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# A Perspective Review on Sugar Industry Wastes, Uses and Treatment Techniques

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## Abstract

The increase in sugarcane production involves a proportional increase in sugar industry waste. As a result of such a growing trend, the sugar industry is observing severe environmental problems due to a lack of permanent solution for their waste management. Therefore, immediate consideration is needed to find suitable methods of waste management. The sugar industry waste and effluent are the main sources of environmental pollution and associated with health risks. In this paper, various sources of solids and liquids wastes from the sugar manufacturing industry are reviewed. Different effective and economical sugar industry wastewater treatment techniques are also discussed. The sources and uses of some waste like bagasse, bagasse fly ash, and pressmud have also been discussed.

**Keywords:** Economical; Wastes; Treatment; Sugar Industry

**Abbreviations:** ABR: Anaerobic Batch Reactor; AFR: Anaerobic Fixed Bed Reactor; UAFB: Up-Flow Anaerobic Fixed; EBPR: Enhanced Biological Phosphorus Removal; PAO: Polyphosphate-Accumulating Organisms; SIWW: Sugar Industrial Wastewater; ECT: Electrochemical Treatment; EPS: Extracellular Polymeric Substances.

## Introduction

According to the Food and Agriculture Organization of the United Nations, there are one hundred and twenty-four countries that produce sugar [1]. Sugarcane (Saccharum officinarum L.) is a worldwide cash crop [2]. Different byproducts have been obtained from the sugar industry and these also play a key role in promoting a number of subsidiary industries. Sugarcane is a multipurpose crop used as a fundamental raw material for the production of paper, boards, electricity, sugar ethanol, and ancillary products. The feeding (green tops) of sugarcane is an important source of energy. Molasses can be used for the production of ethanol on large scale by a distillery. In sugarcane processing bagasse has become a usual option for the sugar industry in the generation of electricity and ethanol. In the paper industry bagasse is a substitute for wood pulp and very important for economic and environmental sustainability [3].

Sugar can be produced from sugarcane by converting into raw juice and after heating and addition of lime, at the end of evaporation steps, the matter changed into raw sugar. Molasses is obtained during evaporation. A useful byproduct known is as pressmud also obtained during clarification. Pressmud is mostly used for fish food and as a fertilizer for crops. During the processing of sugar, various wastes such as bagasse, pressmud, bagasse ash and wastewater also produced. As discussed earlier, different waste materials produced during sugar manufacturing must be treated by economical and effective techniques. Various techniques such as microbial and electrochemical etc. are used for the

treatment of sugar industry wastes.

## Sugar Production Process

In the sugar production process, two main distinct operations are involved: converting sugar cane [1] or sugar beets into raw sugar [2] converting raw sugar into pure sugar. Polysaccharides, starches, gums, lignin, waxes, proteins and other colloidal impurities that impart color or taste to the crystalline products are present in cane and beet sugar extracts. The raw juice then subjected to heating, liming and clarification to separate proteins and colloidal matter [3]. The membrane technology is a highly attractive technology used for the clarification and purification in sugar the production process at the juice extraction stage [4]. Ultrafiltration and microfiltration are used for the removal of colloidal and macromolecular impurities with small or no addition of lime, carbon dioxide, or sulphite before the clarified juice is evaporated and crystallized. Sugar production steps are illustrated in Figure 1.

