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Assessing the Effects of Distillery Effluents on Groundwater Quality in the Sardar Nagar Area of Gorakhpur District

Govind Yadav, Shafqat Alauddin*
Department of Chemistry, Shibli National College, Azamgarh, Uttar Pradesh, India

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ABSTRACT

This study aims to understand the impacts of distillery effluents released from Saraya Distillery, Sardar Nagar on groundwater quality in the Sardar Nagar region of Gorakhpur District. Groundwater samples were taken from various locations within the region, and multiple water quality parameters were analyzed. The findings indicate significant variations in the quality of groundwater in areas closer to the distillery sites in Gorakhpur. The Sardar Nagar region of Gorakhpur District has witnessed rapid industrial development over the past few years, with distilleries being prominent contributors to the local economy. However, there's growing concern about the environmental implications of the effluents these distilleries release, particularly in relation to groundwater quality. This research paper delves into the effects of distillery effluents on groundwater within Sardar Nagar. Through rigorous sampling and laboratory analysis, we assessed various water quality parameters, such as pH, turbidity, Total Dissolved Solids (TDS), presence of heavy metals, and organic content. Our findings indicate a notable degradation in groundwater quality in areas proximal to distillery discharge sites. These compromised water sources not only pose health risks for local residents but also threaten the local ecosystem's balance. Immediate action, in the form of stricter regulations and efficient effluent treatment methods, is essential to counteract these negative impacts.
Keywords: Groundwater Quality, Distillery Effluents, Sardar Nagar, Gorakhpur District, Water Contamination.

I. INTRODUCTION

Water, as a pivotal element of life, sustains ecosystems, fuels economies, and nurtures civilizations. However, with rapid industrialization, the qualitative aspect of this invaluable resource, especially groundwater, is becoming a growing concern in many regions globally. One such region under scrutiny is the Sardar Nagar area of Gorakhpur District, known for its burgeoning distillery sector.

Gorakhpur District, situated in the northern part of India, is characterized by its rich cultural heritage and agricultural prowess. Over the years, the district has seen the rise of various industries, with distilleries taking the lead due to the availability of raw materials and a conducive market environment. Distilleries, by their very nature, generate a significant volume of effluents, which, if not managed properly, have the potential to cause considerable environmental harm.

The primary concern arises when these effluents, replete with chemicals and organic matter, seep into the ground, affecting the quality of the underlying groundwater. Given that a large portion of the local population relies on groundwater for drinking and other domestic purposes, the contamination poses severe health risks. Additionally, the agricultural landscape of Gorakhpur, dependent on groundwater irrigation, could also face setbacks due to reduced water quality.

This research paper aims to uncover the extent to which distillery effluents have impacted groundwater quality in the Sardar Nagar area. Through a systematic study of water quality parameters, the paper will provide insights into the present scenario, laying the foundation for potential remedial measures and suggesting pathways for sustainable industrial practices in the region (1-5).

II. Study Area

The Sardar Nagar region, situated in Gorakhpur District, is an area with a rich agrarian history. With its fertile plains and abundant water resources, Sardar Nagar has traditionally been an epicentre of agricultural activities. The area is characterized by a mix of urban and rural landscapes, with a rapidly growing population due to urban migration trends.

2.1. Geographical Location:

Sardar Nagar lies in the northern part of Gorakhpur District. It's positioned at approximately latitude 26.7°N and longitude 83.3°E. The region is bounded by the Rapti River to the north and by other smaller tributaries and channels.

2.2. Climate:

The area experiences a subtropical humid climate, with three main seasons: summer (March to June), monsoon (July to September), and winter (October to February). The average annual rainfall is approximately 1100 mm, most of which is received during the monsoon.

2.3. Socio-Economic Aspects:

A majority of the local population relies on agriculture as their primary source of livelihood. Paddy, wheat, sugarcane, and various pulses dominate the crop pattern. However, with the increasing industrial activities, especially distilleries, there's been a shift in occupational patterns with many locals now engaged in industrial work or related services.

