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Study of characteristics and concentration of heavy metals present in effluents of sugar industry in western Uttar Pradesh (U.P.)

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Abstract- Rapid industrialization affects the environment in different ways by discharging the large amounts of effluents as waste water in the surrounding water bodies, causing the serious problem to environment. Metal concentration in waste water has threat to atmospheric during the 21st century due its toxicities of biodegradable and non-biodegradable in nature. Heavy metals are strictly regulated and must be treated before being discharged in the environment. Heavy metals concentration in effluent of sugar industry plays important role in maintaining the ecological balance of the natural streams rivers etc. However sugar mill have a great environmental impact upon the surrounding environment. Many countries in the world are affected by presence of heavy metals in effluents. Among the various metals, Pb, Cd, Ni, Fe, Zn, Cr, Cu, As, and Al., are found normally in waste water. Effluents samples were collected in plastic container with lables. Systematic waste water sampling was done at selected points. The samples were collected during winter seasons (February 2024). For this experimentation the sample of effluents were collected before the effluents reaches the effluents treatment plants and after leaving the treatment plant. Samples were analyzed by (AAS) Environmental lab. This paper illustrates the characteristics and concentrations of waste water of sugar effluents with respect to heavy metals. Purpose of this study was to determine the concentration of heavy metals in effluents at inlet point and outlet point before release the water for natural purpose.

Keywords; - Effluents, Heavy metals, Concentrations, Sugar industry.

Introduction – **In** India, there are about 552 sugars mills and is the majors agro-industry in the country which produced 35.5 million tons of sugar during 2024-2025.About 800 tons of industrial wastes (liquid and solid) are discharged daily from sugar factory during crushing season as pressmud, boiler ash and distillery waste water.[1] The purpose of this study was to investigate the sugar mill effluents samples and find out the availability of some heavy metals. The huge demand for fresh water resource in the 21st century can be attributed to population growth advanced agricultural practices and industrial usages.[2]The environmental contamination by heavy metals through industrial wastes is one of the main health problems in industrial countries. Metal contamination can easily enter to food chain if contaminated water, soils and plants are used for food production. The industrial effluents generally consists of organic compounds inorganic complexes and other non biodegradable substance.[3] Heavy metals include Lead (Pb), Cadmium (Cd), Nickel (Ni), Iron (Fe), Zinc (Zn), Chromium (Cr), Copper (Cu), Arsenic (As), and Aluminium (Al) groups of elements. There are different sources of heavy metals in the environment such as natural, agricultural, industrial, domestic effluents, atmosphere sources and other sources. Activities such as mining and smelting operations and agriculture have contaminated extensive areas of world such as Japan, Indonesia and China

mostly by heavy metals such as Cd, Cu and Zn.[4] As in most developing countries including India, the accelerated developments in industry and agriculture in the last few decades have made environmental pollution more noticeable, India is the largest producer of sugar in the world. The sugar industry plays an important role in the economic development of India, but the effluents released produces a high degree of organic pollution in both aquatic and terrestrial ecosystem. Among the effluents discharging industries, sugar mills play a major role in polluting the water bodies. The effluents also affects aquatic bodies. In addition, sugar factory discharge in the environment poses a serious health hazard to the rural and semi-urban populations that use stream and river for agriculture and domestic purpose. Sugar factory effluents that has not been treated properly has an unpleasant odor when released into the environment.[5] The effluents from sugars mills are discharging without treatment into fresh water bodies which makes poor water quality. This polluted water is utilized by human being for drinking, domestics, agriculture and industrial purposes Sugar factories are depends on agriculture which are playing major role for strengthening of national economy and social development of country.[6]

Source of effluents The waste water generated from different sub-streams can be classified as follows-

1- **Mill House-** The effluent consists of water used for cleaning the mill house floor which is liable to be converted by spills and pleased sugar juice (This clearing up operation will prevent growth of bacteria on the juice-covered floor).Water used for cooling of mills also forms part of the waste water from this source. Basically this water contains organic matter like sucrose, bagatelle, oil and grease from the bearings fitted to the mills.

