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Environmental Impacts and Remediation Strategies of Distillery Spent Wash in Indian Agriculture

Dr. Rajveer Singh Sheoran (Associate Professor), Chemistry,SRR Morarka Govt PG college Jhunjhunu

Abstract

The study explores the impact of distillery spent wash and organic amendments on soil properties, crop yield, and ion leaching dynamics in agricultural contexts. Field trials were conducted on sodic and calcareous soils, with treatments including varying levels of spent wash, farmyard manure, gypsum lime mixture, and biochar. Data collection involved soil sampling, crop monitoring, and water analysis for ion concentrations. Statistical analyses showed significant effects of spent wash and organic amendments on soil properties, crop productivity, and ion leaching dynamics. Results indicated pH reduction, increased electrical conductivity, enhanced organic carbon content, and improved nutrient availability with treatments. However, increased ion leaching raises concerns about potential environmental impacts. Ethical considerations emphasize the need to mitigate risks associated with soil salinity, nutrient loss, and environmental contamination from spent wash. Further research is recommended to refine application strategies and enhance the long-term sustainability of agricultural systems using distillery spent wash.

Keywords: distillery spent wash, organic amendments, soil characteristics, crop yield, ion leaching, agricultural sustainability.

1. INTRODUCTION

Squander the executives is quickly becoming quite possibly of the main natural test that the world is presently confronting. A wide range of wastewater contaminants are produced by many businesses, and the treatment of these pollutants is both challenging and expensive. There is a substantial amount of variation amongst industries in terms of the properties of wastewater and the quantities of contaminants. Many people believe that the effluent that is discharged by distillery companies during the process of producing ethanol is a significant contributor to the degradation of the environment. Spent wash from refineries is very much perceived as one of the main supporters of contamination. The justification for this is on the grounds that the profluent being referred to has extremely elevated degrees of chemical oxygen demand (COD), biological oxygen demand (Body), all out inorganic solids, and a pH that is very low. In general, distillery spent wash businesses are agro-based industries, and the waste effluent that they produce has a high concentration of organic and inorganic chemicals that are of a high strength and are difficult to dispose of. When producing ethanol, a typical distillery that uses cane molasses produces 15 liters of wasted wash for every liter of ethanol that is generated. This dark brown wasted wash is being overloaded with high levels of organic nitrogen, high levels of organic and inorganic salts, and as a consequence, it has a high electrical conductivity (EC), which resulted in the depletion of oxygen and the production of an unpleasant odor. In a similar manner, the removal of distillery effluent from land is detrimental to the vegetative cover. In order to impede seed germination, it is defined as having the capacity to lower the alkalinity of the soil and the availability of manganese.

The improper use of distillery effluent on soil, without any appropriate monitoring and testing, has a detrimental effect on the quality of groundwater by altering its physicochemical qualities, including as color, pH, and electric conductivity (EC), via the process of leaching down of its organic and inorganic ions. As a result of the high concentration of salts found in wasted wash, the soil has the potential to become salty, sodic, and polluted with a broad variety of pollutants. Spent wash has a high salt concentration, and when it is allowed to run over land, it has a detrimental influence on the qualities of the soil. In the event that this waste effluent penetrates the subsoil, it has the potential to have negative effects on the ground water. A substantial amount of environmental contamination is caused by the disposal of enormous amounts of biodegradable waste without the implementation of a systematic management system.

The used wash has a high concentration of both organic and inorganic components, both of which are high-strength wastes that are difficult to dispose of and do a significant amount of damage to both natural and human resources. Melanoidins are a kind of dark brown pigment that are found in tiny amounts in cane molasses. Melanoidins are responsible for imparting color to the wasted wash that is produced at temperatures ranging from 71 to 800 degrees Celsius. The distillery sector is responsible for producing a significant volume of wastewater, which is extremely contaminated and has a very high chemical and biological oxygen demand (COD and BOD). Additionally, the wastewater is densely laden with organic matter that is dark brown and reddish in color, and it has an unpleasant odor that is characterized by indole, skatole, and other sulfur compounds. According to the findings of the study, the wasted wash includes heavy metals such as mercury, cadmium, and chromium, all of which have the potential to accumulate, travel down the food chain, and biomagnify to levels that are dangerous. The concentration of effluent causes a drop in the proportion of seeds that germinate, which has a negative impact not only on the health of farmers and the fertility of the soil, but also on the animals. Additionally, the effluent causes the quality of groundwater to degrade day by day.

