

## 1. Introduction

This article is based on a presentation given at the PathogenCombat/EHEDG Hygienic Processing Workshop in Cork, on the 9<sup>th</sup> February, 2010. During the PathogenCombat project, Cocker Consulting Ltd had the objective of working with SMEs on hygienic engineering and design, with a secondary responsibility in the objective of minimising the formation of biofilms and assisting in the development of practical advice on how to remove biofilms once they had formed. The advice contained in the presentations at the PathogenCombat workshops in Ljubljana, Copenhagen, Burgos, Copenhagen and Budapest were based on my background as first, a graduate microbiologist, followed by a doctorate and extensive practical learning in the field of aseptic and hygienic design and engineering. This work included visits in Spain and Ireland to SMEs in the meat, poultry and dairy sectors and visits to these sectors, plus fish processing, on behalf of major Retail and Food Service clients.

This article concentrates mainly on issues applying to open equipment, which is used extensively in meat, poultry, fish and dairy processing.

## 2. Conclusions

- 2.1. To a greater or lesser extent, food-processing organisations operate with hazards and risks to food safety. Risk is the product of the magnitude of a hazard and its probability. In my extensive visits and audits, many food-processing organisations did not have the insight in hygienic design and engineering to assign a probability to the various hazards. They unknowingly accepted an excessive number and magnitude of hygiene risks because the occurrence had also been zero. This was despite that fact that a future occurrence of any one of these hazards could wreck their business and seriously injure or kill consumers.
- 2.2. The importance of good moisture management and hygienic design was not understood. The following examples were repeated (In large organisations and SMEs alike:
  - 2.2.1. Regulators and auditors demanding washing of a dry process area
  - 2.2.2. An emphasis on performing the ritual of cleaning, rather than on prevention by design
  - 2.2.3. Cleaning that was not working properly and leaving a biofilm. Some of these biofilms were not visible in normal light, but they were visible using U.V. light.
  - 2.2.4. Equipment left wet overnight or for a whole weekend after cleaning.
  - 2.2.5. Footwear poorly cleaned on exiting production areas and on re-entering.

