

# DISTILLERY SPENTWASH IN THE CONTEXT OF CROP PRODUCTION – A REVIEW

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## ABSTRACT

Post-methanated distillery spentwash (PMDSW) is a by-product of sugar industry often used as a source of nutrients for a wide array of crops. In the past four decades, PMDSW has been extensively studied in various crop production systems that brought out benefits and concerns associated with this industrial waste water. This review encompasses the impact of PMDSW on changes in soil physical, chemical and biological characteristics, shift in ground water quality, long-term effects and responses of crops. This paper has clearly suggested that the spentwash application has resulted in the changes of soil properties such as impeded hydraulic conductivity, build up of salinity and restricted biological activity transiently as a secondary consequence of intense salt stress. Despite these ill-effects, PMDSW carries macro and micronutrients that facilitate better growth and yield performance in almost all crops that have been experimented. One of the potential hazards associated with PMDSW is the interference with groundwater which is rarely reported or critically analyzed in the context of seasonal and temporal shifts. Overall, this review suggests that the PMDSW can be exploited as a source of nutrients to sustain the crop production with a rider that excessive or continuous use need to be circumvented.

## INTRODUCTION

Irrigation water continues to be the single most important factors dictating the success of crop productivity in arid and semi arid agro-climatic zones. In the past five decades, the water availability has reduced to half and further reduction is fast approaching. This necessitates using every drop of water that can be recycled back to the crop production. Sugarcane based industries are increasing exponentially and many factories adjunct with distilleries in order to balance the price of sugar in the open market besides enhancing energy security of the country. In the distillery industry, for every litre of alcohol produced, about 15 litres of spentwash is released as waste water. Different terminologies are used for this type of effluent in different countries viz., stillage, vinasse, slop, dunder, still residue etc. There are 319 distilleries in India with an installed capacity of 3.25 billion litres of alcohol, generating 48 billion litres of raw distillery spentwash annually (Uppal, 2004). Generally the spentwash is discharged into the water bodies. The effluent is therefore, a major course of water pollution. That's why distilleries have been included in the red category list by the Central Pollution Control Board, India.

The chemical composition of spentwash has been studied extensively and it is well understood that each cubic meter of spentwash carries N, P, K, Ca, Mg, S, and organic matter to the tune of 1.8, 4, 11.5, 1, 2.2, 2.5 and 30kg, respectively (Sengik and Kiel, 1995). Though the composition varies with the origin of the spentwash, the quantity of nutrients that can be added to the crop production is aplenty. One of the serious concerns of the raw spentwash is the high BOD of 50,000 ppm besides excessive salt load (Valliappan, 1998). In order to suppress

the impact of BOD, biomethanation process is recommended wherein the raw spentwash is subjected to anaerobic decomposition process thereby the BOD level is brought down to 85% (Rajkishore, 2008) which is popularly referred as Post Methanated Distillery Spentwash (PMDSW). This wastewater is considered safer to use for crop production as a source of nutrients (Davamani, 2002).

In the past four decades, PMDSW research has been undertaken in cereals, pulses, oilseeds, cotton, sugarcane and vegetable crops. In all the cases, the data have vividly shown that one time land application of PMDSW prior to the cultivation of crops had improved the yield to the tune of 20 to 60 % without associated environmental hazards. However, these studies rarely examined the possible long term impacts of PMDSW on soil characteristics and groundwater qualities. This review has taken painstaking efforts to scan through the literature published in the past and bring out a compendium of dataset that provides insight into the benefits and concerns relating to the usage of distillery effluent in agro-ecosystems.

### Characteristics of spentwash

Spentwash is a dark brown coloured liquid with an unpleasant odour of burnt sugar. The raw spentwash is acidic in nature with the pH ranging from 3.8 - 4.2 (Valliappan, 1998; Saliha, 2005; Soundararajan, 2003), while the primary treated spentwash otherwise known as post methanated spentwash is near neutral (pH of 7.2) in reactions (Rajukkannu *et al.*, 1996). The dark brown colour of raw spentwash is due to the presence of melanoidin of cane molasses which is not decomposed effectively by yeast and methane bacteria in its activated sludge process. In comparison to raw spentwash, the PMDSW contains lower BOD and COD values (Table 1).

