence of samples with more than permissible limit for Cadmium was found to be more in reference area (6.7%) as compared to control area (2.8%). However, results were statistically insignificant (OR=2.5; 95% CI=0.3-21.54). Overall Mercury concentration in both reference (0.07 mg/L) and control area (0.08 mg/L) was above maximum permissible limit. Difference in concentration among reference and control area, however found to be insignificant (p=0.9). Overall high prevalence of samples with more than permissible limit for mercury was observed in control area (88.9%) and reference area (84.4%).

Overall concentration of Lead, Selenium and Nickel was found to be higher in reference area as compared to control area, which was however found to be statistically insignificant (p>0.05). Overall concentration of Arsenic in control area (0.005mg/L) was found to be higher than reference area (0.003mg/L). However, results were found to be insignificant (p=0.4). One hundred twenty six (126) samples of water with 90 and 36 samples of ground and tap water respectively were tested for Arsenic and 52 (57.7%) and 18 (50%) were found to be positive for both ground and tap water respectively, but were within permissible limits.

5.2.4.2 Seasonal variation

5.2.4.2.1 Effluent water

Seasonal trend of effluent water for heavy metal was observed to be summer followed by winter and monsoon (Table-33). The study revealed that overall Copper and Cadmium concentration in effluent water were found to be maximum in winter followed by summe and monsoon which were however found to be statistically insignificant (p=0.7; p=0.8) respectively. Overall concentration of Chromium, Mercury, Selenium, Arsenic and Nick… was observed to be higher in summer followed by winters and monsoon. The difference concentrations was statistically insignificant for these parameters (p>0.05). Overall Lead concentration was found to be maximum during winters (0.0091 mg/L) followed by monsc (0.0077 mg/L) and summer (0.0053 mg/L). However, results were found to be statistically insignificant (p=0.4).

Table 33: Seasonal Pattern of Heavy Metals in Effluent Water

Parameters**	Summer (N=30)	Monsoon (N=15)	Winter (N=45)	Mean (N=90)	MPL
Copper	0.0096	0.0036	0.0099	0.0077	3.0
Cadmium	0.0022	0.0014	0.0024	0.002	2.0
Chromium	0.0569	0.0036	0.0101	0.0235	0.1
Mercury	0.0611*	0.0242*	0.0284*	0.0379*	0.01
Lead	0.0053	0.0077	0.0091	0.0073	0.1
Selenium	0.002	0.0011	0.0014	0.0015	0.05
Arsenic	0.004	0.0029	0.0036	0.0035	0.2
Nickel	0.0137	0.0048	0.0106	0.0097	2.0

* Concentration more than MPL. **All values are in mg/l

5.2.4.2.2 Ground water

Seasonal trend of ground water for heavy metal was observed to be summer followed by winter and monsoon (Table-34). Overall Copper concentration in ground water was found to be maximum during winter (0.009 mg/L) followed by monsoon (0.007 mg/L) and summer (0.0003 mg/L). However, results were found to be statistically insignificant ($p=0.2$). Overall concentration of Cadmium and Selenium was found to be higher in winters followed by summer and monsoon, which was however found to be statistically insignificant for Cadmium and Selenium ($p=0.1$; $p=0.6$ respectively).

Table 34: Seasonal Pattern of Heavy Metals in Ground Water

Parameters**	Summer (N=30)	Monsoon (N=15)	Winter (N=45)	Mean (N=90)	MPL
Copper	0.0003	0.0076	0.0008	0.0029	0.05
Cadmium	0.0013	0.0013	0.0017	0.0014	0.01
Chromium	0.0063	0.0035	0.0032	0.0043	0.05
Mercury	0.1011*	0.1628*	0.0334*	0.0991*	0.001
Lead	0.0010	0.0019	0.0039	0.0022	0.05
Selenium	0.0015	0.0015	0.0020	0.0016	0.01
Arsenic	0.0019	0.0009	0.0116	0.0048	0.01
Nickel	0.0099	0.0010	0.0045	0.0051	0.005

* Concentration more than MPL. **All values are in mg/l

Overall Chromium, Lead and Nickel were found to be maximum in summer followed by winters and monsoon, which was statistically insignificant ($p>0.05$). Overall Mercury concentration was found to be maximum in monsoon (0.1628 mg/L) followed by summer (0.10 mg/L) and winter. However, the difference in concentration was found to be statistically insignificant (p 0.2). Overall Arsenic concentration was found to be maximum in summer (0.002mg/L) followed by winter (0.0016mg/L) and monsoon. However, the difference in concentration was found to be statistically insignificant ($p=0.8$).

5.2.4.2.3 Tap water

Seasonal trend of tap water for heavy metal was observed to be monsoon followed by summer and winter (Table-35). Overall Copper concentration in tap water was observed to be higher in monsoon (0.0065mg/L) followed by winters (0.0046mg/L) and summer (0.0007mg/L). However no significant difference was observed ($p=0.4$). Overall concentration of Cadmium, Lead and Selenium was observed to be higher in winters followed by monsoon and summer. The difference in concentration was statistically insignificant for these parameters ($p>0.05$). Overall concentration of Chromium was found to be maximum in summer followed by monsoon and winter. The results were however, found to be insignificant (p 0.?).

Table 35: Seasonal Pattern of Heavy Metals in Tap Water

Parameters**	Summer (N=12)	Monsoon (N=6)	Winter (N=18)	Mean (N=36)	MPL***
Copper	0.0007	0.0065	0.0046	0.0039	0.05
Cadmium	0.0009	0.0008	0.0060	0.0026	0.01
Chromium	0.0314	0.0052	0.0038	0.0135	0.05
Mercury	0.0513*	0.0347*	0.0400*	0.0420*	0.001
Lead	0.0049	0.0048	0.0113	0.0070	0.05
Selenium	0.0013	0.0026	0.0032	0.0024	0.01
Arsenic	0.0015	0.0017	0.0009	0.0014	0.01
Nickel	0.1671	0.0008	0.0048	0.0577	0.005

* Concentration more than MPL, ** All values are in mg/L, ***MPL Standards USEPA (except Cu, As, Ni); Cu, As, Ni -- WHO

Overall concentration of Mercury and Nickel was found to be maximum in summer followed by winter and monsoon. The difference was, however, found to be statistically insignificant for Mercury (p=0.4) and Nickel (p=0.4). Overall Arsenic concentration was observed to be maximum in monsoon followed by summer and winter, however results were found to be statistically insignificant (p=0.6).

5.2.4.3 Drain wise analysis

5.2.4.3.1 Effluent Water

Buddha Nallah has maximum concentration Lead, Selenium and Nickel among all the drains. The drain wise difference in concentration was found to be statistically insignificant for there metals (p>0.05). East Bein drain has maximum concentration of Chromium and Mercury. The difference was however found to be statistically insignificant for Chromium (p=0.4) and Mercury (p=0.3). Hudiara Nallah has maximum concentration of Cadmium and Arsenic. However the drain wise difference was found to be statistically significant for Cadmium (p=0.03) and insignificant for Arsenic.

5.2.4.3.2 Ground Water

Kala Singha has maximum concentration of Cadmium, Lead and Arsenic, which was however, found to be statistically insignificant among all the drains. East Bein has higher concentration of Copper, Chromium and Nickel. The drain wise difference was however found to be statistically significant for Nickel (0.048) while insignificant for Copper and Chromium (p>0.05). Buddha Nallah has higher concentration of Selenium (0.0033 mg/L). The drain wise difference in concentration was found to be statistically significant (p=0.01).

5.2.4.3.3 Tap Water

Among drains Hudiara Nallah has maximum concentration of Copper, Cadmium, Chromium and Mercury. The drain wise difference was however found to be statistically significant for Mercury (p=0.029) while insignificant for Copper, Cadmium and Chromium (p>0.05).

5.2.4.4 Heavy Metals in Fodder Samples

Lead, Chromium and Cadmium were detected in fodder samples (10) Nickel, Selenium, Arsenic and Mercury were also analyzed but their concentrations were found to be below detectable limit (Table-36).

Table 36: Analysis of heavy metal in fodder samples.

Metals*	Fodder1 (Raja Tal)	Fodder2 (B. B. Singh)	Fodder3 (Khera Bet)	Fodder4 (Raipur**)	Fodder5 (Khera Bet)	Fodder6 (Khun-Khun)	Fodder7 (Raipur**)	Fodder8 (Fatehpur)	Fodder9 (Fatehpur)	Fodder 10 (Raja Tal)	Overall (N=10)
Pb	BDL	BDL	BDL	BDL	5.182	BDL	BDL	BDL	BDL	2.19	1.474
Cr	1.3356	0.7224	1.2642	0.6018	0.7824	0.4746	0.8394	1.4136	1.6122	0.9546	1.0008
Cd	BDL	BDL	BDL	0.024	0.0276	0.0192	BDL	BDL	0.0312	0.042	0.0144

*All values are in mg/L., Villages are shown in parenthesis.**Control Area

5.2.4.5 Heavy Metals in Vegetable Sample

Lead, Chromium and Cadmium were detected in vegetable samples (8). (Table-37) beside Nickel, Selenium, Arsenic and Mercury was also analyzed but their concentration was found to be below detectable limit.

Table 37: Analysis of heavy metals in vegetable samples.

Metals*	Carrot1 (Khera Bet)	Lady Finger1 (B. B.Singh)	Gourd (Lahori Mal)	Lady Finger2 (Raipur)	Carrot2 (Bhoma)	Chillies (Khun-Khun)	Potato (Raja Tal)	Raddish (Fatehpur)	Cauli Flower (Khera Bet)	Tori (Khun-Khun)	MPL***
Lead	1.7168**	1.037**	BDL	0.853	0.513	1.1754**	BDL	0.8364	2.9022**	1.6716**	1.0
Chromium	BDL	BDL	0.6822**	BDL	BDL	3.6042**	3.927**	1.449**	1.0086**	BDL	0.6
Cadmium	0.033	BDL	BDL	0.016	BDL	BDL	0.021	BDL	0.0222	0.026	[illegible]

*All values are in mg/L. ** Concentration more than MPL. *** MPL Standards WHO. Villages are shown in parenthesis.

5.2.4.6 Heavy Metals in Urine Samples

The present study revealed that concentration of heavy metals like Copper, Arsenic, Lead, Mercury and Selenium were reported to be higher in East Bein Drain. Similarly concentration of Nickel and Cadmium were reported to be higher in Buddha Nallah and Hudiara Nallah respectively. However all values for these metals were within permissible limits (Table-38)

Concentration of Arsenic was reported to be higher in reference area of East Bein Drain and Hudiara Nallah as compared to these control area. However, it was higher in control area of Buddha Nallah, as compared to reference area. Mercury concentration was reported to be higher in reference area of East Bein Drain and in control area of Hudiara Nallah. The villages selected for urine samples were Chandan Nagar, Raipur (control) from Buddha Nallah, Lahori Mal, Bhoma (control) from Hudiara Nallah, Khun-Khun, Barnala Kalan (control) from East Bein drain. Mahal from Tung Dhab drain. Kala Singha from Kala Singha drain.

Table 38: Heavy Metals in Urine Samples

Parameters*	Buddha Nallah		Hudiara Nallah		East Bein Drain		Tung Dhab Drain	Kala Singha Drain	MPL (µg/day)
	Reference	Control	Reference	Control	Reference	Control	Reference	Reference	
Copper	0.2	0.04	0.4	0.7	0.45	7.2	0.9	0.2	40
Cadmium	0.03	0.1	0.24	0.1	0.025	0.12	0.052	0.3	0.2-2
Arsenic	0.013	0.04	0.014	0.005	0.045	0.004	0.013	0.03	10-30
Lead	0	0	0.12	0.1	0	1.2	0	0	-
Mercury	2.44	2.4	0.213	1.133	3.3	0.413	1.258	3.3	2-200
Nickel	1.0	0.03	0.6	0.86	0.02	0.1	0.3	0.5	2-8
Selenium	0.06	0.05	0.05	0.03	0.03	0.07	0.05	0.02	-

*All values are in mg/L

5.2.4.6 Bacteriological analysis of ground and tap water

In the present study, a total of twelve samples were collected (10 from reference area and 2 from the control area) from various villages situated along five major drains in the study.

The microbiological analysis of the drinking water samples shows that total coliform were found to be positive in tap water of Khun-Khun (East Bein), Boparai B. Singh and Judge Nagar (Tung Dhab)

E. coli and total coliform was reported to be positive in tap water of Khun-Khun (East Bein), and Boparai B. Singh (Tung Dhab). The latter also showed the presence of total coliform. The ground water samples were negative for total coliform and E. coli.

5.2.5 Micronucleus Assay

Table 39: Age-wise distribution of Study Subject with Micronuclei in Buccal Smear

Age-Group (years)	Study Subjects		OR (95% CI)	Micronuclei Per Cell	
	Reference (N=210)	Control (N=90)		Reference Area	Control Area
10—14	6 (21.1)	6 (51.5)	0.227 (0.051-1.01)	0.0059	0.0312
15—19	10 (40)	4 (36)	1.15 (0.25-5.2)	0.0115	0.0061
20—24	7 (28)	2 (16.6)	1.8 (0.3-10.4)	0.0094	0.0006
25—29	8 (28.5)	1 (11.1)	1.2 (0.2-6.9)	0.0039	0.0029
30—34	7 (33.3)	2 (33.3)	0.9 (0.1-6.4)	0.0128	0.0077
35—39	9 (29)	2 (16.6)	1.2 (0.3-5.6)	0.0089	0.0062
40—44	4 (26.6)	1 (14.2)	2.2 (0.2-24.2)	0.0015	0.0011
45—49	7 (70)	2 (25)	2.3 (0.3-17.5)	0.0052	0.0132
50—54	1 (14.28)	0 (0)	0.8 (06-1.2)	0.0068	0.00
55—59	5 (38.4)	2 (22.2)	1.8 (0.3-11.9)	0.0051	0.0083
60—64	1 (33.3)	2 (40)	0.7 (0.03-14.9)	0.0027	0.0038
	65** (30.95)	21** (25.66)	1.079 (0.627-1.856)	0.0074***	0.0081***

*-Figures in parenthesis represent percent prevalence. **p-0.35 ***p-0.7

The study revealed that out of 210 references and 90 controls prevalence of occurrence of micronuclei was found to be higher in reference area (65; 30.95%) as compared to control area (24; 25.66%), which was however found to be statistically insignificant (p=0.35).

There was no significant association of having positive micronuclei among person residing in reference area (OR-1.079, 95% CI-0.627-1.856). Stratified analysis by age (ORM_{H}-1.097, 95% CI, 0.632-1.904) and sex (ORM_{H}-1.028, 95% CI, 0.594-1.778) revealed that there was no confounding result by age or sex (Table-39).

Micronuclei per cell was found to be higher in reference area than control area in 7 out of 11 age groups studied, especially the younger age groups (15-19, 20-24, 25-29, 30-34, 35-39, 40-44, 45-49 and 50-54 years). The highest MN/cell found in reference area was 0.0128, 0.0115, and 0.00948 in the age group of 30-34, 15-19 and 20-24 respectively.

