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The role of hydrodynamic cavitation and nano-bubbles in wastewater and water treatment

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Abstract

Water scarcity is becoming a major problem in both developed and developing countries. Water resource research, as well as the recycling of wastewater treatment plants, might all contribute to making water resources more sustainable. The purpose of biological wastewater treatment is to progressively oxidize organic contaminants. Many pollutants, rather than being completely converted into carbon dioxide and water, remain stable for biodegradation or just undergo modest structural modifications.On the other hand, enhanced non-living purification processes, such as membrane filtration, UV decomposition, ozonation, and advanced oxidation processes, including cavitation, may be discarded. Cavitation technology has been able to overcome the drawbacks of many systems that require chemicals or high energy input in their processes, and it promises to alleviate the global water crisis by improving the efficiency of water and wastewater treatment. The function of hydrodynamic cavitation in each of the treatment processes is discussed in the next part, which investigates one of the most potential applications of hydrodynamic cavitation, namely wastewater and water treatment.

Keywords: hydrodynamic cavitation, water and wastewater treatment, venturi, vertex diode, air injection

Introduction

Living without water is now regarded as one of the most pressing issues confronting human society, and living without it is unthinkable. Water and wastewater treatment have long been advocated as a long-term solution to this problem. Several water treatment technologies exist, including There are chemical, biological, and other ways, and each of these treatments, despite their benefits, has a number of drawbacks. Cavitation is a process in which cavitation or supercavitation is generated as a result of the abrupt pressure created in the fluid. This cavitation causes bubbles to burst into ultrafine bubbles.Due to cavitation and volatile bubbles consisting of it, it is possible to achieve efficiency equal to or higher than conventional water treatment methods, which have much less energy consumption than these methods. The type of cavitation is one of the main parameters in treatment Among acoustic and hydrodynamic cavitation, by comparing energy efficiency and purification of hydrodynamic cavitation, priority is given. In this research, the geometric parameters of the equipment used in cavitation and the performance and role of each will be examined. Especially the effect of hydrodynamic cavitation in water and wastewater treatment, the prominent role of this technology is realized.

1. Cavitation

Cavitation is the formation of a vapor bubble in a low-pressure liquid environment. Cavitation is comparable to the boiling phenomenon except that boiling is often caused by a rise in the temperature of the liquid, and this rise in temperature is caused by the transfer of heat from solid surfaces. When the pressure in a portion of the fluid drops locally (below the saturated vapor pressure), vapor bubbles develop Figure 1, which burst as soon as the original pressure is reached. Compression shock and ripple shock are caused by this bursting. This explosion generates a significant quantity of energy in a short period of time. In addition to liquid vapors, cavitation bubbles carry gases that were previously soluble in the liquid.

1.1. Cavitation classification

Acoustic cavitation 2. Hydrodynamic cavitation 3. Optical cavitation 4. Particle cavitation.Only the first two approaches are discussed in this study since particle cavitation and optics have no unique industrial applications and are generally utilized for theoretical and laboratory purposes; for example, optical cavitation is used to research the dynamics of cavitation bubbles.[1]

1.1.2. Ultrasonic cavitation

Ultrasonic cavitation (acoustic cavitation) operates by generating high-pressure waves in a liquid environment. When an ultrasonic wave is spread in a liquid media, the repeating pattern of "condensation and reduction of density" causes the sound wave to travel, and owing to the lowering of pressure, very tiny bubbles in locations where density reduction occurs provide structure. Under the correct conditions, compression waves (which cause currents to flow in the liquid) produce the fast development of micro-bubbles, which expand and combine to reach their maximum size and finally burst, producing extreme heat, a process known as cavitation.[2] At high frequencies, we have stable cavitation, and at low frequencies, we have intermittent cavitation. In stable cavitation, the bubbles just oscillate and do not explode, but in intermittent cavitation, the bubbles reach a critical threshold and collapse after many cycles of oscillation. The power consumption of this technology is significant, and as we move away from the horn, the device's influence diminishes; thus, it cannot be used at industrial scales.

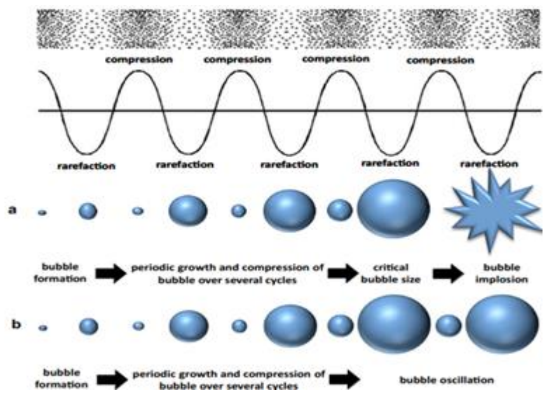

Figure 1- The generation and bursting of bubbles are caused by ultrasonic waves.