The annual treated distillery spentwash obtained in India can supply 16,800 tonnes N, 6,300 tonnes P and 1,26,000 tonnes K and by this it is estimated that Indian distilleries could contribute about 10,000 million rupees annually (Sudaramoorthy *et al.*, 2005).

#### Effect of spentwash on soil properties

The spentwash, being loaded with organic and inorganic substances could bring drastic changes in the physical, chemical and biological properties of soil (Table 2).

#### Soil physical properties

Soil permeability and porosity are the important parameters to be considered when planning for liquid waste disposal to agricultural land. In soils, heavy dose of organic carbon compound due to distillery waste disposal may cause high oxygen demand by bacterial activity under anaerobic condition, which will in turn cause a decrease in infiltration rate and a reduction in hydraulic conductivity due to accumulation of solids (Sweeney and Graetz, 1991). Neves *et al.* (1983) reported that the reduction in hydraulic conductivity by distillery effluent irrigation was due to accumulation of solids at the soil surface. Levy and Vander Watt (1990) observed that increasing amount of K in the exchangeable phase of soil decreased hydraulic conductivity of soils. In contrast to the above statements, Joshi *et al.* (1996) reported an improvement in saturated hydraulic conductivity and reduction in bulk density of the soil with effluent amendment over the control. Soundararajan (2003) reported that the bulk density of the soil was decreased and the particle density remained unchanged in the spentwash applied soils. Moreover, experiments conducted by Chandra *et al.* (2005) revealed that application of distillery spentwash increases the soil hydraulic conductivity.

#### Soil chemical properties

The multifaceted characteristics of spentwash bring about significant changes in the chemical properties of soil. Singh (1969) observed marginal decrease in the soil pH due to neutralized spentwash addition. Conversely, an increase in pH and EC after application of distillery effluent to agriculture fields was also reported (Jadhav and Savant, 1975; Ajamal and Khan, 1988). Mattiasso and Ada Gloria (1985) reported that the organic matter oxidation brought out by microbial activity was responsible for increased pH of the soil treated with distillery effluent. According to Rajukannu and Manickam (1996), the spentwash application reduced the pH and ESP (Exchangeable Sodium Percentage) to safer limits. However, an increase in pH of the soils observed in the post harvest soils might be due to leaching of soluble salts and the oxidation of organic matter. Subash Chandra Bose *et al.* (2002) observed a significant increase in the pH of the post harvest soil due to the application of graded doses of primary treated distillery effluent. However, the increase was only by 0.2 units which fall within neutral reactions even at higher dose of distillery effluent (6.25 lakhs litre ha<sup>-1</sup>).

#### Soil biological properties

The distillery effluent being rich in nutrients and organic matter was found to improve the soil microbial populations. But observations recorded soon after the application of spentwash on soils showed an initial setback in the microbial populations

and enzyme activities (Rajkishore, 2008). Batch *et al.* (1993) observed that the spentwash @ 250 m<sup>3</sup> ha<sup>-1</sup> stimulated the soil microorganisms and increased the dehydrogenase activity of the soil. Murugaragavan (2002) reported that the addition of raw spentwash at 125 m<sup>3</sup> ha<sup>-1</sup> in dry land soils increased the activity of soil enzymes, viz., the phosphatase, dehydrogenase and urease. Further, the application of treated spentwash also increased the activities of these soil enzymes (Rajannan *et al.* 1998; Nandakumar, 2009).

#### Effects of spentwash on soil fertility

Every cubic meter of distillery spentwash contains 1kg of nitrogen, 0.2kg of phosphorus oxide and 10kg of potassium oxide. Most of these nutrients are soluble forms and are easily available to plants. Kulkarni *et al.* (1987) classified spentwash as dilute liquid organic fertilizer with high K content. They observed that N was mostly in colloid form behaving as a slow release fertilizer better than most inorganic N sources.