2- **Waste water from boiling house-** The waste water from boiling house results from leakages through pumps, pipelines and the washings of various section such as evaporators, juice heaters, clarification pans crystals is action and centrifugation etc. The cooling water from various pumps also forms part of water.

3- **Waste water from boiler blow-down-** The water used in boiler contains suspended solids dissolved solid like calcium salts, magnesium salts, sodium salts, fatty salts etc. These salts get concentrated after generation stream from the original water volume. These solids to be expelled time to time to save the boiler being covered up by scales.

4- **Excess condensate-** The excess condensate does not normally contain any pollutants and is used as boiler feed water and the washing operations. Some time it gets contaminated with juice due to entertainment of carry over of solids with the vapours being condensed in that case if goes into the wastewater drain. The treatment requirement in this case is almost negligible and can replace fresh water or let out directly as irrigation water after cooling it to ambient temperature.

5- **Condenser cooling water-** Condenser cooling water is recirculated again unless it gets contaminated with juice, which is possible due to defective entrainment separators, faulty operation beyond the design rate of evaporation etc. If contaminated, the water should go in to the drain invisibly. This volume of water is also increased by additional condensing of vapour of trained from the boiling juice the pan.

6- **Soda and Acid wastes-** The heat exchangers and evaporator are cleaned with caustic soda and hydrochloric acid in order to remove the formation of the deposits of scales on the surface of the tubing. In India, most of the sugar factory let this valuable chemical go into drains. The soda and acid wash contribute considerable amounts of organic and inorganic pollutions and may cause shock loads to waste water treatment once in a fortnight so.[7]

Quantity of effluents generation in various units of sugar factory- The quantity of waste generated by each unit depends on the purpose of the use of water. Some unit of require large quantity of water hence the large quantity of water appears as a waste water and vice versa. The following table shows the range of water used by the various units of sugar factory.

SR NO.	PROCESS	EFFLUENTS m^3/day
01	Mill House	50-80
02	Boiling House	150-200
03	Boiler house(blow house)	40-50
04	Pump cooling water	80-100
05	Sulphur furnaces	14-20
06	Lime Hydrator	14-16
07	Excess condensate	20-30
08	Final effluent	400-500
09	Spray Pond Overflow	400-500

Table-1:- Range of water used by the various units of sugar factory.

MATERIAL AND METHODS

Description of the study area

The study area are selected in north India (Uttar Pradesh) sugar industry situated at district Kasganj, (Uttar Pradesh)

1- Neoly sugar mill, Nagriya district Kasganj (U.P).

Mostly the water source for irrigation was only water canal passes near industry. The existing industry discharge their liquid waste into nearby canal. Accordingly some of the farmers of villages are using this canal water for irrigation for different crops including rice, wheat, vegetables and fruits etc. By keeping this view it was considered that this activity of the industry may cause the adverse effect not only over environment but also on the farmers. The effects appears in the form of health hazards and damage the socioeconomic strata.

Samples collection for effluent water; Water samples were collected from different location (Inlet and Outlet). The water samples were collected in polyethylene bottles directly from the ETP plant when water comes before ETP plant (inlet point) and after release from ETP plant (outlet point). The samples were collected in clean and dry polyethylene bottles. The two bottles immediately acidified with 1ml nitric acid, for later analysis of metals concentrations. The purpose of acid is to keep the metals in solution to avoid adsorption to the container walls.

Apparatus and equipment The instruments used for this study were Atomic Absorption Spectroscopy (AAS). The common laboratory apparatus which were used during study include different sized beakers, Erlenmeyer flasks, funnels, volumetric flask, block digester, fume hood, droppers, glass pipettes, spatula measuring cylinders, vinyl gloves, analytical balance, and conical flasks.

Chemical reagents All the chemicals used were analytical reagents grade. Deionized water and distilled water were used for all preparation and dilution purposes throughout the study. HNO_3 (69%), KCl, H_2SO_4 (98%), H_2O_2 (30%), and HCl were used for digestion. Stock standard solution of 1000 ppm were prepared for some selected heavy metals (Pb, Cd, Ni, Fe, Zn, Cr, Cu, As, Al).