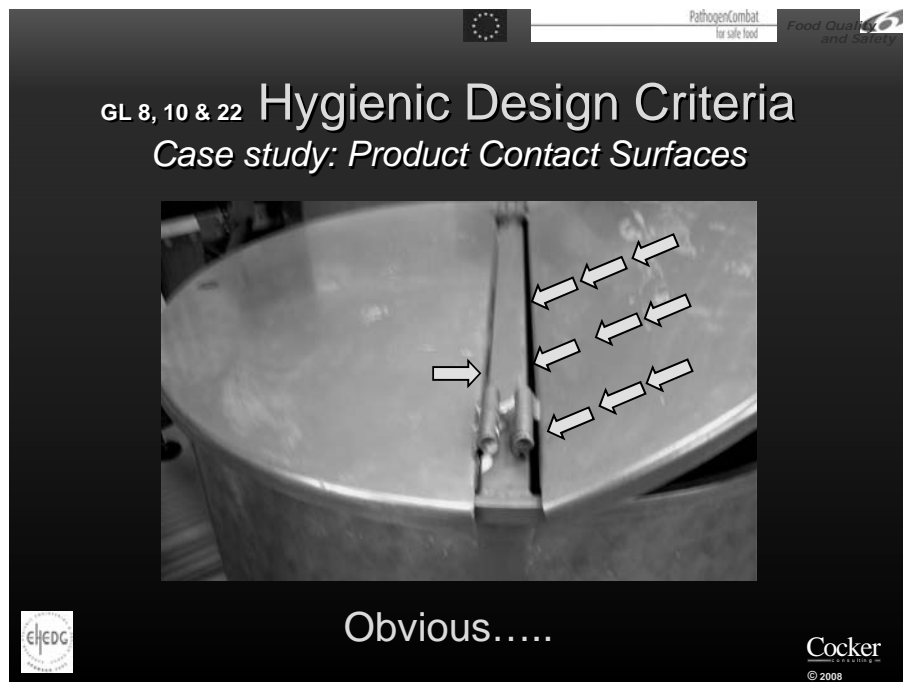
- 2.2.6. Poor drainage, poor access for inspection and cleaning, wet films, condensation and aerosols.
- 2.2.7. There was often a mistaken confidence in the effectiveness of cleaning– most open equipment had many unreachable crevices, formed by unsealed joints, tack welds and threaded fittings yet owners felt that their cleaning was effective.
- 2.2.8. Many suppliers, inspectors, veterinarians and auditors lacked hygiene knowledge.
- 2.2.9. The users were not very aware either.  
There were both product safety and occupational hazards, stemming from poor control of moisture.
- 2.3. The poor moisture control and poor hygienic design was associated with excessive environmental and cleaning costs.
- 2.4. Most new, CE-marked food processing equipment (estimate: over 70%) did not comply with the hygiene provisions of the Machinery Directive, 98/37/EC. (“The Directive”)
- 2.5. The user organisations did not know this and did not understand their rights to have equipment and instructions that could allow them to produce safe food.
- 2.6. Claims related to alleged deficiencies in hygienic design which Cocker Consulting Ltd and fellow consultants had been involved with were settled out-of-court, with confidentiality conditions. This meant that not only were the hygiene provisions of 98/37/EC not policed; there was also a lack of publicity to warn other equipment suppliers of the size of the risk to their businesses. Note: The Directive, 98/37/EC will be replaced by Directive 2006/42/EC from December 2009.
- 2.7. Aggressive fluxes of energy, thermal treatments and chemicals were thought unavoidable. However, hygienic buildings and equipment were needed in order to realise the benefits of “ecological” cleaning methods, longer process times, increased safety and lower costs.
- 2.8. A common target was “visually clean”. This could be misleading (see 2.2.7)
- 2.9. Enforcement and customer demands often suggested poor knowledge
- 2.10. Inspectors, regulators and auditors needed better training in hygienic design.
- 2.11. Operators, fitters, Quality Assurance personnel, engineers and designers also needed better training in hygienic design.
- 2.12. Apart from the knowledge of the design principle, engineers, designers and others needed an outline of the functional properties of microbes that were relevant to the design principles, together with the knowledge of how these functional properties relate to hygienic design. This applied not just in the specific area of equipment design, but also to training and to the whole food production systems, organisations and procedures.
- 2.13. The reasons and evidence for the designs in EN 1672-2 are not explained. More knowledge was needed in the industry of the hygiene provisions of The Machinery Directive and EN 1672-2, the standard that was written to explain how to meet these provisions.

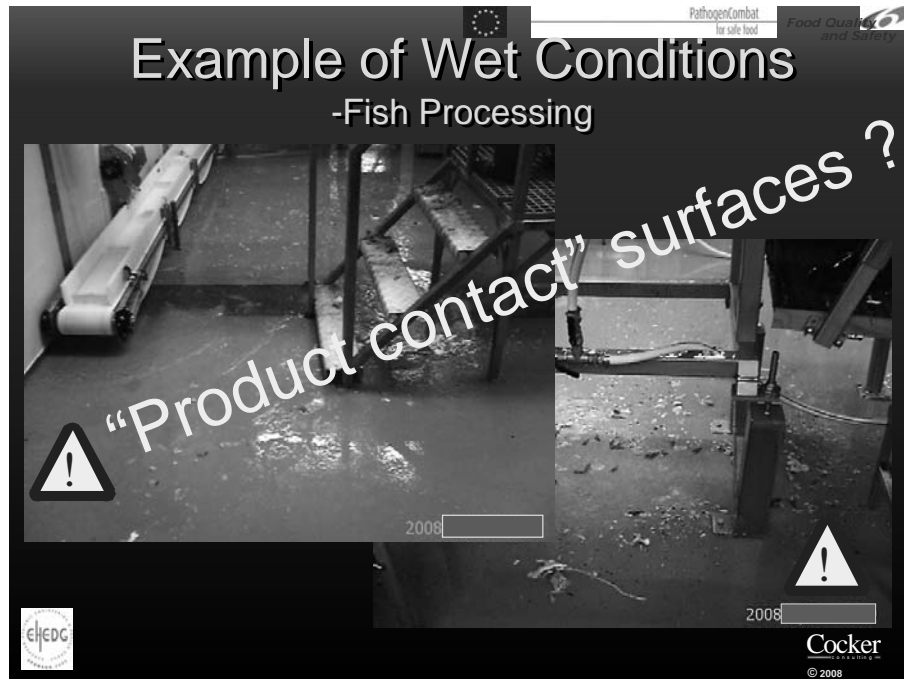
- 2.14. It was concluded that at best the engineers and designers at equipment manufacturers lack the microbiological knowledge mentioned above, which may make the hygienic design principles in EN 1672-2 credible to them and also the skills in food technology necessary to carry out a hygiene risk assessment, as required by The Directive.
- 2.15. A scientific basis for designs and for the validation of equipment, such as that of the European Hygienic Engineering and Design Group (EHEDG), was needed.

