Sewage Waste Water Treatment by the Hydrodynamic Cavitation Method
Chanchal Valvi¹, Dr. Pankaj Gohil², Dr. Hemangi Desai³
Shree Ramkrishna Institute of Computer Education and Applied Sciences, Sarvajanik University, Surat¹,³
Sarvajanik College of Engineering & Technology, Sarvajanik University, Surat²

Abstract - The sewage water sample obtained after secondary treatment, was given treatment with Hydrodynamic Cavitation Method. Physico chemical parameters were determined using standard methods of APHA, before and after treatment at 24 hour in cavitation device. the water quality obtained is comparable to Drinking Water Standards (IS). The water quality parameters selected were: pH, Electrical Conductivity, Turbidity, TS,TSS, DO, Cl-, Alkalinity (as CaCO₃), Cu²⁺, Zn²⁺, Mg²⁺ Hardness, Total Hardness (as CaCO₃), Phosphate and BOD. The highest reduction obtained was 88.88% for Cl-. Except TS, TSS and Cu²⁺ all the parameters were get back in the range of drinking water quality standards. The mechanism supports the reduction in parameter may be due to the collapse of cavities induces effects such as high shear forces, extreme temperatures, shock waves, turbulence, and extreme pressure in the fluid, formation of OHo free radicals provide to reduce pollution. The Cavitation method is proven to be the most effective over the other methods. Because, it does not require any chemical reagent, hence do not produce any hazardous chemical waste and maintain eco-friendly and economically sustainable environment benign technique for the treatment of wastewater.

Index Terms - Hydrodynamic Cavitation Method, OHo free radicals, oxidation mechanism, venturi - orifice, physico chemical parameters, water quality.

I. INTRODUCTION

Wastewater treatment is the process of removing contaminants from wastewater. It includes physical, chemical and biological processes to remove contaminants from wastewater. Industrial and agricultural wastes are discharged into the world’s waterways every day and cause many waterborne diseases. Therefore, there is a need to treat the sewage effluent to improve the water quality and protect and conserve the water resources.

The purpose of sewage and industrial waste water treatment is to extract pollutants by adsorption or membrane techniques and refining the effluent to make it fit for agricultural purpose. It is obvious that non-hazardous organic waste from domestic sewage must be treated separately from toxic industrial wastes.

With the rapid development of economy and the increase in residents’ living standards, there is more and more sewage discharge to be treated. This kind of sewage is characterized by a large amount of organic matter (such as protein, starch, fat, and urea), pathogenic microorganisms, and suspended matter. The main purpose of wastewater treatment is to remove organic matter and nutrients, not to recycle them. The selection of the best treatment process mainly depends on the concentration of pollutants and the nature of the wastewater. The conventional sewage treatment mainly consists of: (i) Preliminary (ii) Primary (iii) Secondary and (iv) Tertiary Steps.

1. Strength of Sewage

The definitions of residential strength wastewater and high strength wastewater vary throughout the research. Residential strength wastewater influent examples range from BOD₅ 100 mg/L – 400 mg/L, TSS 100 – 400 mg/L, and FOG 50 – 150 mg/L. in term of 5 days BOD and COD.

On an average a sewage with 200 mg/L BOD Or <400 mg/L COD is called as a weak sewage, with 500mg/l BOD or1000mg/l COD is called strong sewage and one with >750 mg/l of BOD or > 1500 mg/L of COD is called as extremely harmful sewage. If we consider the average composition of Indian sewage, it contains BOD 280 mg/L, Chloride 200 mg/l, Ammonical Nitrogen 25 mg/L, with the rise in temperature, BOD value also increase.

2. Water Treatment Technology

Water treatment technology has evolved over hundreds of years and is now different for drinking water and sewage.[1-25] Chlorine is primarily used for disinfection when treating
the wastewater for drinking purpose, but in recent years, the development of chlorine disinfection has been hampered by a significant increase in carcinogenic disinfection by-products (DBPS) and the development of drug resistance in some pathogenic bacteria.[26] It is challenging to balance the cost and processing efficiency of sewage treatment technologies such as the Fenton method and membrane separation method. Numerous innovative water treatment techniques have been offered as a solution to the scarcity of conventional water treatment techniques.[27].

The current water treatment technologies face numerous difficulties as a result of the growing number of industry and increasing rate of population growth. Much attention has been given to hydrodynamic cavitation as an effective and environmentally friendly method of water treatment.