Digestion of waste water sample- The water samples from each sampling bottles are mixed thoroughly by shaking. A 50 ml filtered aliquot of water sample was pipette in to a digestion flask. The metal percentage found in the waste water was determined by digestion in 3 ml concentration HNO_3 and 3 ml H_2O_2 below 80^0c for 1 hour until a clear solution was observed. The clear solution was diluted to 100 ml volumetric flask with distilled water and blank digestion was also carried out in the same way.[8] The blank solution contained all reagents except waste water. All samples were digested in triplicates. The digest were analyzed for toxic heavy metals by using AAS in Green admire analytical service private limited lab. The concentration of each metal was calculated using the formula below.

$$\text{Final concentration (mg/L)} = \frac{CM \times DF \times NV}{SV}$$

Where- CM = Concentration of metals

DF = Dilution factor

NV = National volume

SV = Sample volume

Instruments operating conditions Concentrations of Pb, Cd, Ni, Fe, Zn, Cr, Cu, As and Al in the waste water were determined using by AAS in Green admire analytical service private limited lab, metals was Calibration curves for each heavy metal was set to ensure the accuracy of the instrument and to confirm that the results of determination were true and reliable. Standard stock solutions of 1000 ppm for all the metals were obtained. These solution were diluted to the desired concentrations to calibrate the instruments (A100 ppm multi-element solution containing Pb, Cd, Ni, Fe, Zn, Cr, Cu As, and Al was utilized to prepare elemental calibration solutions. This multi-elements solution was diluted with 2% nitric acid to obtain working standards for each metal to interest).[9]

Methodology used- The sample were analyzed by using standard method referring the IS : 17614 (P-1) : 2021. The laboratory instrument used for the testing was AAS.

Result and discussion

sample No. 1

Site- Neoly sugar mill Kasganj.

Source of wastewater – Effluents treatment of plant inlet.

Date / Time sample collection 16/02/ 2024 12.30 pm.

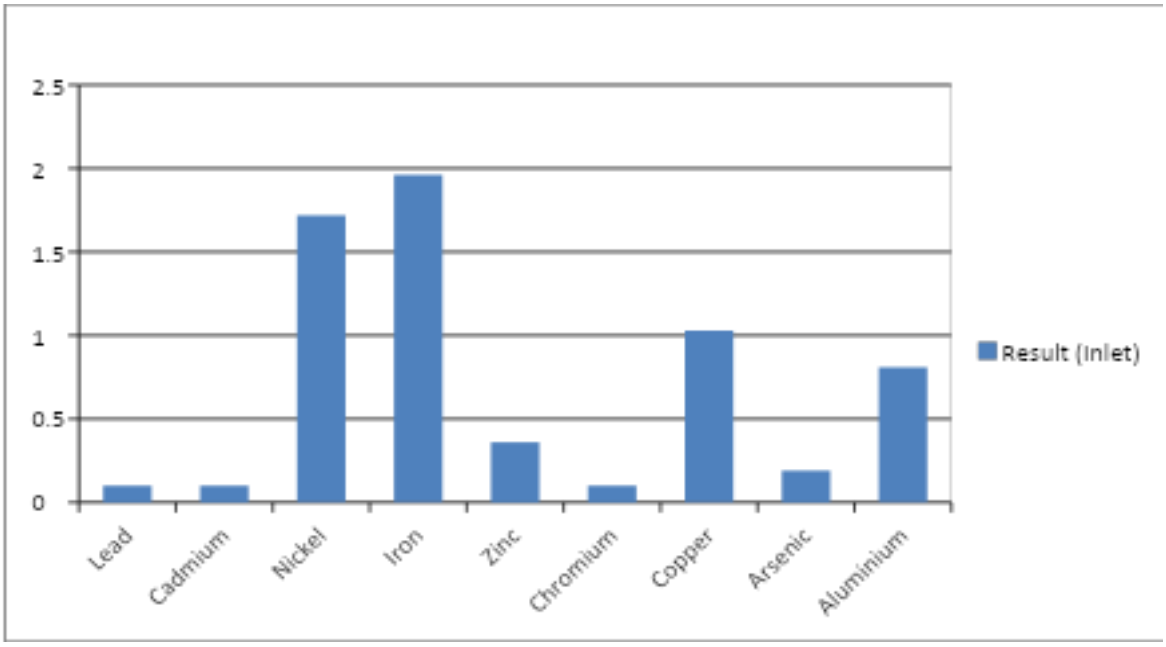
The following results were obtained.

