Total suspended solids removal by high gradient magnetic separation using steel wool at different location

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Abstract. Growing of mankind, society, science and technology in our world is reaching to higher level of human civilization. Therefore, a sustainable treatment procedures are required in order to prevent the consequences of growing civilized situation to the environment. Magnetism has been used as physical treatment for particles or contaminants removal from wastewater. In this experiment, comparison between locations of steel wool has been carried out in order to determine the highest suspended solid removal. Variables has been set such as magnetic strength was 1.4Tesla, flow rate was 1mL/s, 80 gram of steel wool and experiment took 24 hours of circulation time and data recorded for 24 hours. Data were recorded involving control, non-inverted magnet and inverted magnet structure. Non-inverted magnets consists of magnets on same poles while inverted magnet on different poles. As a result, steel wool located inside of pipe was exhibited the highest removal (88.2%) compared to outside of the pipe (83.3%) and both occurred in inverted magnet structure. Therefore, it was indicated that longer exposure time to magnet resulted in greater improvement in removing pollutant. The results obtained and suggests that steel wool located inside of tube with inverted magnet position can be successfully treat wastewater effectively.

1 Introduction

Water indeed the most unquestionably sources which important to human, animal, plants and other living things. Along with majority of various development nowadays, sewage water come from different of sources. Accumulation from household effluent, industrial or organization effluent as well as environmental surrounding (including oil leakage from vehicles, asphalt wear and carbon monoxide emissions) contributed into sewage system. [1]. Consequently, with the different sources of sewage comes with different of many toxic

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substances such as pathogens, heavy metal and organic contaminants which tremendously affected our environmental ecosystem. According to [2], any kind of sectors required a large amount of fresh water to operate also being a part of contributor to the massively outcome of wastewater. Therefore, several precaution need to be looked at such as a very clear and transparent guidelines, effective's methodology and practises and effectively cost investment for selecting management wastewater treatment in developing countries. Those steps were important to start an effective treatment system without continuously being threat to the environment. However, it should not only primarily focused on operating technical but also took humanity values and environmental surrounding activities into the account [3]. It was also has been said by [4] a sustainable system can be developed by the most effective operating design which include appropriate ethic according to local circumstances.

There are three different major treatment process for wastewater namely as physical, chemical and biological. Magnetism is one of the various physical treatment that quite popular to treat wastewater. It was started and patented by Theo Vermeiren in 1958 [5]. Usually, permanent magnets used as the indicator during the process of the treatment. The strength of the permanent magnet have been increased accordingly in order to increase the performance of the wastewater treatment. Effectives of implemented system really depend on evaluation of environmental performance as to marking progress toward more sustainable patterns of human development [6].

2 Theory consideration

High Gradient Magnetic Separation or HGMS is a fundamental concept whereas the assembling of ferromagnetic fibers (steel wool) that located between a pair of magnet and magnetized in a uniformly applied magnetic field. The ferromagnetic fibers arrangement positioned in various ways such as a grid, chaotic tangle or ordered spatial structure [7]. Generally, the magnetic field was appeared where the magnets were located. The basic theory of high gradient occurred when magnitudes of magnetic flux density acted varies during magnetic separation [8]. The more steel wool filling rate in the space created an increasing magnetic field around the permanent magnet but then keeps constant when the matrix reaches magnetization saturation [9]. This phenomenon called as the decreasing of the particle's susceptibility. The recovery of magnetic components were decreasing and constant and therefore gave no effectiveness on wastewater treatment.

In most practical way, glass column or tube has been used as a tool to place with packed with a fibrous, ferromagnetic material such as steel wool. The tube or glass column has been surrounded by magnets which executes magnetic field by trapping the collection of particles from samples as its passes along the tube. Magnetism is a unique physical treatment that helps in water treatment by manipulating the physical properties of contaminants in water. Magnetization of steel wool along with magnetic field around permanent magnets were proved to be effective to achieve higher intensity of the magnetic gradient. In a closer look, the flux lines were exerted much closer and intense at the higher intensity. Therefore, once the sample that contains ionic particles or components allowed to flow through the flux lines, the charges particles were attracted to the magnetized coils thus became detached. Thus, it is essential to cooperate different magnetic field strength and behaviour of coils magnetization in order to achieve better removal performance ([10] and [11]). Figure 1 below has shown the fundamental concept structure for high gradient magnetic separation by using permanent magnets and ferromagnetic fibers.