### 3. Explanations

#### 3.1. The Role of Moisture in the establishment of Biofilms

many microbes, including bacteria, can either swim or grow via films of liquid. Stagnant liquid provides a ready breeding-ground for microbes and cleaning sprays may redistribute pathogens from such pools. Unwittingly, manufacturers may assist this by promoting a wet environment. Even the distinctions of product- and non product-contact surfaces, on which the designs may rely for their hygienic performance, can become meaningless under such conditions.





In case further motivation is needed, the report of the United Kingdom Health and Safety Executive established that 30% of all major injuries were slips and that 90% of these slips were caused by wet floors. 95% resulted in broken bones and 1,000,000 days were lost per annum, at an average compensation cost of STG 4,000 per accident.

### 3.2. The Transport of Microbes through the Air

Because of electrostatic attraction, microbes in the air are inevitably attached to other particles. They have no active means of flying, but are instead always passengers, either in liquid or solid aerosols, or in sprays.

### 3.3. Dry conditions and products

These do not support the growth or propagation of microbes.

### 3.4. Moisture Management

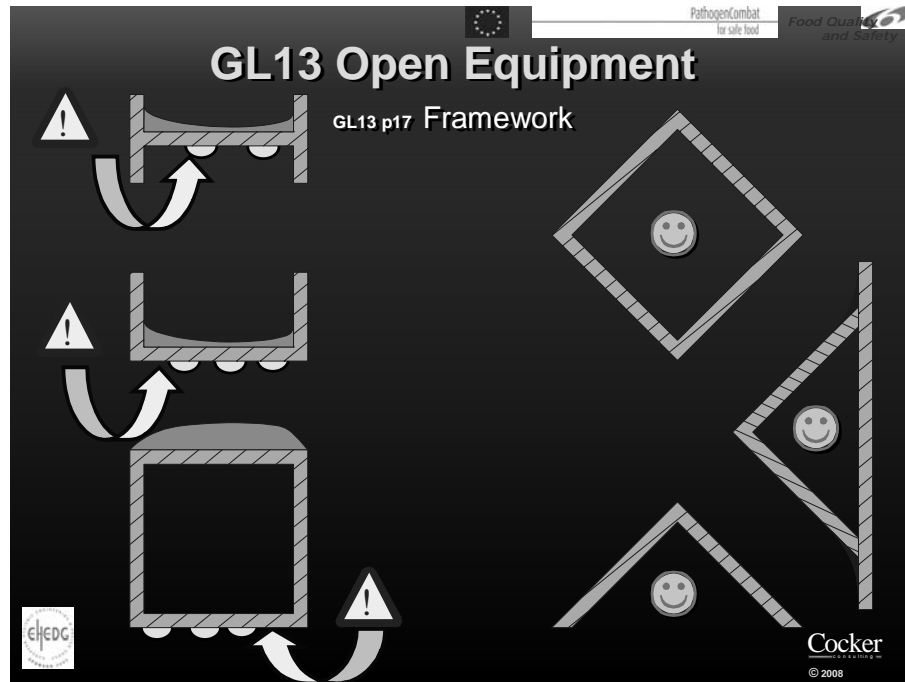
Water is a major component of most food products and processing often involves transfer of this water from the food.

In cleaning, water is the dominant carrier and solvent for soil and detergents.

