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IMPACT OF DISTILLERY EFFLUENT ON AQUATIC ENVIRONMENT: A REVIEW

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ABSTRACT

Distillery wastewater causes serious concern to living organisms resulting in a greater environmental stress. Due to increased pollution that arises from distillery effluent, there is the loss of soil fertility, loss of interaction within livestock, agriculture and biodiversity loss. High biological oxygen demand, chemical oxygen demand, total solids, sulfate, phosphate, phenolics, lignin, toxic metals, oil and greases of spent wash (dark colored wastewater) are likely to deteriorate the water quality of receiving waterbodies, ground water quality, soil and environment health. In aquatic resources, it causes serious environmental problems by reducing the penetration power of sunlight, photosynthetic activities and dissolved oxygen content. Some of the contaminants, such as certain level of minerals or compounds are not only harmful to health, but also create a long term effects such as cytotoxic and genotoxic effect. The distillery effluent altered the morphology, behavior and oxygen consumption rate of fishes. Various significant changes in haematological and biochemical parameters were observed in distillery exposed fishes. Thus, this review article provides a comprehensive knowledge on the distillery wastewater pollutants as well as its toxicological effects on environments, aquatic animals as well as human health. This review article concluded that distillery effluent is capable to affect the life of aquatic animals especially fishes that are sensitive to industrial effluent toxicity.

KEYWORDS: Distillery Effluent, Environmental Pollution, Fish, Spent Wash

Water pollution by discharging of effluents from various industries like chemical, pesticides, fertilizer, pulp and paper, sugar and distillery etc. causes serious problems by altering the physical, chemical and biological characteristic of water in many waterbodies such as rivers, streams, lakes, wetlands and pounds. The discharges of untreated and partially treated industrial effluent depleted the dissolved oxygen content of waterbodies so by interfering with respiratory metabolism they seriously affects aquatic biota and their production because they contain toxic substances detrimental to health (Prakash and Singh, 2020). Due to rapid industrialization many Indian rivers are facing the problems of chemical pollution because these Indian rivers act as temporary reservoirs for drainage of water and industrial effluent.

The safe disposal of wastes discharged from various industries is a serious problem worldwide. Wastewater discharged from industries is regarded as a key source of environmental pollution. In India, industrial pollution has increased due to the large number of distilleries (Chandra *et al*. 2018). A typical distillery, which uses sugarcane-molasses (a by-product of the sugar manufacturing process containing 10–15% minerals (ash), 15–20% non-sugar organic substances, 20% water and 45–50% residual sugars) as raw material for the generation of ethanol; it produces over 1 million litres of wastewater (effluent) daily. Generally in distilleries, the production of one litre of ethanol generates around 12–15 litres of effluent (Chandra and Kumar, 2017).

Distilleries releases enormous amount of waste water known as 'spent wash' which is around 80 % of the raw material to the environment (Farid and Ajay, 2012). The spent wash has a typical unpleasant odour of fruity smell (Thakkar, 2013). It is one of the most difficult waste products to dispose off, because of low pH and dark brown colour. It has high COD and BOD, causing pollution in the receiving water. Spent wash is perceived as one of the serious pollution problems of the countries producing alcohol from the fermentation and subsequent distillation of sugar cane molasses (Ansari *et al*., 2012).

In a developing country like India, distilleries are one of the most polluting industries as 88% of its raw materials are converted into waste and discharged into the water bodies, causing water pollution (Ansari *et al*., 2012). In the distillery, for every litre of alcohol produced, about 15 litres of spent wash is released (Ravikumar *et al*. 2007).

Alcohol serves as a basic chemical for a large number of chemical industries and therefore, demand for alcohol will see a great increase in future and distilleries are fulfilling this demand. The first distillery in India was set up at Kanpur in 1805 for manufacturing rum for the

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army. At present, there are about 315 distilleries with a total capacity of 3250 million litres of alcohol per annum with 40.4 billion litres of effluent, annually (Mohana *et al*., 2009). Liquid wastes from breweries and distilleries posses a characteristically high pollution load and have continued to pose a critical problem of environmental pollution (Ali *et al*., 2015).

Distillery effluent is most of the time disposed into the nearby water and land bodies. This effluent induces higher amount of foreign substances as heavy and toxic metals to the soil and water bodies which poses an adverse effect on the animals, plants and aquatic life (Musee *et al*., 2007; Krishna and Prakash, 2010).