#### Macro and micronutrients

Several workers have reported that there was an increase in N status of soil under spentwash application (Scaloppi *et al.*, 1989; Rajukkanu and Manickam, 1996; Rajkishore and Valliappan, 2010a). Mineralization of organic material as well as the nutrients present in the distillery effluent is responsible for increasing the availability of plant nutrients in soil (Somashekar *et al.*, 1984). Valliappan (1998); Baskar *et al.* (2001); Pushpavalli *et al.* (2002) suggested that distillery spentwash (treated or untreated) should be applied before planting to give sufficient time for natural oxidation of organic materials, which in turn enhances the soil available nutrients. The available N, P, K and micronutrients such as Fe, Mn, Zn and Cu were increased due to the spentwash application as reported by Gopal *et al.* (2001), Selvalakshmi *et al.* (2001) and Annadurai *et al.* (2001). The availability of Cu, Zn, Fe and Mn was increased in the sodic soil amended with spentwash (Bhanooduth, 2006; Valliappan, 1998). The increased micronutrient availability might be due to direct contribution from the spentwash as well as solubilisation and chelation effect of organic matter (Valliappan, 1998).

#### Reclamation of sodic soils

The raw distillery spentwash is acidic in nature and rich in Ca and SO<sub>4</sub>. Therefore, this could be better utilized as an amendment for reclamation of sodic soils similar to gypsum. Singh *et al.* (1980) conducted laboratory studies in soil columns to find out the effectiveness of spentwash in the reclamation of a calcareous saline sodic soil. They observed that the application of spentwash increased the rate of water uptake of the soil. The pH was lowered and the salt content was reduced to safer limits after leaching. The application of spentwash in air dried soil followed by irrigation had greater effect than that of spentwash diluted at the time of application itself in reducing the soil pH and ESP. Exchangeable sodium percentage was reduced from 100 to 2 in the top 15cm when spentwash applied equivalent to 100% gypsum requirement. The untreated spentwash has an acidic pH and contains substantial quantity of beneficial divalent cations viz., calcium and magnesium (Jayachandran *et al.*, 1999). So, the spentwash has a high amendment value and comparable to any chemical amendment recommended for alkali soil reclamation.

Valliappan *et al.* (2001) suggested that one time land application of spentwash at 150 mg kg<sup>-1</sup> soil could be a viable technology for reclamation of non-saline sodic soils.

#### Impact of spentwash on ground water quality

Cruz *et al.* (1991) studied the nitrate pollution in the ground water due to application of spentwash in the sugarcane field over a period of 15 years. They found nitrate in the ground water but not at levels harmful to human health. Similarly, Orlando (1996) observed no NO<sub>3</sub> pollution due to vinasse application. The analytical results of bore well samples collected from the spentwash irrigated fields (for more than 3 years) indicated that there was no percolation of effluent to the ground water even though it was used continuously (Kotteeswaran *et al.*, 1999). Malathi (2002) reported that no pollution on ground water samples collected from open wells near the spentwash applied farmer's field in Theni district, Tamil Nadu as all the quality parameters were below the critical limits. Jain *et al.* (2005) showed that the long-term indiscriminate use of PMDSW could lead to significant leaching of inorganic salts. Although leaching of salts has the potential to affect the quality of groundwater, the actual impact will depend on the rate of recharge of groundwater and initial status of groundwater quality. Somawanshi and Yadav (1990) indicated that addition of undiluted spentwash would result in increased salinity of both soil and ground water where there was not sufficient surface leaching of soil solution. Though several piezometric studies have reported that application of treated spentwash at the rate of 100 m<sup>3</sup> ha<sup>-1</sup> did not contribute for groundwater pollution, it is not advisable to apply PMDSW continuously even at doses < 80 m<sup>3</sup> ha<sup>-1</sup> as there is a possibility of groundwater contamination due to continuous application of PMDSW (Rajkishore and Valliappan, 2010a).

