



Water Pollution In Punjab: Causes, Consequences And Solutions: A Review

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Abstract: This study has been undertaken to examine the major causes and consequences of water pollution in Punjab and aims to find its solution. The review also gives insights into government efforts, local responses and the role of technology in mitigating this problem.

Key Words: Pollution, Pollutants, Contamination, Water, Pesticides

I. INTRODUCTION

Water is a vital substance on the earth. It is second to oxygen for survival. All living organism need water for growth, development and to work. Human beings cannot survive more than three four days without water. About 71% of the earth's surfaces covered with water of which Oceans have covered 96.5% of earth's water. Only 3% of water is fresh water and drinkable water is 1.2% of it. Remaining water is available in ice caps, glaciers and permafrost or buried deep in the ground.

Although World Health Organisation (WHO) sets upper and lower limits of some inorganic components in drinking water, still contaminated and poor quality water is being used in developing countries. It has resulted in various types of illnesses.

The Department of Water Supply and Sanitation, Punjab is providing potable water to 14722 habitations through 8552 ground water and 917 canal-based water supply schemes. The Department has formulated a monitoring protocol according to which all the ground water-based sources i.e. tube- wells and hand-pumps are regularly being tested for basic chemical parameters, heavy metals including uranium once in a year whereas bacteriological parameters are tested twice in a year. Canal water generally does not contain chemical impurities. Hence canal based sources are tested for chemical parameters once in a year. Bacteriological contamination is more prevalent in canal based schemes hence all canal based schemes are tested for bacteriological parameters twice in a year and are tested regularly for bacteriological contamination using H₂S vials in the field. The water testing loads also include samples from treatment plants installed by the department and other institutions/ organizations/ departments. During the initial stages of 1st phase of World Bank project, studies by experts revealed the presence of various contaminants like Uranium, Arsenic, Fluoride and other heavy metals in the ground water of Punjab. All the ground water sources were then tested for heavy metals including Arsenic & Uranium and basic chemical parameters including Fluoride during the years 2009-2013. Subsequently, all the sources were again tested in the years 2013-15 from Baba Atomic Research Centre, Bombay & PBTI, Mohali. These two rounds of sampling

confirmed the presence of contaminants like Arsenic, Fluoride, Uranium and other heavy metals in the groundwater. Keeping in view the deteriorating water quality of ground water sources of Punjab, Department built its own State of Art Regional Advance Water Testing Lab at SAS Nagar in 2015 with sophisticated equipment namely Inductively Coupled Plasma Mass Spectrophotometer (ICP-MS) for Heavy Metals like Uranium & Arsenic and Ion Chromatograph (IC) for anions like Fluoride.

Punjab, a state renowned for its agricultural productivity, is facing a critical challenge of widespread water pollution. This review article examines the sources, extent, and consequences of this environmental crisis.

II. Sources of Water Pollution

* **Industrial Effluents:** Discharge of untreated or inadequately treated wastewater from industries, particularly those in the manufacturing and agro-processing sectors, is a major contributor. Pollutants include heavy metals, chemicals, and organic matter. The Sutlej, Beas, and Ravi rivers, which flow through the state, have been heavily contaminated by industrial discharges. Water at few places has higher concentrations of heavy metals such as Lead, Chromium, Cadmium, Copper, Cyanide, and Nickel etc. around the industrial hubs like Ludhiana, Amritsar, Mandi-Gobindgarh and Kapurthala. Higher concentration of Selenium has been reported from Hoshiarpur and Nawanshahr districts and higher concentrations of Arsenic have been found in Amritsar, Gurdaspur, Hoshiarpur, Kapurthala and Ropar districts. Fluoride having concentrations more than 1.5 mg/l has been reported from Bathinda, Ferozepur, Mansa and Patiala districts. High concentration of Aluminium has been observed in Gurdaspur, Nawanshahr, Hoshiarpur, Patiala, Ropar and Moga districts. The entire south-western belt of the State comprising of Ferozepur, Moga, Barnala, Bathinda and Sangrur districts have high amount of Uranium in the groundwater.¹

* **Agricultural Runoff:** Excessive use of fertilizers, pesticides, and herbicides in intensive agriculture contaminates both surface and groundwater. Nutrient runoff, including nitrates and phosphates, enters rivers and underground aquifers, promoting the growth of harmful algal blooms and increasing the risk of eutrophication.