Figure 13: Drain wise distribution of Micronuclei in Buccal Smear

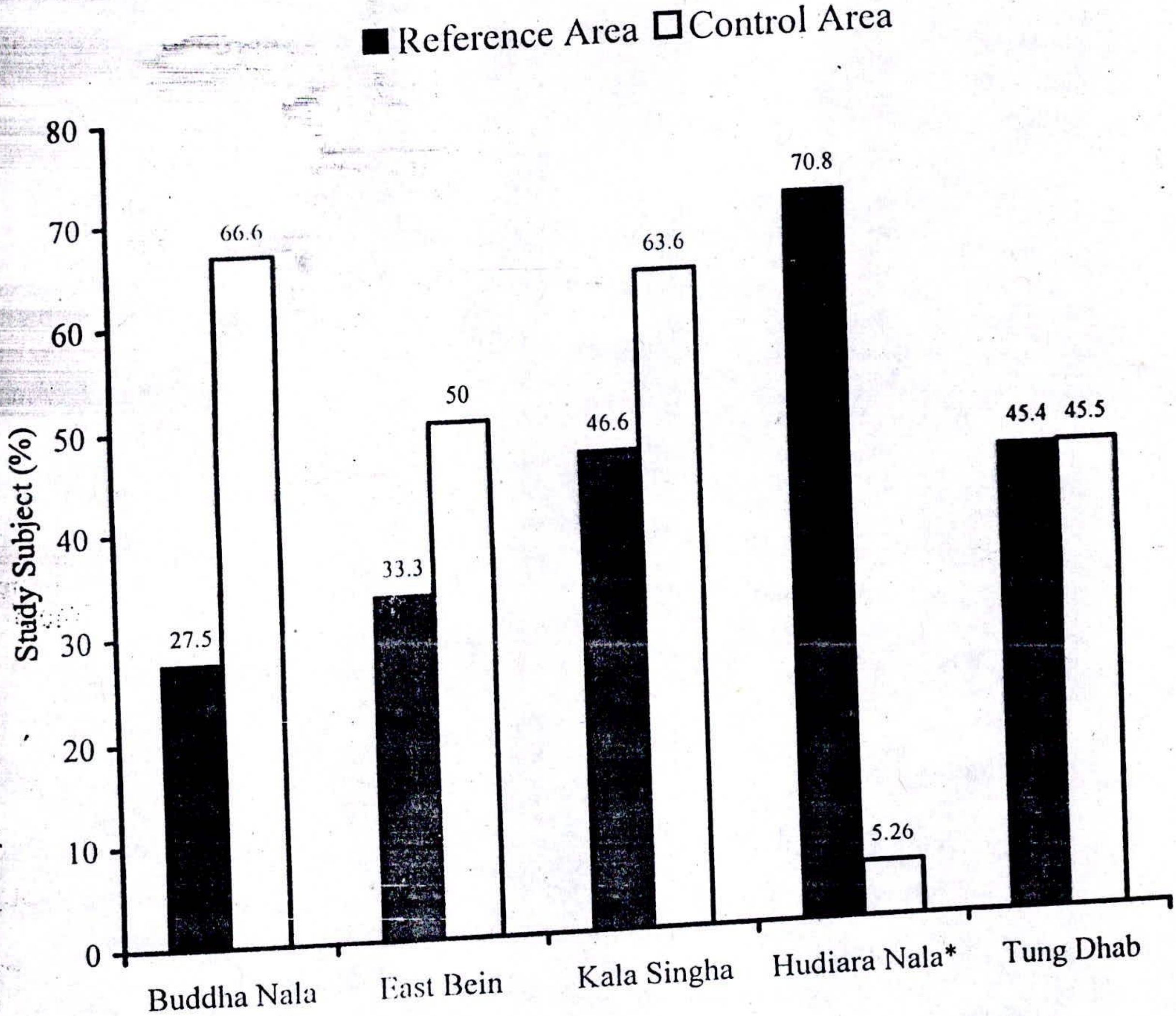


Table 40: Drain-wise distribution of study subjects with Micronuclei in Buccal Smear

Drain	Study subject with MN (%)		OR (95% CI)	Mean MN/cell ± S.D		
	Reference (N=210)	Control (N=90)		Reference	Control	Total
Buddha Nallah	8 (27.5)	6 (66.6)	0.4 (0.1-1.5)	0.005 ± 0.011	0.008 ± 0.016	0.006 ± 0.012
East Bein	10 (33.3)	7 (50)	0.7 (0.2-2.1)	0.005 ± 0.017	0.006 ± 0.013	0.005 ± 0.016
Kala Singha	14 (46.6)	7 (63.6)	0.7 (0.2-2.3)	0.008 ± 0.021	0.020 ± 0.065	0.011 ± 0.039
Hudiara Nallah*	17 (70.8)	1 (5.26)	13.5 (1.6-110.4)	0.007 ± 0.016	0.001 ± 0.004	0.005 ± 0.013
Tung Dhab	15 (45.1)	5 (45.5)	1 (0.3-3.3)	0.001 ± 0.023	0.006 ± 0.013	0.010 ± 0.021
Total	65 (30.9)	24 (26.6)	1.068 (0.6-1.8)	0.007 ± 0.018	0.008 ± 0.031	0.008 ± 0.023

*p<0.05

Drain wise analysis of study subjects for the presence of micronuclei revealed that prevalence of MN in buccal smear was higher in subjects belonging to reference area of Hudiara Nallah (70.8%) as compared to control area (5.26%). which was statistically significant (OR 13.5: 95% CI. 1.6-110.4).

No statistically significant difference in the presence of micronuclei (MN) in buccal smear was detected among study subjects in reference and control area of the remaining drains. Overall highest number of micronuclei per cell was detected in subjects residing in Kala Singha drain area while least in East Bein drain.

5.2.6 Pesticides

Higher prevalence for samples with more than MPL concentration of pesticides was observed for Chlorpyriphos, β-Endosulphan and Heptachlor among all five drains (Table-41). Prevalence of samples with concentration in excess of MPL for Chlorpyriphos, Heptachlor was observed to be maximum in Hudiara Nallah (40% and 50% respectively) and β-Endosulphan was found to be maximum in Buddha Nallah (50%). Statistically there was no drain wise difference found among the five drain areas.

Table 41: Drain wise prevalence of effluent samples with more than permissible limit

Pesticides*	Buddha Nallah (N=16)	Hudiara Nallah (N=10)	Kala Singha Drain (N=10)	East Bein Drain (N=11)	Tung Dhab Drain (N=14)
Chlorpyriphos	5 (31.3)	4 (40)	2 (20)	4 (36.3)	3 (21.4)
β-Endosulphan	8 (50)	3 (30)	2 (20)	3 (27.2)	1 (7)
Dimethoate	0	2 (20)	0	0	3 (21.4)
Heptachlor	4 (25)	5 (50)	1 (10)	3 (27.2)	3 (21.4)
α-Endosulphan	0	0	0	1 (9)	0

*All values are in mg/L

Overall drain wise analysis of samples of ground and tap water revealed that β-Endosulphan and Heptachlor were present in concentration more than permissible limit in each drain (Table-42). Highest prevalence for samples with more than maximum permissible limit of Chlorpyriphos, β-Endosulphan and Heptachlor was found in Hudiara drain (26.3%), Kala Singha Drain (26.6%) and Buddha Nallah (33%) respectively. Aldrin was above permissible limit in 12.5% samples of East Bein Drain. No statistical significant drain wise difference was observed among the five drain areas.

Table 42: Drain wise prevalence of samples with more than permissible limit (Ground & Tap Water)

Pesticides*	Buddha Nallah (N=24)	Hudiara Nallah (N=19)	Kala Singha Drain (N=15)	East Bein Drain (N=16)	Tung Dhab Drain (N=19)
Aldrin	0	0	1 (6.7)	2 (12.5)	1 (5.3)
Chlorpyriphos	2 (8.3)	5 (26.3)	3 (20)	3 (18.8)	4 (21)
β-Endosulphan	5 (20.8)	[illegible] (21)	4 (26.6)	3 (18.8)	4 (21)
Malathion	0	0	1 (6.6)	0	0
Heptachlor	8 (33)	3 (15.8)	4 (26.6)	3 (18.8)	3 (15.8)
α-Endosulphan	0	0	0	0	1 (5.2)

*All values are in mg/L

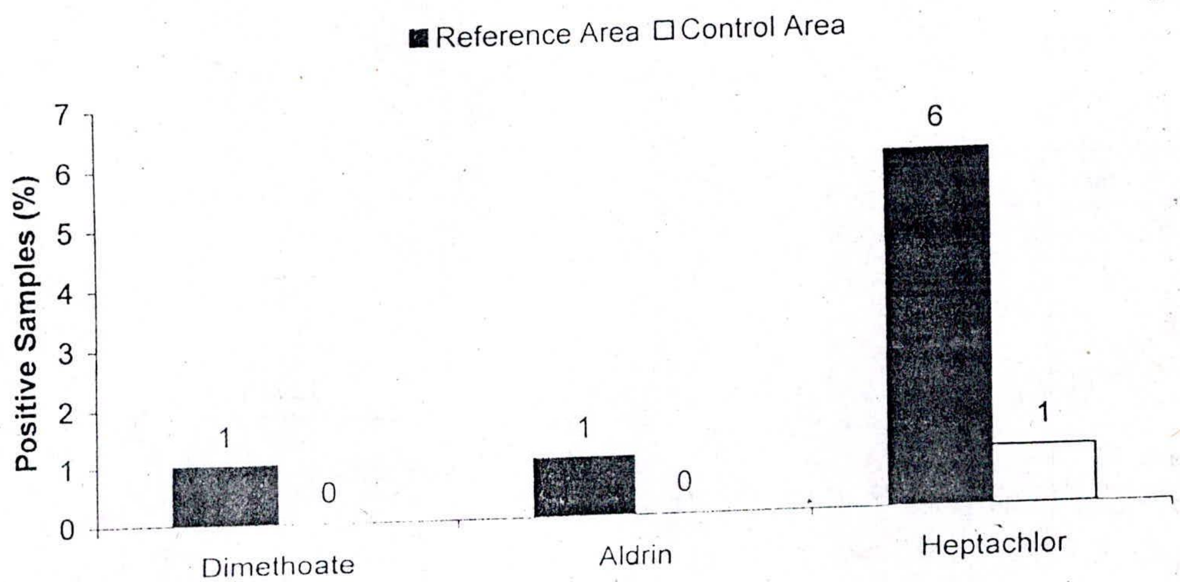
Table 43: Area wise prevalence of samples with pesticides more than permissible limits

Pesticides	Effluent Water			Ground Water			Tap Water		
	Ref. (N=43)	Ctrl (N=18).	OR (95% CI)	Ref. (N=46)	Ctrl. (N=19)	OR (95% CI)	Ref. (N=24)	Ctrl. (N=4)	OR (95% CI)
Chlorpyriphos	13 (30.23)	5 (27.7)	1.1 (0.3-3.8)	10 (21.7)	5 (26.3)	0.8 (0.2-2.7)	0	0	-
B-Endosulphan	10 (23.2)	7 (38.8)	0.5 (0.1-1.5)	9 (19.6)	3 (15.8)	1.3 (0.3-5.4)	0	0	-
Malathion	0	0	-	0	1 (0.09)	0	0	0	-
Dimethoate	5 (11.6)	0	-	3 (6.5)	0	-	1 (4.2)	0	-
Aldrin	0	0	-	3 (6.5)	0	-	1 (4.2)	0	-
Heptachlor	11 (25.5)	5 (27.7)	-	11 (23.9)	3 (15.8)	1.7 (0.4-6.8)	6 (25)	1 (25)	1 (0.09-11.5)
A-Endosulphan	1 (2.38)	-	-	1 (2.2)	0	-	0	0	-

*All values are in mg/l.

Area wise prevalence of samples with pesticides concentration above MPL revealed no statistical significant difference for pesticides among reference and control area (Table-43)

Figure 14: Area wise prevalence of water samples with pesticides more than permissible limits



Overall area wise analysis of mean pesticide levels reveled that Chlorpyriphos is found in excess of permissible limit in effluent, ground and tap water samples of both reference and control except tap water sample of control area (Table-44).

Table 44: Area wise mean pesticide level in water and effluent samples (µg/L)

Pesticides*	Effluent Water		Ground Water		Tap Water		Overall		MPL
	Ref (N=43)	Ctrl (N=18)	Ref (N=46)	Ctrl (N=19)	Ref (N=24)	Ctrl (N=41)	Ref (N=113)	Ctrl (N=41)	
α-Endo	0.1190± 0.7803	0	0.0071± 0.0180	0	-	-	0.0482± 0.482	0	0.1
β-Endo	0.1274± 0.2822	0.2515± 0.3829	0.0619± 0.1384	0.1945± 0.6676	0.1290± 0.2315	0.0261± 0.0522	0.1011± 0.2228	0.2031± 0.5170	0.1
α-HCH	0.1413± 0.3194	0.0417± 0.0649	0.0546± 0.1763	0.0610± 0.1082	0.1060± 0.3221	0.0357± 0.0367	0.0985± 0.2712	0.0501± 0.0853	3
β-HCH	0.0022± 0.0099	0.0147± 0.0450	0.0029± 0.0140	0	0.0709± 0.3227	0	0.0171± 0.3227	0.0065± 0.0302	3
γ-HCH	0.0083± 0.0397	0.0894± 0.3001	0.01[illegible]3± 0.0587	0.0003± 0.0014	0.0175± 0.0741	0	0.0127± 0.0558	0.0394± 0.2007	3
δ-HCH	0.0262± 0.0770	0.2328± 0.6265	-	-	0.0011± 0.0053*	0.0133± 0.0267*	0.0137± 0.0545*	0.1059± 0.4243*	3
Malathion	0.0253± 0.0765	0.0076± 0.0321	0.0077± 0.0263	0.0309± 0.1336	0.0016± 0.0060	0.0062± 0.0124	0.0131± 0.0508	0.0183± 0.0928	0.5
Dimethoate	0.1951± 0.7131	0.0020± 0.0085	0.1181± 0.6374	0	0.0108± 0.0519	0	0.1249± 0.5993	0.0009± 0.0056	0.1
Aldrin	-	-	0.0089± 0.0389	0.0024± 0.0079	0.0032± 0.0111	0	0.4866± 0.0255	0.0465± 0.0054	0.03
Heptachlor	0.0841± 0.2048	0.0978± 0.1791	0.0717± 0.1753	0.0560± 0.1030	0.0511± 0.0712	0.0499± 0.0997	0.0720± 0.1711	0.0737± 0.1400	0.1
4,4-DDT	0.0047± 0.0218	0.0115± 0.0394	0.0373± 0.1331	0.0054± 0.0180	0.0184± 0.0330	0.0106± 0.0213	0.0209± 0.0879	0.0086± 0.0291	1
DDE	0	0.0107± 0.0409	0.0029± 0.0123	0	0.0013± 0.0062	0	0.0015± 0.0084	0.0047± 0.0272	1
Chlorpyriphos	0.0365± 0.0939	0.0843± 0.2197	0.0255± 0.0952	0.0450± 0.1634	0.0121± 0.0466	0	0.0268± 0.0864	0.0578± 0.1823	0.01

*All values are in mg/L

Analysis of effluent revealed that β-Endosulphan and Chlorpyriphos were present in concentration above MPL in both reference and control area. Dimethoate and α-Endosulphan was found in concentration in excess of MPL in reference area alone. γ-HCH was observed to be higher in reference area (less than MPL) than the control area, which was statistically significant. β-Endosulphan and Dimethoate were present in excess of MPL in ground water of control and reference area respectively. Tap water analysis revealed that β-Endosulphan was found above MPL in reference area

5.2.7 Vegetable

Eight vegetable samples were tested for pesticides residue analysis and α -HCH, δ-HCH, γ-HCH, 2,4- DDT, Dieldrin were detected in vegetable samples (Table- 45) however, there concentration were found to be below MPL Besides this Dimethoate, Malathion, Chlorpyriphos and α-Endosulphan were also analyzed but there levels are below detection limits (BDL).

Table 45: Pesticides residue in Vegetables

Pesticides*	Carrot1 (Khera Bet)	Lady Finger1 (B. B.Sinhg)	Gourd (Lahori Mal)	Lady Finger2 (Raipur)	Carrot2 (Bhoma)	Chillies (Khun-Khun)	Potato (Raja Tal)	Raddish (Fatehpur)	Cauli Flower (Khera Bet)	Tori (Khun-Khun)	MPL
α-HCH	0.017	0.054	0.014	0.024	0.085	0.027	BDL	0.122	0.038	0.082	1
γ-HCH	0.037	0.036	0.022	0.018	0.018	0.018	0.236	0.134	0.07	0.102	3
δ-HCH	BDL	0.01	BDL	BDL	BDL	0.005	BDL	0.012	0.014	0.01	3
Dieldrin	0.011	0.015	BDL	BDL	0.005	0.007	0.026	0.032	0.026	0.028	0.1
β-Endosulphan	BDL	BDL	BDL	BDL	BDL	BDL	0.024	BDL	0.036	BDL	2
4,4-DDT	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.014	BDL	3.5
2,4-DDT	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.0216	BDL	0.2

*All values are in mg/L, Villages are shown in parenthesis.

5.2.8 Fodder

Table 46: Pesticides residue in Fodder Samples

Pesticides*	Fodder1 (Raja Tal)	Fodder2 (B. B. Singh)	Fodder3 (Khera Bet)	Fodder4 (Raipur**)	Fodder5 (Khera Bet)	Fodder6 (Khun-Khun)	Fodder7 (Raipur**)	Fodder8 (Fatehpur)	Fodder9 (Fatehpur)	Fodder 10 (Raja Tal)
α-HCH	BDL	BDL	0.092	BDL	BDL	0.058	0.024	BDL	BDL	BDL
γ-HCH	0.09	0.082	0.054	0.024	0.078	0.08	BDL	0.09	0.09	0.144
δ-HCH	BDL	BDL	BDL	BDL	0.016	0.018	BDL	0.02	0.016	0.022
Chlorpyriphos	BDL	BDL	BDL	BDL	0.09	0.104	BDL	BDL	BDL	BDL
Dieldrin	0.018	0.022	BDL	0.014	0.022	0.046	BDL	0.044	0.012	0.056
2,4-DDT	BDL	BDL	BDL	BDL	BDL	0.1338	BDL	BDL	BDL	0:0628

*All values are in mg/L, Villages are shown in parenthesis.

Ten fodder samples were tested for pesticides residue analysis and α -HCH, δ-HCH, γ-HCH, 2,4- DDT, Dieldrin, Chloropyriphos were detected in fodder samples (Table- 46). Besides this Dimethoate, Malathion, α-Endosulphan and β-Endosulphan were also analyzed but were found to be BDL.

5.2.9 Milk

5.2.9.1 Bovine Milk

Overall analysis of Bovine milk revealed the presence of α -HCH, δ-HCH, γ-HCH, 2,4 – DDT, 4,4- DDT, Malathion, Chlorpyrphos, Dieldrin, β-Endosulphan. Overall concentration of α -HCH, Chlorpyriphos, β-Endosulphan was found to be above the MPL (Table- 47). Besides this Dimethoate and α-Endosulphan were also analyzed but their concentration were found to be BDL.

Table 47: Pesticides residue in Bovine Milk Samples

Pesticides*	Bovine1 (C.Nagar)	Bovine2 (Khun-Khun)	Bovine3 (B.B singh)	Bovine4 (Barnala Kalan)	Bovine5 (Raja Tal)	Overall	MPL
α-HCH	0.1195	0.2441	0.1288	BDL	0.4476	0.188*	0.05
γ-HCH	0.0641	0.0493	BDL	BDL	BDL	0.0227	0.05
δ-HCH	0.0063	0.0088	0.0073	BDL	0.0317	0.0108	0.05
Malathion	BDL	0.1399	BDL	BDL	BDL	0.028	0.05
Chlorpyriphos	BDL	0.0239	0.1276*	BDL	0.1229*	0.055*	0.05
Dieldrin	BDL	0.0223	0.0311	BDL	BDL	0.062	0.05
β-Endosulphan	BDL	BDL	BDL	0.2379	0.0191	0.0541*	0.05
4,4-DDT	BDL	BDL	0.134	0.0344	BDL	0.0096	0.05
2,4-DDT	BDL	BDL	BDL	BDL	0.2023	0.0405	0.05

*All values are in mg/L, *Samples with above MPL, Villages are shown in parenthesis,

5.2.9.2 Human Milk

Overall analysis of Human milk revealed the presence of Heptachlor, β-Endosulphan, Chlorpyriphos, α-HCH, 4,4 –DDE and Malathion and there concentration were found to be below MPL but in Hudiara Nallah, the concentration of 4,4 –DDE was found to be above the MPL (Table- 48).