Sr.No.	Parameter	Unit	Result	Standard Method
01	Lead as (Pb)	mg/lit	0.1	IS:17614 (P-1) 2021
02	Cadmium as (Cd)	mg/lit	0.1	IS : 17614(P-1) 2021
03	Nickel as (Ni)	mg/lit	1.72	IS : 17614 (P -1) 2021
04	Iron as (Fe)	mg/lit	1.96	IS : 17614 (P-1) 2021
05	Zinc as (Zn)	mg/lit	0.36	IS : 17614 (P – 1) 2021
06	Chromium as (Cr)	mg/lit	0.1	IS : 17614 (P – 1) 2021
07	Copper as (Cu)	mg/lit	1.03	IS : 17614 (P - 1) 2021
08	Arsenic as (As)	mg/lit	0.19	IS : 17614 (P -1) 2021
09	Aluminium as (Al)	mg/lit	0.81	IS : 17614 (P-1) 2021

Table-2 : Waste water analysis

The following graph shows the concentration of heavy metals present in waste water from the inlet of effluents treatment plant of sugar factory.

Result



Graph-1: Graph showing concentration of heavy metals in the waste water.

After analyzing the samples of waste water before entering the ETP it is found that iron (Fe) content is more than any other heavy metals. A little rise in Lead (Pb), Cadmium (Cd) and Chromium (Cr) level was also considerable for the analysis. It is expected that while processing waste through ETP the concentrations of Fe, and Ni, Cu,Al, will arrive in the permissible level. For this purpose the waste water from the outlet of ETP was also tested.

Sample No. 2

Site- Neoly Sugar mill Kasganj.

Source of waste water- Effluent Treatment plant outlet.