#### Crop response to application of spentwash

The effects of spentwash on crop production are well documented (Rajukkanu and Manickam, 1997; Banulekha, 2007; Rajkishore, 2008). Table 3 shows the beneficial effects of spentwash on a wide range of agricultural crops. In India, two commonly followed practices for land application of distillery spentwash are single pre-sown application of the spentwash and 4 or 5 post-sown applications of the diluted spentwash (Joshi *et al.*, 1996). Under pre-sown application, fields are flooded with spentwash and allowed to dry for 15-30 days (Rajkishore and Valliappan, 2010a). After the spentwash is dried, the fields are ploughed and in this process the spentwash is degraded and mineralized by soil microorganisms which are later recycled into plant biomass. In case of post sown application, the level of dilution varies from crop to crop (Nandakumar, 2009).

#### Sugarcane

The sugarcane is the most researched crop with respect to spentwash since this crop is predominantly cultivated around sugar and distillery industries. Guimarati *et al.* (1968) reported the optimum dose of spentwash application for sugarcane as 419 m<sup>3</sup> ha<sup>-1</sup> with N, P and K supplementation. Distillery effluent at the rate of 135 m<sup>3</sup> ha<sup>-1</sup> in sugarcane was found to increase the cane yield (Cooper, 1975). Gopal *et al.* (2001) proved that the distillery effluent of 1:10 dilution was optimum for the

building up of soil fertility and increasing the yield of sugarcane in sandy soils. Baskar *et al.* (2001) reported that application of pre-treated distillery effluent (40 days before the planting) at graded doses (0, 0.5, 1.0, 1.5, 2.0 and 2.5 lakh litres per acre) progressively increased the cane yield of sugarcane.

#### Rice

Devarajan and Oblisamy (1995) reported that 50 times diluted effluent irrigation in rice recorded the higher grain yield and increased the soil availability of N, P, K, Ca, Mg, micronutrients and organic matter contents. However, Rajannan *et al.* (1998) observed only a normal yield of rice (CO. 43) due to application of spentwash with 50 times dilution. Rajukkannu and Manickam (1996) reported that spentwash applied as amendment to sodic soil at the rate of 5 lakh litres ha<sup>-1</sup> increased grain yield of rice. Annadurai *et al.* (2001) recorded the highest grain yield of rice (ADT 42) for 75 times diluted distillery spentwash treatment, which was on par with 100 times diluted spentwash treatment.

#### Wheat

Soil amended with diluted post methanated distillery effluent increased the yield of wheat and rice grown in sequence (Pathak *et al.*, 1998). Kundal *et al.* (2004) also reported that application of post-methanated distillery effluent to wheat resulted in significant improvement in grain yield.

#### Maize

The cob length, single cob weight, 100 grain weight and grain yield were increased in maize due to the application of spentwash @150kLha<sup>-1</sup> (Mallika, 2001). Sridharan (2007) concluded that one time land application of PMDSW @ 60 m<sup>3</sup> ha<sup>-1</sup> increased the yield of rainfed maize.

#### Pulses

One time controlled pre-sown application of PMDSW @ 80m<sup>3</sup> ha<sup>-1</sup> is an optimum dose for achieving the higher yield of rainfed blackgram (Rajkishore, 2008). In addition to this, PMDSW also increased the macro and micronutrient contents of haulm,

**Table 1: Characteristics of spentwash (Valliappan, 1998; Murugaragavan, 2002; Rajkishore, 2008; Nandakumar, 2009)**

Parameters	Values	
	Raw spentwash	PMDSW
pH	3.8-4.2	7.2-7.8
EC (dSm <sup>-1</sup> )	28-45.2	31-40
BOD	45,000-96,000	8,000-9,000
COD	90,000-1,90,000	33,000-48,000
Total solids	80,000-1,90,000	49,000-51,100
Suspended solids	8,400-61,900	6,200-7,000
Nitrogen	1,200- 5,000	1,200-1,900
Phosphorus	225- 3,030	280-400
Potassium	9,600- 17,400	10,500-12,100
Chlorides	5,000-42,000	7,900-8,500
Sulphates	3,400-9,000	1,050-3,900
Sodium	300-670	621-800
Calcium	2,100-7,000	1,693-2,400
Magnesium	1,700-2,100	976-1,900
Zinc	3.5-10	5.2-7.0
Copper	2.0-5.0	3.0-4.5
Iron	25-87	45-63
Manganese	4.0-5.0	4.5-7.0