Huge amounts of energy may be released into the surrounding liquid during hydrodynamic cavitation, which will have an impact on the surrounding liquid’s temperature (4600 K local hotspots), mechanical properties (150 bar pressures), and chemical properties (hydroxyl radicals). These circumstances can cause bacteria and organic material in sewage to deteriorate. Widespread interest has been shown in hydrodynamic cavitation as a cost-effective water treatment technique that produces no disinfection byproducts [28].

Hydrodynamic cavitation was used for removal of toxic cyanobacteria (Microcystis aeruginosa), green microalgae (Chlorella vulgaris), bacteria (Legionella pneumophila), and viruses (Rotavirus) from water and wastewater. The pharmaceuticals (clofibric acid, ibuprofen, ketoprofen, naproxen, diclofenac. [28]

The sewage wastewater have been treated by phytoremediation and electrolysis,[29,30] Ultrasonic cavitation, photo induced cavitation, and hydrodynamic cavitation are the three main types of cavitation method for the treatment of water and wastewater.

**II. MATERIALS AND METHODS**

**Sampling Site:**
Secondary treatment plant – Bamroli

**Collection of Sample:**
The sewage water sample was collected from the outlet of secondary treatment plant. All the parameters were checked after filtration by Whatman filter paper no.42

**Analysis of Physico-Chemical Parameters:**
Physico chemical parameters of sewage water sample before and after treatment were measured as per APHA &AWWA 23rd Edition 2020. [31]

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Analysis Method as per APHA</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH, Conductivity, Turbidity</td>
<td>Electrometric method</td>
</tr>
<tr>
<td>Total Alkalinity</td>
<td>Titration method</td>
</tr>
<tr>
<td>Chloride</td>
<td>Argentometric method</td>
</tr>
<tr>
<td>DO, BOD</td>
<td>Winkler’s method</td>
</tr>
<tr>
<td>COD</td>
<td>Closed Reflux Spectrophotometric method/COD Analyzer</td>
</tr>
<tr>
<td>TDS, TS, TSS</td>
<td>Oven Drying &amp; Gravimetric method</td>
</tr>
<tr>
<td>Mg$^{+2}$, Ca$^{+2}$ Total HardnessFe$^{+2}$, Cu$^{+2}$, Zn$^{+2}$</td>
<td>Complexometric Titration method</td>
</tr>
<tr>
<td>Na$^+$, K$^+$</td>
<td>Flame Photometric method</td>
</tr>
<tr>
<td>Phosphate</td>
<td>Vanadomolybdophosphoric Acid Spectrophotometric Method</td>
</tr>
<tr>
<td>Phenol</td>
<td>4-Amino Antipyrine Spectrophotometric method</td>
</tr>
</tbody>
</table>

**III. CAVITATION METHOD FOR THE SEWAGE WATER TREATMENT**

When the cavitation approach has been adopted for treating sewage water collected from secondary treatment plant, a small scale hydrodynamic cavitation reactor with cavitation producing equipment was used. We chose the venture nozzle and orifice plate as cavitation producing devices for the small scale hydrodynamic cavitation reactor for this research.

**1. Cavitation**
Fluids are used in the operation of pumps, bearings, and propellers. Cavitation occurs in the fluid whenever the pressure and velocity of the fluid changes. At a constant outside temperature, cavitation results in a low pressure. A two-phase fluid flow phenomenon is cavitation. The free-stream cavitation number is typically used to describe cavitation.

**Types of Cavitation**
Cavitation is used in wastewater treatment, drug delivery, rock cutting, steel plate cutting, marine propellers, and valves, among other things. In general, cavitation includes the generation, growth, and rapid collapse of bubbles or cavities. The collapse of cavities induces effects such as high shear forces, extreme temperatures, shock waves, turbulence, and extreme pressure in the fluid. Among the four types (particle, optic, ultrasonic, hydrodynamic), the last two types of

Table 1: Analysis methods of water quality parameters

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cavitation are widely in use.

**Ultrasonic Cavitation**
When ultrasonic waves pass through a fluid, they cause pressure changes that cause cavitation to occur. Acoustic cavitation is another name for ultrasonic cavitation.

**Hydrodynamic Cavitation**
Localised pressure result from a fluid in motion experiencing a fast shift in its velocity profile.