Distillery wastewater contains various types of recalcitrant organic pollutants including endocrine disrupting chemicals like phthalates are reported and it causes the hormonal imbalance and disturb the reproductive fitness of living organism and ultimately leading to the carcinogenesis (Chowdhary *et al*., 2018). It also affects the domestic animals because they drink it and reduced milk yield. Even the human beings lived in distillery wastewater polluted area is affected by skin allergies, headache, vomiting sensation, irritating eyes, fever, and stomach pain (Choudhary and Arora, 2011).

Utilization of distillery effluent for irrigation purpose can be done with great cares. This is because, distillery effluent imparts higher amount of heavy metals to the soil which will result in various environmental and health problems (Bezuneh and Kebede, 2015). Heavy metals can also affect the plant by inhibiting seed germination, seedling growth, nutrient availability and enzymatic activity (Anuradha and Nagendra, 2012). Accumulation of heavy metal in plant can reach animals through food chain and results in various health problems to the animals as well as human.

Water is one of the most important compounds required for every existing of life therefore adequate supply of fresh and clean water is a basic need for all human beings. Thus there is urgent need to estimate the water quality or pollution status of a waterbody before discharging the industrial effluent.

Characteristics of Distillery Effluent

The physicochemical characteristics of distillery effluent can be determined by the type of raw material utilized and treatment methods performed prior to the discharge of the effluent to the environment which means that the characteristics of spent wash can differ between distilleries (Mikucka and Zielińska, 2020). Generally distillery effluents can be characterized by high level of biochemical oxygen demand (BOD), chemical oxygen demand (COD), phenolic compounds, sulphates, heavy metals, intense brown colour, lower pH, obnoxious odour, high electrical conductivity (EC), organic salts and high inorganic nutrients such as nitrogen, phosphorus, potassium, sulfate, and iron (Mikucka and Zielińska, 2020; Susheel *et al*., 2007). Along with various toxic metals, pesticides and detergents, distillery wastewater also contains a mixture of organic and inorganic salts such as melanoidins (responsible for dark brown colour of spent wash), di-noctyl phthalate, di-butyl phthalate, benzene propanoic acid and 2-hydroxysocaproic acid (Chandra and Kumar, 2017), which are well reported as genotoxic, carcinogenic, mutagenic and endocrine disrupting in nature. These substances lead to environmental pollution and have antioxidant activity, which makes them toxic to microorganisms that are present in wastewater (Ramakritinan *et al*., 2005; Mikucka and Zielińska, 2020). Melanoidins are natural condensation products of sugar and amino acids. It is not decomposed by anaerobic and aerobic treatments and is very complex in nature (Migo *et al*., 1993; Belkacemi *et al*., 2000). The conventional treatment methods are not enough to eliminate melanoidins. Therefore, treated distillery wastewater still contains almost the same dark brown color as before treatment because of the non-biodegradability of the colored compounds (Pant and Adholeya, 2007). This is one of the reasons why distillery wastewater is difficult to treat.

Table 1: Physico-chemical characteristics of Distillery effluent

Characteristics (Units)	Values				
	Mikucka and Zielińska (2020)	Prakash and Singh (2020)	Ali *et al*., (2015)	Ramakritinan *et al*., 2005	Nemade and Srivastava (1997)
pH	4.0-4.5	4.2	3.8-4.4	3.6-9.5	4.1
Total Solids (mg/L)	59,000-82,000	62928	60,000-90,000	35,000-80,000	62852
Volatile solids (mg/L)	38,000-66,000	-	45,000-65,000	10,000-50,000	-
Total Suspended Solids (mg/L)	2,400-5,000	2745	2,000-14,000	2,000-3,000	2241

Total Dissolved Solids (mg/L)	-	5580	-	-	60,611
COD (mg/L)	100,000-150,000	50128	70,000-98,000	20,000-65,000	77001
BOD (mg/L)	35,000-50,000	5312	45,000-60,000	15,000-30,000	-
Nitrogen (mg/L)	1660-4200	-	1000-1200	1000-1900	-
Phosphorous (mg/L)	225-308	-	500-1500	380-1100	-
Potassium (mg/L)	9,600-15,475	-	5,000-12,000	1200-1800	12,458
Sodium (mg/L)	-	-	150-200	-	208
Calcium (mg/L)	2300-2500	-	-	200-350	1660
Magnessium (mg/L)	220-250	-	-	-	934
Sulphate (mg/L)	2100-2300	2598	2000-8000	200-300	3970
Chloride (mg/L)	-	687	5000-8000	600-700	5893
Acidity (mg/L)	-	-	8,000-16,000	-	10913
Hardness (mg/L)	-	6432	-	-	7528