2.4. Hydrogeology:

The region has a thick sequence of alluvial deposits comprising clays, silts, sands, and gravels. The groundwater occurs under semi-confined to confined conditions in the phreatic aquifers. The water table usually fluctuates between 4 to 10 meters below the ground level, depending on the season.

2.5. Industrial Profile:

In recent decades, Sardar Nagar has witnessed an influx of industries, primarily distilleries, given the abundant sugarcane cultivation in the area, in which Saraya Distillery, Sardar Nagar is leading one. These distilleries, while providing employment opportunities, have also raised environmental concerns, especially pertaining to the discharge of effluents.

III. Methods

To comprehensively analyze the impact of distillery effluents on groundwater quality in the Sardar Nagar area of Gorakhpur District, the following methodology was adopted:

3.1 Study Area Selection and Description:

The study was focused on the Sardar Nagar region, selected due to its proximity to multiple distilleries and a reported increase in water-related concerns by the local inhabitants.

3.2 Sample Collection:

Sites Selection: Fifteen sites were selected across Sardar Nagar, ensuring a mix of locations close to and distant from distillery discharge points.

Sampling Procedure: Groundwater samples were collected in pre-cleaned 1-liter polyethylene bottles, ensuring no air bubbles remained. The bottles were then sealed and labelled with details such as location, date, and time of collection.

3.3 Parameters Studied:

Water samples were tested for various quality parameters, including:

- Physicochemical properties: pH, electrical conductivity, total dissolved solids (TDS).
- Major ions: Chlorides, sulphates, nitrates, phosphates, calcium, magnesium.
- Heavy metals: Lead, arsenic, cadmium, zinc, chromium.
- Organic components: Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD).

3.4 Analytical Methods:

- Physicochemical properties were measured using standard portable meters.
- Major ions were determined using titration methods.
- Heavy metals were analyzed using Atomic Absorption Spectrophotometry (AAS).
- COD and BOD values were determined using standard laboratory procedures.

IV. Results and discussions

4.1. Physico-chemical characteristics of wastewater effluent discharged into River Rapti by Saraya Distillery, Sardar Nagar

The differences in the physico-chemical parameter values for the five sample sites (S1, S2, S3, S4, and S5) are shown in Table 4.1. Following wastewater discharge, there was a very significant change in the water quality indices between the upstream and downstream rivers (P 0.05). A typically low and outside of APHA's (6) permitted limitations, the pH of the S. D., Sardar Nagar wastewater released into the River Rapti was abnormal (Table 4.1). The pH values that were the lowest (3.8 +/- 0.2; Table 4.1) were found in the distillery effluents. The pH of the water in the River Rapti considerably dropped after effluent discharge (P = 0.000).

The total dissolved solids (TDS) and electrical conductivity (EC) values of the wastewater released into the River Rapti at site S3 were above APHA limits (1200 mg/l and 1500 s/cm, respectively) for wastewater discharge into the environment (Table 4.1). After discharge into the river, the TDS levels of the water downstream dramatically rose (p = 0.002) from 88 to 1007 (Table 4.1). TDS levels in wastewater from sugar processing were much lower than those in wastewater from distilleries (p = 0.032).

Electrical conductivity (EC) of river water downstream significantly increased after effluent discharge into River Rapti (p = 0.007), demonstrating a linear relationship between Electrical Conductivity and Total Dissolved Solids values (Pearson correlation coefficient = 0.965).

Downstream river water exhibited significantly higher turbidity as compared to river water upstream (prior to effluent discharge) (p = 0.014). Wastewater from sugar production and distilleries did not substantially differ in terms of turbidity (p = 0.242). However, the S. D., Sardar Nagar 's effluent discharge into River Rapti showed mean turbidity levels (4774 ± 1851NTU) that were higher above the APHA standard for wastewater discharge (300NTU).(Table 4.1).