**Hydrodynamic Cavitation**
Hydrodynamic cavitation is one of the advanced oxidation process. The Hydrodynamic – the motion of fluid or the change in flow of fluid. Cavitation – any phenomenon which leads to formation of cavities. Hydrodynamic cavitation is the formation of cavities due to obstruction /change in flow

**IV. HYDRODYNAMIC CAVITATION MECHANISM**

Three mechanisms are involved in hydrodynamic cavitation
- Nucleation
- bubble expansion
- A burst bubble

It is possible to think of hydrodynamic cavitation as the breakdown of the fluid medium under low pressure. The velocity of a fluid increases when it flows via irregular geometries or small orifices. The static pressure falls as velocity increases. Numerous cavities are released (nucleation), if the pressure drops below the local saturated vapour pressure. When the pressure drops, the cavities that are created will developed and collapsed (growth and implosion). Sharp shock waves of energy are released into the surrounding fluids as the cavities collapse. The nanoscale mixing effect, scale-free heating, and adjustable rotor/liquid friction can all be brought about by shock waves.

**Experimental Setup**
The setup consists of an orifice metre, a venturi plate with an inside diameter of 8 mm that operates at atmospheric pressure to be used, a tank (20 lit) for waste water storage and collection, a pump for waste water circulation, and valves for controlling the flow. The schematic diagram of a small scale hydrodynamic cavitation reactor for waste water treatment by using cavitations method is shown below.

**Working Mechanism of the Hydrodynamic Cavitation**
Hydrodynamic Cavitation: Any phenomenon which leads to Formation of cavities. Hydrodynamic cavitation is the formation of cavities due to obstruction / change in flow is such a process in which we will keep some obstruction in flow path of water, because of which cavities will be formed and because of those cavities OHo free Radicals will be formed, Plays main role in the traement by oxidation mechanism,

In case of orifice plate or in venture nozzle case the flow path of water will be reduced very much. Area has been reduced very much because we have placed obstruction device, so when area reduce then velocity increases too much and at the area of cavitating device in any system localised temperature and pressure will increase too much. (Table 2) As soon as water goes downstream in the cavitating device the water will spread in the form of spray or cavities. So cavities are formed just, when they are coming out of the office plate or venturi in downstream side. As soon as, it moves ahead the local temperature and pressure will be back to normal conditions.
And the cavities will burst and when cavities will burst they will form OHo free radicals or superoxide radicals and then OHo free radicals will come to feed tank and meet the wastewater and they oxidize the organic matter from the water tank. When water is re-circulated the temperature of feed tank increases, to maintain the temperature rotating the water is important.

The main reactions taking place in the cavitation zone are the thermal decomposition of chemical moieties as well as oxidation with dissolved oxygen and free hydroxyl radicals produced during the implosion of cavitation bubbles.

For example, the sanitization (disinfection) of water, as well as the degradation of pollutants including sulfide ions and several groups of organic compounds such as sulfur, nitrogen, and oxygen-containing organic compounds, aromatic hydrocarbons, dyes, and pharmaceuticals, has been taken into account while comparing the different cavitation processes.

Table: 2 Readings of Hydrodynamic Cavitation Reactor for Sewage Water.

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Water Quality Parameters (mg/L)</th>
<th>Sewage Water Quality Standards (NGT, 2019)</th>
<th>Drinking Water Standards (IS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>pH (5.5 - 9.0)</td>
<td>7.59</td>
<td>7.21</td>
</tr>
<tr>
<td>2.</td>
<td>Electrical Conductivity (-2.25 mS)</td>
<td>2.25 mS</td>
<td>1.5 mS</td>
</tr>
<tr>
<td>3.</td>
<td>Turbidity (4 NTU)</td>
<td>75.00</td>
<td>65.85</td>
</tr>
<tr>
<td>4.</td>
<td>TS (≤ 100)</td>
<td>480</td>
<td>1 NTU</td>
</tr>
<tr>
<td>5.</td>
<td>TSS (≤ 100)</td>
<td>480</td>
<td>1 NTU</td>
</tr>
<tr>
<td>6.</td>
<td>TDS (≤ 1440)</td>
<td>280</td>
<td>1 NTU</td>
</tr>
<tr>
<td>7.</td>
<td>DO (≤ 5.8)</td>
<td>0.7</td>
<td>3.0</td>
</tr>
<tr>
<td>8.</td>
<td>Cl (≤ 1000)</td>
<td>14.96</td>
<td>88.88</td>
</tr>
</tbody>
</table>

Table 3: Sewage water quality before and after treatment by Cavitation Method.

Analysis of Sewage water Quality Parameters

After obtaining the sample of waste water undergoing secondary treatment, the water is treated using the cavitation method using a venture nozzle and orifice plate. The obtained parameter values are compared with discharged standard of sewage wastewater and also with drinking water standards.