Besides the above pesticides α-Endosulphan, Endosulphate, β, γ, δ- HCH, 4, 4 – DDT, 4, 4 – DDD, 2, 4 – DDT, Dimethoate, Chlordane, Phosphamidon, Aldrin, Dieldrin and Monocrotophos were also analyzed but not detected.

Table 48: Pesticide residue in Human Milk Samples

Pesticides*	Milk-1 (Raipur)	Milk-2 (Raja Tal)	Milk-3 (C. Nagar)	Milk-4 (Khun-Khun)	Milk-5 (Mahal)	MPL
Chlorpyriphos	ND	ND	ND	0.001	ND	0.05
Malathion	ND	ND	ND	ND	0.05	0.05
α-HCH	ND	ND	0.00114	0.002	ND	0.05
Heptachlor	ND	ND	ND	0.002	ND	0.05
β-Endosulphan	ND	ND	ND	ND	0.03	0.05
4,4 –DDE	0.02	0.005	ND	0.0013	0.1135	0.05

*All values are in mg/L, Villages are shown in parenthesis,

5.2.10 Blood

In the present study areawise analysis revealed that concentration of β-Endosulphan, 4,4 – DDE, α-HCH, γ-HCH, δ-HCH were detected in subjects of reference area,as compared to control area of Buddha Nallah.

Heptachlor, α-HCH, β-HCH, δ-HCH were detected in subjects of reference area of Hudiara and Tung Dhab Drain in reference area as compared to but not in control area except Heptachlor.

Heptachlor, α -HCH, β-HCH, δ-HCH, γ-HCH, 4, 4 – DDE were detected in reference area and 4, 4 – DDT, Chlordane were detected in control area of Kala Singha.

Similarly in East Bein Drain, Aldrin, Heptachlor, α -HCH, β-HCH, δ-HCHwere detected in reference area and α -HCH, β-HCH, δ-HCH, γ-HCH were detected in control area of East Bein Drain. (Anneure-3).

5.2.11 DNA Adducts

The amplification of the HPRT gene in case of test samples is expressed here as the percentage of HPRT gene expression in case of the normal healthy control. Lower the percentage amplification, higher will be the presence of DNA adducts (which are indicative of mutations).

Based on the percentage amplification of HPRT genes in the study samples, the subjects were divided in the following groups:

% Amplification of HPRT gene (Compared to healthy control)		No. of patients
>90 %	(Almost Normal)	7 (C-08, 11, 14, 15, 21, 22, 23)
75-90 %	(Moderately Mutated)	8 (C-06, 16, 17, 18, 19, 20, 24, 25)
50-75 %	(Mutated)	3 (C-09, 10, 12)
<50 %	(Highly Mutated)	2 (C-07, 13)

It was observed that the maximum number of cases (8) had moderate mutations (75-90 % gene expression) while 7 cases showed almost normal amplification (>90 %) indicating the absence of mutations. Out of the remaining 5 cases 3 were reasonably mutated (50-75 % amplification) while 2 cases were highly mutated (<50 %).

5.2.12 Quality Control

The data collected by field workers, was comparable with JRF and Medical Officer for epidemiological study. Testing for quality control of 10 samples of water (ground (3), effluent (5), tap (2)) along with one sample each of vegetable and fodder was conducted at Punjab Horticultural Post harvest Technology Center, Punjab Agricultural University, Ludhiana for cross checking the results of testing laboratory. Quality control was done for heavy metal and pesticide residue analysis.

Percentage of agreement for pesticides in effluent, ground and tap water was found to be reasonably comparable in testing and quality control laboratory. Similarly the percentage of agreement for heavy metals in effluent, ground and tap water was also reasonably comparable (80-100%).

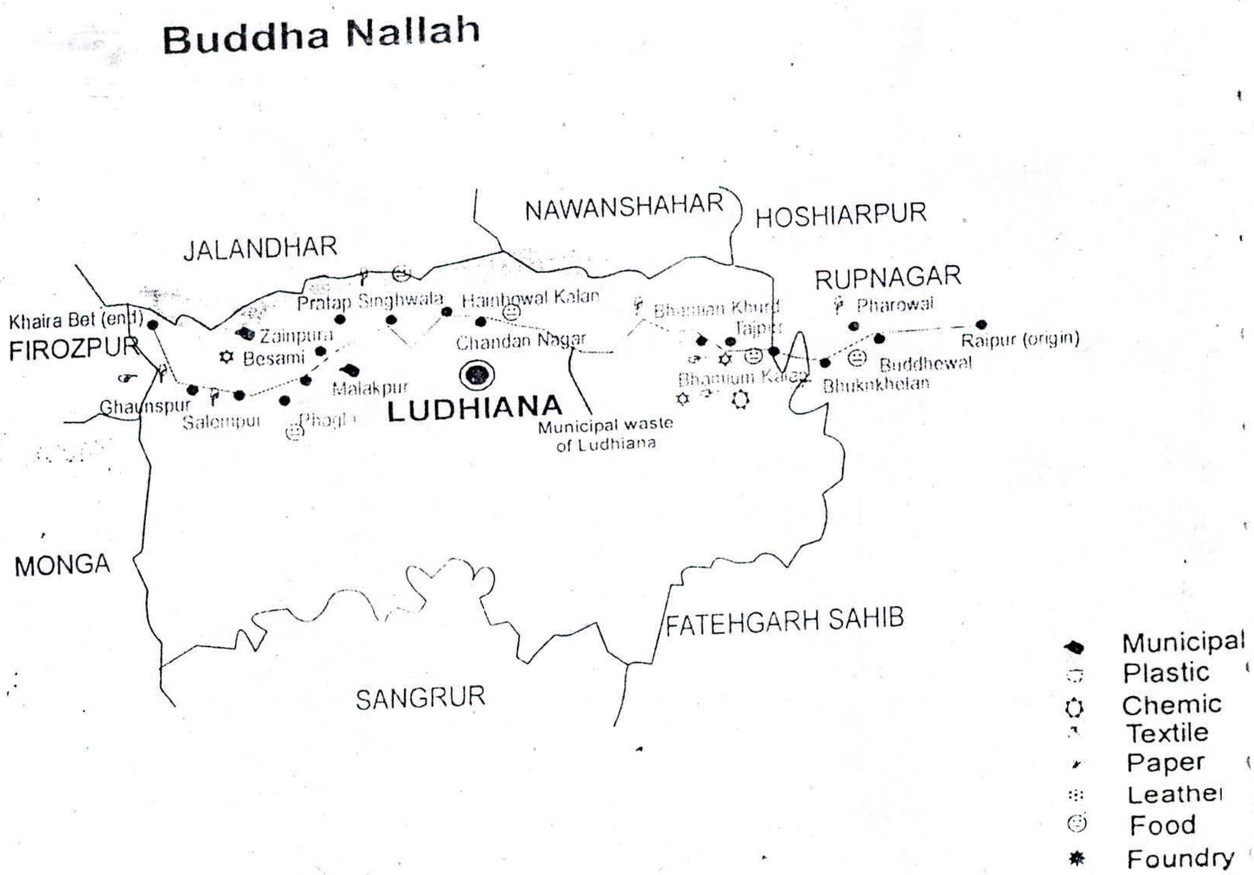
6. Possible source of drain water pollution

The results of drain and village wise laboratory sampling for individual sample for differe parameters are given in Annexure-4.

6.5 Buddha Nallah

The study revealed that overall concentration of Cadmium and Selenium was found to maximum in Midpoint area. It may be because of the presence of food, dying, leath industries in the near by areas which discharge their effluent into the near by drain. Over Copper, Mercury, Lead, Chromium concentration was found to be maximum in downstrea area, may be because of leather, tanning, metal industries in the downstream area. Over concentration of BOD and COD was reported to be maximum in midstream area, may l because of municipal sewage.

Figure 14: Mapping of main industries along Buddha Nallah



Analysis of sampling area along the drain revealed that mid-point area (Chandan Nagar) shows higher concentration of Cadmium, Lead, Selenium, Arsenic, Nickel, COD and BOD (0.003, 0.02, 0.004, 0.003, 0.003, 950, 815) mg/L respectively as compared to upstream and downstream drain area.

Lead concentration was found to be higher in midpoint drain because of Nut and Bolt factory in Pharowal village. Food Industries present in Buddewal and Tajpur village also contain small concentration of Lead. Food cans contain small concentration of Lead. Selenium occurs naturally in environment, it is also present in phosphate fertilizers. Selenium is used in metal alloys (Nut & Bolt). Arsenic and Nickel are naturally present in soil and foodstuff respectively. Cadmium and Chromium concentration is because of dyeing unit present. Concentration of COD and BOD was found to be higher in Chandan nagar (mid-stream point) because municipal waste of Ludhiana city falls before this stream (i.e. mid point). The sewage of the villages falls into this drain. Also effluent of the near by industries fall into this drain, which contain higher concentration of organic and inorganic matter.

Concentration of Copper and Mercury were observed to be higher in downstream area of Buddha Nallah. Concentration was found to be higher as compared to midstream and upstream of Buddha Nallah because metal, tube and dying Industries are present near the lowmstream area.

Concentration of Mercury, Copper, Chromium was found to be above MPL in downstream because of presence of metal, tube and dying units present in near by areas (villages). BOD was observed to be above MPL in midpoint stream because municipal waste of Ludhiana city falls near this point.

The village wise laboratory parameters in water along Buddha Nallah is shown in Table-49

- Effluent water of Khera bet has higher concentration of Heptachlor, β-Endosulphan, Copper, Chromium, Nickel. This pattern was found during all three seasons of the year. Heptachlor was observed to be more than permissible limit in samples of effluent and ground water in Khera Bet.

- Greater proportions of laboratory parameters of effluent water in Khera Bet were observed to be more than the permissible limit than Chandan Nagar and Raipur.
- Noteworthy among these parameters include physical and chemical parameters like Ca, Mg, Cl, F, BOD and COD; heavy metals including Fe, Hg, As, Cd, Cr and pesticides including Beta endosulphan and Heptachlor.

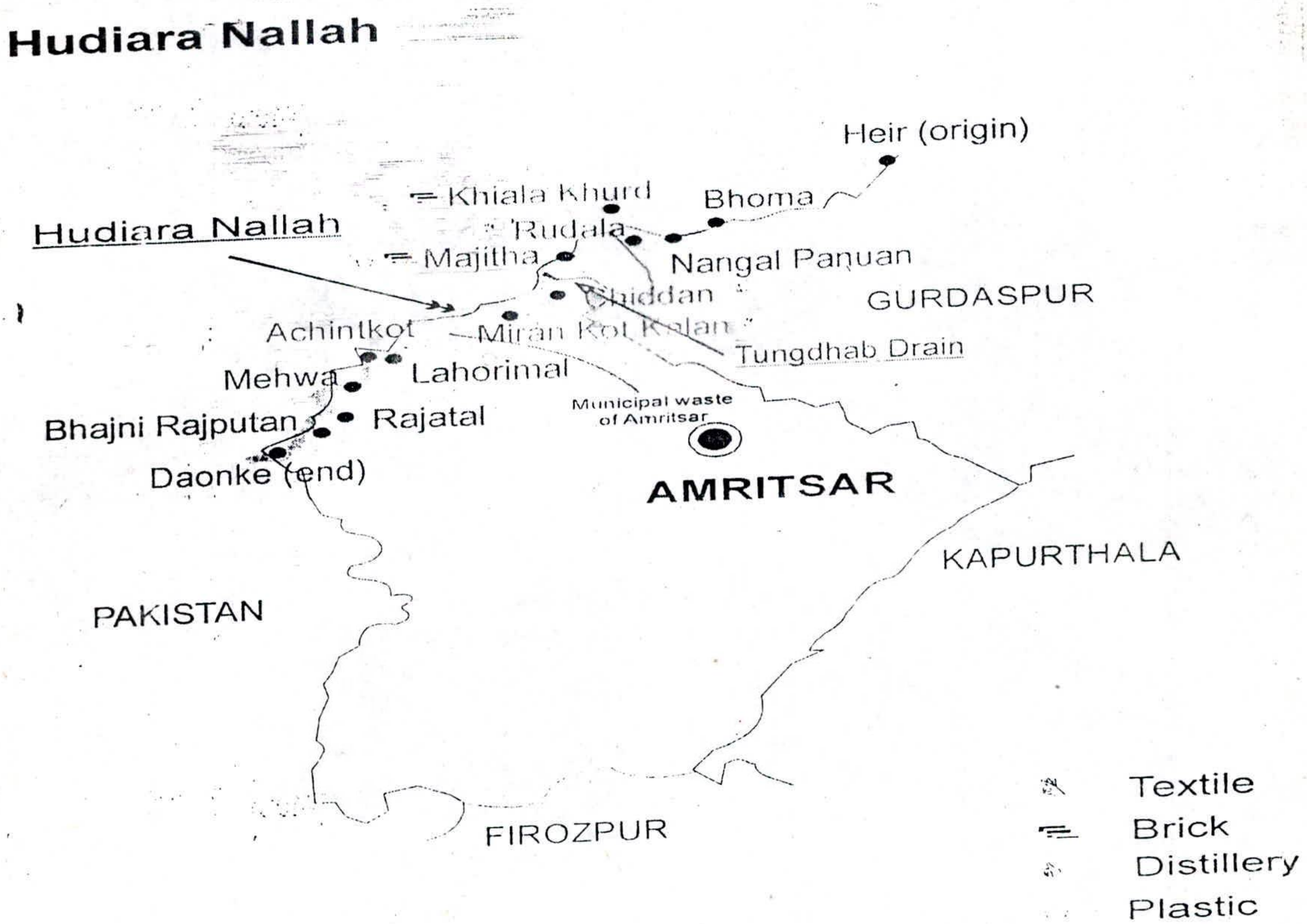
Table – 49: Village wise laboratory parameters in water samples along Budhha Drain