Impact of Distillery Effluent on Environment and Biodiversity

Distillery wastewater causes serious concern to living organisms resulting in a greater environmental stress. Due to increased pollution that arises from distillery effluent, there is the loss of soil fertility, loss of interaction within livestock, agriculture and biodiversity loss. High BOD, COD and other organic compounds like phenols, lignin and oil and greases in spent wash are likely to deteriorate soil, ground water quality and environment health (Choudhary and Arora, 2011). Some of the contaminants, such as certain level of minerals or compounds are not only harmful to health, but also create a long term effects such as cytotoxic and genotoxic effect (Chowdhary and Bharagava, 2018). Distillery effluent may effects the environment in several ways:

1. First, the dark-colored of spent wash (melanoidins) can block the penetration of sunlight, inhibiting photosynthesis and reducing the oxygenation of the water. Low Dissolved Oxygen (DO) in water bodies affect the aquatic life as DO drops, fish and other species are threatened and may get killed (Fitzgibbon *et al*., 1998; Choudhary and Arora, 2011; Ali *et al*., 2015).
2. Second, a high pollution load causes eutrophication of water bodies (Ramakritinan *et al*., 2005). For these reasons, untreated distillery effluent causes depletion of dissolved oxygen in water bodies and harms aquatic flora and fauna (Kharayat, 2012).
3. Discharge of wastewater with high TDS would have an adverse impact on aquatic life and to make unsuitable water for drinking purposes (Thakkar *et al*., 2013; Ali *et al*., 2015) if used for irrigation reduce the crop yield corrosion in water system and pipe line (Choudhary and Arora, 2011) .
4. Suspended solids in wastewater reduce the light penetration and plant production as a result, in receiving water by increasing turbidity it can also clog the fish gills (Choudhary and Arora, 2011; Ali *et al*., 2015).
5. High amount of BOD in the wastewater leads to the decomposition of organic matter under the anaerobic condition that produces highly objectionable products including Methane (CH_4), Ammonia (NH_3), and Hydrogen Sulphide (H_2S) gas (Choudhary and Arora, 2011;Thakkar *et al*., 2013; Ali *et al*., 2015).
6. Fall in DO levels causes undesirable odors, tastes and reduce the acceptability of water for domestic purpose (Choudhary and Arora, 2011; Thakkar *et al*., 2013; Ali *et al*., 2015).
7. In steam generation, DO is one of the most important factors causing corrosion of the boiler material (Choudhary and Arora, 2011; Ali *et al*., 2015).
8. Generally, industrial wastewater changes pH level of the receiving water body. Such changes can affect the ecological aquatic system; excessive acidity particularly can result in the release of hydrogen sulphide (H_2S) to air (Ali *et al*., 2015).
9. Color and odor of the effluent of the distillery were red brown in color with the unpleasant odor of Indol, Sketol and other sulphur compounds (Thakkar *et al*., 2013; Ali *et al*., 2015). These compounds produce obnoxious smell in waterbodies.
10. Spent wash is a complex, multicomponent stream that is known to cause considerable fouling (Choudhary and Arora, 2011).

11. The range of pH reduces soil alkalinity, causes soil manganese deficiency and is also affect the seed germination, plant growth and crop growth when waste water used in irrigation without adequate treatment (Choudhary and Arora, 2011; Thakkar *et al*., 2013).

12. Wastewater can cause soil sodicity, salinity, contamination with a wide range of chemicals, water logging and an aerobiosis, loss of soil structure and increased susceptibility to erosion (Choudhary and Arora, 2011).