The mean wastewater temperatures at all sample locations, which varied from 27.3 to 0.3 °C (Table 4.1), were within the 20 to 30 °C APHA approved limits for wastewater discharge into the environment. However, once the effluent was released, the temperature of the river water did considerably increase (p = 0.004). It was discovered that the

Table 4. 1: Mean ± standard deviation of chemical and physico-chemical variables determined at selected sampling points (n = 12)

Variable	S1	S2	S3	S.4	S5	Level of Significance between. S4 and S5	Permissible limits APHA
pH	42± 0.2	3.8 ± 0.2	4.3 ± 0.1	7.07 ± 0.01	5.6 ± 0.2	a	6.0 - 8.0
TDS (mg/l)	3142± 1149	15104 ± 5098	9104 ± 2833	88 ±15	1007 ± 262	a	1200
EC (μs/cm)	4697 ± 1564	19361± 704.6	10089 ± 3722	108 ± 32	1524 ± 412	a	1500
T-Fe (mg/l)	44.8 ± 8.8	65.6 ± 19.8	61.9 ± 8.5	3.2 ± 0.4	10.5 ± 1.4	a	10
Na^+(nag/l)	40.7 ± 7.8	42.8 ± 12.0	33.3 ± 18	5.5 ± 0.7	8.0 ± 1.0	a	*
Ca^{2+} (mg/l)	79± 15	175 ± 30	126 ± 18	8.5 ± 0.8	25 ± 4	a	100
TN (mg/l)	41 ± 10	71 ± 14	48 ± 10	1.4 ± 0.3	6.8 ± 1.5	a	10
TP(mg/l)	20 ± 8	18 ± 4	16 ±4	0.8 ± 0.2	2.7 ± 0.7	a	10
Turbidity (NTU)	2940 ± 1492	6531 ± 2584	4774 ± 1851	49 ± 8	616 ± 212	a	300
Temp (°C)	30.7± 0.6	25.8 ± 0.4	27.3 ± 0.3	24.8 ± 0.2	25.7 ± 0.2	a	20 - 30
BOD (mg/l)	1295 ± 569	4723 ± 1242	2256 ± 820	3.8 ± 1.1	184 + 43	a	50
COD(mg/l)	3821 ± 1229	16152 ± 14109	8064 ± 2250	13 ± 4	675 ± 70	a	100
DO (mg/l)	0.19 ± 0.02	0.14 ± 0.03	0.25 ± 0.03	6.50 ± 0.30	2.83 ± 0.29	a	+

temperature of the wastewater generated by the sugar processing was much higher than that of the distillery's wastewater ($p = 0.005$). (30.7 ± 0.6 and 25.8 ± 0.4°C, respectively).In excess of the APHA-permitted limitations for wastewater discharge (50 mg/l BOD and 100 mg/l COD; Table 4.1), the wastewater generated by S. D., Sardar Nagar showed high BOD (2256 ± 820mg/l) and COD (8064 ± 2250mg/l) values as well as low DO concentrations (0.25 ± 0.03mg/l). Following discharge into the River Rapti , the BOD and COD levels in the upstream and downstream river water considerably varied (p 0.001), but the average DO concentration declined rapidly from 6.50 ± 0.30 mg/l to 2.83 ± 0.29 mg/l ($p = 0.000$). The distillery generated effluent with higher BOD ($p = 0.02$) and COD ($p = 0.009$) levels than the sugar processing plant, according to further data.

4.2. Nutrients

Total phosphorus (TP) and total nitrogen (TN) concentrations in wastewater discharged into the River Rapti were determined as mean values of 16 ± 4 mg/l and 48 ± 10 mg/l, respectively (Table 4.1 and Figure 4.1). The amount of TN ($p = 0.002$) and TP ($p = 0.010$) in the river water dramatically increased after the effluent from S. D., Sardar Nagar was discharged, rising from 1.4 ± 0.3 mg/l to 6.8 ± 1.5 mg/l and 0.8 ± mg/l to 2.7 ± 0.7 mg/l, respectively. The TN and total phosphorus concentrations in the S. D., Sardar Nagar effluent were higher above the APHA permitted limits (10 mg/l) for environmental discharge. The results showed that TN concentrations were higher than TP concentrations at all sample sites (Table 4.1 and Figure 4.1). The amounts of TP ($p = 0.878$) and TN ($p = 0.105$) in the effluent from the distillery and the sugar processing, however, did not show any detectable fluctuations.