Date / Time of sample collection, 16/02/2024, 12:35

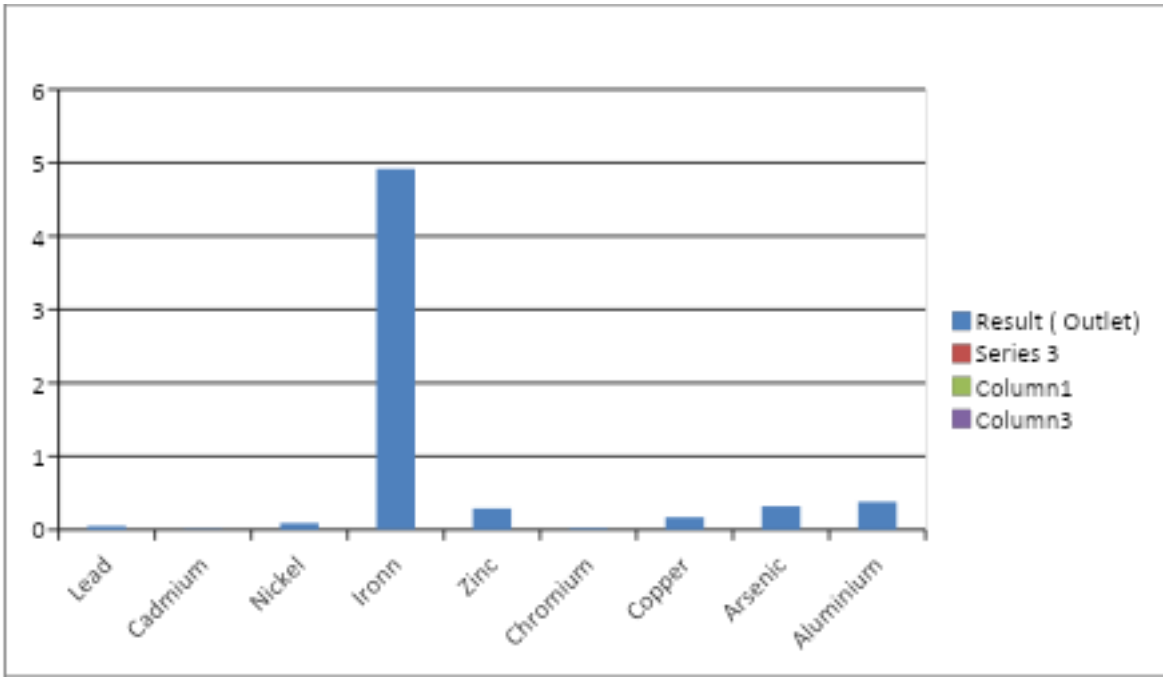
The following results were obtained

Sr.No.	Parameter	Unit	Result	Standard Method
01	Lead as (Pb)	mg/l	0.05	IS : 17614 (P-1) : 2021
02	Cadmium as (Cd)	mg/l	0.01	IS : 17614 (P-1) : 2021
03	Nickel as (Ni)	mg/l	0.09	IS : 17614 (P-1) : 2021
04	Iron as (Fe)	mg/l	4.92	IS : 17614 (P-1) : 2021
05	Zinc as (Zn)	mg/l	0.29	IS : 17614 (P-1) : 2021
06	Chromium as (Cr)	mg/l	0.02	IS : 17614(P-1) : 2021
07	Copper as (Cu)	mg/l	0.17	IS : 17614(P-1) : 2021
08	Arsenic as (As)	mg/l	0.32	IS : 17614 (P-1) : 2021
09	Aluminium as (Al)	mg/l	0.38	IS ; 17614 (P -1) : 2021

Table 3: Waste water analysis

After analyzing the sample of waste water after the leaving the ETP it is found that the Iron (Fe) and Arsenic (As), content is still more that its permissible limit than any other heavy metals. There is a little rise concentration of Lead (Pb), Cadmium (Cd), Nickel (Ni) Zinc (Zn), Chromium (Cr), Copper(Cu), Aluminium (Al) level. Since the waste water after giving the necessary treatment by the factory. The next step is to discharge this water in to the natural water bodies or the natural streams. The excess concentrations of these metals than the permissible limits prescribed by the pollution control board should be removed by using some suitable mechanism. The following graph show the concentration of heavy metals present in waste water from the outlet of effluent treatment plant of sugar factory.

Result



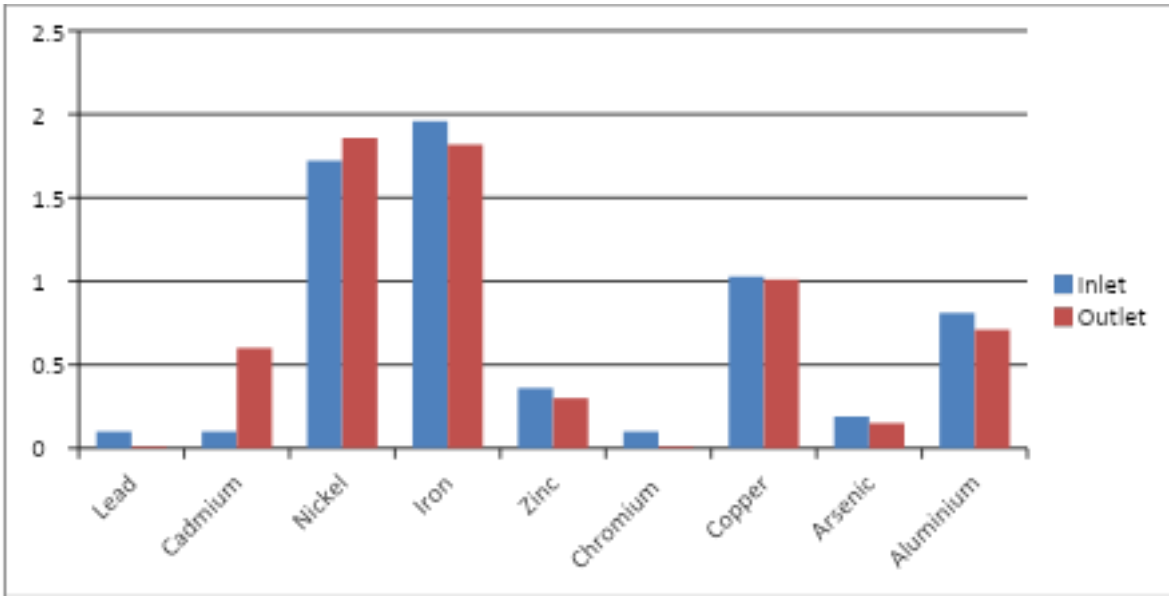
-Graph 2: Concentration of heavy metals in the waste water (Outlet)

