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The Influence of Reynolds Number As Inhibits the Formation of Biofilms inthe Pipeline inFood Industry

[1]SyarifahKeumalaIntan, [2]Sandra Santosa
[1]Department of Civil Engineering , State Polytechnic of Lhokseumawe, Indonesia
[2]Department of Chemical Engineering, State Polytechnic of Malang. Indonesia
Corresponding Author: SyarifahKeumalaIntan

Abstract: Biofilms are formed in piping systems (with water-flow media) in the food industry where nutritional supplies are available regularly for bacteria. Biofilm consists of cells of microorganisms that are firmly attached to a surface so that it is in a stationary state, and not easily separated or moved. In the food industry where water is used both as one of the utility fluids as well as the processes that flow in the piping system; many biofilms are formed and will cause clogging in pipelines. Blockage affects the inefficiency of the process as well as the cost of production. One way to avoid biofilm quick formation is to decrease the water flow rate in the piping system. This study aims to see the impact of laminar and turbulent flow types on the speed of biofilm formation. The laminar stream is marked by the Reynolds Number (N_{Re}) of below 2000 while the turbulent is in the range of N_{Re}above 4000. The experiment was carried out with 25.4 mm diameter of pipe. The results show the average biofilm formation of 0.32mm / week in the laminar flow with N_{Re}2000 and the acceleration of biofilm formation in the average of0.53mm/ week on a turbulent flow with N_{Re}> 3000**.**

Keywords:biofilms, laminar flow, turbulent flow, clogging, Reynolds number

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I. INTRODUCTION

Bacteria that live free (planktonic) in the waters in nature will tend to be attached (sisterly) to a good surface in various abiotic or biotic. This attachment is supported by various factors such as by matrix extracellular [1]. In nature, bacteria which attach in this amount arefar greater than the free living [2]. Microorganisms that are firmly attached to a surface are called biofilms, where their presence causes potential problems in some industries; one of them is the food industry [3]. Concerns occur when pathogenic bacteria attached to the food processing device. If biofilm is not cleaned, the organisms inherent in its development can be detached from surface and contaminate products before production [4]. The problem with this contamination is the occurrence of food decay that will shorten the shelf life as well as the spread of disease through food (food boom disease) [5].

The observation is done directly in the field that is on one of the food industry in Netherland.The industry is engaged in washing potato and vegetable, where the remaining washing water will be treated and reused. In the case of washing process occurs clogging by biofilm on the piping system network they have to clean all the system especially the pipeline every 6 months, it means twice in a year. In a period of 6 months, the formation of the biofilm clogs the pipe nearly 50% of pipe diameter. It is expected that the cleaning process will be longer than 6 months hence the process efficiency must be higher than the current process.

So far the industry attention to the phenomenon of biofilm formation and its impact on the food industry in Netherland is still very big, shows that this phenomenon needs to be of special concern in the food industry. In this study will be observed possibilities the formation of biofilms on the unit operations devices (especially pipes) used in the handling of potatoes and other will be produced such as washing basins, sorting and cleaning, and others, carried out in the original process stages in the industry by taking samples at different points. In this industry microbiological monitoring has been done, but the notion of biofilm takes time to be introduced but the study is aimed purely for a scientific goal, not an investigation or a feasibility study of a business.

This study aims to reduce the speed of biofilm formation by obtaining the best flow in the piping system. The best condition is at the limit of the state of the maximum laminar flow with an indication of the Reynolds number of 2000.One way to prevent the formation of biofilms used in this study is to regulate the flow in the piping system in the process.This can be done by decreasing the water flow rate in the piping system and see the impact of laminar and turbulent flow types on the speed of biofilm formation.

The Reynolds number (Re) is an important dimensionless quantity in fluid mechanics used to help predict flow patterns in different fluid flow situations. At low Reynolds numbers flow tends to be dominated by laminar (sheet-like) flow, but at high Reynolds numbers turbulence results from differences in the fluid's speed and direction, which may sometimes intersect or even move counter to the overall direction of the flow. The laminar stream is marked by the Reynolds Number (N_{Re}) of below 2000 while the turbulent is in the range of Reynolds above 4000.

The formation of biofilm is influenced by flow factor where turbulent flow has an effect on biofilm formation quickly. The fluid-flow velocity had an insignificant effect on the total bacterial numbers and the numbers of viable heterotrophic bacteria in the pressure medium [7].

II. METHODS

The initial phase of the study was carried out by measuring the average water flow rate in the pipeline, pipe diameter and the average thickness of the biofilm formed on the inner wall of the pipe. Having obtained the actual flow rate, then the next is counting the Reynolds number. The Reynolds number obtained will show the type of flow that is, where the Reynolds number is more than 3000, so it can be said the flow is turbulent. After getting the actual flow, then set up a pilot scale with a linear ratio. The experiments were performed by simulating a process with a scale comparison of the parameters of a tenth pipe from the actual one ie from a diameter of 260 mm to 25.4 mm. The waste water is taken from the real process in food industry. The pilot plant scale aims to see if the rate of biofilm formation can be inhibited by converting turbulent flow into laminar. The experiments were carried out for 2 months and data were taken every 3 days intervals to observe the thickness of biofilm formation.