* **Domestic Sewage:** Untreated sewage from urban areas and rural settlements pollutes rivers and streams, leading to high levels of bacteria and organic pollutants. Cities like Amritsar, Ludhiana, and Jalandhar face challenges in providing safe drinking water due to high levels of bacterial contamination and chemical pollutants in local water bodies.

* **Groundwater Overexploitation:** Over-extraction of groundwater for irrigation and other purposes lowers water tables, increasing the risk of contamination from pollutants seeping into the aquifer. Mining activities, particularly in regions like Hoshiarpur and Ropar, have led to the contamination of groundwater with heavy metals and other harmful substances, further reducing the quality of drinking water.

III. Extent of Water Pollution

* **Surface Water:** Rivers like the Sutlej and Beas are heavily polluted, impacting aquatic ecosystems and posing risks to human health.

* **Groundwater:** A significant portion of Punjab's groundwater is contaminated with nitrates, arsenic, and other pollutants, rendering it unfit for drinking and irrigation.

* **Soil Contamination:** Agricultural practices and industrial activities have led to soil contamination, which can further pollute water sources.

IV. Consequences of Water Pollution

* **Human Health hazards:** The chemical parameters above the permissible limit have adverse effect on human health. Hardness, measured as CaCO_3 , when present more than 600 mg/l may affect water supply system (Scaling), lead to excessive soap consumption, calcification of arteries. There is no conclusive proof but it may cause urinary concretions, diseases of kidney or bladder and stomach disorder. Iron in traces is essential for nutrition and high Iron concentration ($> 1.0\text{mg/l}$) in water, though not having major effect on

human health, gives bitter sweet astringent taste, causes staining of laundry and porcelain. Nitrate at very high concentration may cause infant methaemoglobinaemia (blue babies), gastric cancer and may adversely affect the central nervous system and cardiovascular system. Fluoride less than 1.0 mg/l is desirable in drinking water as it prevents dental carries but with very high concentration may cause crippling skeletal fluorosis. Copper is essential and beneficial element in human metabolism. Deficiency results in nutritional anaemia in infants. Large amount gives astringent taste, causes liver damage, central nervous system irritation and depression. In water supply it enhances corrosion of aluminium in particular. The desirable limit of Lead in drinking water is 0.05 mg/l. It is toxic in both acute and chronic exposures. Burning in the mouth, severe inflammation of the gastro-intestinal tract with vomiting and diarrhoea, chronic toxicity nausea, severe abdominal pain, paralysis, mental confusion, visual disturbances, anaemia etc. are some of its manifestations when present in higher concentrations. Common symptoms of mercury poisoning include peripheral neuropathy (presenting as paresthesia or itching, burning or pain), skin discoloration. Other symptoms may include kidney dysfunction (e.g. Fanconi syndrome) or neuropsychiatric symptoms such as emotional lability, memory impairment, or insomnia. Long term exposure to Cyanide affects the thyroid and central nervous system adversely. In drinking water the maximum permissible limit for cyanide is 0.05 mg/l and there is no relaxation in this value as beyond this limit water becomes toxic. Arsenic is a recognized carcinogenic element. The gastrointestinal tract, nervous system, respiratory tract and skin can be severely affected by it. Chronic poisoning is manifested by general muscular weakness, loss of appetite and nausea, leading to inflammation of mucous membrane in the eye, nose and larynx, skin lesions may also occur. Neurological manifestation and even malignant stage-3 tumours in vital organs may also be observed. Humans residing in seleniferous areas of Punjab show loss of hair, malformation of finger and toe nails and progressive deterioration in human health. Animals consuming Selenium rich fodder exhibit typical symptoms of Selenium poisoning. The most consistent clinical manifestations are losing body condition and loss of hair, necrosis of tail, reluctance to move, stiff gate, and overgrowth of hooves followed by cracks gradually leading to detachment from main hoof. Consumption of contaminated water can lead to various health issues, including gastrointestinal diseases, skin problems, cholera, dysentery, and typhoid. Long-term exposure to contaminated water, especially with high levels of pesticides and industrial chemicals, is linked to various chronic health conditions, including cancer, liver disease, and neurological disorders like Minamata disease. Some regions in Punjab face fluoride contamination, leading to dental and skeletal fluorosis, affecting thousands of people.