1.1.3. Hydrodynamic cavitation

In general, hydrodynamic cavitation can be divided into rotational and non-rotational methods.

1.1.3.1.Non-rotational hydrodynamic cavitation

Among non-rotational hydrodynamic cavitation production techniques (Orifice, Venturi, etc.), Venturi is the best choice due to more bubble production variables, optimization, and lower production and maintenance costs. A Venturi is a convergent-divergent nozzle in which the velocity of the fluid rises owing to the constant density of the fluid, and consequently its pressure lowers according to Bernoulli's equation; if the fluid pressure is less than its saturation pressure, cavitation occurs.

2. Research

First, the dimensionless numbers necessary for Venturi design are introduced, and then, with the aid of Fluent software (using article data), the impacts of several Venturi geometry alterations on the flow characteristics of the fluid inside them are explored. Then the advantages of Finally, the impact of venturi air injection on bubble formation will be addressed.Assumptions used while solving the problem using fluent software:1) The fluid is clear and has a density of Newtonian.2) The impact of viscosity depreciation can be neglected.

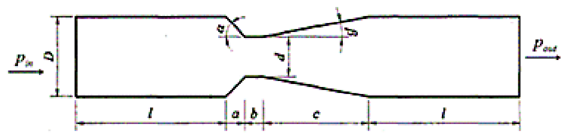

Figure 2-venturi

Dimensionless Number for linear flow venturi[3]:

1) Convergence rate (γ) is written as the following fraction (convergence ratio),

2) Venturi throat length ratio in terms of diameter.

The effect of venturi geometry on fluid flow properties:

1) Effects of convergence ratio (dimensionless γ number),

2) As the convergence ratio (γ) increases, so do the charge and vacuum.

As the convergence ratio increases, the fluid flow in the divergent section requires more length and space to reach the extended state; In other words, the smaller γ, the smaller the area affected by the bottleneck in the expansion (divergent) section.

1) Effects of throat length to diameter ratio (dimensionless number m):

• As the ratio of throat length to diameter increases, the degree of vacuum and mass flux decreases.

It can be said that the maximum speed in the throat is almost unchanged; By comparing two venturi with bottlenecks of different lengths, it can be concluded that the effects of m can be completely ignored.

2) Effects of divergence angle (β):

As the divergence angle (β) increases, the velocity at the venturi output decreases (due to the backflows generated in the divergent section).

3) Effect of inlet and outlet pressure difference:

As the pressure difference between the first and ventricular atria increases, the minimum ventricular pressure (which occurs in the throat) decreases. The main parts in Venturi geometry that have the greatest impact on pressure distribution are Convergence ratio (γ), Divergence angle-Pressure difference at the beginning and end of Venturi.The main parts of Venturi geometry that have the greatest impact on velocity distribution: γ difference in inlet and outlet pressure (flow velocity in Venturi increases with increasing inlet and outlet pressure difference).The effect of rotating flow on the venturi: for current flows with a Schmidt number of roughly 1000, the flow can be applied as a rotation to a venturi. The static pressure loss increases as the flow rotation increases, resulting in more bubbles being produced. A venturi can also produce corrosion and corrosion of the main axis, causing cavitation to rupture in the fluid flow and preventing any harm to the fluid from the venturi[4]. Cavitation occurs at the bottleneck along the central axis due to the form Figure (3).

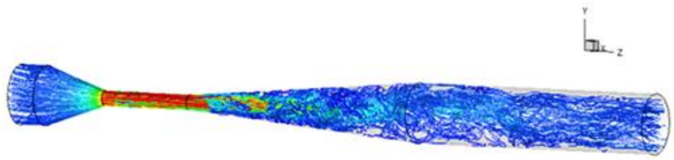

Figure 3-Swirl flow in venturi

3. The introduction of the dimensionless numbers and points required to design the optimum geometry

The rotational flow increases the mobility of the eddy current as well as the mixing of the two liquids. However, if the rotating current intensity is too high, the bubbles will burst (which is undesirable because we aim to create as many bubbles as possible), and the lower the rotational current intensity, the smaller the influence of the rotational current. It reduces static pressure linearly while increasing steam non-linearly.

The appropriate limit for the rotational flow of the dimensionless number is w/u = 0.5; The appropriate value for the γ number is γ= 0.28; Convergence angle (α): 19 degrees; Divergence angle (β): 5 degrees.

3.1 The Effects of air injection on cavitation in Venturi

To evaluate the effects of air injection on cavitation in Venturi, first analyze cavitation in Venturi (linear flow) without air injection, then examine cavitation in the situation where air is injected, and compare the results.