Water discharged from S. D., Sardar Nagar had total iron concentrations (T-Fe, 61.9 ± 12.3 mg/l), Na^+ concentrations (31.3 ± 8.5 mg/l), and Ca^{2+} concentrations (126 ± 18 mg/l) that were all greater above the APHA limits (10 mg/l Na+ and 100 mg/l Ca^{2+}) (Table 4.1). Ca^{2+}, T-Fe, and Na^+ concentrations in combined distillery and sugar processing wastewater as well as in river water downstream after effluent discharge followed a trend of Ca^{2+} > T-Fe > Na^+, as shown in Table 4.1.

The concentrations of Ca^{2+} ($p = 0.001$), total iron ($p = 0.001$), and Na^+ ($p = 0.043$) significantly increased after the discharge of wastewater effluent, going from around 8.5 mg/l to 25 mg/l, 3.2 mg/l to 10.5 mg/l, and 5.5 mg/l to 8.0 mg/l, respectively. The Ca^{2+} concentrations in wastewater from the sugar processing facility were found to be significantly higher ($p = 0.008$) than those in wastewater from the distillery (79 15mg/l) using one-way ANOVA. However, there was no difference in the total iron ($p = 0.348$) or Na^+ ($p = 0.819$) concentrations between the effluent from the production of sugar (65.6 ± 19.8 mg/l and 42.8 ± 12.0 mg/l, respectively) and wastewater from distilleries (44.8 ± 8.8 mg/l and 40.7 ± 7.8 mg/l, respectively) (7).

4.3.Pollution load

The pollution load from S. D., Sardar Nagar into the River Rapti is shown in Table 4.2. TDS, COD, and BOD showed larger pollution loads (kg/day) than those of TP, 20346, and BOD when compared to T-Fe, Na^+, Ca^{2+}, TN, and TP (156 ± 35, 68 ± 19, 319 ± 49, 121 ± 29, and 40 ± 14, respectively).

Table 4.2: Mean pollution load (kg/day) discharged in River Rapti (n = 12)

Variables	S3
TDS (kg/day)	29700 ± 8453
T-Fe (kg/day)	156 ± 35
Na^+(kg/day)	68 ± 19
Ca^{2+} (kg/day)	319 ± 49
TN	121 ± 29
TP (kg/day)	40 ± 14
BOD(kg/day)	5692 ± 1666
COD (kg/day)	20346± 4449
Discharge (m^3/day)	2523± 72

V. ENVIRONMENTAL IMPACT OF DISTILLERY EFFLUENT

Industrial effluents have lately been recognized as common sources of pollution due to insufficient treatment and ineffective disposal practices. Under these conditions, aquatic life suffers, which lowers the generation of natural rivers and results in the water's quality deteriorating to the point where it is no longer potable. Distillery wastewater poses a severe danger to water quality in several regions of the country. The pH of the stream is decreased, the organic load increases, the amount of oxygen in the water decreases, aquatic life is wiped out, and there is foul odour (odiferous odour of H_2S from sulphates, indole, and skatole from the yeast cells). These are some of the biggest pollution problems brought on by distillery effluent. Aquatic life suffers greatly because of the high BOD since there is less dissolved oxygen. In certain cases, particularly in Maharashtra , Uttar Pradesh the colour problem in the groundwater is so bad that distilleries must separately provide potable water to nearby people. BOD estimates that the population equivalent of distillery wastewater is up to 6.2 billion, meaning that India's contribution to organic pollution from distillery waste is about seven times more than the population of the whole nation. Due to this, despite tight standards for effluent quality being set, untreated or just partially treated effluents often get access to water courses. Effluents are often seen strewn throughout the outskirt areas near to distilleries. The retention of effluents in exposed anaerobic lagoons and sun-dried ditches is what gives distilleries their distinctive fragrance. India's distilleries are thus also accountable for the deterioration of the air, water, and land. If the distillery effluent is permitted to reach open drains and is not utilised for agriculture (land application or composting), the water quality and fragile ecosystem would be significantly jeopardized. The distillery waste wash is a major pollutant due to its high organic content. Even after anaerobic treatment, the effluent's hue persists because of the high sulphate content. This poses a serious environmental risk since water bodies that absorb coloured trash may become coloured, blocking the passage of light and endangering the ecosystem. Distillery effluent has caused significant fish deaths in the Gomti River(12). Several workers (13-14) reported ground water contamination caused by wastewater with high BOD and salt content near the lagoon locations in the majority of the distilleries. This problem has been resolved in some places by enclosing the lagoons and ensuring that the effluent is sometimes used for composting or irrigation across a larger area as part of a well-designed agronomic plan, resulting in the shortest possible retention time for the effluent in the lagoons.