The pesticides have deleterious effects on health. Several of the pesticides are carcinogenic and cause long term harmful effect on health, in case contaminated water is continuously used for long term for human consumption). The organo-chlorine pesticides are more persistent and most toxic, therefore some of these pesticides are banned or regulated. The organo-phosphorous compound have short life span in the environment and these break down rapidly and pose less danger to wild life and contamination to ground water in comparison to organo-chlorine pesticides. Pesticides in drinking waters of Punjab indicate genotoxic effects which are not yet manifesting but are in the pre-carcinogenic phase. Besides causing acute and chronic toxicity, pesticides are affecting the immune system in general and other sensitive systems leading to immuno- suppression, immuno-potential and hypersensitivity of the host against infectious and non-infectious diseases as well as causing glomerulonephritis, rheumatoid arthritis, carcinogenicity, reduced fertility, increased cholesterol, high infant mortality, varied metabolic and genetic disorders and reduced lifespan in humans and livestock populations. There is abundant evidence that many pesticides produce their acute toxic action by inhibiting enzymes. The excessive use of chemical fertilizer like urea, DPK, NPK and pesticides (insecticides and weedicides) in Punjab have resulted in the disorders of endocrine glands such as thyroid, parathyroid, pituitary, kidneys and adrenals.

*Environmental Degradation: Water pollution disrupts aquatic ecosystems, leading to fish deaths, loss of biodiversity and degradation of water bodies. Excessive nutrients from agricultural runoff lead to the eutrophication of water bodies, resulting in low oxygen levels and the formation of harmful algal blooms.

*Agricultural Impact: Water pollution harms the soil by increasing salinity and making it less fertile. The contamination of irrigation water with pesticides and chemicals reduces crop yields. Polluted water also affects the nutritional quality of crops, making them unsafe for consumption.

* Economic Impacts: Water pollution affects agriculture, tourism, and other sectors, leading to economic losses.

Parameters	Arsenic	Fluoride	Uranium	Selenium	Mercury	Iron	Nitrate	Mixed Heavy Metals
No. of affected habitations	803	282	171	74	41	21	56	77

Figure-1: Water quality status of Punjab

Table-1: Categorisation of Chemical Parameters

Parameters	Acceptable limit BIS / AERB mg/l	Permissible limit as per BIS / AERB
Mandatory Parameters		
Arsenic	0.01 ppm	No Relaxation
Fluoride	1.0 ppm	1.5 ppm
Nitrate	45 ppm	No Relaxation
TDS	500 ppm	2000 ppm
Iron	1.00 ppm	No Relaxation
Emerging parameters		
Uranium	30 ppb	60 ppb
Selenium	0.01 ppm	No Relaxation
Mercury	0.001 ppm	No Relaxation
Aluminum	0.3 ppm	0.2 ppm
Cadmium	0.003 ppm	No Relaxation
Nickel	0.02 ppm	No Relaxation
Chromium	0.05 ppm	No Relaxation
Lead	0.01 ppm	No Relaxation

ppb – parts per billion equivalent to microgram per litre
ppm – parts per million equivalent to milligram per litre
TDS - Total Dissolved Solids

The water quality status as on 01.04.2021 is indicated below.