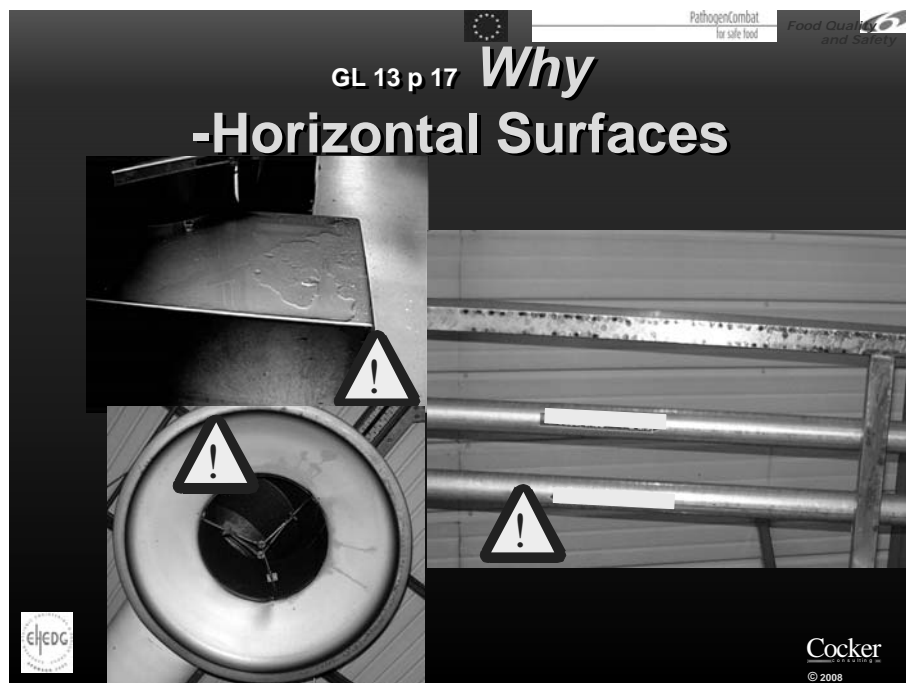
There are two forms of water removal, which may be viewed as (a) Passive (better) and (b) Active (poorer).

- 3.4.1. Passive moisture removal is the result of a preventive strategy, embodied in the basic principles of hygienic design. (See the free-to-download Document #8 [www.ehedg.org](http://www.ehedg.org) .) The key point is that equipment and its surroundings need to shed liquid quickly and to retain it only on demand, for example by closure of a drain valve

or by turning a vessel upright. There was poor recognition of the ability of horizontal surfaces to retain liquids, especially downwards-facing surfaces. Many of these downwards-facing surfaces were not easily accessible for inspection or cleaning. This adaptation of a schematic from the EHEDG Trainers' Toolbox illustrates the point for framework.



The following image shows the effect underneath a ventilator and underneath adjacent cylindrical and square-section piping:



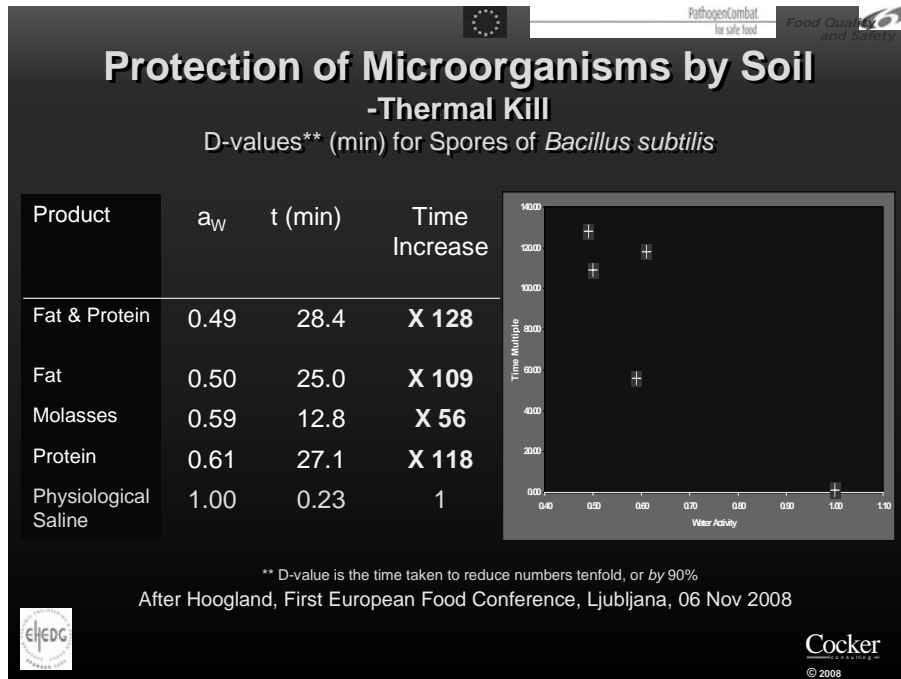
And below are such areas immediately above a conveyor belt:



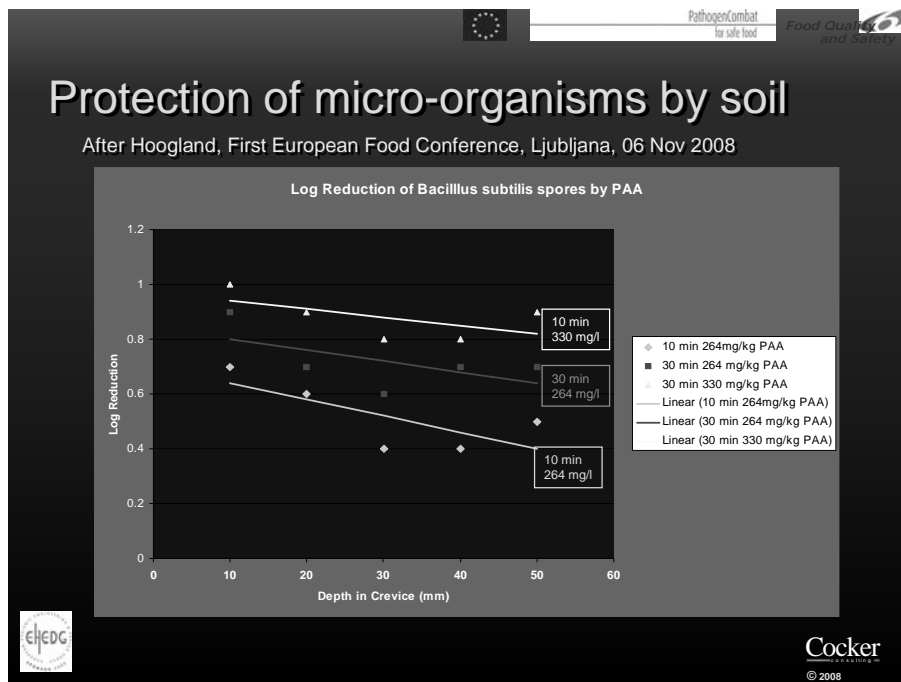
Active moisture removal usually consumes energy, for example ventilation, extraction, heating and the use of absorbent materials, rubber blades, and, for closed systems, vacuum. It is often necessary after wet cleaning.

#### 3.4.2. Protection of Microorganisms by Soil

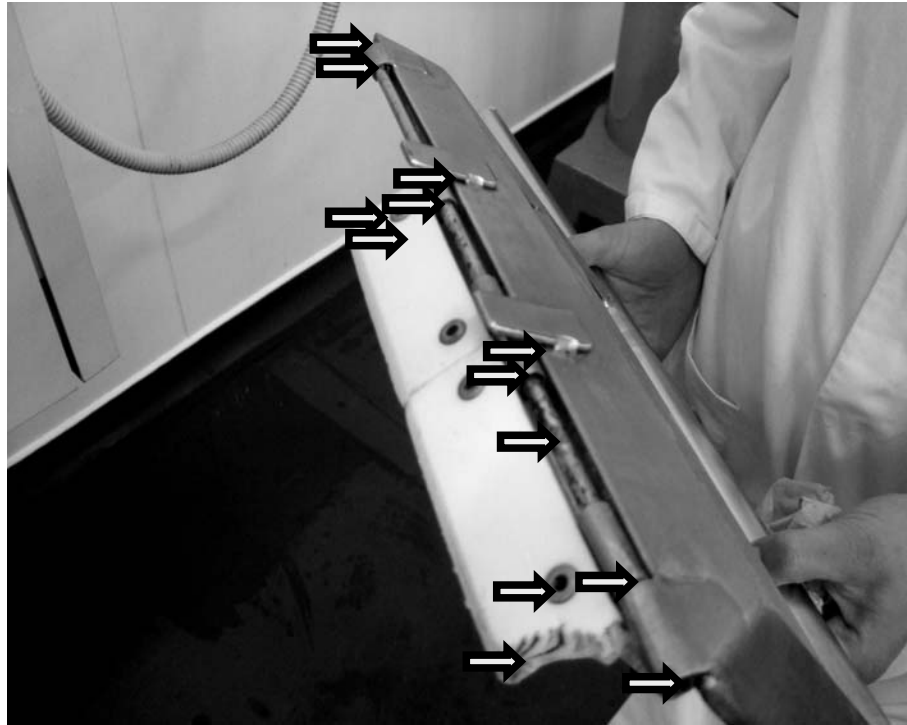
Residues of food products and biofilms on equipment have been shown to protect microorganisms from respectively thermal and chemical treatments designed to kill them.