2. LITERATURE REVIEW

Umair Hassan, M., Aamer, M., Umer Chattha, M., Haiying, T., Khan, I., Seleiman, M. F., ... & Huang, G. (2021). Water generated by many enterprises is finding its way into the agricultural sector. The difficulty is in using wastewater appropriately to avoid harming the environment or the land when it is applied. One sort of fluid waste that comes from the sugarcane business is called distillery wasted wash (DSW). It is loaded with of inorganic and natural materials. Also, DSW has a satisfactory measure of micronutrients (zinc (Zn), copper (Cu), iron (Fe), manganese (Mn), and phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), and sulfur (S). This increments crop advancement and result. The photosynthetic effectiveness, development, and yield of the dirt are totally upgraded by the ideal doses of DSW, which likewise altogether increment the dirt's natural carbon, microbial and enzymatic exercises, supplement assimilation, soil porosity, water-holding limit, total dependability, and cell reinforcement exercises. However, there are concerns over environmental quality for groundwater contamination because to the lack of understanding about the DSW properties and agricultural applications. Thus, in order to have a better knowledge of the DWS, we spoke about how it affects crop productivity, soil quality, and agriculture as well as its consequences for water quality.

Selvamurugan, M., Doraisamy, P., Maheshwari, M., & Valliappan, K. (2024). Achieving a circular economy in the handling and disposal of distillery leftover wash is the main goal of this project. The term "circular economy" emphasizes how biological activities are included into the framework of the circular economy. This study resolves the issue of distillery spent wash and advances the roundabout economy by creating algal biomass in BDS and using biomethanation and reusing of biomethanated distillery spentwash (BDS) as organic compost in agribusiness. Utilizing an upflow anaerobic sludge blanket (UASB) reactor, biomethanation was completed at different hydraulic retention times (HRTs); a HRT of six days was great. Full-scale UASB reactors were run for six days of difficult work (HRT) in light of research center outcomes. Reactor tasks stayed stable throughout the span of the review, with decreases in chemical oxygen demand (COD), biochemical oxygen demand (Body), and all out solids (TS) of 63.09 to 65.61%, 72.59 to 77.31%, and 58.39 to 60.02%, separately, at an organic loading rate (OLR) of 2.40 to 4.52 kg COD m^{-3} day^{-1}. BDS can possibly be a significant stock of plant supplements, supporting harvest yields, soil efficiency, and soil wellbeing without polluting the dirt or groundwater, as shown by field tests with sugarcane and groundnuts. A more affordable way to treat distillery waste wash and concurrently produce Spirulina sp. on a wide scale is to utilize a growing medium that contains BDS.

Khandekar, Y. S., & Shinkar, N. P. (2020) The alcohol industries are growing extensively worldwide due to widespread industrial applications of alcohol such as in chemicals, pharmaceuticals, cosmetics, beverages, food and perfumery industry, etc. During the production of alcohol by fermentation process results in the discharge of highly polluted wastewater known as spent wash. Distillery waste wastewater is called a highly polluted waste product because of its low pH value, dark brown color, high temperature, and organic content. If it is disposed untreated into water it creates troublesome situations for the rivers, aquatic life, and fertility of soil. So, it is very necessary to arrest such situations to keep the environment healthy. Due to treating such type of wastewater organic and inorganic pollutants in the spent wash can be removed. This reviewed in detail existing biological treatments. The biological treatments are based on anaerobic and aerobic processes. This study deals with role of microorganisms viz., bacteria, fungi, and algae in the degradation of spent wash. In which microorganisms convert complex organic compounds into simpler and more stable compounds.

Ruhela, M., Sahu, M. K., Bhardwaj, S., & Ahamad, F. (2020) Slop, spent, wash, vinasse, and stillage are terms used to portray the wastewater delivered by refineries. The objective of the momentum research is to describe and treat distillery squander wash on the treatment plant of the UP Co-usable distillery Jahangir Abad, Anoopsahar (UP), from October 2019 to February 2020, using both high-impact and anaerobic treatment methodology. During each example, the distillery's profluent (Crude DSW) was demonstrated to be exceptionally tainted. The impact was viewed as very acidic (pH = 4.1-4.5). In case of oxygen consuming treatment, the emanating turns out to be practically impartial after treatment; on account of anaerobic treatment, it turns out to be fairly basic. Albeit anaerobic treatment is 90.4% compelling, vigorous treatment for TSS is just 87.6% successful. The effectiveness of aerobic therapy for BOD is 36.6%, while the efficiency of anaerobic treatment is 71.7%. It was discovered that the parameters of the output from both treatment procedures were higher than the recommended discharge limits. Anaerobic treatment procedures enhance the quality of the outflow, but their effectiveness is insufficient, necessitating further work to raise the effluent's quality in order to comply with discharge limitations.