3.2 Cavitation without air injection

In general, there are three cavitation modes in Venturi: plate cavitation, cloud cavitation, and super cavitation. In the case without air injection, cavitation is formed in a relatively symmetrical state with a known length and frequency. On the other hand, when air is injected, this symmetry and its specific length and frequency are drastically reduced to the point that in the diet or in the case of super cavitation, these features are completely eliminated. According to Figure 4, cavitation begins to grow in the Venturi throat (plate cavitation), then after some expansion, a return jet is produced in which the fluid returns below the cavitation plate (in the Venturi throat direction) and causes production. Cavitation becomes cloudy. The cavitation cloud explodes when it reaches the venturi divergent region (because the pressure in this region is much greater than the pressure in the throat region), and this process is repeated at a certain frequency; The frequency due to the repetition of this cycle is determined by the drop frequency fs; when the pressure in the throat is not low enough, plate cavitation does not develop enough (it does not grow long enough) to form a cloud of cavitation after that .When the cavitation cloud reaches the venturi diverging zone (where the pressure is significantly higher than in the throat region), it bursts, and the process is repeated at a set frequency. The drop frequency fs determines the frequency owing to the cycle's repetition. Plate cavitation does not develop sufficiently (it does not grow long enough) to generate cloud cavitation when the pressure in the throat is not low enough[3,4].

4. Aeration (or air injection) in Venturi

The aeration phenomenon drastically raises the pressure in the cavitation region and the accompanying pressure waves display a shock wave, and aeration of a cavitation regime can induce the existence of a super cavitation zone.

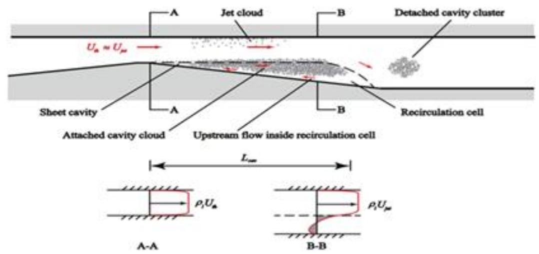

Figure 4- Schematic of 3 cavitation regimes in Venturi

- The pressure drop between the inlet and outlet of the venturi is greater in the case of air injection than in the case of no air injection, which increases cavitation production;
- The cavitation number decreases from column a'to column c', which increases cavitation, and thus we will have super cavitation in the last column, as shown in Figure 6.
- The volume of air injected by moving in the diverging section of the venturi grows until it bursts and changes into extremely small bubbles, some of which leave the venturi with a fluid flow and the other part of which returns to the region in the form of a jet.Cavitation returns; these return bubbles are formed by the (divergent) venturi of the cycle space.In the c' (supercavitation) state, the bubbles are large enough to reach the top and bottom of the venturi and are limited by the shape and dimensions of the venturi.

Negative pressures are generated to create cavitation volatile bubbles in the rotational technique of producing hydrodynamic cavitation, which involves creating a rotational motion inside a reactor. The current also moves in a rotating manner in the first type of these reactors (rotor-stators), which produces cavitation by rotating the moving parts inside the reactor. After passing through the distances and holes installed, it experiences static pressure drop and cavitation. As it turns out Figure 5 depicts a cavitation-generating reactor with holes drilled in the unit[1].

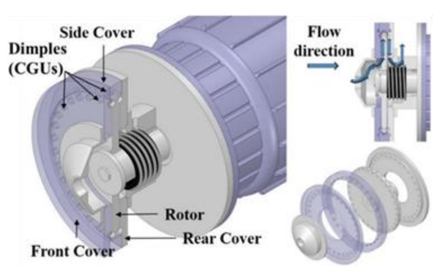

Figure 5-rotational cavitation reactor

In the second type of rotary reactors, by creating a rotational flow with the help of passive structural design and without consuming energy, the cavitation process can be performed and bubbles can be produced on micro and nano scale. In the design of these reactors shown in Figure (7, 8 and 9) and its name is the vortex diode; It is observed that the current leaves the central axis after entering the reactor radially[5].

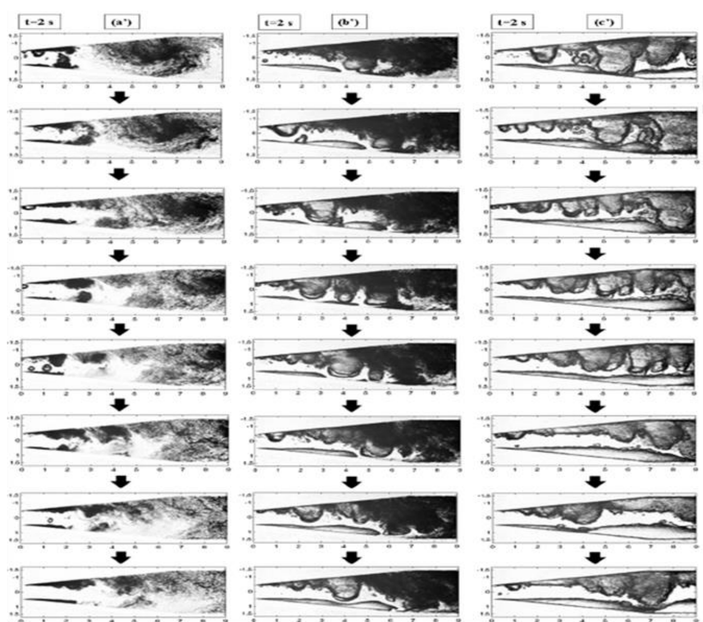

Figure 6- The photo obtained from the experimental setup shows the development of cavitation by injecting air in time steps (delta t = 10-3) (a ') = 1:74; (b ') = 1: 65; / (c') = 1:45