Sample	Area	February		March		May		July		October		December	
		Detected	>MPL	Detected	>MPL	Detected	>MPL	Detected	>MPL	Detected	>MPL	Detected	>MPL
EW	Khera Bet	Ca,Mg,NH_3,P,Fe, Cl,F,Cu,Cd,Cr, Hg,Ni,Se,As,COD BOD, β-Endo, Heptachlor-HCH	Mg,Fe,COD, BOD,F, β-Endo, Heptachlor	Ca,Mg,NH3,P,Cl,F Cu,Cd,Cr, Hg,Ni,Se, Fe,As,COD,BOD	Fe,COD,BOD,F	Cd,Cr,Hg,Pb,Ni,Se,As,COD,BOD,Ca,Mg,NH3,P,Cl,F,Heptachlor, β-Endo	COD,BOD,F,Ni, β-Endo,Heptachlor	Cd,Cr,Hg,Se,As,COD,BOD,Ca,Mg,NH3,P,Cl,F	Fe,COD,BOD,F,Hg	Cd,Cr,Hg,Ni,COD,BOD,Ca,Mg,NH3,P,Cl,F,Se,As	Mg,Fe,COD,BOD,F,Hg	Cu,Cd,Pb,Se,As	Hg
EW	Chadan Nagar	Ca,Mg,NH_3,P,Fe, Cl,F,Cu,Cd,Cr, Hg,Ni,Se,As, COD,BOD, β-Endo	Mg,COD, BOD,F, β-Endo	Ca,Mg,NH3,P,Cl,F Cu,Cd,Cr, Hg,Ni,Se, Fe,As,COD,BOD	Mg,COD,BOD,F	Cd,Cr,Pb,Ni,Se,As,Hg,COD,BOD,Ca,Mg,NH3,P,Cl,F,α-HCH, β-HCH,δ-HCH, β-Endo	Mg,COD, BOD,F, β-Endo	Cd,Cr,Hg,Ni,Pb,Se,As,COD,BOD,Ca,Mg,NH3,P,Cl,F	Ca,Mg,COD,BOD,F,Hg	Cd,Cr,Hg,Ni,Pb, Se,As,Ca,Fe,Mg, NH3,P,Cl,F,Se,As,β-HCH,δ-HCH,γ-HCH,Malathion, Phospmid[illegible]	Ca,COD,BOD,F,Hg,Chlorpyriphos	Cd,Cu,Hg,Pb,Se,As	Hg
EW	Raipur	Ca,Mg,NH_3,P,Cl,F Cu,Cd,Cr,Hg,Ni, Se,As,COD, BOD,Heptachlor	Cr	Cr,Hg,As, Ca,Mg,NH3,P,Cl,F,Se,COD, BOD	As	Cd,Hg,Pb,As,COD,BOD,Ca,Mg,NH3,P,Cl,F,Dieldrin,Malathion,α-HCH,γ-HCH, β-HCH, β-Endo	Ca,Mg,COD,Hg, β-Endo	Cd,Hg,Pb,Se,As,COD,BOD,Ca,Mg, NH3,P,Cl,F		Cr,Hg,Ni,Se,Ca, Mg,NH3,P,Cl,F, Se,As	Mg,BOD	Cu,Se,As	
GW	Chadan Nagar	Ca,Mg,NH_3,P,Cl, F,Cu,Cd,Cr, Hg,Ni,Se, As,Heptachlor	Mg,F	Cd,Hg,Se, As,Ca,Mg, NH3,P,Cl,F	F,Hg	Cd,Cr,Hg,Se,As,Ca,Mg,NH3,P,Cl,F,4,4-DDT,α-HCH	F,Hg	Cd,Cr,Hg,Se,As,Ca,Mg, NH3,P,Cl,F	Mg,F,Hg	Cr,Hg,Ni,Se,Ca, Mg,NH3,P,Cl,F, Se,As	Mg,F,Hg	Cu,Cd,Hg,Pb,Se,As	
GW	Raipur	Ca,Mg,NH_3,P,Cl,F Cu,Cd,Cr,Hg,Ni, Se,As,Heptachlor	Mg,F	Cr,Hg,As, Ni,Ca,Mg, NH3,P,Cl, F,Se	F,Ni,Hg	Cd,Cr,Hg,PB,Se,As,Ca,Mg,NH3,P,Cl,F,Heptachlor,α-HCH, β-Endo	Mg,F,Hg, β-Endo,Heptachlor	Hg,Ca,Mg,NH3,P,Cl,F	F,Hg	Cd,Cr,Hg,Ni,Ca, Mg,NH3,P,Cl,F, Se,As	Mg,F,Ni,Hg	Cu,As,Se	
GW	Khera Bet	Ca,Mg,NH_3,P,Cl, F,Cu,Cd,Cr,Hg,Ni, Se,As, Heptachlor, α-HCH	F, Heptachlor, F	Cu,Cr,Ni, Se,As,Ca, Mg,Fe,NH3,P,Cl,F	Fe,F	Cd,Cr,Hg,Pb,Se,As,Ca,Mg,NH3,P,Cl,F,4,4-DDT,α-HCH, β-Endo	Mg,F,Hg, β-Endo	Cu,Hg,Se,Ca,Mg,NH3,P,Cl,F	F,Hg	Hg,Ni,Se,Pb,Ca, Mg,NH3,P,Cl,F, Se,As	F,Se,Hg	Cu,Hg,Se,As	
SW	Khera Bet	Ca,Mg,NH_3,P,Cl,F Cu,Cd,Cr,Hg, Ni,Se,As,α-HCH,DDE	Ca,Mg,Pb	Cd,Cr,Hg, Pb,As,Ca, Mg,NH3, Cl,F,Se	Ca,Hg	Cr,Pb,As,Ca,Mg,NH3, P,Cl,F,Heptachlor,4,4-DDT,α-HCH, β-Endo	Ca,Mg, β-Endo,Heptachlor	Cu,Hg,Se,Ca,Mg,NH3,P,Cl,F	Ca,Mg	Cr,Hg,Pb,Ni,Se, Ca,Mg,NH3,Cl,F, Se,As,γ-HCH,Malathion	Ca,Mg,Ni,Hg	Cu,Cd,Pb,Se,As	Cd
GW	Chadan Nagar	Ca,Mg,P,Cl, F,Cu,Cd,Cr,Hg, Ni,Se,As,Heptachlor	Ca,Mg,F	Cd,Cr,Hg, Pb,Ca,Mg, NH3,P,Cl, F,As,Se	Ca,F,Hg	Cd,Pb,Hg,Ca,Mg,NH3, P,Cl,F,Dimethoate,heptachlor,4,4-DDT,α-HCH,δ-HCH, β-Endo	Ca,Mg,F, Heptachlor	Hg,Se,Ca,Mg,NH3,P,Cl,F	Mg,F,Hg	Cd,Cr,Hg,Pb,Ni, Se,As,Ca,Mg,NH3,P,Cl,F,Se,As,α-HCH,Heptachlor	Ca,Mg,F,Cd, Ni,Hg,Pb	Cu,Cd,Pb,Se,As	

6.5 Hudiara Nallah

The study revealed that concentration of Cadmium, Chromium, Mercury, Nickel, COD and BOD was observed to be maximum in mid-stream area. Concentration of Chromium was found to be maximum, may be because of textile mill in the near by area. Chromium is also used to make molds for the firing of bricks. Concentration of COD and BOD may be because of municipal waste of Amritsar city, which falls into Hudiara Nallah, and effluent of khasa distillery. Effluent of Tung Dhab Drain also falls into Hudiara drain.

Figure 15: Mapping of main industries along Hudiara Nallah



The village wise laboratory parameters in water along Hudiara Nallah are shown in Table-50.

- All villages along the Hudiara Nala recorded more than permissible limit of mercury and fluoride in effluent, ground and tap water.

- Effluent water of Lahori Mal has more than permissible concentration of Dimethoate, Heptachlor, 4,4-DDT, Alkalinity and Nickel. Tap (tap) water of Lahori Mal has higher concentration of Cadmium, Chromium, Lead, Selenium, Flouride and its ground water has higher concentration of Hardness and Copper.
- Effluent water of Raja Tal has higher concentration of α-HCH, β–HCH., Endosulphan, Malathion and its ground water has higher concentration of DDE .
- Effluent water of Bhoma has higher concentration of β–Endosulphan, γ-HCH, Chlorpyriphos, Lead, Flouride and Arsenic its ground water has higher concentration of Hardness.

Table – 50: Village wise laboratory parameters in water samples along Hudiara Drain

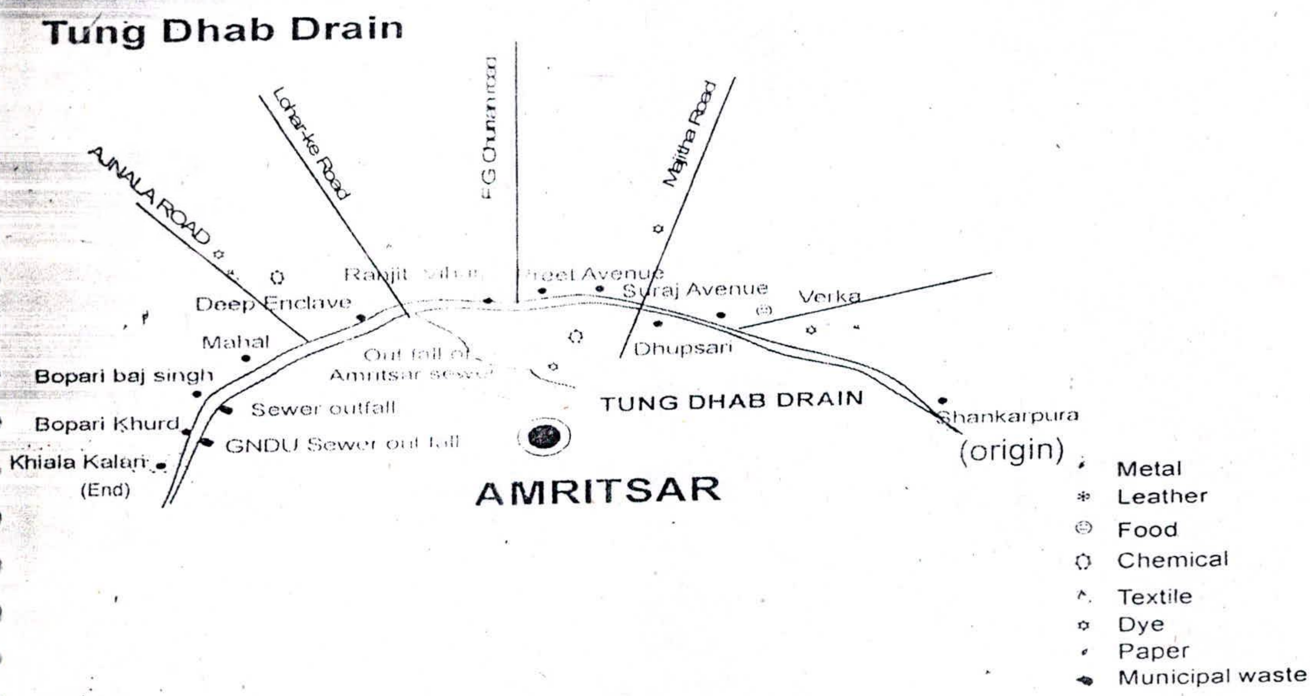
Sample	Village	Feb Detected	Feb >MPL	March Detected	March >MPL	May Detected	May >MPL	July Detected	July >MPL	October Detected	October >MPL	December Detected	December >MPL
EW	Lahori Mal	Ca,Mg,NH3,P,Fe,Cl,F,Cu,Cd,Cr,Hg,Ni,Se,As,COD,BOD,Dimethoate,Heptachlor, α-HCH	Mg,COD,BOD,F,Hg,Dimethoate,Heptachlor	Cd,Cr,Hg,Pb,As,COD,BOD,Ca,Fe,Mg,NH3,P,Cl,F,Se	Mg,COD,BOD,F,Hg	Cr,Hg,Pb,Ni,As,COD,BOD,Ca,Mg,NH3,P,Cl,F,Heptachlor,4,4-DDT, β-HCH	Mg,COD,BOD,F,Hg, β-Endo,Heptachlor	Cu,Cd,Cr,Hg,As,COD,BOD,Ca,Mg,NH3,P,Cl,F	Mg,COD,BOD,F,Hg	Cd,Cr,Hg,Ni,Se,COD,BOD,Ca,Fe,Mg,NH3,P,Cl,F,Se,As	Ca,Mg,COD,BOD,F,Hg	Cd,Hg,Cr,Pb,Se,As	Hg
EW	Raja Tal	Ca,Mg,NH3,P,Fe,Cl,F,Cu,Cd,Cr,Hg,Ni,Se,As,COD,BOD,Heptachlor	Mg,Hg,Dimethoate,Heptachlor	Cu,Cd,Cr,Hg,Ni,Se,As,COD,BOD,Ca,Fe,Mg,NH3,P,Cl,F	Mg	Cu,Cd,Hg,Se,As,COD,BOD,Ca,Mg,NH3,P,Cl,F,4,4-DDT,α-HCH,γ-HCH, β-HCH, β-Endo	Hg, β-Endo	Hg,Pb,Ni,As,COD,BOD,Ca,Mg,NH3,P,Cl,F		Cu,Cd,Hg,Ni,Se,As,COD,BOD,Ca,Mg,NH3,P,Cl,F,Se,As, β-Endo,Dimethoate,Malathion,γ-HCH	Mg,Hg	Cr,Hg,Pb,Se,As	H
EW	Bhoma	Ca,Mg,NH3,P,Fe,Cl,F,Cu,Cd,Cr,Hg,Ni,Se,As,COD,BOD,β-Endo,Heptachlor,-HCH,γ-HCH	Mg,F,Hg,β-Endo,Heptachlor,Chlorpyriphos	Cd,Cr,Hg,Pb,As,COD,BOD,Ca,Mg,NH3,P,Cl,F,Se	Ca,F,As,Hg	Hg,Pb,Se,As,COD,BOD,Ca,Mg,NH3,P,Cl,F,Heptachlor,α-HCH, β-Endo	Mg,F,Hg, β-Endo,Heptachlor	Cu,Pb,As,COD,BOD,Ca,Mg,NH3,P,Cl,F	F	Cd,Cr,Hg,Pb,Ni,Se,As,COD,BOD,Ca,Mg,NH3,P,Cl,F,Se,As	Ca,Mg,F	Cd,Cr,Hg,As,Se	Hg
GW	Lahori Mal	Ca,Mg,NH3,P,Cl,F,Cu,Cd,Cr,Hg,Ni,Se,As,Heptachlor,α-HCH	Mg,F	Cd,Cr,Hg,Pb,Se,As,Ca,Mg,NH3,P, [illegible] Cl,F	Mg,F,Hg	Cd,Cr,Hg,As,Ca,Mg,NH3,P,Cl,F,Heptachlor,α- [illegible] 4-DDT,α-HCH,γ-HCH, β-Endo	Ca,Mg,F,Hg, β-Endo,He [illegible]	Cu,Hg,Pb,Ca,Mg,NH3,P,Cl,F [illegible] NH3,P,Cl,F	Ca,Mg,F,Hg [illegible] Hg,Heptachlor	Hg,Ni,Pb,Ca,Mg,NH3,Cl,F,Se,As [illegible] Mg,NH3,P,Cl,F,Se,As,Heptachlor,α-HCH,β-Endo,Malathion,,γ-HCH,Heptachlor,Phospmidan	Ca,Mg,F,Hg [illegible] g, β-Endo,Chlorpyriphos	Cu,Hg,As,Se	Hg
GW	Bhoma	Ca,Mg,NH3,P,Cl,F,Cu,Cd,Cr,Hg,Ni,Se,As, β-Endo,Heptachlor	Ca,Mg,F,Hg, β-Endo	Cd,Cr,Hg,As,Ca,Mg,Cl,F,As,Se	Ca,Mg,F,Cd,Hg	Cd,Cr,Hg,Pb,As,Ca,Mg,NH3,P,Cl,F,Heptachlor,4,4-DDT,α-HCH	Ca,Mg,F,Hg	Cd,Cr,Hg,Pb,Se,As,Ca,Mg,NH3,P,Cl,F	Ca,Mg,F,Hg	Cd,Cr,Hg,Pb,Ni,Se,Ca,Mg,Cl,F,Se,As	Ca,Mg,F,Hg,Ni	Cu,Hg,Se,As	Hg
SW	Lahori Mal	Ca,Mg,NH3,P,Cl,F,Cu,Cd,Cr,Hg,Ni,Se,As,Heptachlor,α-HCH	F,Hg	Cd,Cr,Hg,Pb,Se,As,Ca,Mg,NH3,Cl,F	Mg,F,Cr,Hg	Cu,Cr,Hg,Ni,Se,As,Ca,Mg,NH3,P,Cl,F,Heptachlor,α-HCH	Ca,Mg,F	Cd,Cr,Hg,Pb,Se,As,Ca,Mg,NH3,P,Cl,F	Ca,Mg,F,Hg	Cu,Cd,Hg,Pb,Ni,Se,Ca,Mg,Cl,F,Se,As,β-Endo,Malathion,γ-HCH	Ca,Mg,F,Cd,Ni	Cu,Hg,Se,As	
EW	Lahori Mal	Ca,Mg,NH3,P,Fe,Cl,F,Cu,Cd,Cr,Hg,Ni,Se,As,COD,BOD,Dimethoate,Heptachlor,α-HCH	Mg,COD,BOD,F,Hg,Dimethoate,Heptachlor	Cd,Cr,Hg,Pb,As,COD,BOD,Ca,Fe,Mg,NH3,P,Cl,F,Se	Mg,COD,BOD,F,Hg	Cr,Hg,Pb,Ni,As,COD,BOD,Ca,Mg,NH3,P,Cl,F,Heptachlor,4,4-DDT, β-HCH	Mg,COD,BOD,F,Hg, β-Endo,Heptachlor	Cu,Cd,Cr,Hg,As,COD,BOD,Ca,Mg,NH3,P,Cl,F	Mg,COD,BOD,F,Hg	Cd,Cr,Hg,Ni,Se,COD,BOD,Ca,Fe,Mg,NH3,P,Cl,F,Se,As		Cd,Hg,Cr,Pb,Se,As	Hg

6.5 Tung Dhab Drain

The study revealed that concentration of Cadmium, Chromium, Lead, Selenium, BOD and COD was observed to be maximum in midstream area. Concentration of Cadmium, Chromium, Lead was observed maximum which could be because of paper mills, food industries, dying textile and metal alloy industries in the near by areas. BOD and COD was observed to maximum may be because Tung Dhab drain mid stream receives outfall of sewers and effluent of verka milk plant and also municipal waste of Amritsar city.

Concentration of Cadmium and Mercury was observed to be more than MPL may be because of dying, pharmaceutical health aid near by Tung Dhab drain. Domestic effluent of military Cantt. and Guru Nanak Dev University also falls directly into Tung Dhab drain. Industrial area, which includes 126 industries, includes 81 dying houses, 2 vanaspati, 5 pulp and paper mills and 31 pickup and electroplating units, 3 dairy units, 1 distillery and one chemical industry. Out of 126 industries, 34 discharges their waste water directly into Tung Dhab drain which ultimately falls into Hudiara Nallah.

Figure 16: Mapping of main industries along Tung Dhab Drain



The village wise laboratory parameters in water along Tung Dhab drain is shown in Table-51.

- Mahal village had more than permissible concentration of Mercury, Dimethoate in effluent water while it recorded concentration of α–Endosulphan and Malathion more than permissible limits in ground water.
- Effluent water of Boparai Baj Singh has higher concentration of α–HCH, Heptachlor, Dimethoate, Nickel, Selenium, Arsenic and hardness. Its tap (tap) water has higher Alkalinity, δ-HCH, Aldrin, Chromium and Lead concentration and its ground water has higher Cadmium, 4,4-DDT.
- Effluent water of Shankarpura has higher concentration of β–Endosulphan, β-HCH and Chlorpyriphos and its ground water has higher concentration of γ–HCH.