Comparative study of heavy metals in sugar industry effluents waste water (Inlet and Outlet):

Sr. No.	Parameter	Unit	Inlet of ETP	Outlet of ETP
01	Lead as (Pb)	Mg/l	0.1	0.05
02	Cadmium as (Cd)	Mg/l	0.1	0.01
03	Nickel as (Ni)	Mg/l	1.72	0.09
04	Iron as (Fe)	Mg/l	1.96	4.92
05	Zinc as (Zn)	Mg/l	0.36	0.29
06	Chromium as (Cr)	Mg/l	0.1	0.02
07	Copper as (Cu)	Mg/l	1.03	0.17
8	Arsenic as (As)	Mg/l	0.19	0.32
09	Aluminium as (Al)	Mg/l	0.81	0.38

Table 4 : Comparative overlook of ETP inlet and outlet parameters.

Following graph show comparative concentrations of heavy metals present in the waste water at inlet and outlet of effluent treatment plant of sugar factory which can be utilized for the treatment of the waste water in the ETP so that the concentration of the heavy metals can be minimized before the discharge in to the natural water bodies.



Graph 3: Comparative concentration of heavy metals in the waste water (inlet and outlet)

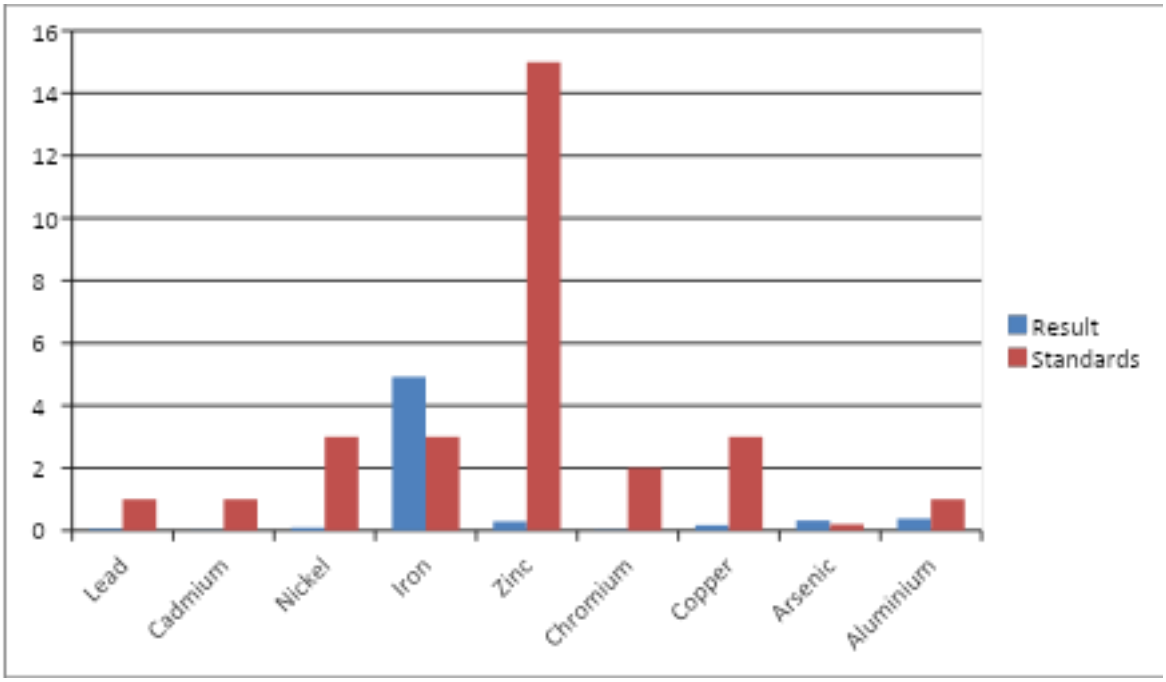
General comments on heavy metal analysis- After performing heavy metal analysis it is found that the concentration of **Iron (1.96 / 4.92), Arsenic (0.19/ 0.32),** but the presence of heavy metals in waste water after giving treatment by ETP waste. So it is necessary to remove these metals before the waste enter into the natural water bodies. The following table show the concentration of metals which are being received by the water bodies even after giving treatment in ETP.