Research Stage

The stages of research includes;, the preparation, which are measuring ofwaste water flow rate, thickness of biofilm formed in some points in the pipeline, the diameter of the pipes, the physical property of influent and effluent which are density and viscosity. The next stage is setting up the pilot plant scale unit for simulating the process. The data collection and analysis of each stage can be described as follows:

1. Preparation of Waste Water Treatment from the site

Influent and effluent of water were taken from the site and there were some data collected directly such as diameter of the pipes, biofilm thickness inside the pipes, flow rate in the pipe system and also measuring density, viscosity. Some data were also collected from the data log i.e. running time, cleaning period.

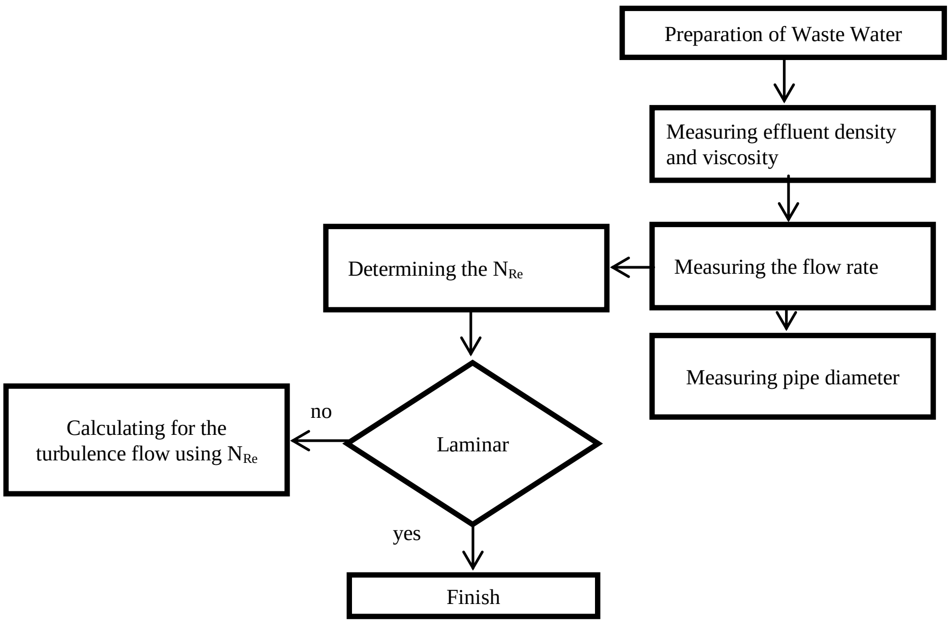

Fig. 1: Flow diagram of preliminary stage study

The purpose of the preliminary study stage is to determine the amount of biofilm that causes clogging in piping and the length of time of formation. Biofilm is formed by 50% pipe diameter for 6 months and causes blockage in the piping system. The amount of waste water flow is 173.7 m^3/h and the next step is to calculate the Reynolds number.

2. Calculation the type of water flow inside the pipes

There are several parameters obtained from field surveys such as viscosity, density, pipe diameter and current water flow rate. Those data are shown in table 2 below:

Table 1. Data of influent water

No.	Parameters	Symbols	Value	Units
1	The viscosity (kinematic) of influent	υ	1.009×10^{-6}	m^2/s
2	The density of influent	ρ	1	Kg/l
3	Pipe diameter (inside)	D	0.2	m
4	Thickness of biofilm	Db	0.1	m
5	The flow rate of influent in the pipes	Q	173.7	m^3/hr

Source: Field Data (2017)

From the data above, the N_{Re} of current wastewater flow can be calculated as follows:

$N_{Re} = \frac{\rho . v . D}{\upsilon}$………………[6].

v = Q/A

Q = 173.7 kg/hr

Q = 173.7 / 3600 kg/s

Q = 0.04825 kg/s

A = ¼π D^2

= ¼. 3.14. $(0.2)^2$

= $0.0314 m^2$

v = Q/A

= 0.04825/.0314

= 1.537 m/s

N_{Re} = $(1.537 \times 0.2)/1.009 \times 10^{-4}$

= 3045.84

From the data above shows that the flow of water in the food industry is in the turbulent flow type because the Reynolds number is at 3045.84, the flow type must be converted to laminar flow in Reynolds number of 2000. In order to reduce the biofilm formation quickly hence the Reynolds number of 2000 must be applied in the piping system. The wastewater flow rate is then calculated as follows:

NRe=(ρ.v.D)/υ

v = (NRe . υ)/D

= (2000. 1.009 x10-4)/0.2

= 1.009

Q = 1.009 x .0314

= 0.0316826 m^3/s

= 0.0316826 x 3600 m^3/h

= 114.06 m^3/h

The above calculation shows that the water flow should be reduced to 114.06 m^3/h hence the wastewater flow rate is decreasing by 34% of the current water flow. The percentage as calculated below:

$$\text{Decrease percentage (\%)} = \frac{(173{,}7-114.06)}{173{,}7} \times 100\% = 34\%$$

3. Set up an experiment with a pilot plant scale

An experiment were set up using 10 L of mixing tank and connected with 2 parallel pipes of 200 m length, 25.4 mm diameter of PVC pipe. The biofilm formation thickness were measured every 3-4 days (or once a week) interval for 2 months. One pipe is regulated with turbulent flow rate of 17.37 m^3/h and the other with Laminar flow rate of 11.46 m^3/h.