Table – 51: Village-wise laboratory parameters in water samples along Tung Dhab

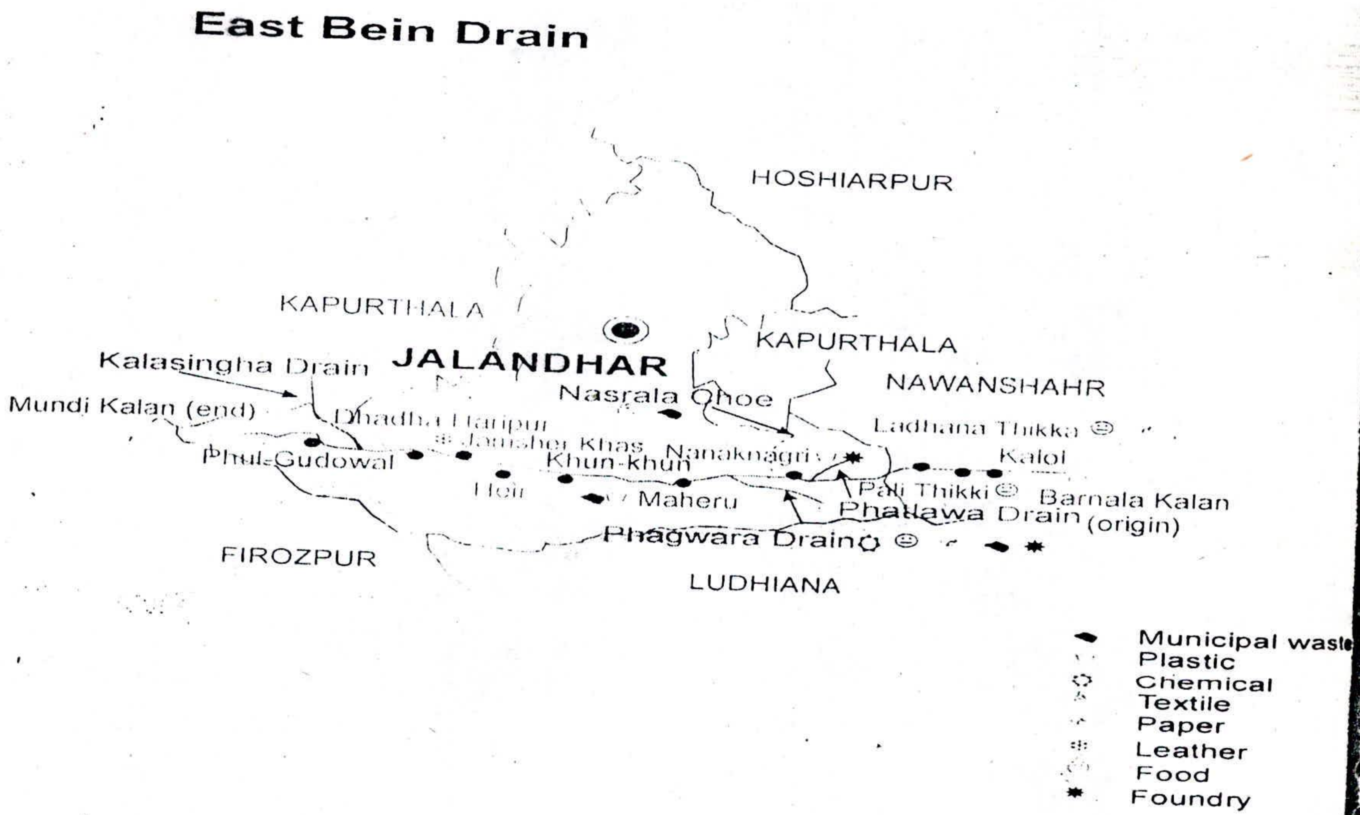
Sample	Village	Feb		March		May		July		October		December	
		Detected	>MPL	Detected	>MPL	Detected	>MPL	Detected	>MPL	Detected	>MPL	Detected	>MPL
EW	Shankarpura	Ca,Mg,NH_3,P,Cl,F, Cu,Cd,Cr,Hg,Ni,Se, As,COD,BOD,Heptachlor, β-HCH,α-HCH	Mg,F,Hg,Chlorpyriphos	Cd,Cr,Hg,Pb,As, COD,BOD,Ca,Mg,NH_3,P,Cl,F,Se, β-HCH,Heptachlor,4,4-DDT,γ-HCH	Mg,F,Hg	Cr,Se,As,COD,BOD,Ca,Mg,NH_3,P,Cl,F,α-HCH, β-Endo	F, β-Endo	Cu,Cd,Cr,Pb,As,COD,BOD,Ca,Mg,NH_3,P,Cl,F	Mg,F	Cu,Cr,Cd,Hg,Ni,Pb,COD,BOD,Ca,Mg,NH_3,P,Cl,F,Se,As	Ca,Mg,F,Hg	Cu,Hg,As,Se	Hg
EW	Mahal	Ca,Mg,NH_3,P,RCl,Fe,Cl,F,Cu,Cd,Cr,Hg,Ni,Se,As,COD,BOD,Heptachlor	Ca,Mg,COD,BOD,F,Hg,Dimethoate	Cd,Cr,Hg,Pb,As,COD,BOD,Fe,Ca,Mg,NH_3,P,Cl,F,Se	Ca,Mg,COD,BOD,F,Hg	Hg,Se,COD,BOD,Ca,Mg,NH_3,P,Cl,F	Ca,Mg,COD,BOD,F,Hg	Cd,Cr,Hg,PB,Se,As,COD,BOD,Ca,Mg,NH_3,P,Cl,F	Ca,Mg,Fe,COD,BOD,F,Hg,Heptachlor	Cu,Cd,Hg,Pb,Ni,Se,As,RCl,COD,BOD,Ca,Fe,Mg,NH_3,P,Cl,F,Se,As,β-Endo,Malathion,α-HCH,Aldrin,Heptachlor	Ca,Mg,COD,BOD,F,Hg	Cd,Hg,Pb,Se,As	
EW	Boparai B Singh	Ca,Mg,NH_3,P,Fe,Cl,F,Cu,Cd,Cr,Hg,Ni,Se,As,COD,BOD, β-Endo,Heptachlor	Ca,Mg,COD,BOD,F,Hg,Dimethoate	Cu,Cr,Ni,As,COD,BOD,Fe,Ca,Mg,NH_3,P,Cl,F,Se	Mg,COD,F	Cr,Hg,Pb,Ni,Se,As,COD,BOD,Ca,Mg,NH_3,P,Cl,F,Heptachlor,α-HCH	Ca,Mg,COD,BOD,F,Hg,Heptachlor	Hg,Pb,COD,BOD,Ca,Mg,NH_3,P,Cl,F	Ca,Mg,F,Hg	Cd,Cr,Hg,Ni,Se,As,COD,BOD,Ca,Fe,Mg,NH_3,P,Cl,F,Se,As	Ca,Mg,COD,BOD,F,Hg β-Endo	Hg,Pb,Se,As	
GW	Mahal(	Ca,Mg,NH_3,P,Fe,Cl,F,Cu,Cd,Cr,Hg,Ni,Se,As, α-Endo,α-HCH,δ-HCH	Mg,F,Hg,α-Endo	Cd,Cr,Hg,Se,As,Ca,Mg,NH_3,P,Cl,F	Mg,F,Hg	Cd,CR,Hg,Pb,Se,As,Ca,Mg,NH_3,P,Cl,F,Heptachlor,4,4-DDT,α-HCH	Ca,Mg,F,Hg,Heptachlor	Cu,Cr,Hg,Pb,Ca,Mg,NH_3,P,Cl,F	Ca,F,Hg	Cd,Hg,Pb,Ni,Se,Ca,Mg,NH_3,P,Cl,F,Se,As,α-HCH,Malathion,Phospmidan	Ca,Mg,F,Hg,Chlorpyriphos	Cu,Hg,Pb,Se,As	Hg
GW	Boparai B Singh	Ca,Mg,NH_3,P,Fe,Cl,F,Cu,Cd,Cr,Hg,Ni,Se,As,Heptachlor,α-HCH	Mg,F,Hg	Cd,Cr,Hg,Ca,Mg,NH_3,P,Cl,F,As,Se	Mg,F,Hg	Cd,Cr,Hg,Pb,As,Ca,Mg,NH_3,P,Cl,F,Heptachlor,4,4-DDT,α-HCH,δ-HCH, β-Endo	Mg,F,Hg, β-Endo	Cd,Cr,Pb,Hg,As,Ca,Mg,NH_3,P,Cl,F	F,Hg	Cu,Cr,Hg,Ni,Pb,Se,As,Ca,Mg,NH_3,P,Cl,F,Se,As	Mg,F,Hg	Cu,Hg,Pb,Se,As	Hg
GW	Shankarpura	Ca,Mg,NH_3,P,Fe,Cl,F,Cu,Cd,Cr,Hg,Ni,Se,As, β-Endo,Heptachlor,γ-HCH,α-HCH	Mg,F,Hg	Cd,Hg,Pb,Se,As,Ca,Mg,NH_3,P,Cl,F	Mg,F,Hg	Cr,Pb,Se,As,Ca,Mg,NH_3,P,Cl,F,Heptachlor,α-HCH,γ-HCH	Ca,Mg,F	Cu,Cr,Hg,Pb,Se,Ca,Mg,NH_3,P,Cl,F	F,Cu,Hg	Cd,Hg,Ni,Se,Ca,Mg,NH_3,P,Cl,F,Se,As	Ca,F,Hg	Cu,Cr,Hg,Se,As	Hg
SW	Boparai B Singh	Ca,Mg,NH_3,P,Fe,Cl,F,Cu,Cd,Cr,Hg,Ni,Se,As,Heptachlor,α-HCH	Mg,F,Hg,Heptachlor	Cd,Cr,Hg,Pb,Ca,Mg,Cl,F,As,Se	F,Cr,Hg,Pb	Cd,Cr,Hg,Pb,As,Ca,Mg,NH_3,P,Cl,F,Heptachlor,α-HCH,δ-HCH, β-Endo	TA,Mg,F,Hg, β-Endo	Cd,Cr,Hg,PB,Se,As,Ca,Mg,NH_3,P,Cl,F	TA,Mg,F,Hg	Cr,Hg,Ni,Pb,Se,As,Ca,Mg,NH_3,P,Cl,F,Se,As, β-Endo,α-HCH,δ-HCH,Malathion,Aldrin,4,4-DDT,Phospmidan	Mg,F,Hg,Aldrin	Hg,Pb,Se,As	Hg
EW	Shankarpura	Ca,Mg,NH_3,P,Cl,F, Cu,Cd,Cr,Hg,Ni,Se, As,COD,BOD,Heptachlor, β-HCH,α-HCH	Mg,F,Hg,Chlorpyriphos	Cd,Cr,Hg,Pb,As, COD,BOD,Ca,Mg,NH_3,P,Cl,F,Se, β-HCH,Heptachlor,4,4-DDT,γ-HCH	Mg,F,Hg	Cr,Se,As,COD,BOD,Ca,Mg,NH_3,P,Cl,F,α-HCH, β-Endo	F, β-Endo	Cu,Cd,Cr,Pb,As,COD,BOD,Ca,Mg,NH_3,P,Cl,F	Mg,F	Cu,Cr,Cd,Hg,Ni,Pb,COD,BOD,Ca,Mg,NH_3,P,Cl,F,Se,As	Ca,Mg,F,Hg	Cu,Hg,As,Se	Hg

6.5 East Bein Drain

The study revealed that concentration of Cadmium, Copper, Selenium, Arsenic, COD and BOD (0.003, 0.03, 0.004, 0.004, 0.01, 339, 272) mg/L respectively were observed to be higher in mid stream area of East Bein drain i.e. Khun Khun village.

Nickel is source of foundry, foodstuff etc. Arsenic and Selenium are naturally present in certain soils and grains, cereals and meat respectively. Selenium is present in phosphate fertilizer. Chemical industries are present in Phagwara. Cadmium and Chromium concentration was found to be maximum in midstream area may be because of presence of spinning mill in Nasrala Choe. Also Arsenic used as insecticide applications on farmland. Excessive fertilizers and pesticides reach water systems through tap runoffs. Major crops grown in Hoshiarpur are rice, wheat, maize, sugarcane and sunflower.

Figure 17: Mapping of main industries along East Bein Drain



Maximum concentration of BOD and COD was observed to be maximum in midstream drains can be because of East Bein received municipal waste of Nawanshahar. Pathlawa drain was one of the major sources of pollution in East Bein. This carried the effluent of M/s Ankit Paper, Sarla Khurd. Phagwara drain besides carrying domestic effluent from Phagwara besides carrying industrial effluent of four major industries at Phagwara viz. M/s Oswal Agro, M/s Surjit Starch, M/s JCT and M/s Punjab bone mill. Discharge of Phagwara drain is received by East Bein drain.

Concentration of Lead and Chromium was observed to be maximum in downstream drain might be because of presence of tanning and leather industries present in Jamsher khas. Effluent from Kala Singha drain was also received by East Bein drain. Concentration of Mercury, Cadmium, Chromium, Lead was observed to be above MPL might be because of food, plastic, paper, tanning, spinning and leather industries present in East Bein drain.

The village wise laboratory parameters in water along East Bein drain is shown in Table-52.

- Mercury, fluoride, calcium and magnesium were found to be more than permissible limit in effluent water of all the villages along East Bein drain.
- Effluent water of Khun-Khun has greater than MPL of Cadmium, Nickel, Selenium, Arsenic, α-Endosulphan, Malathion, Chlorpyriphos and Alkalinity and its ground water has higher concentration of β- Endosulphan, β-HCH, δ-HCH and Aldrin .
- Effluent water of Barnala Kalan has higher concentration of α–HCH, Heptachlor, 4,4-DDT, DDE and Mercury.
- Ground water of Phul Goddowal has higher concentration of Alkalinity, hardness and Copper.

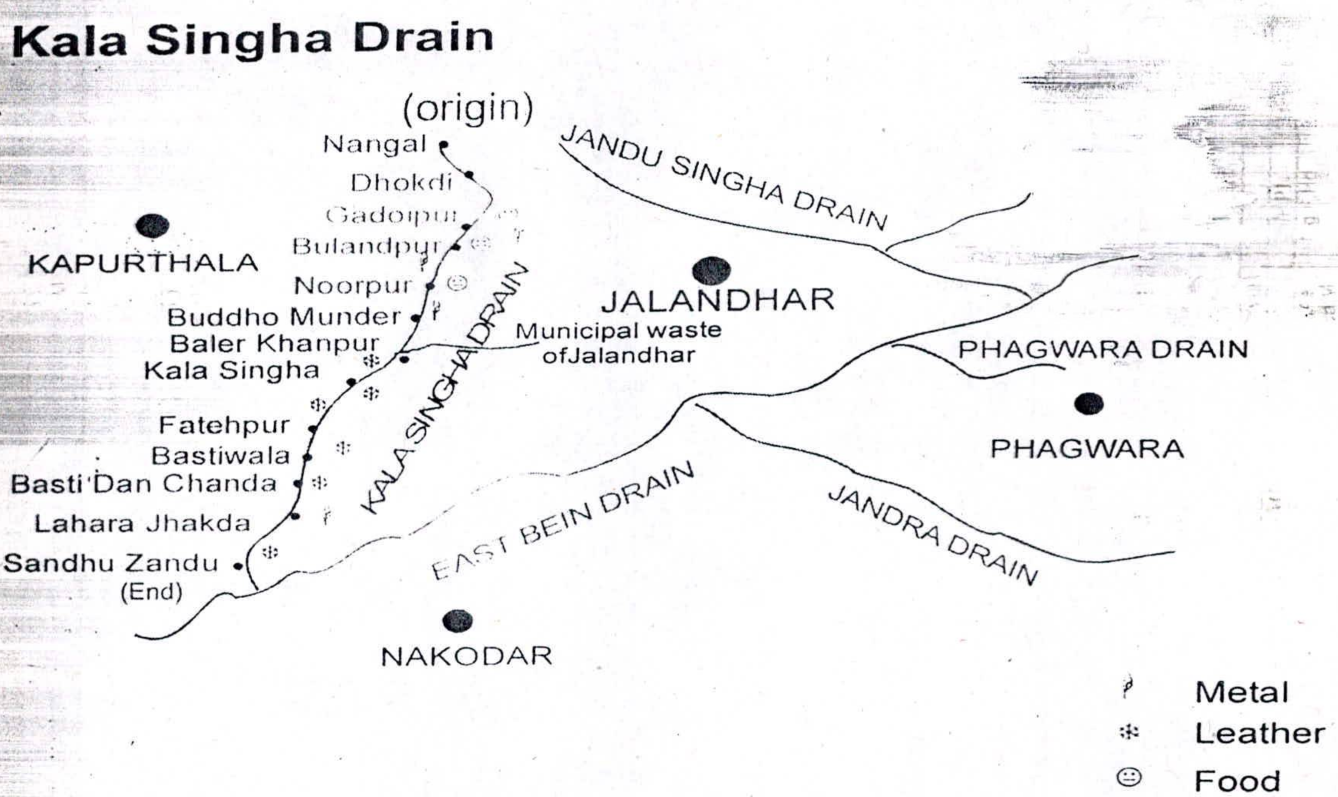
Table – 52: Village-wise laboratory parameters in water samples along East Bein