Table 2: Impact of various constituents of distillery effluents on environment

Constituents of effluent	Indicators	Effects
Organic Matter	BOD, COD, Total organic carbon	Depleted oxygen when discharged into water leading to the death of fish and other aquatic organisms.
		Odours generated by anaerobic decomposition causes nuisance
Alkaline or acids	pH	Death of aquatic organisms at extreme pH range.
		Affects microbial activity in biological wastewater treatment process.
		Affects the solubility of heavy metals in the soil and availability and/ or toxicity in waters.
		Affects crops growth.
Nutrients	Nitrogen, Phosphorous, Potassium	Eutrophication of algal bloom when discharged to water or stored to lagoons. Algal blooms can cause undesirable pdours in lagoons. Nitrogen as nitrate and nitrite in drinking water supply can be toxic to infants. Toxic to crops in large amounts.
Salinity	EC, TDS	Imparts undesirable taste to water. Toxic to aquatic organisms. Affects water uptake by crops.
Heavy metals	Cd, Cr, CO, CU, Ni, Pb, Zn, Mu	Toxic to Plants and animals. Neurotoxicity
Solids	TSS	Reduces soil porosity, leading to reduced oxygen uptake Can reduce light transmission in water, thus compromising ecosystem health. Smothers habitats odour generated from anaerobic decomposition.

Source: Kharayat (2012)

Thus it can be concluded that by discharging spent wash with high TDS, BOD and COD, distillery effluent have deleterious effect on aquatic environment. The high BOD and COD in waste water leads to the decomposition of organic matter under the anaerobic condition that produced methane, ammonia, hydrogen sulphide, low dissolved oxygen in water affects the aquatic life and reduces the acceptability of water for domestic purpose.

Impact of Distillery Effluent on Aquatic Animals

The release of untreated and semi-treated distillery effluents into aquatic ecosystem seriously affects aquatic biota and their production. Distillery effluent may effects the environment in several ways.

Morphological Changes

Generally distillery effluent causes excessive secretion of mucous, dullness of body colour, darkness of gills becomes and occurrence of epidermal lesions in exposed fishes (Singh *et al.*,,, 2011).

Behavioural Changes

Distillery effluent altered the behavior and oxygen consumption rate of fish and would bring deleterious changes in the physiology of gills of freshwater fish. The oxygen consumption rate was decreased in effluent exposed fish (Ramakritinan *et al*., 2005; Prakash and Singh, 2020). Low Dissolved Oxygen (DO) in water bodies affects the life aquatic animals by increasing the surface activity and opercular movements of fishes. Distillery effluent induces the surfacing activity of aquatic animals due to enhanced oxygen demand for respiration (Haniffa and Augustian, 1989). The erratic movements, opercular beat and surface activity of fish increased significantly with increasing concentration of effluent and duration of exposure (Singh *et al*., 2011; Prakash and Singh, 2011).

Reproductive Changes

The distillery effluent reduces the fecundity of fish. The reduction in absolute fecundity may be attributed to the interference of effluent constitutions in the oogenesis as well as vitellogenesis process (Shukla and Shukla, 2015).

Haematological Changes

Distillery effluent significantly altered the haematological parameters such as TEC, TLC, DLC, platelets, haemoglobin contents, PCV and ESR as well as haematological indeces like MCH, MCHC and MCV of aquatic animals. Srivastava *et al.*,,, (2007) reported that distillery effluent increases the RBC, Hb % and MCHC with increasing the MCV and MCH in fishes. The significant increase in erythrocytes count, haematocrit (PCV) and clotting time with significant decrease in leucocytes count, lymphocytes and thrombocytes were observed in distillery effluent exposed fish, *Colisa fasciatus* (Shukla and Shukla, 2013). This increase in circulating RBC reflect the hypoxic condition (Ramakritinan *et al*., 2005) resulting the secondary polycythemia. Fish compensate the hypoxia condition (poor oxygen uptake) via release of large number of mature RBC in general circulation (Shukla and Shukla, 2013). The significant decrease in WBC count in effluent stress was due to sharp decline in the number of lymphocytes and thrombocytes. Such changes may be due to the enhanced secreation of adrenocorticotrophic hormone secreted by adenohypophysis which results in blood titers of corticosteroids which bring about the lysis of lymphocytes and thrombocytes (Shukla and Shukla, 2013).