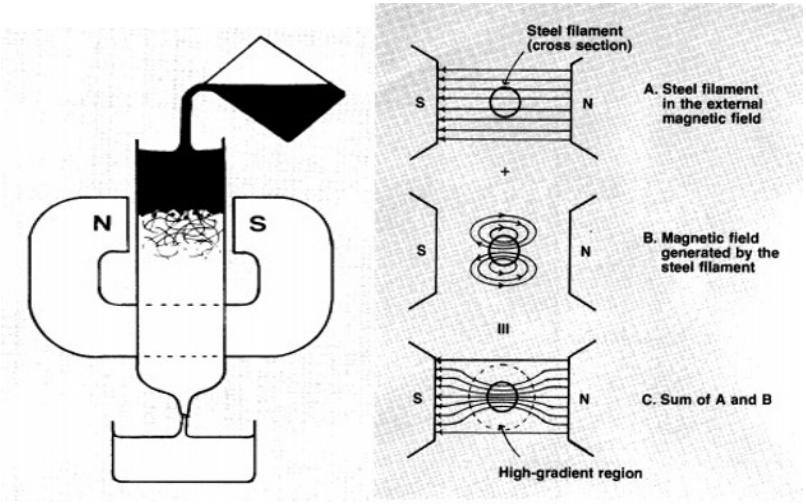

Fig. 1. Diagram of high gradient magnetic separation.

2.1 Magnetization and exhibition of magnetic field

Particles can be categorized as positively charged (positive χ) or negatively charged (negative χ), where χ is their magnetic susceptibility. Molecules' electron inside magnetic susceptibility could be divided into polar and non-polar molecules. These molecules were played a big part of removal process during HGMS. The illustration in Figure 2 has shown the reaction of polar and non-polar molecules acted towards magnetic field. At the absence of magnetic field, polar molecules were positioned randomly therefore positive and negative charges almost impossible to attract to each other. On the other hand, non-polar molecules also move aimlessly as the charges were coincide in the centers of the molecules. However, when the particles were applied to the magnetic field, the polar molecules were automatically aligned according their charges while non-polar charges were separated according to negative and positive charges [5]. This phenomenon was ultimately important as it was recognized causing the particle to coagulate and aggregate right after the molecules formed their positive and negative charges alignment [9].

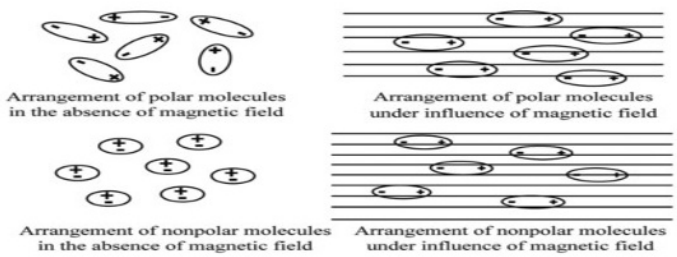

Fig. 2. Polar and non-polar molecules illustration.

2.2 Magnetic memory

One of the contributing factors that effected coagulation and aggregation process was magnetic memory. It was occurred to the any particles that has been exposed to magnetic

field continuously at certain intensity, particles can maintain their magnetization properties. It happened to change the sample molecules therefore the particles were attracted to the different poles and became large thus easily to aggregate. This indicates that the magnetic memory stored by the aggregates can last almost permanently [12]. The results were also supported by [13], who claimed that changes in the molecular structure are caused by magnetic memory. For particles, higher magnetic memory is proven to improve the aggregation, but the condition is not so applicable for bacteria or microorganisms.

3 Material and experimental

Several parameters have been fixed in early stages of the experiment. The samples were tested using 1.4 Tesla magnetic strength with full 24 hour circulation time by allowing the particles flow through 80 gram of steel wool at 1 mL/s flow rate. Fresh wastewater was collected from Indah Water Konsortium (IWK) two times a week to run the experiment. Total suspended solids test have been carried out as a pilot test in order to determine the optimum operating design among control, non-inverted magnet and inverted magnet structure as shown in Figure 3.

All of the structure contains 80 gram of steel wool and location of the steel wool has been altered to be inside and outside of the pipes. However, only non-inverted magnet and inverted magnet structure were surrounded by permanent magnets. At non inverted structure, the magnets were placed at the same poles which north to north poles and south to south poles. While at inverted magnet structure, the permanent magnets were facing at the different faces of poles which north to south poles. At the end of the experiment, it was expected to be inverted magnet structure with inside steel wool located would be expected most effective to remove suspended solids. Figure 4 has shown steel wool located outside outer pipe (between two different diameters of pipes) on the left side while location of steel wool located inside the pipe on the right side.