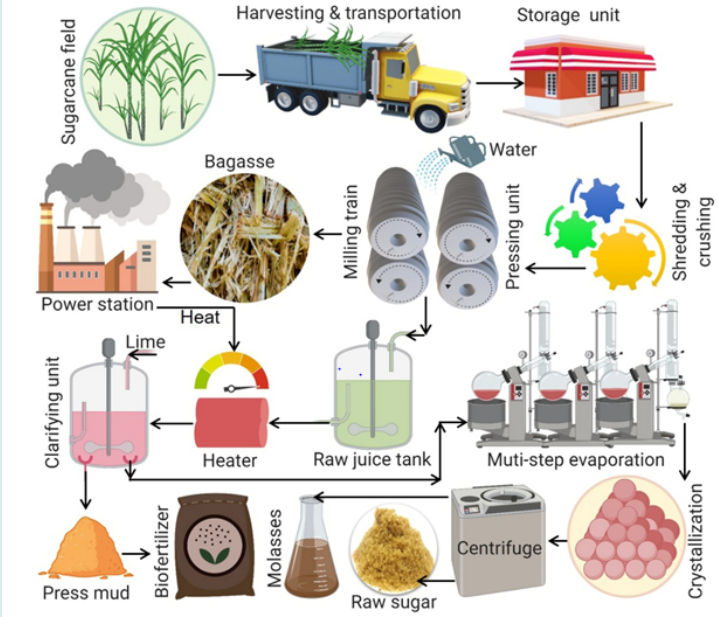


**Figure 1:** Sugar production steps at industrial level [4].

## Types of Sugar Industry Wastes

### Pressmud

Sugarcane is one of the most popular ingredients in the manufacturing of sugar and ethanol. Sugar and alcohol generation comprises four major types of waste products; cane residue left in the field after cane harvesting, bagasse; spent wash and pressmud [5]. Bagasse is the left residue after cane crushing and fuel resource for industry [6]. Pressmud is the waste created by the compressed sugar industry waste from the cane juice filtration. It is a good fertilizer source. Around 12 million tons of pressmud (filter cake) are produced by sugar mills in India as waste from double sulphitation processes. The pressmud is usually wasted in open areas. Dry pressmud can be used for energy production as it contains a higher fuel percentage. Pressmud drying procedure in sunlight is shown in Figure 3. It is also a strong biogas source because it contains approximately 5-15% sugar content. Pressmude is focused on the utility of fertilizer because it is rich in many micronutrients [7].

Grinded pressmud has been shown in Figure 4. Pressmud is the compressed sugar industry waste generated during the filtration of cane juice [8]. A schematic diagram for the formation of pressmud waste from the sugar industry has been shown in Figure 2 and steps of the sugar production in sugar industry are also illustrated in Figure 1. The percentage of ingredients and main ingredients in pressmud are given in Tables 1 and Table 2 respectively. Pressmud can be utilized to make biogas. Many organic materials may be used for the generation of biogas are given in Table 3. Through anaerobic fermentation, biogas is produced. In anaerobic fermentation, organic matter is decomposed by the action of microorganisms into carbon dioxide and biomass by various and parallel reactions in the absence of oxygen. Pressmud

contains a high percentage of nutrients and can be used as fertilizer. It is also used to synthesize citric acid by Aspergillus niger in a solid-state fermentation system [9].