Biochemical Changes

The biochemical parameters such as glucose, glycogen, protein, lipid, cholesterol and nucleic acids of fish were also influenced by distillery effluent (Singh *et al*., 2011; Prakash and Singh, 2011; Shukla and Shukla, 2012a & b). The distillery effluent significantly increased the Blood Sugar, protein, lipid, SGOT and SGPT level where as the serum bilirubin and cholesterol was significantly decreased in the fish (Srivastava *et al*., 2007; Prakash and Singh, 2011). The significantly increase in blood glucose and lactic acid level with increasing the level of liver glycogen and lactic acid in fishes lead to hypoxia condition and anaerobiosis during period of treatment of distillery effluent (Ramakritinan *et al*., 2005). The distillery effluent elicited a severe hypoxia anaerobic glycolysis to meet the energy demand under effluent stress (Saroj *et al*., 2013). The blood glucose level increases in distillery exposed fishes were due to increase in the breakdown of liver and muscles glycogen or due to decrease the synthesis of glycogen from glucose. Hyperglycemia is helpful to provide increased demand of energy to detoxify the toxicant and to overcome stress (Singh *et al*., 2011). The increased level of serum glutamic oxaloacetic transaminase (SGOT) and serum glutamic pyruvic transminase (SGPT) in distillery effluent exposed fishes was the indication of liver damage and possible myocardial damage under the stress of effluent (Singh *et al*., 2011).The decrease in the amount of bilirubin in distillery effluent exposed fishes was due to malfunction of liver and causes less secretion of bilirubin into blood and leads to hypobilirubinea (Singh *et al*., 2011). Increased in blood plasma protein level in effluent exposed fish was due to depletion of protein in liver and muscles and released into blood to fulfill the energy requirement during stress condition (Prakash and Singh, 2011). The liberated glucose metabolized from liver glycogen is transported to other organs through blood to meet the energy requirements necessitated by the accelerated movements of the fish under stressful condition to adopt themselves to toxic effluent medium (Saroj *et al*.,2013). Decreased in serum cholesterol in effluent treated fish to counteract toxic effect produced and further stabilization of the toxicant to prevent harmful effect caused by distillery effluent (Prakash and Singh, 2011). The decrease in glycogen, lipid and protein level in the liver, muscles and testis of effluent exposed fish was due to inhabitation of carbohydrate (Ramakritinan *et al*., 2005), lipid and protein metabolism and breakdown of stored food stuff to meet additional energy requirements under a stress of low oxygen uptake. During stress, muscular activity increases in fish, which require more oxygen to meet the energy demand and consequently more amount of glucose rapidly utilized. Fish try to meet this condition by increasing respiratory rate by drawing more amount of oxygen from contaminated water (Saroj *et al*., 2013). The suspended particle in the effluent act as an inhibitors of various enzymes like lactate dehydrogenase (LDH) and succinate dehydrogenase (SDH) enzyme (Ramakritinan *et al*., 2005) as well as lipase, phosphatases and esterases (Prakash and Singh,2011) in liver, and muscles. During stress condition rate of glycolysis in fish tissues was increases due to activated LDH activity. LDH convert the pyruvate into lactate which is accumulated in blood and tissues (Ramakritinan *et al.*, 2005). This hyperlactemia was due to the formation of lactic acid through glycolysis and glycogenolysis from the tissue of the liver through blood (Saroj *et al.*, 2013). Distillery effluent depleted the activity of SDH (respiratory enzyme) in fish. It could be attributed to decreased oxygen consumption under distillery effluent stress (Ramakritinan *et al.*, 2005). Thus it can be concluded that physiology especially respiratory, circulatory and reproductivity mechanism(s) of fish exposed to distillery effluent are greatly affected and this results in a shift or emphasis towards anaerobiosis at tissue level during sublethal intoxication.

CONCLUSION

Distillery industries plays an important role for us and several products we obtained from it, but due to excessive use of its products large amount of its production is required which results in discharge of excessive amount of spent wash. Generally this waste effluent was drained out to waterbody without properly treated that hazardously affecting the quality of water hence to overcome this problem treatment of waste water of distillery industry is must required. This review article concluded that distillery industries use in huge amount of water, various types of chemicals and raw materials in the production of alcohol, which generates huge amount of spent wash. Due to reddish brown in colour, alcoholic odour, highly acidic nature, very high TDS, BOD and COD, this waste water is considered as an environmental hazards, therefore, there is an urgent need to address the limitations in the existing methods and to develop new treatment techniques and processes that provide a complete solution to the treatment of distillery spent wash.

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