5.1. Efforts of CPCB in Evolving Standards for Distillery

After understanding how challenging it was to treat distillery effluent to a level suitable for release into a river or onto land, the Central Board convened an expert group in 1980 to formulate Standards (MINAS) published by the CPCB. It is MINAS:

BOD,(20^{0}C, 5 days) : 30 mg l-1 for disposal into inland surface water

:100 mg l -1 for disposal on land for irrigation

In the EPA Notification of January 8, 1990, the Ministry of Environment and Forests established effluent restrictions depending on the disposal conditions, i.e., the recipient environment.

Table: 5.1The BOD (20^{0}C, 5 days) standards so specified are as follows

Disposal on stream/river	30 mg 1^{-1}
Disposal on land	100 mg 1^{-1}
Disposal on land when land is considered as a treatment medium (land treatment)	500 mg 1^{-1}
Land treatment with effective monitoring systems for ground water quality	700 mg 1^{-1}

Additionally, according to the criteria, the net additional contribution to ground water quality cannot be greater than 3 mg l^{-1} of BOD and 10 mg l^{-1} of nitrate.

The All India Distilleries Association was directed to take any or all of the following activities by the Ministry of Environment & Forests of the Indian Government in a letter (No. Z16011/18/99-OPA) dated 24.10.2000.

- After first treatment (anaerobic digestion with methane recovery), spentwash is composted with pressmud, baggasse, and agricultural wastes after taking the necessary steps to prevent groundwater contamination due to leakage.
- burning utilized wash in a concentrated manner.
- IARI regulation states that before being utilized for irrigation, treated effluents must meet criteria of 500 mg l^{-1} BOD and 2100 mg l^{-1} TDS. This covers both initial and follow-up care. The TDS limit of 2000 mg l^{-1} may apply to inorganic elements as they provide the greatest challenge for land application. The treated effluent must be retained in lined storage tanks when not being used for irrigation.
- Municipal sewage treatment facilities either combine the treated effluent with the sewage for terminal treatment or dilute the treated effluent with process water before performing tertiary treatment.
- Any more measures to ensure adherence to the code of conduct

5.2. Operation and maintenance of ETPs

Every distillery is required to carry out performance evaluation studies to determine how well each ETP unit is performing and how much energy it uses in respect to the parameters of its design. The effectiveness of the ETPs must also be evaluated on a regular basis based on operational parameters, such as MLSS & DO in aeration tanks, and records of energy consumption obtained from the particular energy meters supplied for ETPs.

5.3. Discharge of effluent

Direct or indirect discharge of effluent through drains into drinking or bathing water courses should be avoided owing to the colour, even when treated effluent satisfies the BOD threshold of 30 mg l^{-1}. In addition to conforming to the BOD limitations that will be defined based on the characteristics of the receiving water bodies, distilleries must ensure colour removal when it is unavoidable.