Sample	Village	Feb		March		May		July		October		December	
		Detected	>MPL	Detected	>MPL	Detected	>MPL	Detected	>MPL	Detected	>MPL	Detected	>MPL
EW	Khun Khun	Ca,Mg,NH3,P,Fe,RCl,Cl,F,Cu,Cd,Cr,Hg,Ni,Se,As,COD,BOD, α-Endo,β-Endo,α-HCH,Heptachlor	Mg,F,Hg,α-Endo, β-Endo,Heptachlor	Cu,Cr,Hg,Ni,Se,As,COD,BOD,Fe,Ca,Mg,NH3,P,Cl,F	Mg,F	Cu,Hg,Ni,Se,As,COD,BOD,Ca,Mg,NH3,P,Cl,F	Mg,F,Hg	Cd,Cr,Hg,Pb,COD,BOD,Ca,Mg,NH3,P,Cl,F	Ca,F,Hg	Cu,Cd,Cr,Hg,Pb,Ni,COD,BOD,Ca,Fe,Mg,NH3,P,Cl,F,Se,As,β-Endo,Malathion,Phospmidan	Ca,F,Hg β-Endo,Chlorpyriphos	Cu,Cd,Cr,Hg,Pb,Se,As	Hg
EW	Phul Guddowal	Ca,Mg,NH3,P,Fe,Cl,F,Cu,Cd,Cr,Hg,Ni,Se,As,COD,BOD,β-Endo,Heptachlor,α-HCH	Mg,F,Hg	Cu,Cd,Cr,Hg,Pb,Se,As,COD,BOD,Fe,Ca,Mg,NH3,P,Cl,F	TA,Mg,F,Cr,Hg	Cr,Hg,Ni,Se,As,COD,BOD,Ca,Mg,NH3,P,Cl,F,α-HCH	Mg,F,Hg	Cu,Hg,Pb,As,COD,BOD,Ca,Mg,NH3,P,Cl,F	Ca,F,Hg	Cu,Cr,Hg,Pb,Ni,COD,BOD,Ca,Mg,NH3,P,Cl,F,Se,As	Ca,Mg,F,Hg	Cr,Hg,Pb,Se,As	Hg
EW	Barnala Kalan	Ca,Mg,NH3,P,Cl,F,Cu,Cd,Cr,Hg,Ni,Se,As,COD,BOD,Heptachlor	Ca,Mg,F,Hg	Cu,Cr,Hg,Ni,Se,As,COD,BOD,Ca,Mg,NH3,P,Cl,F, β-Endo,Malathion,DDE,α-HCH,δ-HCH	Ca,Mg,F,Hg, β-Endo,Heptachlor	Cd,Hg,Pb,COD,BOD,Ca,Mg,NH3,P,Cl,F	TA,Ca,Mg,F,Hg	Cd,Cr,Hg,As,COD,BOD,Ca,Mg,NH3,P,Cl,F	Mg,F,Hg	Cd,Cr,Hg,Ni,Se,COD,BOD,Ca,Mg,NH3,P,Cl,F,Se,As	Ca,Mg,F	Cu,Cd,Hg,Se,As	
GW	Khun Khun	Ca,Mg,NH3,P,Cl,F,Cu,Cd,Cr,Hg,Ni,Se,As,Heptachlor, β-HCH	Mg,F	Cd,Cr,Hg,Se,Ca,Mg,NH3,Cl,F,As,Heptachlor,4,4-DDT	Ca,Mg,F,Hg	Cd,Cr,Hg,Pb,Se,As,Ca,Mg,NH3,P,Cl,F,Aldrin,α-HCH,δ-HCH	Ca,Mg,F,Hg	Hg,Pb,Se,As,Ca,Mg,NH3,P,Cl,F	TA,Ca,F,Hg,Heptachlor	Cd,Hg,Ni,Se,Ca,Mg,NH3,P,Cl,F,Se,As,β-Endo,α-HCH,Malathion,Aldrin,Heptachlor,4,4-DDT,Phospmidan	Mg,F,Ni,Hg,Aldrin, β-Endo,Chlorpyriphos	Cu,Hg,Se,As	
GW	Phul guddowal	Ca,Mg,,P,Fe,Cl,F,Cu,Cd,Cr,Hg,Ni,Se,As, β-Endo,Heptachlor,α-HCH,δ-HCH	Mg,Fe,F,Cu,Ni,Hg, β-Endo	Cd,Cr,Hg,Se,As,Ca,Mg,NH3,Cl,F	Ca,Mg,F,Hg	Cd,Cr,Hg,As,Ca,Mg,NH3,P,Cl,F,Aldrin,Heptachlor,4,4-DDT,α-HCH,δ-HCH	TA,TH,Ca,Mg,F,Hg	Cr,Hg,Ni,Se,Ca,Mg,NH3,P,Cl,F	TA,Ca,Mg,F,Hg	Cd,Cr,Hg,Se,Ni,Ca,Mg,P,Cl,F,Se,As	Ca,Mg,F,Hg	Cu,Cd,Cr,Hg,Pb,Se,As	Cu,Hg
GW	Barnala Kalan	Ca,Mg,NH3,P,Cl,F,Cu,Cd,Cr,Hg,Ni,Se,As,Heptachlor	Mg,F,Hg	Cd,Cr,Hg,Se,As,Ca,Mg,NH3,P,Cl,F,α-HCH	Mg,F,Hg	Hg,As,Ca,Mg,NH3,P,Cl,F	F	Cd,Cr,Hg,Se,As,Ca,Mg,NH3,P,Cl,F	Mg,F,Hg	Cd,Cr,Hg,Ni,Se,Ca,Mg,NH3,Cl,F,Se,As,β-Endo,Malathion	Ca,Mg,F,Ni,Hg	Cu,Hg,Se,As	Hg
SW	Barnala Kalan	Ca,Mg,NH3,P,Cl,F,Cu,Cd,Cr,Hg,Ni,Se,As,Heptachlor	Mg,F,Hg	Cd,Cr,Hg,Ca,Mg,P,Cl,F,As,Se, β-Endo	Mg,F,Hg, β-Endo,Heptachlor	Cd,Cr,Hg,Pb,As,Ca,Mg,NH3,P,Cl,F	Ca,Mg,F,Hg	Cd,Cr,Hg,Pb,As,Ca,Mg,NH3,P,Cl,F	Ca,Mg,F,Hg	Cd,CR,Hg,Ni,Se,Ca,Mg,NH3,P,Cl,F,Se,As	Ca,Mg,F,Ni,Hg	Cu,Hg,Se,As	
EW	Khun Khun	Ca,Mg,NH3,P,Fe,RCl,Cl,F,Cu,Cd,Cr,Hg,Ni,Se,As,COD,BOD, α-Endo,β-Endo,α-HCH,Heptachlor	Mg,F,Hg,α-Endo, β-Endo,Heptachlor	Cu,Cr,Hg,Ni,Se,As,COD,BOD,Fe,Ca,Mg,NH3,P,Cl,F	Mg,F	Cu,Hg,Ni,Se,As,COD,BOD,Ca,Mg,NH3,P,Cl,F	Mg,F,Hg	Cd,Cr,Hg,Pb,COD,BOD,Ca,Mg,NH3,P,Cl,F	Ca,F,Hg	Cu,Cd,Cr,Hg,Pb,Ni,COD,BOD,Ca,Fe,Mg,NH3,P,Cl,F,Se,As,β-Endo,Malathion,Phospmidan	Ca,F,Hg β-Endo,Chlorpyriphos	Cu,Cd,Cr,Hg,Pb,Se,As	Hg

6.5 Kala Singha Drain

The study revealed that concentration of Cadmium, Chromium, Mercury, and Lead was observed to be maximum in its midstream area may be because of tanning, forging metal and food industries present near by areas which discharge their effluent into the Kala Singha drain. Concentration of BOD, COD was found to maximum in midstream area because of Jalandhar municipal waste which falls into East Bein before mid point area and also because of dairy effluent which falls into East Bein drain.

Figure 18: Mapping of main industries along Kala Singha Drain



The village wise laboratory parameters in water along Kala Singha drain is shown in Table-53

- Mercury, calcium, magnesium and fluoride were found to be more than permissible limit in effluent water samples of all villages. Mercury and fluoride were observed to be more than MPL in ground and tap water samples of these villages too.

- Effluent water of Fatehpur has higher concentration of Hardness and β-Endosulphan and its ground water has higher concentration of Arsenic and Mercury .
- Effluent water of Kala Singha has higher concentration of α –HCH, 4,4-DDT, Chlorpyriphos, Nickel and Selenium.
- Effluent water of Nangal has higher concentration of Copper, Alkalinity and its ground water has higher concentration of Aldrin and Heptachlor.

Table – 53: Village-wise laboratory parameters in water samples along Kala Singha drain

Sample	Village	Feb		March		May		July		October		December	
		Detected	>MPL	Detected	>MPL	Detected	>MPL	Detected	>MPL	Detected	>MPL	Detected	>MPL
EW	Nangal(J)	Ca,Mg,NH3,P,Cl,F, Cu,Cd,Cr,Hg,Ni,Se, As, COD,BOD,Heptachlor	Mg,FHg	Cr,Hg,Ni,Se,As,COD,BOD,Ca,Mg, NH3,P,Cl,F	Mg,F	Hg,As,COD,BOD,Ca,Mg,NH3,P,Cl,F	Mg,F,Hg	Cd,CR,Hg, Pb,As,COD,3OD,Ca, Mg,NH3,P, Cl,F	TA,Ca, Mg,F,Hg	Cu,Cr,Ni,COD,BOD,Ca,Mg,NH3, P,Cl,F,Se, As	Ca,Mg, F	Cu,Hg,Se, As	
EW	Kala Singha(J)	Ca,Mg,NH3,P,Fe,Cl, RCl,F,Cu,Cd,Cr,Hg, Ni,Se,As,COD,BOD, Heptachlor	Mg,COD,BOD,F Hg	Cu,Cr,Hg,Ni,Se,As,COD,BOD,Fe,Ca,Mg,NH3,P,Cl,F	TA,Mg COD,BOD,F,Hg	Cd,Cr,Pb,Se,COD,BOD,Ca,Mg,NH3,P,Cl,F, Heptachlor,α-HCH	Mg,COD,BOD, F,Hg,Heptachlor	Cd,Cr,Hg, Pb,COD,BOD,Ca,Mg, NH3,P,Cl, F	TA,Mg, COD,BOD,F,Hg	Cd,Cr,Hg, Pb,Ni,SE,As,COD,BOD,Ca,Fe,Mg,NH3,P,Cl,F,Se,As, β-Endo,Phosphomidan	Ca,Mg, COD,BOD,F,Hg, β-Endo,Chlorpyriphos	Cr,Hg,Se, As	
EW	Fatehpur(J)	Ca,Mg,NH3,P,Fe,Cl, F,Cu,Cd,Cr,Hg,Ni,Se,As,COD,BOD, β-Endo,Heptachlor	Mg,F,Hg, β-Endo	Cu,Cr,Hg,Ni,As,COD,BOD,Fe,Ca,Mg,NH3,P,Cl,F,Se	TA,Ca Mg,F,Hg	Cd,Cr,Hg,Ni,As,COD,BOD,Ca,Mg,NH3,P,Cl,F	TA,Ca Mg,F,Hg	Cr,Hg,Pb, Se,As,COD,BOD,Ca, Mg,NH3,P, Cl,F	TA,Ca,F	Cd,Cr,Hg Pb,Ni,Se,COD,BOD,Ca,Fe,Mg,NH3,P,Cl,F, Se,As,β-Endo,α-HCH	Ca,Mg COD,BOD,F,Hg	Hg,Se,As	Hg
GW	Kala Singha(J)	Ca,Mg,P,Fe,Cl,F,Cu,Cd,Cr,Hg,Ni,Se,As, β-Endo,Heptachlor,α-HCH	Ca,F,Hg, β-Endo	Cd,Hg,Pb,As,Ca, Mg,P,Cl,F,Se	Ca,Mg, F,Hg	Cd,CR,Hg,Pb, As,Ca,Mg,NH3,P,Cl,F	Ca,Mg, F,Pb,Hg	Hg,As,Ca, Mg,NH3,P, Cl,F	Ca,Mg, F,Hg	Cd,Cr,Hg, Pb,Ni,Se,Ca,Mg,NH3, Cl,F,Se,As	Ca,F,Hg	Cu,Cd,Hg, Se,As	Cd
GW	Fatehpur(J)	Ca,Mg,NH3,P,Cl,F, Cu,Cd,Cr,Hg,Ni,Se, As, Heptachlor,α-HCH	Mg,F,Hg	Cd,Cr,Hg,Pb,As, Ca,Mg,Cl,F,Se	Mg,F,Hg	Cd,Cr,Hg,As,Ca,Mg,NH3,P,Cl,F	F,Hg	Cr,Ni,Se,As,Ca,Mg,NH3,P,Cl,F	Ca,F	Cd,Cr,Hg, Ni,Se,As,Ca,Mg,P,Cl, F,Se,As	Ca,Mg, F,As,Hg	Cu,Hg,Se, As	
GW	Nangal(J)	Ca,Mg,NH3,P,Fe,Cl, F,Cu,Cd,Cr,Hg,Ni,Se,As,Heptachlor	Mg,F,Hg	Cd,Hg,Pb,As,Ca, Mg,Cl,F,Se, Aldrin,α-HCH	Mg,F,Hg,Heptachlor	Hg,Ni,As,Ca,Mg,NH3,P,Cl,F	Mg,F	Cd,Cr,Hg, Pb,As,Ca, Mg,NH3,P, Cl F	F,Hg	Cu,Cd,Hg, Pb,Ni,Ca, Mg,NH3,Cl,F,Se,As	Ca,Mg, F,Hg	Hg,Se,As	Hg
SW	Kala Singha(J)	Ca,Mg,NH3,P,Cl,F, Cu,Cd,Cr,Hg,Ni,Se, As, β-Endo,Heptachlor,α-HCH	F,Hg, β-Endo,Heptachlor	Cd,Cr,Hg,As,Ca, Mg,P,Cl,F,Se,Heptachlor,4,4-DDT	Mg,F,Hg	Hg,Ca,Mg,NH3,P,Cl,F	Mg,F,Hg	Cd,Cr,Hg, As,Ca,Mg, NH3,P,Cl, F	F,Hg	Hg,Ni,Se,Ca,Mg,NH3, Cl,F,Se,As,β-Endo	F,Hg	Cu,Hg,Se, As	Hg
EW	Nangal(J)	Ca,Mg,NH3,P,Cl,F, Cu,Cd,Cr,Hg,Ni,Se, As, COD,BOD,Heptachlor	Mg,FHg	Cr,Hg,Ni,Se,As,COD,BOD,Ca,Mg, NH3,P,Cl,F	Mg,F	Hg,As,COD,BOD,Ca,Mg,NH3,P,Cl,F	Mg,F,Hg	Cd,CR,Hg, Pb,As,COD,BOD,Ca, Mg,NH3,P, Cl,F	TA,Ca, Mg,F,Hg	Cu,Cr,Ni,COD,BOD,Ca,Mg,NH3, P,Cl,F,Se, As	Ca,Mg, F	Cu,Hg,Se, As	

Discussion

The present study was conducted in the area of five major drains in Punjab to ascertain the effects of effluent pollution on human health and water quality. A total of 5371 and 2018 person were selected by a systematic random sampling from reference and control area respectively and interviewed to elicit information on various morbidities. Samples of tap, ground and effluent water; vegetables; fodder; bovine and human milk; blood; urine and faecal smears were collected from February 2006 to March 2007. Water samples were tested for physical and chemical parameters; concentration of heavy metals and pesticides and levels of organic pollution by estimating BOD and COD values.

Overall distribution of persons in the reference and control area revealed that the study population in two areas was similar in terms of socio-demographic characteristics; smoking and alcohol consumption habits. A higher prevalence of utilization of drain water for irrigation in fields ($p<0.05$) was observed among residents of reference area. Significantly higher proportion of study subjects from reference area had an industry discharging its waste in close proximity to its source of drinking water ($p<0.05$). Statistically significant association for occurrence of gastrointestinal problems, water related vector borne diseases (malaria, dengue), skin, eye and bone problems was observed among persons residing in reference area ($p< 0.005$).

Higher occurrence of skin allergy, gastritis, hypertension, joint pains and respiratory problems has also been reported during an assessment of impact of industrial effluent on human health in Noyyal river basin area in Tamilnadu which is affected by the effluent discharge from dyeing and bleaching factories in Tirupur, a major hosiery center in South India. The city of Ludhiana also has numerous industrial including hosiery units involved in dyeing which discharge their effluent into Buddha drain. Drain wise stratified analysis for morbidities also reaffirm this finding, which shows a significantly higher association of gastrointestinal, skin, eyes, and bone problems among residents of Buddha drain. A similar study conducted in Noyyal river basin in Coimbatore, Erode and Korur districts to study the nature and impact of effluent water pollution on human health among households in 31 villages organized three health camps to perform a primary survey for health status. It was observed from all the three camps that there were symptoms of skin allergy, gastritis and respiratory problems among villagers. On an average, one forth of the villagers attending these camps had one of the symptoms of water borne diseases [1]

A survey of prevalence of general health problems in the present study revealed that hair and fingernail loss was observed to be significantly higher among residents of reference area ($p<0.05$). A case study to observe the environmental pollution of paper and pulp industry with respect to human health problems conducted in Srikakulam (Andhra Pradesh, India) reported higher occurrence of hair loss form hand and fingers and other dermal problems among mill workers and residents of village situated within a radius of half kilometers of mill [2].

Occurrence of mottling of teeth which was observed to be significantly higher in the residents of reference area correlates well with average fluoride level of tap and ground water more than the permissible limit set by WHO [3] High levels of fluoride in the ground water is also validated by WHO analysis which reports that 16.2% samples tested in Punjab had fluoride level in ground water in excess of 1.5mg/l. High fluoride levels were also reported in district Bhatinda (11.7mg/l). Punjab is known as an endemic state for dental and skeletal flourosis.

Another study from Punjab reported fluoride levels in Jalandhar, Amritsar and Ludhiana as 0.55ppm, 0.45ppm, and 0.22ppm respectively. Present study however reported higher average level of fluoride with 60% and 69% samples of ground and tap water respectively having fluoride level more than 1.5mg/l. No significant difference in fluoride levels of ground water was observed between areas affected by effluent pollution and those not affected. These high fluoride levels are due to excessive tapping of ground water for irrigation purpose and other sources, which leads to leaching of fluoride in earth's surface into the water.