Name of District	Arsenic	Fluoride	Uranium	Selenium	Mercury	Iron	Nitrate	Mixed Parameters (Cadmium, Lead, Nickel, sulphate etc)	Grand Total
Amritsar	332	0	0	0	0	1	0	0	333
Barnala	0	4	10	2	0	0	5	1	22
Bathinda	0	3	1	0	0	0	0	1	5
Faridkot	5	6	0	0	0	0	0	7	18
Fatehgarh Sahib	2	40	3	2	0	1	3	3	54
Fazilka	12	10	29	0	9	4	0	31	95
Ferozepur	46	13	43	0	28	2	14	2	148
Gurdaspur	224	0	0	0	3	0	0	2	229
Hoshiarpur	13	0	8	4	0	0	0	0	25
Jalandhar	1	0	0	15	0	1	2	6	25
Kapurthala	6	0	0	1	0	1	0	1	9
Ludhiana	1	1	4	18	1	1	9	0	35
Mansa	2	0	0	0	0	0	4	0	6
Moga	3	4	42	2	0	2	2	0	55
Patiala	12	185	9	4	0	7	0	19	236
Ropar	30	0	0	9	0	0	10	0	49
Sangrur	1	5	21	4	0	1	3	4	39
SAS Nagar	2	5	0	0	0	0	0	0	7
SBS Nagar	0	1	0	11	0	0	3	0	15
Tarn Taran	111	5	1	2	0	0	1	0	120
Grand Total	803	282	171	74	41	21	56	77	1525

Figure-2: Water quality status of various districts of Punjab

V. Result & Discussion

The reviewed area lies in the region of Punjab, India. The mean sea level of Bathinda district is 216 m and it is located between 30.21° N and 74.9455° E. The soil of Bathinda is calcareous & sandy which covers 3367 sq. km, which is the second largest in Punjab after Ferozepur district. The climate of Bathinda is semi-arid having large difference in winter and summer temperature.²

Different physiochemical parameters of drinking water of Bathinda area were compared with BIS and WHO limit. The pH of drinking water samples was found within permissible limit which ranges from 6.8 to 7.3. The turbidity of the samples ranged from 0.36 to 3.47 NTU and mean turbidity was 2 NTU. In this area 31.58% of the total samples have turbidity more than the BIS permissible limit.

The alkalinity was lowest at Hanuman Chowk (66mg / L) and Highest at Bambiha village (660 mg / L). The mean concentration of the alkalinity was 373 mg / L. The pH in Bathinda district was found within the permissible limit but the turbidity in the study region was higher than the safe limit.³ Distribution of Cations and Anions The cations (Sodium [Na], Potassium [K], Calcium [Ca], Magnesium [Mg], Ammonium ions [NH₄⁺] and Lithium [Li]) and anions (Chloride [Cl⁻], Sulphate [SO₄²⁻], Nitrate [NO₃⁻], Nitrite [NO₂⁻] and Fluoride [F⁻]) are the major ions/constituents in drinking water, representing the water quality and the