(Except pH all values are in mg L<sup>-1</sup> unless otherwise stated)

**Table 2: Impact of spentwash on soil characteristics**

Impacts	Reference
Adverse effect on water retention, hydraulic conductivity and water stable aggregates	Jadhav and Savant (1975)
Mn deficiency in soil	Agarwal and Pandey (1994)
High K in spentwash was deleterious to soil health.	Biswas <i>et al.</i> (1998)
Increased organic carbon, Ca, Mg, N, P, K and micro nutrients.	Baskar <i>et al.</i> (2001); Rajkishore (2010a)
Dose more than 250 m <sup>3</sup> ha <sup>-1</sup> was detrimental	Mahimairaja and Bolan (2004)
Increased percent water stable aggregates and water retention capacity, but decreased the penetration resistance and salinity build up observed	Hati <i>et al.</i> (2007)
Fungi and actinomycetes population were inhibited soon after the application of PMDSW	Rajkishore (2008)
Macro aggregates high and micro aggregates low in spentwash applied soil	Biswas <i>et al.</i> (2009)

**Table 3: Effect of spentwash on agricultural crops**

Crop	Response	Reference
Sugarcane	Improved cane yield upto 250 m <sup>3</sup> ha <sup>-1</sup> per acre 375 m <sup>3</sup> ha <sup>-1</sup> increased the yield	Baskar <i>et al.</i> (2001) Subash Chandra Bose <i>et al.</i> (2002)
Rice	5 lakhs litres ha <sup>-1</sup> to sodic soil improved grain yield 50 times dilution increased yield 75 to 150 m <sup>3</sup> ha <sup>-1</sup> to the non saline sodic soil increased grain yield	Rajukkannu and Manickam (1996) Devarajan and Oblisami (1995) Saliha (2005)
Wheat	Upto 50 times dilution increased the yield	Pathak <i>et al.</i> (1998); Kundal <i>et al.</i> (2004)
Maize	150 m <sup>3</sup> ha <sup>-1</sup> improved cob length and grain yield	Mallika (2001)
Blackgram	80 m <sup>3</sup> ha <sup>-1</sup> improved the yield and quality	Rajkishore (2008)
Groundnut	40-50 times dilution increased shelling per cent, oil and crude protein content.	Devarajan <i>et al.</i> (1998)
Soybean	30 times dilution increased the yield	
Sunflower	30 times dilution increased the yield and oil content	
Bhendi	50 to 75 times dilution improved the crop quality and yield	Rathinasamy and Lakshmi-Narashimhan (1995)
Coconut	100 litres tree <sup>-1</sup> year <sup>-1</sup> applied in monthly splits increased the nut yield	Soundarrajan <i>et al.</i> (2007)
Redgram	30 m <sup>3</sup> ac <sup>-1</sup> increased the yield	Nagappan <i>et al.</i> (1996)
Cashew	175 litres /tree increased the yield	Nagappan <i>et al.</i> (1998)
Turmeric	50 m <sup>3</sup> ha <sup>-1</sup> ha <sup>-1</sup> as basal + 2.5 tonnes ha <sup>-1</sup> biosuper + 75 per cent NPK increased the yield	Davamani (2002)
Sweet Sorghum	84 m <sup>3</sup> ha <sup>-1</sup> increased the grain yield	Selvakumar (2006)
Fodder grass	37.5 m <sup>3</sup> ha <sup>-1</sup> improved the biomass of Cumbu Napier Hybrid	Banulekha (2007)

shell and grains, nitrate reductase activity in leaves, seed protein and methionine content of blackgram grains (Rajkishore and Valliappan, 2010b).

### Cotton

Raw distillery spentwash was found to lower the incidence of two major sap feeding insects in cotton viz., the plant louse and white fly (Sundaramurthy, 1998). In addition the incidence of bollworm was also significantly decreased on cotton crops treated with an insecticide in combination with spentwash. The yield of seed cotton was significantly enhanced by this treatment from 851 (in control) to 1270 kg ha<sup>-1</sup>.