V. RESULTS & DISCUSSION

After collecting the samples of sewage waste water (after secondary treatment) and giving treatment by Cavitation Method, the results obtained are shown in table 2.
<table>
<thead>
<tr>
<th>No.</th>
<th>Parameters</th>
<th>Value</th>
<th>Units</th>
<th>Value</th>
<th>Units</th>
<th>Value</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>Alkalinity (as CaCO₃)</td>
<td>80.00</td>
<td>mg/L</td>
<td>50</td>
<td>mg/L</td>
<td>30</td>
<td>mg/L</td>
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<tr>
<td>10</td>
<td>Cu²⁺</td>
<td>44.48</td>
<td>mg/L</td>
<td>15.03</td>
<td>mg/L</td>
<td>6.45</td>
<td>mg/L</td>
</tr>
<tr>
<td>11</td>
<td>Zn²⁺</td>
<td>5.0</td>
<td>mg/L</td>
<td>5.0</td>
<td>mg/L</td>
<td>5.0</td>
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<tr>
<td>12</td>
<td>Mg²⁺ hardness</td>
<td>66.66</td>
<td>mg/L</td>
<td>66.66</td>
<td>mg/L</td>
<td>66.66</td>
<td>mg/L</td>
</tr>
<tr>
<td>13</td>
<td>Total hardness (as CaCO₃)</td>
<td>0.00</td>
<td>mg/L</td>
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<td>mg/L</td>
<td>0.00</td>
<td>mg/L</td>
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<tr>
<td>14</td>
<td>Phosphate</td>
<td>0.00</td>
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<td>mg/L</td>
<td>0.00</td>
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<tr>
<td>15</td>
<td>BOD</td>
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<tr>
<td>16</td>
<td>Na⁺</td>
<td>21.62</td>
<td>mg/L</td>
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<td>mg/L</td>
<td>21.62</td>
<td>mg/L</td>
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<tr>
<td>17</td>
<td>K⁺</td>
<td>35.14</td>
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<td>mg/L</td>
<td>35.14</td>
<td>mg/L</td>
</tr>
<tr>
<td>18</td>
<td>Phosphate</td>
<td>0.00</td>
<td>mg/L</td>
<td>0.00</td>
<td>mg/L</td>
<td>0.00</td>
<td>mg/L</td>
</tr>
</tbody>
</table>

The sewage water sample obtained after secondary treatment, the water quality obtained was comparable to Drinking Water Standards (IS), except Electrical Conductivity, Turbidity, TDS, Cu²⁺, Zn²⁺. Which was then treated with Hydrodynamic Cavitation Method. After treated with Hydrodynamic Cavitation Method, except Cu²⁺, all the parameters were found according to quality of Drinking Water Standards.(IS) (Table 3)

![Water Quality Parameters](image1)

![Water Quality Parameters](image2)

![Water Quality Parameters](image3)

Fig. 3 Sewage water quality parameters after Hydrodynamic Cavitation Treatment

Fig: 4 % Reduction of sewage water quality parameter after 24 hrs treated by Hydrodynamic Cavitation Method.
The mechanism supports the reduction in parameter may be due to The collapse of cavities induces effects such as high shear forces, extreme temperatures, shock waves, turbulence, and extreme pressure in the fluid, formation of OHo free radicals provide oxidation mechanism to reduce pollution.

VI. CONCLUSION

The sewage water sample obtained after secondary treatment, was given treatment with Hydrodynamic Cavitation Method. Physico chemical parameters were determined using standard methods of APHA, before and after treatment at 24 hour in cavitation device. the water quality obtained is comparable to Drinking Water Standards (IS). The water quality parameters selected were: pH, Electrical Conductivity, Turbidity, TS,TSS, TDS, DO, Cl-, Alkalinity (as CaCO3), Cu2+, Zn2+, Mg2+ hardness, Total Hardness (as CaCO3), Phosphate and BOD. The highest reduction obtained was 88.88% for Cl-. TDS-TSS-TS were reduced in the range (46 to 49%) Cu2+ and Zn2+ - heavy metals were get reduced upto 69.56%, Mg2+ was reduced upto 66.66%. Except TS, TSS and Cu2+ all the parameters were get back in the range of drinking water quality standards. The mechanism supports the reduction in parameter may be due to the collapse of cavities induces effects such as high shear forces, extreme temperatures, shock waves, turbulence, and extreme pressure in the fluid, formation of OHo free radicals provide to reduce pollution. The Cavitation method is proven to be the most effective over waves, turbulence, and extreme pressure in the fluid, formation of OHo free radicals provide oxidation mechanism to reduce pollution.

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