All the systemic and general health problems were observed to be higher among females. Eye, bone, kidney problems along with hair/nail loss and numbness of fingers were observed to be significantly higher among the females ($p<0.05$). Men have larger average lean body mass and higher water content, resulting in higher distribution volume for water-soluble substances, thus more dilution. Women on the contrary have larger relative fat mass, thus larger distribution volume for fat-soluble substances. Most environmental chemicals are lipophilic. Many of them pass readily through skin/dermal route which is important for formal and informal occupational exposures, as well as exposures from cleaning agents, cosmetics and other products applied to skin [5]. Another study observed that women are more vulnerable to cadmium and lead. Cadmium accumulates in the renal area and in the bone, causing renal dysfunction and osteoporosis [6,7]

Besides fluoride, ground and tap water in the study area had higher than permissible limit of pH, calcium and magnesium with no significant difference between reference and control areas.

The present study revealed higher than permissible levels of BOD and COD in effluent water from reference area. Similar results have also been reported by another study, which found the BOD level in Buddha drain water in the range of 233 to 960 mg/L. Four major industries in Ludhiana have been reported to be discharging their wastes into the Buddha drain without any effective treatment. This high level of BOD and COD indicate indiscriminate discharge of domestic sewage, industrial waste and diary discharges into the drain without any treatment [8]. Another study conducted in the Buddha drain area to assess the quality of ground water for domestic purpose along Buddha drain in Ludhiana city has also reported higher than permissible COD level [9]. This is also an indicator that organic pollution in the form of high BOD and COD level of effluent drains is contaminating the adjoining ground water sources. The influence is more towards right hand side than left hand side [9].

Mercury levels were found to be more than permissible limit in over 80% samples of ground water from both reference and control areas. Mean concentration of mercury was also observed to be higher than maximum permissible limits in both areas. Mercury primarily affects the central nervous system causing tremors, emotional lability, insomnia, memory loss, headache and polyneuropathy [10]. Study population in reference area had significantly occurrence of symptoms like headache, numbness of finger (paraesthesias). Other toxicities due to excessive mercury on human health include gastrointestinal symptoms like nausea, vomiting, diarrhea, renal toxicity, redness and burning of eyes and conjunctiva. Similar morbidities were observed among the study population in the present study.

Other studies have also observed neurotoxicity [11-12], gastrointestinal symptoms [13], renal toxicity [13-14], irritation and sensitization [15-16] due to excessive exposure to mercury. Sources of mercury include broken thermometer and BP apparatus, electrical switches, fluorescent light bulbs, batteries and paints. It is also used as a fungicide, insecticide and wood preservative. The city of Ludhiana where the Buddha drain passes has 400 electroplating units. Amritsar and Jalandhar also have units involved in electroplating, manufacturing switches and bulbs and also metal industry. Waste from these, together with broken thermometers and BP apparatus from hospitals and households and broken electric bulbs and tubes could be culpable causes of heavy mercury contamination of ground and tap water.

Besides Mercury being more than permissible limit, water samples also detected heavy metals such as Cadmium, Chromium, Copper and Lead. Cadmium compounds are currently being used in re- chargeable Nickel- Cadmium batteries. These products are rarely re-cycled, and are often dumped together with household waste. Recent data indicate that adverse health effects of cadmium exposure may occur at lower exposure levels then previously anticipated, primarily in the form of kidney damage but possibly also bone effects and fracture. Many individuals in Europe already exceed these exposure levels and the margin is very narrow for large group [17]. Although Arsenic was detected in 70% of effluent, 57.1% ground and 50% of tap water samples, however its levels were within maximum permissible limits (0.01 mg/L).

A dietary survey on adult men (20-40 years) belonging to low-income groups from sewage and tube well irrigated areas in Ludhiana city near Buddha drain reveals that intake of lead, cadmium and nickel by men in sewage irrigated area was 3-6 times than that in tube well irrigated area. Dietary lead intake was 116% of the maximum tolerable limits while cadmium intake being four times the maximum permissible limit. Mercury concentration was not analyzed by this study [18]. Other studies have also noted deleterious effect of heavy metal contamination of Buddha drain water on aquatic life and enhanced human consumption of heavy metals in Ludhiana and Jalandhar [19-20]. Metal industries and electroplating units, which are in abundance in the study towns, are noteworthy incriminating sources of heavy metal pollution. Besides these, industries involved in manufacture of batteries could be responsible for heavy metal pollution of water bodies.

The potential adverse impact of the chemicals and heavy metals depends on many factors, including the level and duration of exposure, the potency of chemical, the mechanism of action, and interactions among those chemical and heavy metals [21]. This makes it difficult to identify the relative contributions of individual substances to the physiologic alterations and to determine the degree of toxicity present in the environment that contains diverse mixtures and various concentrations of substance and pollutants.

Heptachlor, β-Endosulphan and Chloryriphos pesticides were found in concentrations exceeding the maximum residue limit among 22.5%, 21.5% and 16.1% samples of ground and tap water samples. Other pesticides whose concentrations in ground and tap water were observed to be more than the permissible limit in the present study included Aldrin (8.6% samples) and one sample each of Endosulphan and Malathion. Other studies done elsewhere in the country have not detected such high pesticides levels with a study from Jaipur reporting all drinking water samples to be contaminated with various organochlorine pesticide residues of DDT and its metabolites, HCH and its isomer, Heptachlor and its epoxide and Aldrin. However only a few exceeded the permissible limits[25]. Another study, which analyzed organochlorine insecticide residues in drinking and ground water, detected their presence, although below maximum contaminated level prescribed by WHO[26].

A study from Punjab done to assess the water quality of East Bein drain in 1998 reported DDT concentration in the range of 0.8 to 4.42 mg/L in drain water. The concentration of various parameters in the ground water sample was found to be well within the prescribed standards[27].

High pesticide level in ground and tap water enters the human food chain through vegetables grown in such soil. Pesticide contaminated fodder consumed by milch cattle leads to increased secretion of pesticides in milk. Monitoring of human and bovine milk is important from two standpoints. Firstly, pesticides tend to accumulate in the fat and are relatively easy to isolate and measure; and secondly to evaluate their potential risk to infants, who rely solely on mother's milk for a substantial period[28]. Residues of these compounds in human milk have been extensively reported in India and elsewhere.

Two out of five bovine milk samples tested in the present study revealed Chloropyriphos residues in excess of tolerance limit. Dieldrin was found to be in excess of maximum residue limit in one sample. Any one organochlorine or organophosphate or both pesticide residues were detected in all the five samples tested at 0.05 mg/kg (2,4 DDT, Malathion and 4,4 DDT) and 0.005 mg/kg (α-HCH, γ-HCH, δ-HCH, Chlorpyriphos, Dieldrin, β-Endosulphan) detectable limits for respective pesticides. All the fodder samples (10) tested in the present study revealed one or more pesticide residue with Dieldrin being the most commonly detectable pesticide.

A multicentric study to assess the pesticide residue in selected food commodities collected from different states of the country showed that DDT residues were found in about 82% of the 2205 samples of bovine milk collected from 12 states of India. About 37% samples contained DDT residues above the tolerance limit of 0.05 mg/kg (whole milk basis). The proportion of samples with residues above the tolerance limit was maximum in Maharashtra (74%) followed by Gujarat (70%), Andhra Pardesh (57%), Himachal Pradesh (56%) and Punjab (51%)[29].

An assessment of Organochlorine pesticide residue levels in dairy milk and buffalo milk from Jaipur city during 1993-96 revealed that these milk samples were contaminated with DDT, DDD, HCH, heptachlor and Aldrin. Seasonal variation of these pesticides was also reported with maximum residue levels in winter season[30].

Another study conducted in Bhopal, Madhya Pardesh revealed that endosulphan concentration in breast milk exceeded the γ -HCH, chlorpyriphos and malathion concentrations by 3.5, 1.5 and 8.4 fold respectively. Through breast milk, infants consumed 8.6 times more endosulphan and 4.1 times more malathion than the average daily intake level recommended by the World Health Organization[31].Other studies in India have also shown contamination of dairy milk and its products with high residues of persistent organo chlorine insecticides like DDT and HCH[29-31] especially prior to imposition on ban of their use.

A study was conducted in Ludhiana, Punjab from February 1994 to December 2001 to assess status of contamination of milk with pesticide residues, particularly after the imposition of bans on the use of DDT and HCH in agriculture and public health programs (Malaria control). The study results clearly indicated a change in contamination of liquid milk with significant decline in DDT and HCH residues. Lindane residues predominated in liquid milk samples, which was present in 53.3% out of total 92 samples[32].

Health hazards posed by pesticides include acute toxicity manifesting in the form of gastrointestinal effects (nausea, vomiting, and loss of appetite), skin and allergic reactions. Chronic exposure to pesticides leads to delayed neurotoxicity (peripheral neuritis and behavioral changes), carcinogenic and oncogenic diseases, reproductive toxicity (abortion, still birth, neonatal death, congenital birth defects), lung and kidney damage and effect on immune system[33].

Gastrointestinal and skin manifestations were significantly higher in the reference area population of the present study. Although only 5 cases of diagnosed cancer were detected from the reference area as against none in the control area, micronuclei analysis in buccal smears revealed a significantly ($p<0.05$) higher proportion of individuals with micronuclei in reference area (31%) than control area (25%). Mean ground water pesticide concentration were observed to be higher in reference area for eight out of twelve pesticides which were detectable. Similarly tap water showed ten pesticides with higher concentration in reference area.

Micronucleus test of exfoliated cells in epithelial tissue have been used to evaluate the genotoxic effects produced by low doses of carcinogenic substances or carcinogenic mixtures, to which human populations are exposed[34-35]. It detects injuries that survive at least one mitotic cycle as compared to comet assay, which identifies repairable injuries or alkali-label sites[36].

A study done among ten battery renovators (exposed to lead) and ten car painters (exposed to petroleum sub-products) and ten age matched controls for both group respectively revealed significantly higher mean cells with micronuclei among the two exposed groups compared to their respective control groups. There was also variation in individual results on each exposed group which control group was quite homogenous[37]. Tobacco consumption in every form and alcohol has been implicated to be causing DNA damage manifesting in the form of micro nuclei[38]. However present study had two study groups with similar habits of tobacco and alcohol consumption thus strengthening the hypothesis of environmental water pollution in form of pesticides and heavy metals to be causing mutagenic changes among the population. Limited DNA adducts studies has also shown varying degree of mutations in 65% subjects in reference area.

A study conducted among residents of Mahal village situated 0.5 km from the Tung Dhab drain in Amritsar, Punjab has shown statistically significant and higher DNA damage in peripheral blood lymphocytes as detected by comet assay. The study attributed this DNA damage to higher content of heavy metals including Pb, Cd, Ni, Cr and Zn which could have reached the ground water of Mahal village through seepage and lateral movement of water from Tung Dhab drain reported to have high contents of these heavy metals[39]. The present study has also reported higher content of Cd, Cr, Hg, Pb and Se beyond the permissible limits in reference area. Another epidemiological study of cancer cases reported from village of Talwandi Sabo block in district Bhathinda, Punjab observed higher prevalence of cancer cases and cancer related deaths in the area attributable probably to the higher consumption of pesticides, tobacco and alcohol[40].

With tobacco and alcohol consumption remaining low and similar between the two groups, heavy metals and pesticides pollution of ground and tap water appears to be most probable cause for the pre-cancerous cellular activity among study population. A study conducted in Jaipur to determine the association of higher levels of pesticides and breast cancer indicated that organ chlorine pesticides (DDT, DDD, DDE, Dieldrin, Heptachlor and HCH) were found to be significantly high among breast cancer patients irrespective of age, diet and geographic distribution[41].

Other studies have also demonstrated carcinogenic and mutagenic effects of pesticide exposure [42-44]. The difference in micronuclei detected among study population of reference and control area could also be due to higher levels of cadmium, lead and mercury detected in reference area. Cadmium, lead, mercury, arsenic and nickel are heavy metals known to be causing DNA damage leading to mutagenecity[45]. It is difficult to pinpoint one simple cause but is more likely due to an interaction of both heavy metals and pesticides.

Pesticides exposure is known to have reproductive toxicity. Data on reproductive toxicity was collected from 1106 couples where males were associated with spraying of pesticides (OC, OP and carbonates) in cotton fields. Data was also collected from 1020 unexposed couples matched for age and socio-economic status. Analysis of reproductive performance gave the following incidence rates for the former and the latter groups respectively: abortion 26% vs 15%, still birth 8.7% vs 2.6%, neonatal deaths 9.2% vs 2.2% and congenital defects 3% vs 0.1%[46]. A cytogenetic study revealed a significant increase in chromatic breaks and gaps in chromosomes in the peripheral blood in grape garden workers exposed to pesticides[47].

The present study data on reproductive toxicity revealed a high average rate of abortion per household in reference area (0.07) versus the control area (0.03), which is statistically significant ($p<0.05$). The study also revealed higher rates of premature births and stillbirths in reference area. Delayed milestones among children were observed to be significantly higher in reference area (OR= 3.6; 95% CI 1.3-10.3).

It is concluded that inorganic and organi pollution is an important problem in all major drains as reflected by higher BOD, COD, heavy metals (Hg, Cu, Cd, Cr, Pb) and pesticides residue (Chlorpyriphos, Malathion, Dimethoate, Aldrin, Heptachlor, α-Endosulphan, β-Endosulphan) in reference as compared to control area. This is also reflected by higher level of heavy metals (Hg, Cu, Cd, Pb, Cr) besides pesticides residue (Chlorpyriphos, Malathion, Dimethoate, Aldrin, Heptachlor, α-Endosulphan, β-Endosulphan) in ground and tap water which has affected the food chain and human health as reflected by higher concentration of these heavy metals and pesticides seen in samples of vegetables, fodder, bovine and human milk, urine and blood in reference area as compared to control area. Mercury and fluoride level has been found to be consistently more than permissible limits in reference and control areas. There is an evidence of genotoxicity as reflected by higher mean micronuclei per cell in reference population as compared to control area, which is significant in subjects belonging to reference area of Hudiara Nallah. Limited DNA adduct studies has shown mutations of varying degree in 65% of blood samples as compared to controls. The health effects of water pollution is reflected by significantly higher association for occurrence of gastrointestinal problems, water related vector born diseases (Malaria, Dengue), skin, eye and bone problems in the reference population. Average abortion rates among women and delayed milestones among children are significantly higher in reference area. There is no evidence at present of higher chronic health problems due to genotoxicity since environmental pollution takes long time even in decades to reflect in chronic diseases.

Conclusions

1. There is high level of inorganic and organic pollution in the five-wastewater drains of Punjab (Hudiara Nallah, East Bein Drain, Kala Singha Drain, Buddha Nallah, Tung Dhab Drain), which is reflected. by higher BOD and COD found in wastewater. Beside this heavy metals like mercury, copper, cadmium, selenium, chromium and lead were also higher which may be due to inadequate or untreated sewage water from municipal and industrial sources.
2. In villages along Buddha Nallah; Calcium, Magnesium, Flouride, Mercury, β-Endosulphan, Heptachlor were found to be more than MPL in effluent, ground and tap water. Beside these, effluent water has higher COD and BOD, Ammonia, Phosphate, Chloride, Chromium, Arsenic and Chlorpyriphos, which were found to be more than MPL. Ground water has also higher concentration of Nickel and Selenium whereas tap water has higher concentration of Lead, Nickel and Cadmium.
3. In villages along Hudiara Nallah: Calcium, Magnesium, Flouride, Mercury were found to be higher than MPL in effluent, ground and tap water. Beside this, effluent water has higher COD and BOD, Dimethoate, Heptachlor, β-Endosulphan and Chlorpyriphos. Ground water has also higher concentration of Cadmium, Nickel, β-Endosulphan, Heptachlor, Chlorpyriphos.
4. In villages along Kala Singha Drain, Calcium, Magnesium, Flouride, Mercury and β-Endosulphan were found to be higher than MPL in effluent, ground and tap water. Beside this, effluent water has higher COD and BOD, Heptachlor and Chlorpyriphos. Ground water has higher concentration of Lead, Arsenic and Cadmium.
5. In villages along East Bein Drain, Calcium, Magnesium, Flouride were observed to be more than MPL in effluent, ground and tap water. Beside this, effluent water has higher concentration of α-Endosulphan , β-Endosulphan and Heptachlor. Ground water has higher concentration of Iron, Copper, Nickel, β-Endosulphan, Heptachlor and Aldrin. Tap water has also higher concentration of Nickel.
6. In villages along Tung Dhab drain, Magnesium, Flouride, Mercury, Heptachlor and β-Endosulphan were found to be higher than MPL in effluent, ground and tap water. Also effluent water has higher concentration of COD and BOD, Calcium, Chlorpyriphos and

Dimethoate. Ground water has higher concentration of α-Endosulphan and Copper whereas tap water has also higher concentration of Chromium and Lead.