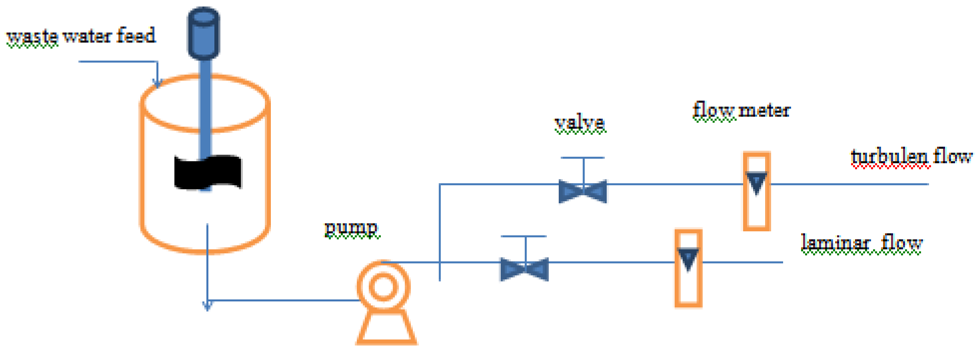

Fig. 2: Waste water process flow diagram (pilot scale)

The fig 2above mention about the process begins with drains the waste water into the stirred tank. Furthermore, waste water from the tank is pumped into 2 parallel pipes with different flow rate. The amount of waste water flow is regulated using a valve and monitored using a flow meter. Pipe with waste water flow rate of 17.37 m^3 / h is in the turbulent zone whereas in pipes with waste water flow rate of 11.46 m^3 / h are in the laminar zone. The thickness of the formed biofilm is observed and measured every 3-4 days for a period of 2 months.

III. RESULT AND DISCUSSION

Experimental data and calculation

Experiments were carried out for approximately 2 months showed the results of biofilm thickness measured every 3-4 days showed a significant biofilm thickening. The average biofilm formation of 0.32 mm / week in the laminar flow with N_{Re} 2000 and the acceleration of biofilm formation in the average of 0.53 mm / week on a turbulent flow with N_{Re}> 3000. The data obtained then plotted in a graph shows the thickness of biofilm versus time.

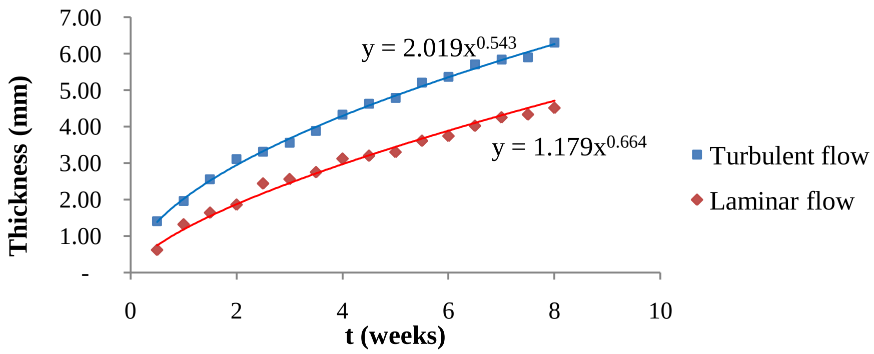

Fig. 3. Biofilm ThicknessvsTime

From the data above fig.3, itcan be seen that there is a difference form of curve between turbulent and laminar flow. The curves for turbulent flow look very fast in terms of biofilm formation whereas for laminar flow the curve is lower in terms of biofilm formation.

This has proven the influence of a significant flow type on the biofilm formation process on the pipeline.

Below is the equation derived from turbulent and laminar flow curves:

Turbulent Flow :

$$y = 2.0196x^{0.5438}$$

Laminar Flow :

$$y = 1.1798x^{0.6649}$$

The two equations above can be used to calculate the thickness of the biofilm that will be formed over a period of time. As an example, the thickness of the biofilm formation will reach 50% of pipe diameter in 10 months in the laminar stream while for the turbulent flow it takes only 6 months (calculated and simulated using the above equations).

The above statement will help for the food industry to be able to determine the period of time required for the cleaning process.

IV. CONCLUSIONS

The formation of biofilms by microorganisms that occur in the piping system in the food industry has been known to cause the inefficiency of the process that is blockage of the pipes. One of the food industries in Netherland encountered the problem. Cleaning is done every 6 months or 2 times in a year. This study aims to decrease the formation of biofilms for cleaning process to be extended to more than 6 months. Biofilm formation can be inhibited by establishing laminar region of fluid flow. It was found that the waste water flow in that food industry is in the turbulent region, so it must be converted into laminar region of flow (Reynolds number = 2000). The results showed significant cleaning time that is from every 6 months (2 times in a year) increases to every 10 months (once a year).

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