### Oil seeds

Seed hardening with spentwash (10% and 20%) significantly improved the germination and growth parameters of crops like groundnut (VRI-2) and gingelly (CO-1), (Murugaragavan, 2002).

### Vegetable crops

In Bhendi (PKM-1), the use of 50 to 75 times diluted spentwash increased its quality and yield (Rathinasamy and Lakshmi-Narashimhan, 1995). 20 percent increase in the yield of potato as a result of spentwash application was reported by Sharma (2001).

### Turmeric

Treated spentwash @ 50kL ha<sup>-1</sup> as basal + biosuper @ 2.5 t ha<sup>-1</sup> + 75 per cent NPK significantly increased the growth and

yield of turmeric (Davamani, 2002).

### Sweet sorghum

The highest yield of grain (2.96 t ha<sup>-1</sup>), cane juice (16.62 t ha<sup>-1</sup>) and ethanol (2184 litres ha<sup>-1</sup>) in sweet sorghum were observed for one time land application of PMDSW@ 84m<sup>3</sup> ha<sup>-1</sup> when compared to 100 per cent recommended fertilizer - NPK and control (Selvakumar, 2006).

### Fodder grass

Banulekha (2007) concluded that both PMDSW @ 37.5 m<sup>3</sup> ha<sup>-1</sup> with supplementation of 25 per cent of recommended N and 60 per cent of recommended P prior to planting improved the biomass yield, quality of Cumbu Napier hybrid fodder upto three cuttings.

### Research gaps

Four decades of investigations unequivocally demonstrated that utilization of treated distillery spentwash enhances crop productivity, soil fertility besides saving considerable amount of inorganic fertilizers. However these dataset needs be proved on long term sustainability and stability basis by taking into consideration associated land and water degradation. Though research on utilization of distillery effluent was undertaken for a wide array of crops, almost all published results are restricted to short term field experiments. Researchers should focus on long term effects of spentwash on crop productivity, soil nutrient dynamics, microbial diversity and ground water quality. Some

agricultural universities recommend controlled land application of spentwash once in two years. However, even in such cases, the long term assessment is lacking and it is necessary to pay attention on this direction. Moreover, some of the negative results arising after the use of distillery effluent are often not reported. Only when such information if any is published, the scientific community can resolve for effective utilization of this nutrient rich waste. On the other side, the role of distillery industries is pivotal for ensuring fair conduct of field experiments during research tie-ups with investigating organizations. Though lot of information is available in the area of distillery waste management in agriculture, data on effect of spentwash application on bio-geo-chemical cycles, plant physiological adaptations to excess potassium, quality of farm produce is still lacking.

#### Lack of extension support from industries

Distilleries disposing their spentwash on land do not give adequate attention to the propagation of applicability of the spentwash for agricultural use. Most of the industries consider it as a waste which has to be disposed clandestinely either to water courses or if possible into the agricultural land. The value of the spentwash as a resource is scarcely recognised. The best strategy to remove these constraints would be to recognize the distillery spentwash as an important source of nutrients for agriculture. However, a sustainable agronomic package has to be developed which ensures increased crop yields without causing any environmental hazards. When these techniques are available to the farmers they can be convinced to accept the practice of irrigating their fields with diluted spentwash which would reduce fertilizer cost especially in rainfed agriculture and augment availability of water for irrigation. Once this nutrient rich liquid waste is recognised as a resource and finds use in agriculture, the basic problem of water pollution will be automatically solved to a great extent.

#### CONCLUSION

The lessons learned from more than four decades of research in a wide range of crops reveals the various beneficial aspects like increased soil macro and micronutrient status, enzyme activities and improved crop productivity as a result of treated spentwash application to agricultural soils. The existing dataset recommends one time controlled land application of post-methanated distillery spentwash for crop production. Extensive literature review in this area concludes that the controlled land application of post-methanated distillery spentwash is an alternate and effective strategy of disposal which offers double benefit of water pollution control and utilization for agricultural production. However, information is scarce on the environmental impact of distillery spentwash especially in long term application of post methanated distillery spentwash.

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