According to the figures, the generation of bubbles occurs in the reactor's centre axis (Figure 8 displays the vortex contour, and it is apparent that we have the biggest pressure drop in the central axis.) As a result, damage to the reactor's internal surfaces caused by conventional cavitation is substantially prevented. In comparison to other rotary reactors and non-rotary cavitation reactors like Orifis and Venturi, hydrodynamic cavitation in a vortex diode has various advantages, including faster bubble generation and enhanced pore formation. In addition, unlike a venturi or aperture, bubbles form in the fluid flow stream, which reduces the danger of wear and tear on the reactor surfaces.

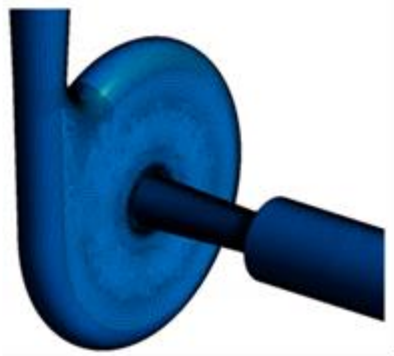

Figure 9-vortex diode

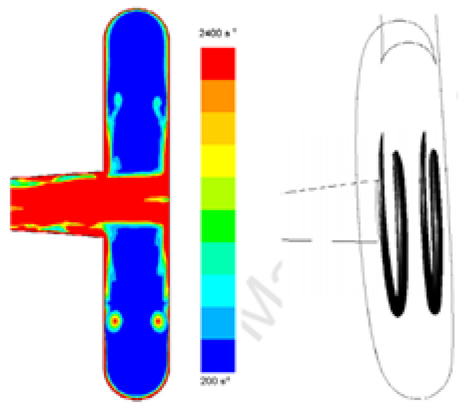

Figure 8- Diodex vortex contour in axial tube

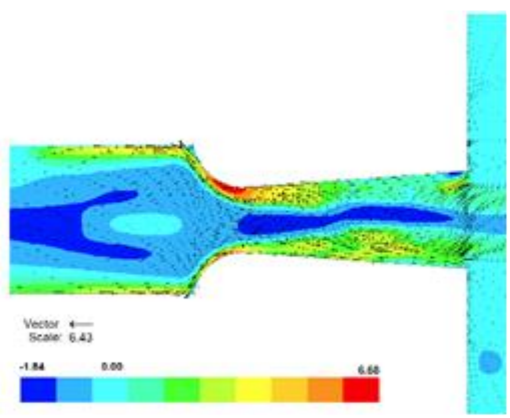

Figure 7- Speed vectors in diode vortex

5. Vortex diode components and related dimensionless numbers for optimal design

According to Figure (7), each vortex diode consists of 3 parts: the tube that enters the tank tangentially, the tank itself, the tube that exits axially from the tank; According to Figures 7 and 9, we show the diameter of the tank D and the thickness (height) of the tank with H and the diameter of the pipe that exits the tank axially with dc.

• The D / H ratio is an important dimensionless number with an optimum range of 5 – 5.5.

The optimal range for the dimensional number D / dc is between 4 ~ 4.5.

• E` is the resistance fraction or ratio that indicates a measure of cavitation production or cavitation production potential[6].

$$E' = S_R / S_F$$

This phrase must be valid:

D>D/dc>D/H

According to all the above modes and the test results, the best mode is when D / H = 5, D / dc = 5 and D = 120 mm.

Water scarcity is becoming a major issue in both developed and developing countries today. The hunt for additional water supplies or even the recycling of wastewater treatment plants can all contribute to a more sustainable use of water resources. The goal of biological wastewater treatment is to achieve full mineralization by gradually oxidising organic contaminants. On the other hand, many components of waste are stable for biodegradation or just undergo minor structural changes rather than being completely converted to carbon dioxide and water. Advanced non-living purifying processes, such as membrane filtering, UV decomposition, ozonation, and advanced oxidation processes, such as cavitation, on the other hand, may be abolished.