concentration of cations and anions, respectively. Na concentration in the study region ranged from 6.04 to 665 mg/L and the mean concentration in the region was 227 mg/L. The mean concentration of K, Ca, Mg, NH_4^+ and Li was 17.53, 43.39, 40.10, 0.41 and 1.01 mg/L, respectively. It has been found that K is present in most of the collected samples (84.21% samples). Ca in collected water samples varied from 7.48 to 43.39 mg/L. The mean concentration of the Mg, NH_4^+ and Li was 40.10, 0.41 and 1.01 mg/L, respectively in the study area. Among the major anions, the concentration of Cl^- ions ranged from 4.38 to 475 mg/L and its mean concentration was 115 mg/L in the drinking water of the study area. Cl^- , SO_4^{2-} , NO_2^- and F^- were detected in all samples, however NO_3^- was present in only 63.16% samples. Mean concentration of SO_4^{2-} was 235 mg/L and it varied from 7.61 to 1020 mg/L in the drinking water samples. Maximum and minimum concentration of SO_4^{2-} was in Jai Singh Wala-2 (1020 mg/L) and Dhuplai (7.67 mg/L), respectively. Nitrate and nitrite in drinking water of the study area ranged from 0 to 36.60 mg/L and 0.05 to 1.84 mg/L, respectively. Fluoride ion concentration was highest in the sample collected from Central University of Punjab (1.55 mg/L).⁴ Distribution of Carcinogenic Elements in Study Area shows the concentration of 11 trace elements which exist in different carcinogenic group. Drinking water of the study area was affected by carcinogenic elements such as As, Be, Cr, Cu, Co, Hg, Se, U, Cd, Ni and Zn. As was detected in all samples (n=19) but the concentration of the As in the drinking water of the Bathinda district was below the permissible limit. The maximum concentration of Cr was 359.96 ppb (Lehra Mohabbat) and minimum concentration was 66.24 ppb (Dayalpur Mirza). Cr concentration in drinking water was found above the permissible limit for all the samples of the study area. The Cr concentration in drinking water of South-Western Punjab is up to 228 ppb. Hg concentration ranged from 4.6 to 21.3 ppb and the mean concentration was 11.9 ppb in the study area, higher than the BIS permissible limit. The highest concentration of Hg was found at Bambiha (21.3 ppb). The prescribed safe limit for nickel (Ni) in drinking water is 20 ppb and the concentration of Ni exceeded the permissible limit for all 19 sites. The concentrations of Ni in the study area have been observed in the range of 25.49 - 39.93 ppb, with mean concentration of 32.25 ppb. The Ni concentration was reported 308 ppb, which is almost 10 times higher than the mean concentration of our observation. In the study region, Be was detected in the drinking water samples, however, the concentration was below the BIS and WHO permissible limits. Out of 19 samples, only two samples exceeded the acceptable limit of Cu concentration (Nasibpura-442 ppb and Mehma Surja-400 ppb) however, it was within the BIS permissible limit. The Uranium (U) concentration ranged from 1.17 to 190 ppb in the drinking water samples, with mean concentration 32.04 ppb. Das et al. 2017 also reported U in South-West Punjab varying from 0.5 to 579 ppb. Mean concentration of Zn, Cd and Co in the study area was 32.29 ppb, 0.60 ppb and 0.75 ppb, respectively.³

VI. Health Risk Assessment

The health risk assessment due to oral exposure through drinking water was computed for humans. The drinking water sample collected from Mandi Kalan (B13) is highly hazardous to human health due to the Hg content. Moreover, the concentration of Cr & Ni can pose moderate health hazard, and other trace elements (As, Cu, Se, U, & Cd) have the potential for the adverse effect. Drinking water samples from Pitho (B1), Lehra Mohabbat (B2), Rampura Paul (B4), Jai Singh Wala (B7), Dhupali (B9), Bhai Rupa (B11), Gill Kalan (B15), Ganga (B16), and Bathinda (B17) were low in health hazard, but have potential for adverse health impacts. Samples from Mehma Sarja (B3), Bambiha (B5), Hanuman Chowk (B6), Jai Singh Wala (B8), Bhai Rupa (B10), Dayalpur Mirza (B12), Central University of Punjab temporary campus (B18), and Nathana (B19) were found to be moderately hazardous to human health due to high concentration of Hg. Sample from Nasibpura (B14) was moderately hazardous to human health due to the prevailing concentration of Cr, Cu, Hg, and Ni. In this study, the Hazards Quotient (HQ) value of Hg, Cr, Ni, and Cu exceeded the value of 1 in 10, 2, 2, and 1 numbers of samples, respectively, and can be considered as the key metals causing carcinogenicity.