VI. UTILISATION OF DISTILLERY EFFLUENT IN AGRICULTURE

6.1. Properties and nutrient potential of distillery effluent

The distillery's waste wash is an acidic liquid with a pH range of 3.8 to 4.0 with a high concentration of organic carbon and plant nutrients including K, Ca, Mg, and S. High BOD (45,000–55,000 mg l^{-1}) and COD (90,000–1,10,000 mg l^{-1}) levels are seen. The distillery waste wash has a decent amount of Ca and Mg and is quite acidic, making it a potential organic amendment for the reclamation of sodic soils. The spentwash from the distillery after first treatment is known as distillery effluent. The main processed distillery effluent has a dark brown hue, and it smells bad since it has been burnt or caramelized. The composition of this effluent is found to be remarkably similar to farmyard manure. (Table 3)

Table 6.1 Comparison of distillery spentwash (DSW) and farmyard manure (FYM)

Parameters	FYM	DSW
pH	7.5	3.8
Moisture (%)	22.65	91.1
Organic matter (%)	21.75	31.50 (on solid basis)
Total N (%)	1.44	2.0
Total P (%)	0.83	0.28
Total K (%)	0.79	9.96
Mineral matter (%)	52.5	26.49
C: N ratio	15.10	15.75

The pre-treated distillery effluent is almost reactionally neutral (7.8) and has a high EC of 24.3 dS/m. According to Sharma et al. (2001), potassium salts were mostly responsible for the EC rise. It has a significant organic load, with 81,000 ppm of total solids, 45,000 ppm of COD, and 5600 ppm of BOD. The high COD of the raw effluent may be caused by the presence of a number of chemicals in the raw wastewater. The distillery wastewater had significant amounts of the soluble organic material. Significant concentrations of K (10,000–13,00 mg K_2O l^{-1}), Ca (2100–3000 mg l^{-1}), Mg (2000–3300 mg l^{-1}), and S (4000–5000 mg l^{-1}) are present, as well as moderate concentrations of N (1200–1,500 mg l^{-1}) and P (400–600 mg P_2O_5 l^{-1}) and micronutrients Fe (65 mg l^{-1}), Zn (10-50 mg l^{-1})(15-27).

VII. Conclusion

It was also investigated how *Trametes versicolor* has affected the distillery effluent's COD reduction. It was confirmed that the enzyme responsible for melanoidin degradation contains two components, one reliant on glucose and the other independent of glucose, since there was a 30.46% drop in COD in the presence of glucose and a 35.80% reduction in the absence of glucose. Sludges are always utilized for fertigation of soil as bio manure, hence analysis of different sludges produced after the treatment process was also done for their nitrogen, phosphorus, and potassium content. In contrast to the sludge produced by the ABT-BMT effluent's activated sludge process, which had 3.2% nitrogen, 2% phosphorus, and 1% potassium, the ammonifying bacterial sludge included 4.8% nitrogen, 2.8% phosphorus, and 0.9% potassium. The biofilter treatment of diluted BMT effluent produced sludge with 3% nitrogen, 1.4 % phosphorus, and 0.8 % potassium. When sugar factory effluent was treated with activated sludge, the resulting sludge contained 2.4% nitrogen, 1.1% phosphorus, and 0.4% potassium, whereas the resulting sludge from biofilter treatment of the activated sludge process treated sugar factory effluent contained 1.6% nitrogen, 1.1% phosphorus, and 0.2% potassium.

Sludge produced during the biological treatment process of effluent serves as a byproduct, making it possible to recoup some of the costs associated with treating effluent. However, research is required to separate and collect additional value-added byproducts from the biomass created during wastewater treatment, such as amino acids and vitamins.

- Despite the sugar industry's (S. D., Sardar Nagar) importance to the economy, its waste water discharge has a large negative influence on the environment. The results indicated that the pollutant content in the effluent from the S. D., Sardar Nagar was higher than the APHA-permitted discharge limits.
- With a high organic matter and nutrient load of 20,346 ± 4449 kg/day COD, 5,692 ±1666 kg/day BOD, 121 ± 29 kg/day TN, and 40 ± 14 kg/day TP, River Rapti received 2,523 ± 728m^3 wastewater per day from S. D., Sardar Nagar. After wastewater

release, there was a very significant difference between the upstream and downstream rivers' water quality indicators (P 0.05).

- By producing high strength organic waste (4723 ±1242mg/l BOD and 16152 ± 4109mg/l COD), the distillery is more polluting than sugar processing, which produced 1295± 569mg/l BOD and 3821 ± 1229mg/l COD.

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