6. Types of wastewater treatment methods

Wastewater treatment includes processes during which the types of pollution caused by chemical and microbiological compounds, etc. in wastewater are greatly reduced and can be reused using processes. In general, it can be Classified wastewater into the main category:

1- Sanitary sewage: which includes sewage of residential areas and hospitals

2- Industrial wastewater: which includes wastewater from industrial centers and production units such as chemical factories, power plants, etc.Each of the mentioned items can be refined by various processes according to the desired quality and quantity.

6.1 Common methods of wastewater treatment

Physical treatment is a set of methods that use physical qualities and physical forces to execute wastewater treatment activities. Littering, granulation, flotation, sedimentation, and other processes are examples of these. Many of these technologies perform wastewater pre-treatment, which is also known as primary treatment in the treatment business.At this point, no chemicals are employed in the process. Mud or sedimentation, which is the process of suspending (insoluble-heavy particles) wastewater, is one of the most used physical wastewater treatment processes. Pure water can be separated from the precipitated particles as the insoluble substance settles. Aeration is another physical purifying method. This procedure entails the circulation of air through water in order to supply it with oxygen. The third method is filtration, which is used to filter all contaminants. In this method, certain types of filters can be used to treat wastewater and separate contaminants and insoluble particles in it. Oil and grease on the surface of some Sewage can also be easily removed through this method. For this process, various types of sewage degreasing devices can be used[7].

6.1.1 biological treatment

Biological treatments, such as detergents, human wastes, oils, and food, are utilised at this stage to degrade organic materials in wastewater. Organic stuff in wastewater is metabolised by microorganisms in biological materials. There are three types of cases in this one.

Mechanism of aerobic respiration: Bacteria decompose organic materials and convert carbon dioxide, which plants may use. This procedure makes use of oxygen. Aerobic microorganisms are employed for wastewater treatment in these technologies, which include activated sludge, extensive aeration, MBBR, MBR, and SBR.Fermentation is used to ferment waste at a certain temperature in an anaerobic manner. The anaerobic process does not need oxygen.Composting is an aerobic process that involves mixing wastewater with sawdust or other carbon sources to remediate it[8].

Secondary treatment removes most of the solids in the wastewater, but some of the wastewater-soluble nutrients such as nitrogen and phosphorus may remain and be difficult to dissolve.

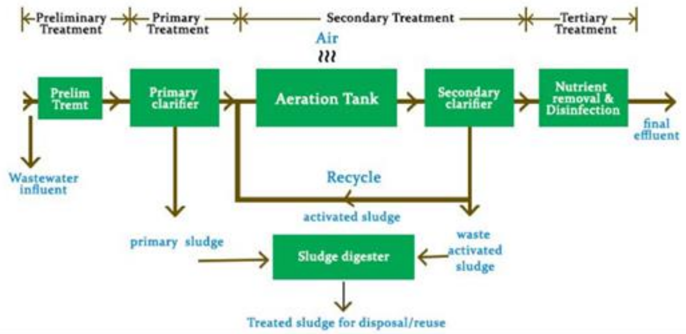

Figure 10-biological treatment

6.1.2. Chemical treatment

Chemical treatment refers to a set of procedures for treating various effluents using chemical reactions and chemicals. Chemical flocculation, electrical flocculation, and other ways are among them. These methods are frequently employed in the treatment of industrial waste. This step of treatment involves the use of chemicals as well as water, as it is a chemical therapy. Chlorine is a common chemical molecule of the oxidant family, and it is commonly employed to destroy bacteria that contribute to the degradation of pollutants. In wastewater treatment, ozone is also regarded as one of the most important oxidising agents. The neutralisation procedure is one of the methods for bringing water to its normal pH of 7 by adding an acid or base. Chemicals prevent bacteria from reproducing in water, thus purifying the water[9].

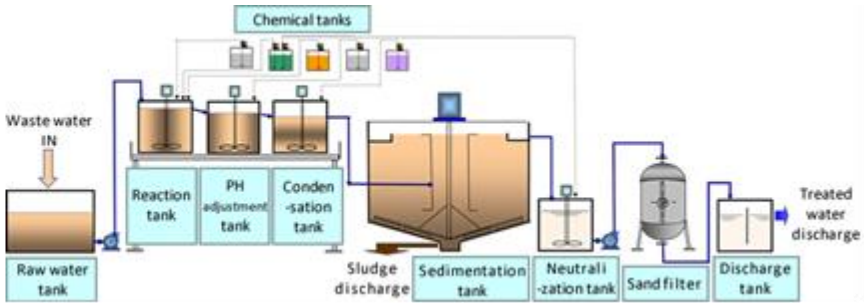

Figure 11-Chemical treatment

6.1.3. Sludge treatment

This step involves the separation of solid and liquid in which the minimum residual moisture in the solid phase, and the least solid particles in the isolated liquid phase are required. An example of this is the dewatering of sludge from an industrial wastewater treatment plant or wastewater treatment plant, where the residual moisture in the solids determines the disposal value and determines the main quality of the pollution load returning to the treatment plant. There is always a need to minimize both The use of acoustic cavitation to purify water and wastewater is a well-known method. However, the use of hydrodynamic cavitation as the only method or in combination with other techniques such as ultrasound has recently been suggested and used. The first section provides an overview of techniques that use hydrodynamic cavitation to treat water and wastewater[9].

