Fouling Deposits in Food Industries: The Challenges in Pursuing the GBI-IEB

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INTRODUCTION

In the 21st Century, as fuel and gas prices keeps increasing, issues of green technologies, renewable energy and resources have attracted many premiers. In Malaysia, the National Green Technology Policy was launched on 24 July 2009, in order to control the impact of fuel and gas prices on the national economy. One of the objectives of this policy is to reduce energy usage, while at the same time increase economic growth.

In line with this, the Green Building Index (GBI) for Industrial New Construction (INC) and Industrial Existing Building (IEB) was launched on 7 June 2011, as a rating tool to promote sustainability in energy and water utilisation, indoor environmental quality, site planning, management, material and resource utilisation and innovation. GBI recognition provides company stature in conserving rapidly depleting fossil fuels and the environment. In addition, Malaysia also provides attractive incentives under the Budget 2010 and under the Ministry of Energy, Green Technology and Water for those who have obtained GBI certification.

In the food industry, the issue of sustainability is not only limited to energy utilisation, but also includes water and cleaning chemical utilisation. However, many food production owners are not aware about fouling deposit, which is a major hurdle to overcome before "Green Factory" recognition becomes a reality. Here, the background of fouling deposit is described.

WHAT IS FOULING DEPOSIT?

The deposition of dissolved or suspended material or the growth of biological organisms is commonly found in fluids involved in heat exchange. This may generate the accumulation of unwanted deposits on the surface of the heat exchanger, known as the fouling deposit. Figure 1 shows the fouling deposit of fresh milk after pasteurisation.

Figure 1: Fouling deposit of fresh milk after pasteurisation

The presence of fouling deposit means more fuel is needed to maintain the processing, and this can impact production because its formation can impede the heat transfer, and increase the resistance to fluid flow and maintenance work (Somerscales & Knudsen, 1981).

Both inorganic and organic materials can generate fouling. Each processing material will lead to different fouling mechanisms. Table 1 identifies fouling mechanisms and its level of problem for fluids from different industries (Garrett-Price *et al.*, 1985). Among those industries, fouling in the food industry is most critical. For the importance of food safety, it is compulsory to ensure that a processing plant maintains hygienic conditions.

Table 1: Several types of fouling mechanisms and their level of problems in some industries. Adapted from Garrett-Price et al. (1985)

Type of Industry	Fouling Mechanisms					
	Chemical reaction	Crystal-lisation	Biologi-cal	Particulate	Corro-sion	Freez-ing
Food and kindred products	Major	Major	Medium	Minor / Major	Minor	
Wood and paper products	Minor	Major	Minor	Minor	Medium	
Chemical and allied industries	Minor / Major	Medium	Medium	Minor / Medium	Medium	
Petroleum refineries	Major	Medium	Medium	Minor / Medium	Medium	
Glass, concrete				Minor / Major		
Electricity generation		Medium	Major	Major	Minor	Major

Table descriptions (Bott, 1995):

- ***Chemical reaction fouling,*** *is when the deposit forms because of chemical reactions at the heat transfer surface. Heat exchanger surface is not a reactant but can catalyse the reaction.*
- ***Crystallisation fouling*** *is the formation of solid due to deposition from solution onto the heat transfer surface. Insoluble salts, fats and waxes may crystallise on cooled surfaces, whereas reverse soluble salts, e.g. calcium carbonate, crystallise onto heated surfaces.*
- ***Biological fouling*** *is the formation of organic films consisting of microorganisms and their products (microbio fouling) and the attachment and growth of macrooganisms (macrobio fouling) such as barnacles or mussels.*
- ***Particulate fouling*** *happens when small suspended particles accumulate onto the heat transfer surface. Products of chemical reactions, upstream corrosion products and ambient pollutants are examples of suspended particles.*
- ***Corrosion fouling*** *occurs when processing fluid reacts with the heat exchanger material and produces corrosion products on the heat transfer surface.*

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IMPACT OF FOULING DEPOSIT

The application of thermal processing is vitally important in maintaining the hygienic condition and reducing the concentration of harmful species (bacteria, etc.) in processing. As a result, fouling builds up rapidly and daily cleaning is often needed in food plants for maintaining the quality of food products in terms of being safe to eat, providing good nutrition and for it to look good. For instance, daily cleaning is routine in the dairy industry (Visser & Jeurnink, 1997). Fouling in the food industry is more severe than in other industries. This is due to the heat sensitivity of the food substance that promotes fouling.