Comparative study of heavy metals outlet waste water of sugar industry and Central pollution control board

Sr. No.	Parameter	Unit	Result	Standards
01	Lead	Mg/l	0.05	1.0
02	Cadmium	Mg/l	0.01	1.0
03	Nickel	Mg/l	0.09	3.0
04	Iron	Mg/l	4.92	3.0
05	Zinc	Mg/l	0.29	15
06	Chromium	Mg/l	0.02	2.0
07	Copper	Mg/l	0.17	3.0
08	Arsenic	Mg/l	0.32	0.2
09	Aluminium	Mg/l	0.38	1.0

Table- 6 Heavy metals concentrations and its standards

Graph 4 : Comparative concentration of heavy metal in standard of control pollution board and result found in ETP plant (Outlet) of sugar industry:



Effect of effluents- Organic and inorganic pollutants presents in the Sugar effluents. The immediate oxygen demands by these effluents cause rapid depletion of dissolved oxygen of the receiving streams resulting in anaerobic conditions. Iron as black sulfide leading to unsightly appearance. All these effects make the water totally unfit for fish and other aquatic life. Also the dissolved and suspended solids deteriorate slowly resulting in obnoxious odor. Further, suspended impurities block the drainage and detaches. The excess oil and grease content is a nuisance which prevent aeration. The effluent which are coming from sugar industry if it is directly used for agricultural purpose it will affect the soil fertility as well as it affect the plant growth and seed germination.[10] Reported Sugar mill effluents having highly toxic chemical and heavy metals are affecting aquatic flora fauna. Economically important value which are under threat due to discharge of sugar industry effluent into fresh water ecosystem. This is due to depletion of dissolved oxygen.[11]

Conclusion- Since the effluents of sugar industry is not able to release into natural stream directly. After passing through treatment plant, which removes many impurities such as excess concentration of Iron (Fe), Arsenic (As), which bad effect on the human being and for the natural environment. Intake of Arsenic can severe arsenic, pigmentation problems, nausea, skin and kidney, cancer, lungs, metabolic system, cardiovascular system, immunological system, and endocrine. Iron the most common cause is an inherited called hemochromatosis Fatigue, weakness, and dizziness, pale skin, shortness of breath chest pain. Hence it is necessary to lower the concentration of these metals and bring them to required level before releasing in to the natural streams.

Suggestions- * Industries should be installed in low laying areas away from the public locality. * Industrialist should use such raw materials which will give maximum good products and less toxic waste in fewer quantities. *Industrialist should check their instruments/ equipment to avoid leakage. * Workers should make proper use of raw materials and should carefully to avoid unnecessary waste.* Each company should promote among its employees and individual since of environmental responsibilities making them at least aware about environmental pollution.*Each industry should follow environmental policies regulations and environmental protection acts to conserve the environment.*Each industry should have ETP plant to treat the effluents, Which can be further used for the agricultural purpose.*Solid waste should be stored and of making its use for the purpose of land fill or on waste land.

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