Cavitation is the disintegration of a liquid medium at extremely low pressure. This ties cavitation to the continuous environment's mechanical field and is used in situations where the liquid is either stationary or moving. If the amplitude of an oscillating pressure field applied to the free surface of a static or near-static liquid in a tank is large enough, cavitation bubbles may form within the liquid's volume.Acoustic cavitation is the name for this type of cavitation. Cavitation can, however, happen in a flowing fluid. This phase change occurs in liquid currents due to low pressure caused by high local velocities. The liquid environment subsequently decomposes at one or more weak points (gas bubbles, contaminants), resulting in bigger "cavities" (bubble clouds) whose shape is heavily influenced by the flow structure. The flow follows a specific pattern in the evolved cavitation process, which is the subject of this article, in which cavitation structures of various shapes and sizes are brought together from the connected cavity. When the pressure difference between the external and interior connected cavities causes the flow lines to bend toward the cavity and the surface below it, extended cavitation occurs. This closes the attached cavity and forms a stationary point where the current is divided into an external stream that attaches to the wall and the re-inlet jet moving upstream carries a small amount of fluid into the cavity.

As the new jet rises, it loses its acceleration, rises, and "decreases" the cavitation associated to it, causing the super cavitation to separate (fall). The mainline traps the cloud downstream, causing it to explode forcefully at the pressure recovery area. Rotation around the structure during separation can cause distortion, breakage, and other problems. The connecting cavity begins to grow at the same moment, and the procedure is repeated on a regular basis. The little cavity expands and develops larger and larger when the system pressure lowers or the flow velocity increases. The superconducting current is nothing more than a huge cavity filled with quasi-stable vapour, in which significant pressure and temperature fluctuations are rare and are not accompanied by noise or vibration. When a cavitation bubble is generated, it may undergo a severe collapse during which a strong shock wave is emitted, with pressures in the (Gp) region and a temperature of 10,000 regional Kelvin, respectively, can be expected[10].

These conditions are ideal for cleaning the substrate's mechanical surface, washing the membrane, and advanced oxidation of chemical components. Smaller organic molecules, which would be more difficult to disintegrate using traditional biological techniques, are decomposed utilising extreme pressure and temperature caused by cavitation decay. Cavitation is also responsible for the biodegradation of organic contaminants. Cavitation can be used in conjunction with activated sludge for conventional biological therapy. Current industrial wastewater treatment systems do not involve hydrodynamic cavitation. Despite the fact that these approaches are employed in the lab, they are rarely used in the real world. This appears to be owing primarily to a lack of communication among researchers. Environmentalists concentrate their efforts on ultrasonic cavitation, whereas engineers are unaware of the benefits of cavitation and still regard it as a dangerous phenomenon. Hydrodynamic cavitation has the potential to become an energy-efficient treatment method that eliminates the need for expensive chemical reagents. Cavitation, being a physical event, does not develop any new compounds in the water or water, and so has no effect on the environment once the water has been released. Finally, because micro-pollutants, such as endocrine disrupting chemicals, have received so much attention, it is envisaged that their presence in the treated water will be greatly reduced as the cavitation wastewater treatment process develops. Some studies show that cavitation can also be used to disinfect waste and drinking water.New applications of hydrodynamic cavitation in other fields such as increasing the production of biogas from waste activated sludge and homogenization of pulp in paper production, etc. can be mentioned. In this section, an overview of recent applications in which hydrodynamic cavitation for treatment Water and wastewater will be used with a focus on pharmacy, bacteria, microalgae and viruses removed[11].

7. Pharmaceutical materials

Pharmaceutical waste is now acknowledged as a growing environmental issue. Drugs are made for human and veterinary treatment, as well as for animal husbandry. Most medicines undergo metabolic changes in target organisms, which diminish their pharmacological action and facilitate their release. Some medications are excreted as unaltered molecules, as a main metabolite, or as a group of various metabolites, depending on the metabolism. Because certain levels of medications discharge unmodified chemicals into the target organisms, It can penetrate several sectors of the environment, and as production and consumption increase, the environmental load increases as well. Drugs can infiltrate the environment in a variety of ways (hospitals, families, unused drugs, animal disposal, etc.).

In general, effluents from wastewater treatment plants are considered to be the most important point source. Research also shows the detrimental effects that these compounds can have on aquatic organisms. These studies confirm the need to improve or upgrade conventional wastewater treatment, as a protocol, and to ensure that sufficient Good quality water is available, the Water Framework Guidelines came into force in 2000[10].