All the analyzed organoleptic parameters except turbidity and TDS were well within the limits prescribed by BIS for drinking water. The turbidity was higher than the desirable limit for 57.8% of the samples, but was within the permissible limit for drinking water. The TDS content of 84.2% samples exceeded the desirable limit for drinking water, however only 10.5% exceed the permissible limit. 2. In the study area, Ca, Mg and NH_4^+ content in the analyzed drinking water samples exceeded the desirable limit for 5.3%, 63.1%, and 31.6% samples, respectively. Similarly, Cl^- , SO_4^{2-} , and F^- content exceeded the desirable limit

for drinking water in 10.5%, 47.4%, and 5.3% samples, respectively. Also, the total hardness and total alkalinity exceeded the desirable limit in 84.2% and 52.6% samples, respectively. Based on Hazards Quotients (HQ), sample from Mandi Kalan is highly hazardous to human health and samples from Mehma Sarja, Bambiha, Hanuman Chowk, Jai Singh Wala, Bhai Rupa, Dayalpur Mirza, Nasibpura, Central University of Punjab temporary campus, and Nathana are moderately hazardous to human health, and rest were low in health hazard.

VII. Addressing Water Pollution

Combating water pollution in Punjab requires a multi-pronged approach:

- * **Strict Regulations:** Implementing and enforcing stringent environmental regulations on industries and agriculture.
- * **Wastewater Treatment:** Promoting and investing in effective wastewater treatment plants for both industrial and domestic effluents.
- * **Sustainable Agriculture:** Promoting sustainable agricultural practices, such as organic farming and integrated pest management, to reduce reliance on chemical inputs.
- * **Groundwater Management:** Implementing measures to conserve groundwater and prevent overexploitation.
- * **Public Awareness:** Raising public awareness about the importance of water conservation and pollution prevention.

VIII. Government Policies and Initiatives

- **National Water Quality Monitoring Programme (NWQMP):** This program monitors water quality at various points across the country, including Punjab, providing data on the level of pollutants in water bodies.
- **Punjab Pollution Control Board (PPCB):** The PPCB has been working on monitoring industrial effluents and wastewater treatment. However, enforcement of regulations remains a challenge.
- **Integrated Water Resource Management:** The Punjab government has taken steps toward Integrated Water Resource Management (IWRM) to balance the demand for water with its sustainable use. These initiatives focus on reducing pollution from various sources, improving sewage treatment, and promoting water conservation.

IX. Challenges in Addressing Water Pollution

Lack of Awareness

- While farmers and industrialists are often unaware of the long-term consequences of water pollution, the public awareness campaigns need greater outreach, especially in rural areas.

Enforcement Issues

- Enforcement of environmental laws is weak due to corruption, lack of resources, and a fragmented approach among local and state authorities.
- Excessive reliance on groundwater for irrigation has led to the depletion of aquifers, aggravating the problem of water scarcity and quality deterioration.

X. Solutions and Mitigation Measures

Sustainable Agricultural Practices

- **Adopting Organic Farming:** Encouraging organic farming can help reduce the dependence on chemical fertilizers and pesticides, leading to better water quality.
- **Water-Efficient Irrigation:** Implementing efficient irrigation techniques like drip irrigation can help conserve water and reduce runoff.
- **Promoting Cleaner Technologies:** Industries must adopt cleaner technologies and better wastewater treatment systems to reduce the discharge of harmful effluents into rivers and groundwater.
- **Zero Liquid Discharge (ZLD) Systems:** ZLD systems ensure that industries recycle all wastewater, eliminating any discharge into water bodies.

Improvement in Sewage Treatment Infrastructure

- **Upgrading Urban Sewage Systems:** Expanding and improving sewage treatment facilities in urban areas can help reduce the flow of untreated sewage into rivers and water bodies.

Conclusion

Water pollution is a serious challenge facing Punjab, with significant implications for human health, the environment, and the economy. Addressing this issue requires a concerted effort from the government, industries, farmers, and the public. By adopting sustainable practices and implementing effective pollution control measures, Punjab can safeguard its water resources and ensure a healthy future for its people.

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