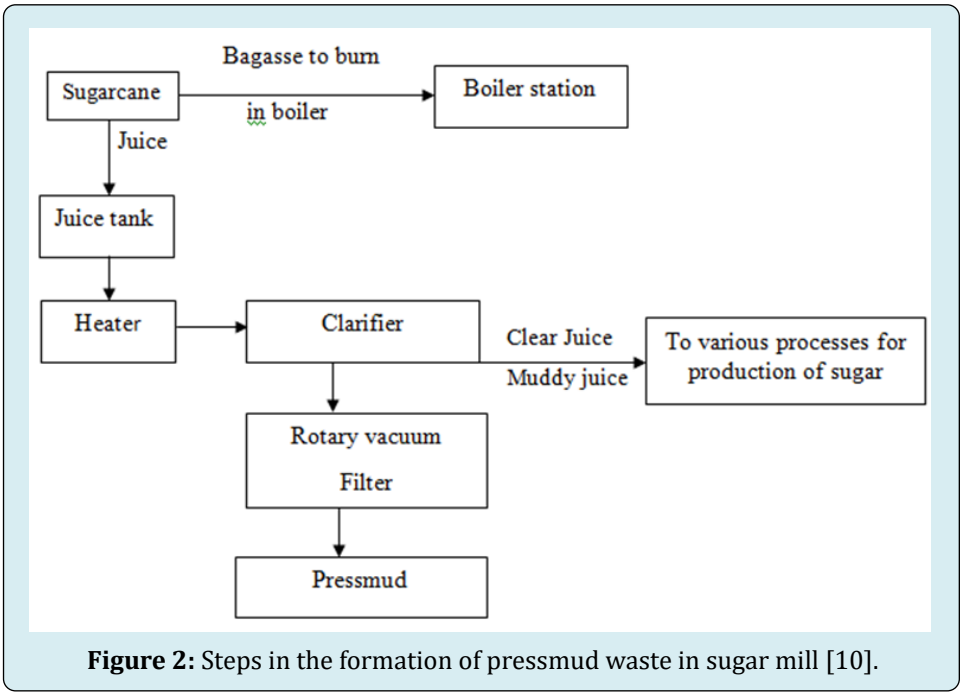


**Figure 2:** Steps in the formation of pressmud waste in sugar mill [10].

| Ingredients | Percentage |
|---|---|
| Crude protein | 5-14% |
| $SiO_2$ | 4-10% |
| MgO | 0.5-1.5% |
| PO | 1-3% |
| CaO | 1-4% |
| Crude wax | 5-14% |
| Fiber | 15-30% |
| Sugarcane | 5-15% |
| Total ash | 9-10% |

**Table 1:** Percentage composition of pressmud [11].

| Nutrients | Percentage |
|---|---|
| Copper | 0.05% |
| Zinc | 0.01% |
| Nitrogen | 1.90% |
| Manganese | 0.03% |
| Sodium | 0.10% |
| Sulfur | 0.10% |
| Phosphorus | 1.80% |
| Potassium | 0.90% |
| Calcium | 4.30% |
| Magnesium | 6.70% |

**Table 2:** Main nutrients of pressmud [11].

| Waste Generating Source | Organic Waste |
|---|---|
| Agro-industry wastes | Sugarcane bagasse, rice ban, tea wastes, oil cake, vegetable and fruit processing wastes, coffee pulp, distillery wastes, pressmud, tobacco wastes, sawdust etc. |
| Crop waste | Straw, sugarcane trash, silage liqor weeds, spoiled fodder, crop stubble etc. |
| Animal wastes | Wool wastes, urine and excreta from man and domesticated animals, tannery wastes, fishery wastes etc. |
| Forestry litter Municipal waste | Sewerage, Kitchen waste, domestic refuse, bark, leaves, twigs etc. |
| Aquatic sources | Fresh and marine algae, aquatic plant etc. |

**Table 3:** Some biogas generating organic materials.

Pressmud is a soft, spongy, amorphous and dark brown material produced in excess amount during sugar cane clarification after removal of raw juice from sugar cane [12,13]. Approximately 36-40 kg press mud is obtained per one tone of cane crushing [14]. It contains essential inorganic elements like N, P, K, Ca, Mg, Fe and Mn have a chemical composition similar to that of the cattle dung [15]. Pressmud is low cost and easily available suitable for the farming system can reduce the cost of fish food.

**Figure 3:** Pressmud drying in sunlight [1].

**Figure 4:** Grinded Pressmud [1].

## Properties of Pressmud

**Physical Properties:** Regular use of pressmud compost, animal manures municipal biosolid and crop remains are very useful in maintaining the fertility, tilth and productivity of cultivating soils [16]. Pressmud (filter cake) is one of the best byproducts of the sugar industry [17] which can be used for supplying many nutrients to soil plants due to favorable effects on soil structure, texture, water absorbing capacity, porosity, infiltration, bulk density and hydraulic properties [18]. Utilization of pressmud improves the aeration and drainage of soils while in sandy soils it helps in the retention of moisture. When added to agricultural fields it increases the productivity of cane, improves the juice quality and also promotes the ammonifying power of the soils [19]. Chromium is a toxic substance that affects plant growth. When plants take up much quantity of chromium then the rate of photosynthesis is decreased and plant growth is affected. It has been shown that by using pressmud the toxic effects of chromium on plants can be removed [11].

**Chemical Properties:** Pressmud obtained by sulphitation process has acidic properties hence can be applied on alkaline soils while pressmud obtained through carbonation process can be used in acidic soils. Many tons of pressmud produced annually creates great disposal problems for the sugar industry and environmental pollution. Recently it is made usable as fertilizers for agricultural crop production and to lower environmental pollution. The micronutrients such as nitrogen (N), phosphorus (S), Magnesium (Mg), calcium (Ca) and potassium (K), etc. increase the fertility of agricultural soil [11].