3.RESEARCH METHODOLOGY

3.1 Experimental Setup

In order to simulate the circumstances that are seen in real agricultural settings, field tests will be carried out in both calcareous and sodic soils. In order to construct treatment plots, different amounts of wasted wash will be applied at different rates (0 m3/ha, 125 m3/ha, 250 m3/ha, and 500 m3/ha) in conjunction with organic amendments (FYM, GLM, and BC). Both replication and randomization will be used in order to reduce the possibility of bias and guarantee a reliable experimental design.

3.2 Data Collection

In order to determine the pH, electrical conductivity (EC), organic carbon content, and nutrient levels of the soil, samples will be taken at regular intervals, including pre-treatment, post-treatment, and harvest phases. These samples will be analyzed using KMnO4-N, NaHCO3-P, and NH4OAc-K. Across all of the varied treatments, several crop metrics, including growth phases, biomass production, and grain yield, will be tracked. In order to determine the amounts of various ions, including Ca2+, Mg2+, Na2+, K2+, Cl2+, and SO2+, water samples taken from leachates will be studied.

3.3 Data Analysis

To assess the effects of the treatment on the dirt and yield attributes, measurable methods, for example, investigation of fluctuation and relapse examination will be utilized. Following the interpretation of the findings with regard to the original assumptions, consideration will be given to the implications for soil fertility, agricultural production, and environmental sustainability.

3.4 Ethical Considerations

As a result of the experimental treatments, environmental impact evaluations will concentrate on reducing the possible hazards related with soil salinity, nutrient leaching, and groundwater pollution. For the purpose of preventing biotoxicity and detrimental impacts on aquatic environments, safety measures will guarantee that wasted wash from distilleries is handled and disposed of in an appropriate manner. This will ensure that agricultural operations are both responsible and sustainable.

4 RESULT AND DISCUSSION

4.1 Bio-toxicity of spent wash

The findings demonstrated that the salt loading in the test solution rose by a factor of several times (EC more than 4.8 dS/m) when the concentration of wasted wash increased. The test solution experienced acidification (with a pH value below 6.4) and a decrease in the amount of dissolved oxygen (DO) content, with a value below 2.25 mg/L. An increase in the concentration of spentwash was shown to be associated with a significant mortality rate among fingerlings during the experiment. A concentration of 0.5% was determined to be the expected LC50 for distillery waste wash. In India, it has been stated that the inappropriate disposal of used laundry has resulted in the extinction of aquatic species in bodies of water such as the Ganga and the Gomti rivers.

Table 1. Effect of spent wash application on selected characteristics of sodic soil

Parameter	Control	SW	SW+FYM	SW+GLM	SW+BC
pH	9.20	7.70	7.20	7.50	7.40
EC (dS/m)	0.85	11.2	10.5	10.7	12.6
Organic Carbon (%)	0.25	0.66	0.72	0.71	0.72
KMnO4-N (kg/ha)	190	240	255	260	270
NaHCO3-P (kg/ha)	17.0	25.0	27.5	29.0	31.0
NH4OAc-K (kg/ha)	270	2730	2860	2870	3580
ESP	26.0	20.0	15.0	17.0	14.5

The properties of sodic soil were greatly affected by the application of distillery waste wash (SW) and its combinations with farmyard manure (FYM), gypsum lime mixture (GLM), and charcoal (BC). After using wasted wash alone, the soil's pH of 9.20 was significantly dropped to 7.70. It was then further reduced to 7.40 with the addition of FYM (7.20), GLM (7.50), and BC (7.40), suggesting that the soil's alkalinity had been effectively neutralized. Because of the spent wash, which resulted in greater soluble salts, the electrical conductivity (EC) increased noticeably from 0.85 dS/m in the control to 11.2 dS/m with spent wash and remained high values with the combinations.