Fig. 3. From left: control, non-inverted magnets and inverted magnets structure.

Fig. 4. Left side is steel wool on the outside and right side is steel wool on the inside.

4 Results and discussion

By incorporating a statistical format, the standard lends itself to a more precise analysis. As a result, the different location of steel wool has shown various rate of suspended solids removal at control, non-inverted magnet and inverted magnet structure. Both of the suspended solids removal using steel wool at the inside and outside pipes have shown inverted magnet structure dominated as higher rate to remove contaminants from samples. From Figure 5 below has shown comparison between steel wool locations effected the removal rate of suspended solids. At the inside steel wool recorded 88.2% suspended solids removal compared to the outside steel wool was only 83.3%. Most of the suspended solids removal has been increasing after 21 hours of circulation time indicated that longer exposure time to magnet resulted in greater improvement in removing particles or contaminants. Therefore, each particles could have a greater opportunity to flow through magnetic flux lines and having maintainable maximum magnetization effect.

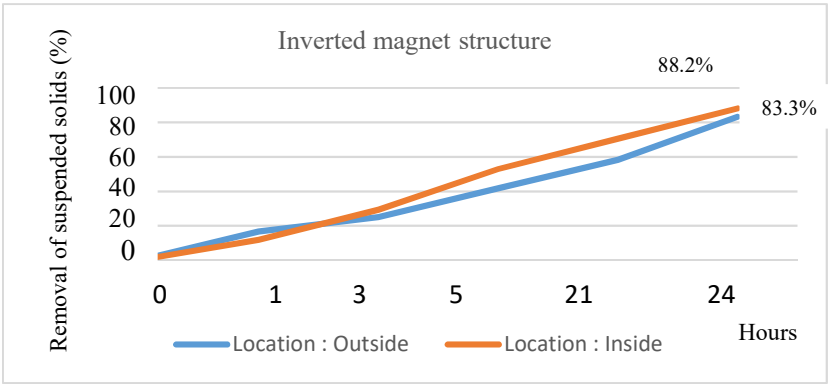

Fig. 5. Comparison of suspended solids removal between inside and outside steel wool.

The surface area from steel wool was ultimately effected the performance of removal rate. Literally, the non-smooth surface was purposely to increase the magnetic gradient. The steel

wool surface areas were varies with flux lines produced by magnetic field. Therefore, an interaction created at the magnetic field to attract any particles or contaminants to collide to each other and aggregate. During the experiment, samples from container were flowing into the pipes using a peristaltic pump. When the samples flow through the magnetic field, each particles have been magnetized by three type of field namely as uniform field produced by permanent magnet, a field produced by the ferromagnetic filter element (steel wool), and the interaction field produced by the magnetic moments of the particles. From scientifically view, the movement of particles from samples were cause by magnetic force which perpendicular to the magnitude of flux lines emitted by permanent magnets. There were several forces acted at the each substances or particles or contaminants namely as competitive forces, gravitational forces, resultant forces and fluid forces. The charges particles were flow through the pipes along with magnetic force and aligned according to their charge.

Therefore, the pollutant particle size has changed according to magnetic separation efficiency. The essential condition of separating pollutants effectively by magnetic force is that the magnetic force on pollutant particles is stronger than total competitive forces. It is thus clear that the magnetic field exerts a tremendous influence on treatment effect, and increase the field contributes to the removal of suspended solids. From calculation in Microsoft Excel, *p*-value has been found significant in non-inverted ($0.0346 < p$-value: 0.05) and inverted ($0.0314 < p$-value: 0.05) magnet as both value are smaller than *p*-value.

5 Conclusion

The results obtained and the observation made in this study draw some conclusions. The different position of steel wool has been found affected the performance of suspended solids removal. It is proved that the field gradient can be increased by changing magnetic polarities and using steel wool matrix inside the pipe. Inverted magnet has been proved to be most effective to attract particles and enhanced the performance to treat wastewater. Different poles of magnet has been proven attracted stronger than the same poles. When stronger magnetic flux concentrated in the center of field gradient, particles were magnetized and aligned with charges and easy to remove from sample. The experiment will be continue by using another different magnetic strength, flow rate as well as proportion of steel wool. Therefore, an optimum correlation of parameters can be acknowledge to enhance the operating design.

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