**Biological Properties**: Pressmud is taken as fertilizer to increase organic carbon in soil and its application also increases the bacterial, fungal and actinomycetes population. These microorganisms play an important role in the decomposition of organic materials to release beneficial nutrients for plant growth. Nitrogen (N) and higher carbon (C) biomass contents in soil treated with pressmud show changes in soil organic matter content due to microbial enzyme activities. Pressmud application increases the number of non-spore forming bacteria and different fungi like Neurospora crassa, Trichoderma viride, Aspergillus sp. and Penicillium sp. [19].

**Uses of Pressmud:** Pressmud contains a high percentage of nutrients hence can be used as fertilizer. It can also be used in fish foods under a semi-intensive fish culture system. In traditional diets, rice bran may be replaced by pressmud up to 50% to get growth of common carp comparable with that on a traditional diet. The optimum use of complex carbohydrates in pressmud is facilitated by the common carp [20].

## Bagasse

Sugarcane waste residues are grouped into two kinds, bagasse, and pressmud (filter cake). A huge amount of sugarcane bagasse is produced and destroyed or bunt in developing countries insufficiently causing environmental

pollution. Both these wastes are the same in properties, but they are used as different bio-resources. In the sugar manufacturing industry, sugarcane stalks are chopped into small pieces and cane juice is obtained. Residual material that will be left behind from this operation, consisting of fibrous remains of the cane sugar is known as bagasse. Besides, the precipitate in the form of sludge slurry after filtration is called filter cake or pressmud. It has about 70% water and used as fertilizer [21].

### Bagasse Ash

In the sugar-producing industry, bagasse ash is obtained by burning bagasse. It is a cellular fibrous waste obtained after the extraction of sugar juice from cane mills. Recently, it is used as a biofuel and in the production of paper and pulp and construction materials. About 3 tons of wet bagasse is a byproduct of the sugar cane industry for every 10 tons of crushed sugarcane. As bagasse is burnt then bagasse ash is obtained. The utilization of these waste products task is a challenging task for a researcher through economic and environmental hazardous [22]. The bagasse fly ash, an industrial waste-producing from the sugar industry, its disposal is a most problematic task and being used as filler in construction materials. In some prime industries for the removal of toxic heavy metals, bagasse fly ash is being used as adsorbent materials [23]. Bagasse fly ash is economical and recently used for the removal of zinc from water. Removal of heavy metals from water by activated carbon is very efficient, but the use of commercially available activated carbon is less, particularly in developing countries, because it is expensive and difficult to regenerate. It is necessary to dispose of these wastes by using low-cost adsorbents from wastewater [24].

### Sugarcane Leaves

The leaves of sugarcane are burnt in the field thus producing fly ash that severely damages soil microorganism diversity, and increases environmental concerns. It contaminates the air and the residues affect the environment and cause respiratory diseases such as asthma [25].

### Molasses

Molasses are a by product generated during the sugar crystallization process. The composition of molasses depends upon the type of sugarcane, the agro-climatic conditions of the crop growing region, sugar production process, storage and handling. Molasses is mostly used in alcohol distilleries because of containing formative sugars that are the best source of carbon for the metabolism of microorganisms [2]. Sugarcane molasses-based distilleries produce 7 to 15 L effluent/L alcohol that is cauterized by high chemical oxygen demand and biochemical oxygen demand, low pH and dark brown color. The dark color is due to by complex compounds such as caramel, melanoidins, carotenoids, polyphenols, anthocyanins, chlorophyll, and tennis, etc [26].

## Wastewater

Different heavy metals like copper (Cu), lead (Pb), manganese (Mn), zinc (Zn), oil, grease and some other chemicals are toxic substances in wastewater, which have very toxic effects on living organisms [27]. Sugar industry wastewaters are produced mostly by cleaning processes like washing the floor of milling house, vacuum pans, clarifiers, centrifugation and a different division of boiling house excreting large volume of wastewater. Wash water also used for filter cloth of rotary vacuum filter and cleaning of lime water periodically and $SO_2$ producing house are the part of wastewater. Heat exchangers and evaporators cleaning with NaOH and HCl to eliminate the deposit on tube's surface releasing inorganic and organic pollutants into wastewater. Wastewater is also produced from the leakage of pumps, pipelines, centrifuging hose [28]. In addition to this, wastewater is also produced from boiler blow down and spray pond overflow from condenser cooling water that is released into wastewater. Sugar industry wash water contains lost cane juice in different operations, bagasse particles, detergents, lubricant oil and grease for lubrication and solid sugar lost the during manufacturing process. It also contains organic and inorganic nutrients [28]. The quality and composition of wastewater depend on the production processes, equipment and product composition [29].