7. There is high concentration of heavy metals in drinking water supply based on canal water viz. mercury, copper, cadmium, chromium and lead which was found due to hospital waste, untreated or partially treated effluent discharged from the industries, domestic sources and tap run off. There is a evidence of these metals entering into food chain as reflected by these metals found in samples of fodder, vegetable and urine samples tested.
8. Fluoride in water has been found to be consistently more than permissible limits (1.5 mg/L). Dental and skeletal flourosis has been found to be an important public health problem None of the water sample had flouride level below 0.5mg/L.
9. Heptachlor, β-endosulphan and Chloripyriphos pesticides were found in concentrations exceeding the maximum residue limit in 25%, 21.5% and 16.11% samples of ground and canal water based drinking water supply. Pesticides were also detected in fodder, vegetable, blood, bovine and human milk samples. . This shows that pesticides have entered into food chain. The possible reasons for detection of these pesticides may be due to agricultural run off and irrigation of fields with drain water.
10. Gastrointestinal problems (diarrhea, vomiting etc), water related vector borne diseases (malaria, dengue), skin, eye and bone problems were significantly higher among persons residing in reference area as compared to control area ($p<0.05$). Neurotoxicity is also being manifested in reference area.
11. Delayed milestones among children and abortion rates among women were significantly higher in reference area.
12. Total coliform and E. coli counts were found to be higher in drinking water in some of the reference areas (East Bein. Tung Dhab).
13. Prevalence of Micronuclei indicating genetic damage was significantly higher in reference area of Hudiara Nallah as compared to control area. DNA adduct analysis which is also an indicator of genetic damage detected non specific varying mutations in 65% of blood samples

Recommendations

Technical committee comprising of undersigned members held its meeting on 14/09/2007 at School of Public Health. Department of Community Medicine. PGIMER. Chandigarh to review the report of the PPCB study on Effect of effluent disposal on water quality and human health among people living in close proximity to major waste water drains of Punjab. The committee recommended that

1. There is a need for regular monitoring of water quality of drains. industry and municipal bodies for organic and inorganic pollution. The Municipal Committees and regulatory bodies need to strictly enforce the relevant rules for water pollution.
2. Water Supply and Sewage Board. Punjab should undertake steps for provision of safe drinking water and proper disposal of sewage. Rural development and Panchayati raj department should encourage panchayats in rural area to plan. construct, manage and maintain their own water supply and sanitation facilities as a model. which is successfully being implemented in Gujarat.
3. The local bodies department should support Municipal Corporations committees of major towns in Punjab to setup sewerage/solid waste treatment facilities. Similarly. industry should treat their effluent before discharging into water bodies and it should be strictly enforced by regulators.
4. Water Supply and Sewage Board should also do regular monitoring of drinking water quality. It should include monitoring of physical & chemical parameters. heavy metals. pesticides and bacteriological testing. Strict action should be initiated against defaulters. The board should also setup or identify regional laboratories in the state in public or private sector to undertake tests for water quality including heavy metals and pesticides.
5. The Health Department should establish a surveillance system to identify acute and chronic effects due to heavy metals and pesticides. Regional laboratories in government or private sector should be identified to monitor heavy metals and pesticides in urine and blood. Local health authority designated by health department should undertake monitoring the level of heavy metals and pesticides in the food. Similarly Biomedical Waste Management rules should be strictly followed in all health institutions of the state to prevent possible contamination of drinking water with mercury.

6. Agriculture and dairy development department should undertake regular monitoring of pesticide and heavy metal levels in food grains, vegetables, fruits and milk.
7. Environment or Cooperative department should promote voluntary action for restoration of water quality of major drains as demonstrated by experience of eminent people working on Buddha Nallah and East Bein. Government should extend full support for people carrying out such voluntary activities.
8. Further studies for identification of DNA adduct are needed to identify the specific heavy metals and pesticides involved in genotoxicity. Similarly, source identification for water pollution from industry and municipal committees should be undertaken.

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Annexure-1

Performa

EFFECT OF EFFLUENT DISPOSAL ON WATER QUALITY & HUMAN HEALTH AMONG PEOPLE LIVING IN CLOSE PROXIMITY TO BUDDHA NALLAH, HUDIARA NALLAH, EAST BEIN DRAIN, KALA SINGHA DRAIN & TUNG DHAB DRAIN IN PUNJAB.

School of Public Health, Department Of Community Medicine,

PGIMER, Chandigarh

PUNJAB POLLUTION CONTROL BOARD

Date of Survey ☐☐ ☐☐ ☐☐☐☐

Section (A) GENERAL INFORMATION

1. ID No. ☐ ☐☐ ☐☐☐☐

2. Name of the Respondent____________________

3. **Address:** House No:. __________ Street/Mohalla Name__________

Local landmark __________ Town/Village: __________

Tehsil /Distt. __________ PIN Code __________

Telephone No. __________

4. Total Family Members: ☐☐

5. Per capita Family Income : (Per Month) in Rs. ☐

1. =Below 840 2. =840-2499 3.= 2500-4199

4.=4200-8399 5. =8400-16,799 6. 16,800 or above

6. Housing Details:

6(a) Type of Locality 1. =Residential 2.=Industrial 3.= Commercial ☐

4.= Farm Land 5.= Other, Specify______

6(b) Number of years residing in the present place: ☐☐

SOCIOECONOMIC AND OCCUPATIONAL STATUS

Mem. ID	Name	Relationship With Respondent (Code 1)	Age	Sex (Code2)	Marital Status (Code 3)	Level of education (Code 4)	Occupation (Code 5)	Occupational exposure due to chemicals & fumes 1=Yes,2=No 9=N.A.

1: 1= Self 2 = Father 3 = Mother 4 = Husband 5 = Wife 6 = Brother 7 = Sister 8 = Son 9=Daughter
10 = Other, Specify

2: 1= Male 2 = Female

3: 1= Married 2 = Unmarried 3 = Widowed 4 = Divorced

4: 1=Illiterate 2 = Literate 3 = Primary 4 = Middle 5 = Metric 6=Secondary 7= Degree, PG, Professional degree, Honors Degree

5: 1=Professional 2=Semi-professional, clerical, shopkeepers. 3=Farm owner 4= Farmer
5= Farm Labourer 6= Skilled worker 7= Semi-skilled 8= Unskilled 9= Unemployed

SECTION (B) ASSESSMENT OF WATER QUALITY

a) Drinking water pollution

1. **Source of Drinking Water** 1. Shallow Hand pump 2.= Deep Hand pump
   3. = Tap (Municipal supplies) 4. = Shallow Well 5 = Deep Well ☐
   6 = Others, specify ______
2. Do you think water is polluted: 1 = Yes 2 = No ☐
   If No, Skip to Q.3
   If Yes 2(a) Is it colored? 1=Yes 2 = No ☐
   (b) Is it turbid? 1 = Yes 2 = No ☐
   (c) Is it bitter in taste? 1=Yes 2 = No ☐
   (d) Does it stains the utensil? 1=Yes 2 = No ☐
   (e)Any foul smell? 1=Yes 2=No ☐
3. For how long have you been consuming this water?(yrs) ☐☐
4. Do you provide any treatment to water before drinking: 1= Yes 2=No ☐
   If no, Skip to **b)**
   If yes, purification method used: 1 = Boiling 2 = Filter
   3. Chlorination 4 = Others, Specify ______

b) Industrial water pollution

1. Is there any industry close to drinking water source? 1= Yes 2= No ☐
   If no, Skip to **c)**
   If yes 1a. Specify type of industry ______
   1b. App. distance of industry from your water source. (Kms)______
   1c. Do industries dispose off solid waste in open space? 1= Yes 2= No ☐
   1d. Do industries dispose off waste water in open drain? 1=. Yes 2.= No ☐
   1f. Is that waste from industries coming to your field
   (if occupation is Agriculture) 1= Yes 2= No ☐

c) **Solid Waste/Sanitation**

1. Do you have access to a toilet facility 1. = Yes 2. = No
2. Type of Toilet facility: 1 = Septic tank 2= Dry pit 3=Open air defecation
   4= Sanitary latrine 5 = other, Specify ____________
3. Is there a public toilet facility in your area 1= Yes 2 = No
4. Do you have access to a refuse/garbage disposal facility:1=Yes 2=No
5. (i) Is there wastewater stagnation near your area 1=Yes 2=No.
   (ii) Source of stagnated water 1= Industrial waste water 2= Rain water
   3=Sewage/waste water. 4 = Other, Specify____________
   (iii) If yes, how many days does the inundation remains
6. Do you have problem with insects/ rats/ other disease vectors: 1=Yes 2=No

d) **Agricultural Practices**

1. Are you involved in agricultural practices? 1 = Yes 2= No
   If no, Skip to e)
2. Do you use insecticide/pesticide in your fields? 1= Yes 2.= No
3. Do you use waste water/nallah water for irrigation? 1=Yes 2= No

e) **Household perception of Environmental Problem in the Locality**

Environmental Problem	Ranking (1=No pollution, 2=Pollution, 3=Severe pollution)
1. Industrial water pollution	
2. Ground water pollution	
3.Waste water pollution	
4. Solid waste pollution	
5. Any other (Specify)	

SECTION –(C)
HEALTH ASSESSMENT FOR ADULTS (12 yrs. or more)

1) GENERAL INFORMATION

Member ID	Code					
1. Proxy/Direct Interview	1=Proxy, 2=Direct					
2. Member's name	Full Name					
3. Age	In years					
4. Sex	1=Male, 2=Female					
5. Smoking habits: If no, skip to Q6.	1=Yes, 2=No					
5a. If yes, Type of Tobacco Smoke	1=Cigarette 2=Bidi, 3=Hukka 4=Others					
5b.Smoking history	Frequency (sticks per day)					
	Duration (in yrs)					
6. Any habit of Tobacco chewing	1=Yes 2=No if no, skip to 7.					
6a. If yes, Specify Duration	Duration (in yrs)					
7. Alcohol Habits	1=Yes2=No 9=N.A. if no skip to Q2.					
7a. If yes, frequency & duration	Freq.(No. of days per week)					
	Duration (in yrs)					

2) GASTROINTESTINAL ASSESSMENT

Do you suffer from any of following Symptoms?

Give Detail as 1= Persistently 2= Frequently 3= Occasionally 4= No

Member ID	Code					
1. Cramps						
2. Nausea						
3. Constipation						
4. Do you pass loose stool frequently	1= Yes, 2 =No (if yes go to 3a. otherwise skip to 4.)					

4a. Watery stools	1 Yes. 2 No					
4b. With mucus	1 Yes 2=No					
4c. With fever	1 Yes. 2=No					
4d. Accompanied with blood	1 Yes. 2=No					
5. Have you had yellowness of eyes?.	1 Yes. 2=No					
6. Do you experience frequent loss of appetite?	1 Yes 2=No					

3) WATER RELATED VECTOR BORNE DISEASES

Member ID	Code					
Have you suffered from any of following diseases?						
1) Malaria	1=Yes 2=No					
2) Dengue	1 Yes 2= No					

4) SKIN PROBLEMS

Member ID	Code					
1. Do you experience any skin problem? (If no, Skip to Q .6)	1 Yes 2=No					
2. Is there any redness/itching of skin?	1= Yes 2=No					
3. Any other lesion on skin?	1 Yes 2 No					
3a. If yes, specify	1 On exposed areas 2 Distributed evenly on exposed surface 3 Patchy/ linear					

5) EYE PROBLEMS

Member Id	Code					
1) Do you suffer from any eye problem?	1=Yes 2=No If no, skip to Q7.					
1a. Is there any irritation/itching in eyes?	1 Yes 2 No					
1b. With redness	1 Yes 2 No					
1c. With watery discharge	1 Yes 2 No					

6) BONE PROBLEMS

Member ID	Code					
1.Are you suffering from Bone problems? (If no, Skip to Q. 8)	1=Yes 2=No If no, skip to Q8.					
1a. Pain in Bones	1=Yes 2=No					
1b. Are they getting fractured easily?	1 Yes 2=No					

7) KIDNEY PROBLEMS

Member ID	Code					
1a. Do you suffer from any kidney problem? (List 1)	1=Yes 2=No If no, Skip to Q9.					
1b. If yes, specify						

(List 1 =Puffiness of face, Burning micturition, Blood in urine, Pain in loins)

8) OBSTETRICAL PROBLEM (ONLY FOR EVER MARRIED FEMALES)

Member ID	Code					
1. Have you ever been pregnant?	1= Yes 2=No If no, skip to Q10					
2. No. of pregnancies						
3. No. of live births						
4. No. of still births						
5. No. of abortions						
6. No. of premature births						

9) MISCELLANEOUS

Member ID	Code					
Record of any of the following conditions:						
1. Mottling of teeth	1= Yes 2=No					
2. Discoloration of teeth	1= Yes 2=No					
3. Hair / fingernail loss	1= Yes 2=No					
4. Numbness in finger or	1= Yes 2=No					

toes						
5. Mental retardation	1 Yes 2 No					
6. Cancer	1 Yes 2 No					
6a. If yes, Specify site						
7. Thyroid Problem	1 Yes 2 No					
7a. If yes, specify (List 2)						

(List 2 = Goiter, Loss/Gain of wt.)

10). ILLNESS IN LAST TWELVE MONTHS

Member ID	Code					
1. How was your health over the last 12 months?	1 very good, 2=good, 3 average, 4=poor, 5 very poor					
2. During the past 12 months, have you had any illness?	1 Yes 2 No					
2a. If yes, What was the illness?	Specify					
2b. How many times?	Mention frequency					

SECTION- D

HEALTH ASSESSMENT FOR CHILDREN (LESS THAN 12 YEARS)

Member ID	*Code*					
1.Proxy/direct interview	1 Proxy, 2=Direct					
2. Name	Full Name					
3.Sex	M 1, F 2					
4.Age	Exact no. of years					

GENERAL HEALTH STATUS

Member ID	*Code*					
1.How would you rate the child's health as compared to other children of his/her age?	1 Good 2 Average 3 Poor					
2. Had the child born with low birth wt. (Less than 2.5 kg)	1 Yes 2 No					

2a. If yes, specify	1=Pre-term 2=Term					
3. Is child born with any congenital disorders?	1=Yes 2=No					
3a.If yes, specify	1=Single defect 2= Multiple defects					
3b.Specify the defect/s						
4. Does the child suffer from developmental disability/delayed milestones?	1=Yes 2= No					
4a. Was the child cried normally at birth?	1=Yes 2=No					
4b.Was baby turned blue at the time of birth?	1=Yes 2=No					
4c. Language delay	1=Yes 2= No					
4d.Mental Retardation	1=Yes 2= No					
4e. Specify any physical features (List 3)						

(List 3 = Simian crease, Polydactyly, Syndactyly)

HEALTH PROBLEMS

GASTROINTESTINAL PROBLEMS

Member ID	**Code**					
Record incidence of any of the following conditions:						
1.Cramps	1=Yes 2=No					
2.Nausea	1=Yes 2=No					
3.Do you pass loose stools frequently?	1=Yes 2=No If no, skip to Q. 4					
3a.Watery stools	1=Yes 2=No					
3b. With mucus	1=Yes 2=No					
3c. With fever	1=Yes 2=No					
3d. Accompanied with blood	1=Yes 2=No					
4.Constipation	1=Yes 2=No					

MISCELLANEOUS

Record incidence of any of the following conditions:						
1.Mottling of teeth	1 Yes 2 No					
2. Blue line on gums.	1 Yes 2 No					
3. Pain in bones	1 Yes 2 No					
4.Irritation/itcing in eyes	1 Yes 2 No					
5. Headache	1 Yes 2 No					
6.Malaria	1 Yes 2 No					
7.Dengue	1 Yes 2 No					
8.Hepatitis / Jaundice	1 Yes 2 No					

ILLNESS IN PAST THREE MONTHS

Member ID	Code					
1. During Past three months have you had any illness?	1 Yes. 2 No					
2.What was the illness?	Specify					
3. If it was diarrhea then no. of episodes of diarrhea in last 3 months.						

CONSENT

I have been explained about all the aspects of this study and I hereby give my consent to participate in the study.

Signature/Left Thumb Impression .... Date.....................
of the Interviewee

Name of Investigator .... Signature ....
of Investigator

Anneuxre-2

Laboratory Requisition Form

School of Public Health
Deptt. of Community Medicine
PGIMER Chandigarh

EFFECT OF EFFLUENT DISPOSAL ON WATER QUALITY & HUMAN HEALTH AMONG PEOPLE LIVING IN CLOSE PROXIMITY TO BUDDHA NALLAH, HUDIARA NALLAH, EAST BEIN DRAIN, KALA SINGHA DRAIN & TUNG DHAB DRAIN IN PUNJAB

Date:.................... Sample No:..................

CONSENT

I have been explained about all the aspects of this study and I hereby give my consent to participate in the study.

Signature/Left Thumb Impression............. Date.................

Name of Investigator......................... Signature of Investigator...................

Name:		
Age:		
Sex:		
Address:		
Phone No.		
Name of specimen:		
Examination required:		
Collected on	Date	Time

REPORT: ....

....

Anneuxre-3

Pesticides in Blood

Pesticides	Buddha Nala		Hudiara Nala		East Bein Drain		Kala Singha drain		Tung Dhab Drain	
	Reference	Control	Reference	Control	Reference	Control	Reference	Control	Reference	Control
4,4-DDT	0	0	0.000335	0	0	0	0	0.0035	0	0
Aldrin	0	0	0	0	0.00008	0	0	0	0	0
Chlordane	0	0	0	0	0	0	0	0.0005	0	0
β -Endosulphan	0.0013	0	0	0	0	0	0	0	0	0
4,4 - DDE	0.00195	0	0	0	0	0	0.001375	0	0	0
Heptachlor	0	0	0.00072	0	0.0005	0	0.000375	0	0.00041	0.00066
α-HCH	0.000477	0	0.000135	0	0.0001	0.0002	0.000025	0	0.00006	0
β-HCH	0.00016	0.00156	0.000555	0	0.000665	0.00007	0.00126	0	0.00077	0
γ-HCH	0.00018	0	0	0	0	0.000137	0.00033	0	0.035115	0
δ-HCH	0.000075	0	0.000115	0	[illegible]	[illegible]	[illegible]	0	[illegible]	0