It has also been demonstrated that the deeper the crevice, the greater the protection that is afforded by the soil.



There are plenty of examples of such crevices in recently-purchased equipment, such as this at an SME dairy:



The dairy in question was considering purchase of a further scraped surface heat exchanger, so advice was provided on improved designs,

#### 4. The “Phoenix”

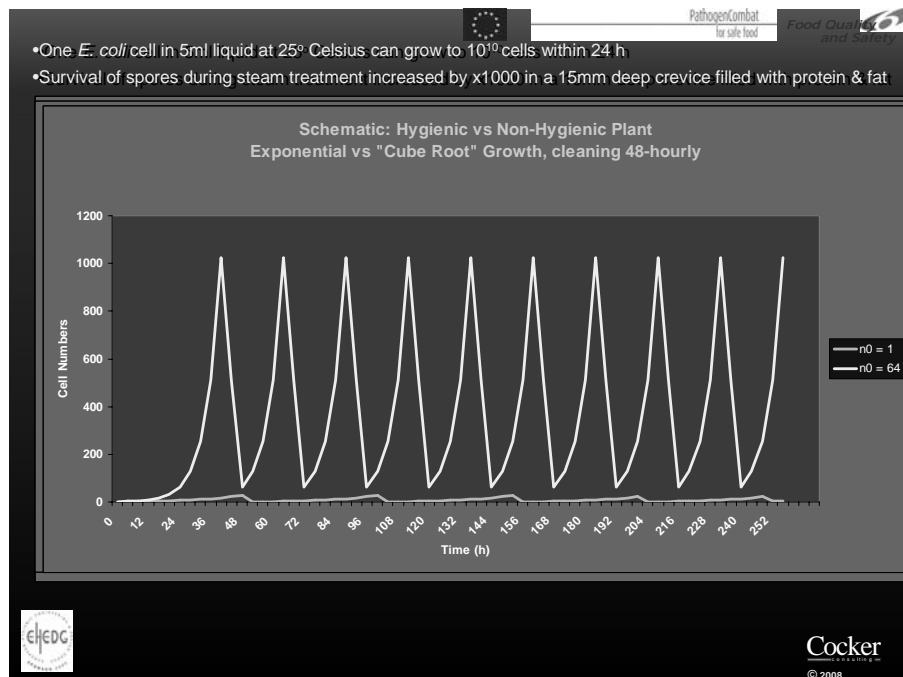
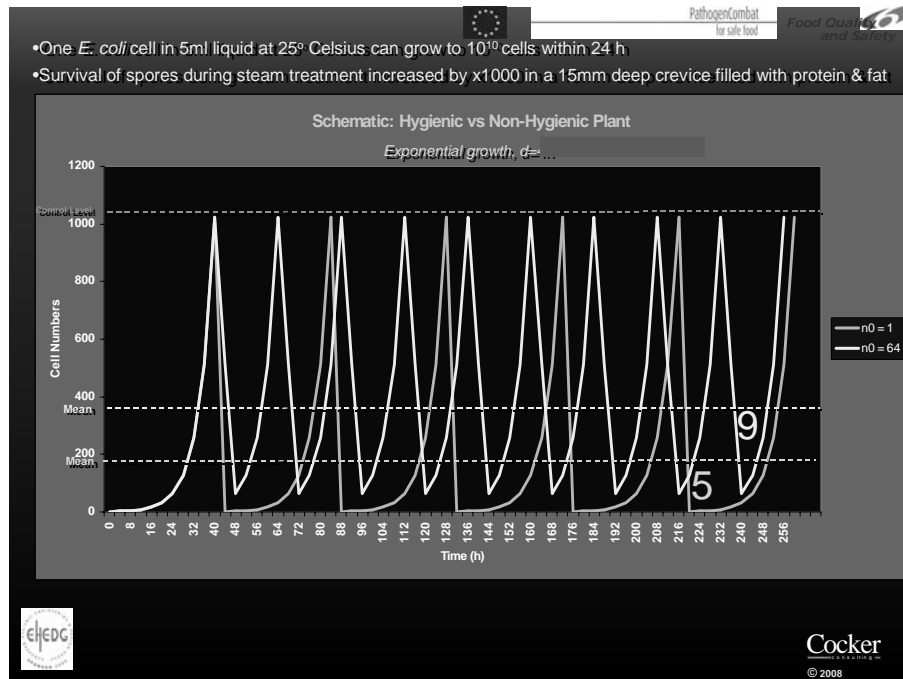
- 4.1. A principle difference between microbial contaminants and other contaminants such as chemicals and foreign bodies is that microbes are capable of re-growing after any setback. Dilution is perfectly effective for controlling chemical contaminants, for example, but usually offers only temporary relief, where microbes are concerned.