Dairy products (Burton, 1968; Miettinen *et al.*, 1999), cheese sauce (Li *et al.*, 2004), mayonnaise, tomato paste (Cheow & Jackson, 1982b), and fruit juices (Jiraratananon & Chanachai, 1996) are among some of the food products which create fouling problems during processing. Table 2 lists the behaviour of major food substances. Fouling which consists of protein is classified as tenacious. Generally, food contains several components; for example, ice cream consists of fat, protein, sugar and salt. Due to its heterogeneous structure, food fouling is complex to understand.

Table 2: The nature of food deposits deposit during production, the effect of heating and the solubility of the deposit (Grassoff, 1997)

Component deposited	Solubility	Ease of removal	Change upon heating
Sugar	Water soluble	Easy	Caramelisation: more difficult to clean
Fat	Water and alkali soluble	Difficult	Polymecrisation: more difficult to clean
Protein	Water insoluble, alkali soluble, slightly acid soluble	Very difficult	Denaturation: very difficult to clean
Mineral salts	Water solubility is variable but most are acid soluble	Easy to difficult	Interactions with other constituents: generally easier to clean

As the food industry demands frequent cleaning, more precautions are needed. If fouling build-up is not monitored appropriately, increased maintenance, fuel costs and capital expenditure are likely (Fryer *et al.*, 1995; Pritchard, 1988). Production cost will increase as well. In addition, a huge penalty could be incurred if food product safety is compromised. Hasting (1995) reported that the cost of food contamination could reach as high as £400 million. This value is high as food contamination can be fatal to consumers and result in a huge loss of consumer confidence in the brand.

COST FOR FOULING PROBLEMS

Fouling problems add to production costs. Total fouling cost in a year could be represented as a percentage of GNP (Gross National Product). These percentages were computed for top industrialised countries (e.g. the United States, the United Kingdom, Germany and Japan) by Garrett-Price *et al.* (1985) and Pritchard (1988). Müller-Steinhagen (2000) multiplied these percentages with the 1992 GNP of these countries to obtain the fouling costs of that year. Table 3 shows that the total fouling cost for these countries are higher compared to the figures for less industrialised countries.

Table 3: Total fouling costs per annum in 1992, calculations are base on percentage of Gross National Product (GNP) taken from Dynamic Descaler's

Country	Fouling Costs as % of GNP	1992 GNP ($billion)	Fouling Costs ($million)
UK	0.25	1000	2500
US	0.25	5670	14,175
New Zealand	0.15	43	64.5
Australia	0.15	309	463
Germany	0.25	1950	4875
Japan	0.25	4000	10,000
Total Industrialised World	0.20	22,510	45,020

Source: (http://www.process-controls.com/techsales/Dynamic_Descaler/energy_cost.htm)

In the food industry, one of the major costs is attributed to cleaning. Several factors that influence the cleaning cost have been listed by Gillham (1997):

- Cleaning chemical usage.
- Energy consumption to heat up and pump the cleaning solution.
- Production loss because of cleaning,
- Waste water treatment from the cleaning process,
- Cost for labour to dismantle the equipment before proceeding with the cleaning work, and
- Plant downtime cost during cleaning.

Generally, environmental cost is the greatest cleaning expenditure. Cleaning chemicals are also a relatively high expenditure in cleaning. It was revealed that the global sales of cleaning chemicals is over $1 billion per year (Kane & Middlemiss, 1985). The cleaning costs in the food industry are more expensive than other process industries.

Thus it is vital to reduce the usage of cleaning chemicals, cut down on water processing and cleaning time, and use equipment that is hygienically designed. Optimum cleaning will cut down fouling cost and protect the environment.

CURRENT EFFORTS TO SOLVE FOULING DEPOSIT PROBLEMS

Much work has been done to reduce fouling formation. However, the need to change product ingredients and process conditions for reducing fouling are not appropriate for most food production. Many methods have been invented to mitigate fouling problems such as the use of mechanical removal, modified surfaces and cleaning in place. Mechanical methods, such as ice pigging (Quarini, 2002), are generally limited to the shape of the equipment (e.g. tube heat exchanger). The application of modified surface technology in the food industry is still under investigation as the invention of a new surface which has better functions (e.g. chemical resistant, corrosion resistant, abrasive wear resistant, electrical properties and non-stick) is difficult (Bornhorst *et al.*, 1999; Muller-Steinhagen *et al.*, 2000).

Cleaning-in-Place (CIP) is the most commonly applied technique to mitigate food fouling. However, regular CIP can be uneconomic in terms of downtime and materials (Changani *et al.*, 1997). Nowadays, the food market is being dominated by gigantic retailers such as Tesco, Asda and Sainsbury. Because of the high competition, food industries must offer cheaper prices. One way to achieve this is by reducing production cost. This can be done by adopting the optimum cleaning method. To optimise cleaning, it is essential to understand the removal mechanisms and have some knowledge of material behaviour during cleaning. This can reduce maintenance cost and production losses.