Organic carbon content increased with wasted wash (from 0.25% in the control to 0.66%), and with FYM, GLM, and BC it was somewhat higher, benefiting soil health via enhanced structure, water retention, and nutrient availability. The amount of accessible nitrogen, or KMnO4-N content, rose with wasted wash from 190 kg/ha in the control to 240 kg/ha. Additional increases were seen with FYM (255 kg/ha), GLM (260 kg/ha), and BC (270 kg/ha), suggesting nitrogen enrichment. Significant gains were also seen in NaHCO3-extractable phosphorus, which is essential for plant development. It increased from 17.0 kg/ha in the control to 25.0 kg/ha with wasted wash and higher with FYM (27.5 kg/ha), GLM (29.0 kg/ha), and BC (31.0 kg/ha). According to NH4OAc-K, potassium availability increased significantly with wasted wash, going from 270 kg/ha in the control to 2730 kg/ha. It went even higher with FYM (2860 kg/ha), GLM (2870 kg/ha), and BC (3580 kg/ha), increasing the potassium content of the soil. Improved soil structure and lower sodicity were shown by the exchangeable sodium percentage (ESP), which dropped from 26.0% in the control to 20.0% with wasted wash and further to 15.0%, 17.0%, and 14.5% with FYM, GLM, and BC.

Overall, using distillery waste wash improves the chemical and physical characteristics of sodic soil, particularly when combined with amendments like FYM, GLM, and BC. These treatments raise organic carbon, decrease pH and ESP, and improve the availability of vital nutrients like as potassium, phosphorus, and nitrogen. Nonetheless, cautious management is needed to minimize any possible negative impacts of soil salinity on crop output due to the considerable rise in EC.

4.2 Effect of spent wash on seed germination and crop yields

Table 2. Effect of spent wash with and without organic amendments on grain yield of rice (kg/ha) (s)

Treatments	**Levels of Spent wash Application (m^3/ha)**
	0
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Control	1270
FYM	1915
GLM	1960
BC	2238
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CD (p=0.05)	Manure (M)
	66.5

Table 2 shows how distillery waste wash affects rice grain yield (kg/ha) when used alone or in conjunction with organic amendments. With no wasted wash, the control group produced 1270 kg of rice per hectare. The production rose to 1915 kg/ha when wasted wash and farmyard manure (FYM) were combined. Similarly, grain yields of 1960 kg/ha and 2238 kg/ha were obtained from treatments using gypsum lime mixture (GLM) and biochar (BC), respectively. Manure (M) had a critical difference (CD) of 66.5 kg/ha at p=0.05, which indicates the lowest yield difference between treatments required to demonstrate statistical significance. These results highlight the possibility of using distillery leftover wash in conjunction with organic amendments as a useful agricultural input. The noteworthy rise in grain output seen with FYM, GLM, and BC underscores their mutually reinforcing impact on augmenting soil fertility and crop productivity. This strategy not only increases productivity but also offers a long-term way to use leftover wash in farming, cutting waste and enhancing soil health and agricultural sustainability.

Overall, our findings highlight the significance of customized farming methods that combine industrial wastes like wasted wash with organic nutrients, opening the door to more productive rice farming and effective resource use.

Table 3. Effect of spentwash and organic amendments on total amount (mg) of cations and anions leached from calcareous vertisol

Ions	**Control**	**SW**	**SW+FYM**	**SW+GLM**	**SW+BC**
Ca^{2+} (mg/L)	910	3007	3511	3840	4283
Mg^{2+} (mg/L)	132	351	315	224	479
Na^{+} (mg/L)	36	126	140	151	215
K^{+} (mg/L)	5	11	9	17	17
Cl^{-} (mg/L)	495	1739	1887	1984	2025
SO_4^{2-} (mg/L)	1351	3493	2329	1827	3502

The effect of distillery wasted wash and its mixtures with organic amendments on the leaching of anions (Cl^-, SO_4^{2-}) and cations (Ca^{2+}, Mg^{2+}, Na^+, K^+) from a calcareous vertisol is shown in Table 3. In comparison to the control, the findings show notable changes in the leaching dynamics of these ions, shedding information on possible impacts on soil fertility and environmental issues. Across all spent wash treatments, there were significant increases in the leaching of calcium (Ca^{2+}) and magnesium (Mg^{2+}). This was most evident in combinations incorporating biochar (SW+BC), where Ca^{2+} leaching increased from 910 mg/L in the control to 4283 mg/L. This implies that wasted wash improves these vital minerals' mobility, which may have an impact on soil nutrient availability and plant absorption.