7.1 Mechanism of Pharmaceutical materials removal

Acidic textiles, carbamazepine, and diclofenac, for example, are resistant to removal by biological wastewater treatment, making them more likely to damage the environment. In the environmental evaluation of new non-biotechniques, it is reasonable to prevent the introduction and probable negative effects of bio-resistant substances as a precaution. Various advanced chemical and photochemical purification procedures, such as photonolysis and advanced oxidation processes, have been extensively studied. The majority of this research focuses on the removal of a few medicines rather than combinations, and in matrices that are far less complex than wastewater. Furthermore, sophisticated treatment techniques such as hydrodynamic cavitation have yet to be properly investigated for their ability to remove several medicines from wastewater.

Hydrodynamic cavitation has been demonstrated to successfully remove carbamazepine and the physiologically resistant diclofenac, implying that more research into the elimination of other medications is required. After hemolytic splitting of water molecules, localised temperatures above 5000 K cause the creation of different radicals (mostly OH° and H°) during hydrodynamic cavitation. Organic molecules can decompose at three different locations during hydrodynamic cavitation. 1- in the gas phase, i.e. inside bubbles, where volatile compounds are thermolytically decomposed and OH is formed; 2) at the gas-liquid interface, where non-volatile and hydrophobic compounds are decomposed; and 3) in the liquid mass phase, where non-volatile and hydrophilic compounds are decomposed[12]. Because only a small amount of radicals reach the liquid mass phase, because they react either by themselves or in the presence of any oxidizing compound, the removal of organic compounds depends on their physicochemical properties. To intensify the process of hydrodynamic cavitation and improve the removal of compounds found in the liquid mass phase, the addition of external oxidants such as hydrogen peroxide (H_2O_2) as a source of radicals is also an option. The effect of temperature on the removal of various organic compounds by cavitation has also been investigated. For various compounds (eg, increasing the temperature from 30 to 40 ° C has increased the degradation of alachlor. These studies show that the optimum operating temperature must be determined experimentally for a particular system in order to achieve the highest hydrodynamic cavitation efficiency[10].

7.1.1. Bacteri

While the majority of bacteria are harmless or even useful, some are dangerous. Tetanus, typhoid, diphtheria, syphilis, cholera, foodborne disease, leprosy, and tuberculosis are all infections caused by pathogenic bacteria, and they are all major causes of death. They can also aid in the treatment of other major world diseases, including pneumonia. The effective eradication of Legionella pneumophila has caught the attention of many researchers due to the recent outbreak and reported instances of Legionnaires' illness (from 4.1 per million in 1993 to 11.8 per million in 2008). Pemophila is found at low concentrations in all sources of natural fresh water. Engineered water systems, such as hot water distribution systems, cooling towers, humidifiers, and fountains, have all been shown to have the bacterium[13]. However, an increase in the quantity of germs in water systems poses a potentially fatal risk to human health wherever aerosolization happens (between 15 and 20% of sick people). The effects of cavitation, which start with ultrasonics, are described below. It is well-known in the field of bacteria. Acoustic cavitation is widely regarded as a successful sterilising technology, but it has drawbacks, including the inability to treat greater quantities (batch operation), poor scalability from laboratory to industrial scale, and high costs. Operational efficiency is high. In contrast, just a few researchers have looked at the use of hydrodynamic cavitation to kill germs. Researchers looked into the influence of hydrodynamic cavitation on Escherichia coli disinfection in a laboratory-scale system. Cavitation was created using a rotor in a thin layer of water circulating from one reservoir to another.Experiments have shown that hydrodynamic cavitation is very effective in reducing the ability of bacteria to divide. Another group of researchers theoretically and experimentally considered hydrodynamic cavitation as an advanced oxidation process to understand the mechanisms involved in Escherichia coli.

In contrast to the results obtained by acoustic cavitation, where chemical reactions are caused by radicals, they achieved the results. The importance of OH cannot be overstated. According to theoretical predictions and experimental evidence, the disinfection of hydrodynamic cavitation with relatively modest pressure fluctuations (low frequency) is mostly attributable to bacterial mechanical disruption. Thus, those setups and operating parameters that induce large bubbles, wide pressure variations, and a greater number of cavitation events maximise the disinfection rate (i.e., conditions found in venturi tubes). Hydrodynamic cavitation jets have been found to be quite successful in lowering the concentration of all of these species, and their effectiveness is superior to acoustic cavitation[10].

7.1.2. Bacterial removal mechanism

Due to the massive size of the organisms, processes connected with the decomposition of cavitation bubbles, such as local temperatures above 5000 K, which lead to the creation of different radicals (mostly OH and H) and subsequent oxidation, are unlikely to be important for bacterial eradication. Shock waves, shear flow, supercritical water conditions, pressure, and temperature, which accompany the collapse of the invading bubble, are all removed by bacterial size scales. Furthermore, new research suggests that a quick drop in pressure at the commencement of bubble formation might play a significant (and perhaps crucial) role in bacterial damage[14].