### Techniques for the Treatment of Sugar Industry Wastewater

There are three methods are very important for the treatment of sugar industry wastewater is

**Biological Methods:** Sugar industry wastewater generally contains volatile fatty acids, and sugar that is biodegradable, so anaerobic and aerobic treatments methods are employed [28].

**a) Aerobic Treatment**

Aerobic treatment is used to degrade the organic matter in the presence of oxygen. In traditional aerobic methods, the sugar industrial effluent is treated by using of trickling filters, activated slims, aerated bayous or their combination [30]. The effluent of sugar industry can easily be biodegraded except oils and greases that are not degraded aerobically because of the generation of methane during hydrolysis [31]. A number of experiments have been carried by many researchers on batch recorder for the verification of validity of aerobic methods in treating sugar industry waste water. It was concluded that from the results that aerobic treatment

of wastewater presents a promising reduction in pollutants [28].

**b) Anaerobic Treatment**

Anaerobic treatment process is used for the removal of industry pollutants. It is very important technique than aerobic treatment. In aerobic method for the treatment of industrial waste, less energy is to be needed due to the degradation of organic matter and production of methane gas. As a consequence, decrease in sludge formation and sludge disposal cost is also reduced [32]."

Anaerobic treatment method has many advantages over aerobic waste treatment. Because less energy is required due to the production of methane gas. Anaerobic batch reactor (ABR), anaerobic fixed bed reactor (AFR) [33] up-flow anaerobic fixed (UAFB) reactor [34] are commonly used in the treatment of wastewater during anaerobic treatment process.

**c) Microbiologically Removal of Nitrogen, Phosphate and Sulphate from Sugar Industry Wastewater"**

- **Removal of Nitrogen from Sugar Industry Waste Water"**

Nitrogen is removed from wastewater in a simple and common way. For this purpose, bacteria are used for nitrification and denitrification for the removal of nitrogen from wastewater. The nitrogen removal process is completed by two steps (1) conversion of ammonia ($NH_3$) to nitrate through Nitrosomonas and (2) Oxidation of nitrate ($NO_3$) by Nitrobacter. The denitrification is carried by heterotrophic bacteria, which change nitrate to harmless nitrogen gas [35]. There are many other bacteria being used in the elimination process. There are several other bacteria that are being used in nitrogen releasing processes like Aerobacter Micrococcus, Staphylococcus, Lactobacillus, Xanthomonas, Staphylococcus, Lactobacillus and Achrompbacter [4]. Some microalgae are also responsible for removing nitrogen from wastewaters [36].

- **Removal of Phosphate from Sugar Industry Waste Water**

Phosphorus in wastewater is removed by enhanced Biological phosphorus removal (EBPR) technique one of the prevalent methods due to cost-effectiveness and environment-friendly [37]. This treatment method is a concern with a class of microorganism known as polyphosphate-accumulating organisms (PAOs) that has much potential for the removal of phosphorus [38]. There are some other bacteria, which are identified PAOs as Proteobacteria [39] Pseudomonas, Micrococcus, Aeromonas, and Athrobacter used for the biological recovery of phosphorus [40]. The certain bacterial consortium also eliminates phosphates [41]. Phosphate can also be removed by consortium of bacteria and algae that is a very effective technique [42].

- **Removal of Sulphate from Sugar Industry Waste Water**

Sulfate ions are frequently present in natural water. The contamination of sulfate ions in water causes diarrhea, alteration and dehydration in methemoglobin and sulfhemoglobin levels in animals and humans by taking large amounts [43]. It also affects adverse consequences for freshwater species. The sulfate contamination can be reduced to hydrogen sulfide by bacteria under anaerobic bacteria [44].