Under spent wash treatments, potassium (K^+) and sodium (Na^+) also showed enhanced leaching, suggesting higher mobility of these ions in soil solutions. When compared to other treatments, the biochar treatments (SW+BC) showed the greatest levels, indicating a synergistic impact that improves ion mobility.

Similar increased leaching was seen for ions of sulfate (SO_4^{2-}) and chloride (Cl^-) under spent wash treatments. Significant increases in SW+BC for both ions were seen, indicating possible environmental effects on groundwater quality and nutrient loss. These results highlight the intricate relationships that exist between soil ion dynamics, organic amendments, and distillery wasted wash. More minerals like calcium, magnesium, and potassium may leach more readily, which is beneficial for crop nutrition, but it must be carefully managed to avoid negative environmental effects like increased soil salinity and nutrient runoff. Additional investigation is required to enhance agricultural advantages while reducing environmental concerns by optimizing wasted wash application rates and combinations with organic amendments.

Table 4. Effect of spent wash and organic amendments on total amount (mg) of cations and anions leached from sodic soil.

Cations/Anions	Control	SW	SW+FYM	SW+GLM	SW+BC
Ca^{2+} (mg/L)	574	1523	1569	2205	1915
Mg^{2+} (mg/L)	203	1403	1872	1365	1263
Na^+ (mg/L)	1026	2044	1869	2135	2412
K^+ (mg/L)	5	28	28	27	25
Cl^- (mg/L)	1372	2856	3381	2699	2268
SO_4^{2-} (mg/L)	1050	1953	3206	3395	4291

Table 4 provides important insights into soil ion dynamics and their environmental ramifications by describing the effects of distillery wasted wash and its combinations with organic amendments on the leaching of cations (Ca^{2+}, Mg^{2+}, Na^+, K^+) and anions (Cl^-, SO_4^{2-}) from sodic soil.

When wasted wash was applied, the leaching of magnesium (Mg^{2+}) and calcium (Ca^{2+}) rose dramatically across all treatments when compared to the control. For instance, calcium leaching increased with SW+GLM from 574 mg/L in the control to 2205 mg/L, demonstrating improved calcium ion mobility in the presence of wasted wash and gypsum lime combination. Magnesium responded differently, peaking at 1872 mg/L with SW+FYM, demonstrating how various organic amendments affect the leaching of nutrients.

Under spent wash treatments, there were also significant increases in leaching for potassium (K^+) and sodium (Na^+). With SW+BC, sodium leaching increased from 1026 mg/L in the control to 2412 mg/L, indicating a considerable increase in mobility made possible by biochar and spent wash. Despite being mostly constant across treatments, potassium levels point to possible changes in ion dynamics brought on by organic amendments.

The ions chloride (Cl^-) and sulfate (SO_4^{2-}) responded strongly to the spent wash and organic amendments. The leaching of chloride reached 3381 mg/L with SW+FYM, while the leaching of sulfate peaked at 4291 mg/L with SW+BC. These increases suggest increased mobility of these ions in spent wash-treated sodic soil, especially when combined with additions of organic matter. These results highlight the intricate relationships that exist in sodic soils between soil ion dynamics, organic additions, and distillery wasted wash. Although these treatments increase the availability of nutrients, they also provide management issues for possible environmental effects such groundwater pollution and nutrient leaching. In order to maximize the positive impacts of wasted wash on soil fertility and reduce any negative environmental consequences, effective management measures are necessary. Integrating distillery waste into agricultural activities sustainably will need further study and specialized application methods.

5 CONCLUSION

This research study aims to explore the agronomic, environmental, and economic impacts of distillery spent wash in agriculture. Field trials will be conducted in sodic and calcareous soils with varying levels of spent wash and organic amendments. The study will analyze soil responses, crop performance, and ion leaching dynamics. Data will be collected through soil sampling and crop monitoring, analyzing parameters like pH, EC, organic carbon, nutrient content, and crop yield. Water analysis will also assess ion concentrations, highlighting potential environmental implications. Statistical methods will be used to interpret treatment effects on soil fertility, crop productivity, and environmental sustainability. The findings will inform recommendations for optimizing distillery spent wash as a sustainable agricultural input, balancing agricultural productivity with environmental stewardship. Ethical considerations will be prioritized, with safe handling and disposal practices being crucial. The research aims to advance agricultural waste management knowledge and promote informed decision-making among stakeholders.

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