CLEANING-IN-PLACE (CIP)

CIP was invented to simplify the old cleaning method in which the equipment was dismantled before cleaning. In this process, hot cleaning chemical is circulated through the plant (Alfa-Laval, 1987). Müller-Steinhagen (2000) and Liu & Macchietto (1993) agree that CIP is better than mechanical methods. CIP usually involves several steps as given in Table 4.

Table 4: Cleaning cycles in CIP (Christian, 2003)

Cycles	Function
Pre-rinse	The stage where loose deposit is removed from the processing surface. Water is often used in this stage.
Detergent cycle	Deformation of deposit and most removal occur here. Generally assisted by using acid or alkali base cleaning agent. Some of the CIP methods need more than one detergent cycle, in this case intermediate rinse is needed.
Post-rinse	Water is use to rinse out the processing area from remaining deposit and detergent residues.
Sanitization	Disinfection and surface conditioning process.
Final rinse	Water is circulated until the required degree of clealiness is reached. Then proceed with production activity.

All industries have their own degree of cleanliness to attain. This degree of cleanliness can be down to the nano-scale, also known as atomically clean. Physically clean aims to clean the surface until it looks clean but chemical residues may remain. Chemically clean ensures the surface is fully clean from any substance that may affect product processing. Biologically clean means that the surface has a level of microorganisms that is not harmful.

Normally, the objective of CIP in food production is to have a chemically clean surface. There are two types of CIP treatment that are recognised in milk processing (Timperley & Smeulders, 1987):

i) Two-stage: the first stage uses alkali while the second stage uses an acid base.

ii) Single-stage: a formulated detergent is used, which contain compounds, such as sodium hydroxide, surface active and chelating agents, to enhance cleaning.

Sodium hydroxide (NaOH) is a common cleaning chemical and has been used in several studies of food fouling (Cheow & Jackson, 1982a; Romney, 1990; Bird & Fryer, 1991; Gillham, 1997; Liu *et al.*, 2007). Owing to its highly alkali condition (usually pH 12 to pH 13), NaOH promotes the break of peptide bonds in protein. However, acid is required to remove the mineral layer. The addition of sequestrents and detergents in single-stage cleaning chemicals enable both deposits to be removed simultaneously.

Several researchers have studied the optimisation of the CIP processes. Hiddink & Brinkman (1984) and Timperley & Smeulders (1987) compared the two types of CIP treatment and found that the single-stage treatment is more economical due to reductions in rinsed water, energy consumption and downtime. Smaili *et al.* (1999) scheduled and minimised the length of the cleaning periods to reduce the cost of cleaning in sugar processing plants, which are described in a series of papers (Smaili *et al.*, 2002b; Smaili *et al.*, 2002a). However, several studies have also been done to investigate the optimal cleaning for tropical food producers.

CONCLUSION

Malaysia's awareness of fouling deposit problems and the importance of cleaning in the food industry is very low. This is due to a lack of educational and promotional effort from the related authorities.

For an industrialist, without the proper cleaning technique, the production cost will significantly increase due to chemical usage, water wastage, maintenance work, heating of fuel, downtime and production loss. As for its effect on the public, the competitive price of convenient foods can be difficult to obtain and the over discharge of cleaning effluent can pollute our water resources.

Consequently, the related authorities must make sufficient efforts to comprehend the importance of cleaning, enforce a specific standard of CIP on the food industries, and educate Malaysian consumers on this issue. Industrialists must also take serious action to ensure that hygienic processing is maintained. As consumers, we should be aware of the current practice in modern countries that have a better control system for monitoring their food producers. ■

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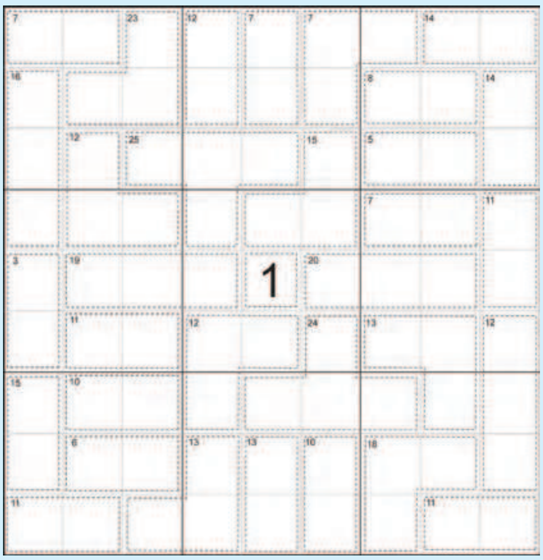

1SUDOKU Centerpiece "1"

by Mr. Lim Teck Guan

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(*Solution is on page 43 of this issue.*)