Although biological wastewater treatment is a less costly, more effective and environment- friendly technique but some limitations and disadvantages have been observed. The biological technique is a slow method due to long term technique. The microbes need nutrients where they are placed and gradually decreased resulted in the insufficiency of the system [45]. Very large aeration tanks and land areas are required by microbes. Different biological, physical and chemical treatment methods have been used to eliminate contaminants from water. Adsorption method is cost-effective, simplicity in design and working offers the best way for producing high quality treated water [46].

**Electrochemical Treatment of Sugar Industry Wastewater:** Organic wastewater treatment by aerobic and anaerobic technique is an acceptable process due to its efficiency for COD and BOD removal [47]. Though, all classical available biological methods for sugar industrial wastewater (SIWW) treatment are not possible due to the large area and high capital of operational cost requirement. It has been observed that electrochemical treatment (ECT) of sugar industrial wastewater is an economical alternative method than conventional methods when fails to reduce pollution [48]. An ECT method has many benefits as it is efficient to remove contaminants in a compact reactor with a simple controller for controlling the operation of the process. This treatment method is not specific but applicable to various contaminants without the generation of unwanted side products.

**Physical Methods for Water Treatment**

**a) Coagulation and Flocculation**

Coagulation is very important physicochemical technique for the treatment of wastewater. Both coagulation and flocculation take place in successive step used to break the forces among suspended solid particles [49]. Coagulation can be defined as use of positively charged salts of metal ions that cause particle destabilization and charge neutralization. Coagulation acts on the colloid particles of size 10-7 cm in diameter. Coagulation processes are used to treat suspended solid particles from the water. The Flocculation is due to the

successful collision that takes place as destabilized particle are brought each other by the hydraulic shear force in a quick mixing [50]. Coagulation and Flocculation are usually carried out through sedimentation, filtration and disinfection at primary stage and completed by chlorination. This technique for water treatment is used worldwide [51]. Different types of coagulants are employed in the particular water treatment processes for making water usable for consumers. The coagulants can be categorized into biological coagulants, inorganic coagulants and synthetic polymers [52].

**b) Chemical Precipitation Method**

Chemical precipitation method is usually followed for the removal of heavy metals from inorganic industrial effluent. These are conventional techniques produce insoluble precipitation of heavy metals in forms of hydroxide, phosphate, sulfide, and carbonate. The insoluble metal precipitates are produced by hydroxide technique and easy to remove them from polluted water. This technique can be improved by changing critical parameters such as pH, temperature, initial concentrations and ion charges [53]. The solubility of various metals can be reduced at pH 8.0 to 11.0 [49]. In chemical precipitation methods, heavy metals ions react with chemical precipitant agents and insoluble solids particles are formed [54]. Solid phase can easily be separated by from solution by filtration or sedimentation [55].

In chemical precipitation processes, chemical precipitant agents react with heavy metal ions and change them into insoluble solid partic.

**Sludge Treatment:** The sludge is composed of aggregates made of constituent components including functional microbes and secreted extracellular polymeric substances (EPS) that are suspended in wastewater, with the bioaggregates in activated sludge basin being named as flocs [56]. The flocs have very complicated interior structure [57] with water strongly bound with the solid phase that is difficult to be released from solid surface via mechanical means [58]. Therefore, the sludge has non-Newtonian fluid-like behavior in suspension form and has visco-elastic characteristics in dewatered cake form [59]. Oily sludge is an industrial waste generated from various petrochemical production processes such as crude oil exploration, transportation, storage, and refining [60].

## Conclusion

The sugar industry generates many toxic substances in the environment. The main by-products generated from the sugar industry are pressmud, bagasse, bagasse fly ash, and molasses. These by-products are converted to obtain valuable products will decrease environmental pollution to large extent. Additionally, wastewater is treated by different processes to reduce environmental pollution through electrochemical and microbiological treatment methods. Effective waste management is very helpful to reduce the effects on biodiversity. It is concluded that the sugar industry should be considered as an economic resource and its by-products can be changed into useful products. Thus, effective and economic methods are available to utilize the sugar industry wastes in better ways.

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