7.1.3 Cyanobacteria and microalgae

Cyanobacteria and microalgae are among the most essential organisms in aquatic environments for primary production, nutrient cycling, and energy exchange. Microalgae are eukaryotic creatures with a cellular cell wall and cellular cytoplasm separated into parts, whereas cyanobacteria are prokaryotic species without cellular organelles. Almost all planktonic cyanobacteria, including as Microcystis, Afanisomenon, and Nodolaria, have gas vacuoles that regulate their location in the water column and are sensitive to high pressure and shear stresses.Concentrations of cyanobacteria and microalgae in eutrophic stagnant waters can substantially induce algal blooms, which can cause a variety of issues in distribution, storage, cooling, and purification systems, aquaculture, and natural stagnant waters. Faster clogging of filters and pipes, high water turbidity, lower dissolved oxygen concentrations at night, and changes in surrounding plants and animals are all caused by increased algal biomass. Microalgae can also get past filters and into the drinking water system, where they feed bacteria and fungi that can cause health issues. These poisons can build up in fish and shellfish, putting consumers at danger[10].

7.1.4. Mechanism of microalgae and cyanobacteria removal

Cyanobacteria and microalgae can be removed from water using chemical, biological or physical treatment. The simplest and cheapest way to remove them is chemical purification. By adding chemicals to water such as herbicides, light sensitizers, and algae flocculant chemical bubbles can be effectively reduced[15]. However, chemical treatment has several disadvantages, including: 1) toxicity to non-target organisms; 2) production of secondary pollutants; 3) Heavy metals enter the water and accumulate in the environment. Physical methods for removing cyanobacteria mainly include acoustic cavitation and hydrodynamic cavitation. Acoustic cavitation is generally a successful method of counteracting the growth of cyanobacteria, in which gas vacuoles inside algal cells act as nuclei for acoustic cavitation. Hydrodynamic cavitation has similar effects on cyanobacteria as acoustic cavitation. During hydrodynamic cavitation, the formation of cavities is followed by the immediate explosion of cavities in rapid pressure and fluid changes. High local temperatures, high pressures, and the formation of hydroxyl radicals during hydrodynamic cavitation affect algal cells, causing the collapse of gas vacuoles, damage to the photosynthetic apparatus, and membrane structures in the cells. The breakdown of gas vacuoles leads to rapid deposition of cells, while damage to the photosynthetic apparatus and cellular ultrastructure inhibits algal growth and leads to their death. The effects of hydrodynamic cavitation on algae depend on the hydraulic characteristics of the cavitation tube, inlet pressure, number of cavities, algal concentration and operating time[10].

The advantages of hydrodynamic cavitation don't stop there, especially since fine particle flotation has long been used to remove contaminants from fluids. The use of nanobubbles to significantly boost fine particle flotation recovery is a critical issue. In recent years, he has been studying the science of flotation. The key properties of nanobubbles are their high density, extended life, and quick return to hydrophobic surfaces, which will be utilised to remove pollutants from water and purify it, as will be discussed further down. Fine bubbles (micro-nanobubbles) have a significant impact on gas retention, which is critical in industries such as wastewater and water treatment for the flotation of minerals and dust, organic matter, chemicals, metal ions, and oils on the floor. Separation of amine and sulfate sediments has been done using dissolved air flotation method, however, the flotation rate of the study is very low and almost inefficient on an industrial scale. In a specific gas content, the use of volatile bubbles can reduce the consumption of benthic chemicals, which reduces the cost of preparing chemicals and contaminating the fluid with these materials. Producing nanobubbles with good stability is the most important technological challenge in flotation technology that the designed system provides this capability. Two-stage hydrodynamic cavitation designed to be installed in flotation systems to take advantage of the unique characteristics of volatile bubbles in the treatment of fluid, water and wastewater[16].Due to their strong adhesion to hydrophobic surfaces, nanobubbles have a unique ability to clean all types of surfaces and small pores, and due to the high surface-to-volume ratio, they can contain more levels of contaminants and clean filtration surfaces and fine cavities. They have the ability to penetrate there, while this feature is very important in wastewater and water treatment processes because the presence of the smallest concentration of these microorganisms will allow them to multiply and pollute.

Result

Cavitation is utilised in a wide range of sectors, but the application of it in wastewater and sewage treatment was the focus of this article. In the first half, we investigated the beneficial impacts of air injection, rotating flow, and venturi geometry variation on bubble formation in the first half, and we investigated why the vortex diode has the most optimal and greatest bubble production among rotary current reactors. Cavitation's impact on water and wastewater treatment is being investigated. The benefits and drawbacks of hydrodynamic cavitation versus alternative treatment approaches are discussed.

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