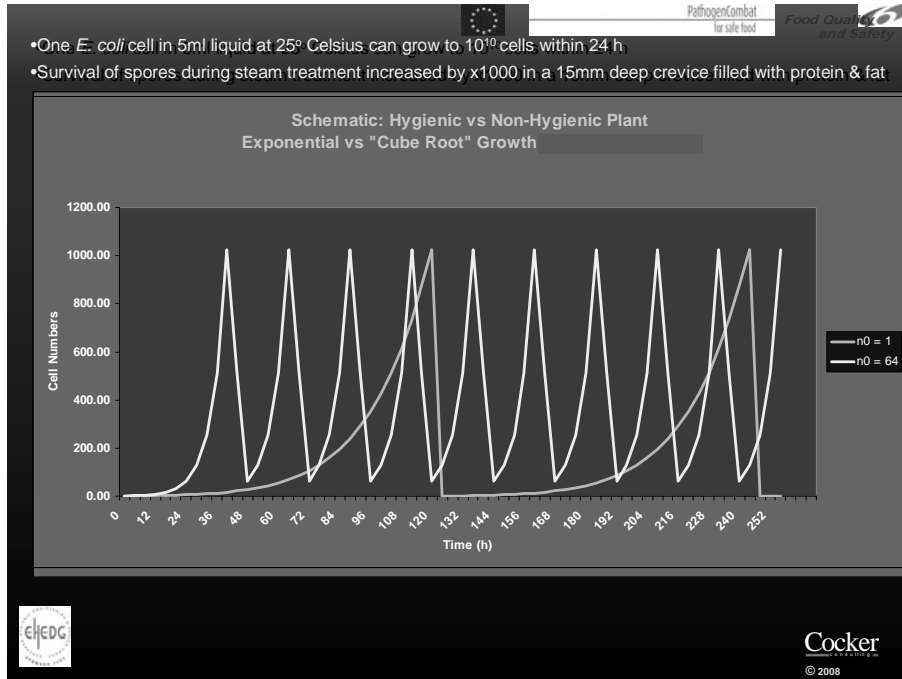
A typical sequence is that crevices and hidden surfaces collect proteins, fats and microbes, and then escape effective cleaning and detection, even though 99.99% of the rest of the surfaces are very well cleaned and disinfected. The managers involved conclude on the basis of visual inspection and possible point sampling of accessible surfaces that they have clean equipment. Each crevice is then a ready locus of contamination, which can lead to dissemination and biofilm formation, and then in turn to more frequent contamination events and to increased contamination-levels. This is especially so if the equipment does not have dry surfaces.

It is worth ensuring that all concerned understand the importance and mechanics of biofilm consolidation, which is measured in hours and days and is characterised by physiological and metabolic changes that lead to increased resistance to lethal agents, increased adhesion and an ability to survive in the presence of low nutrient concentrations. As

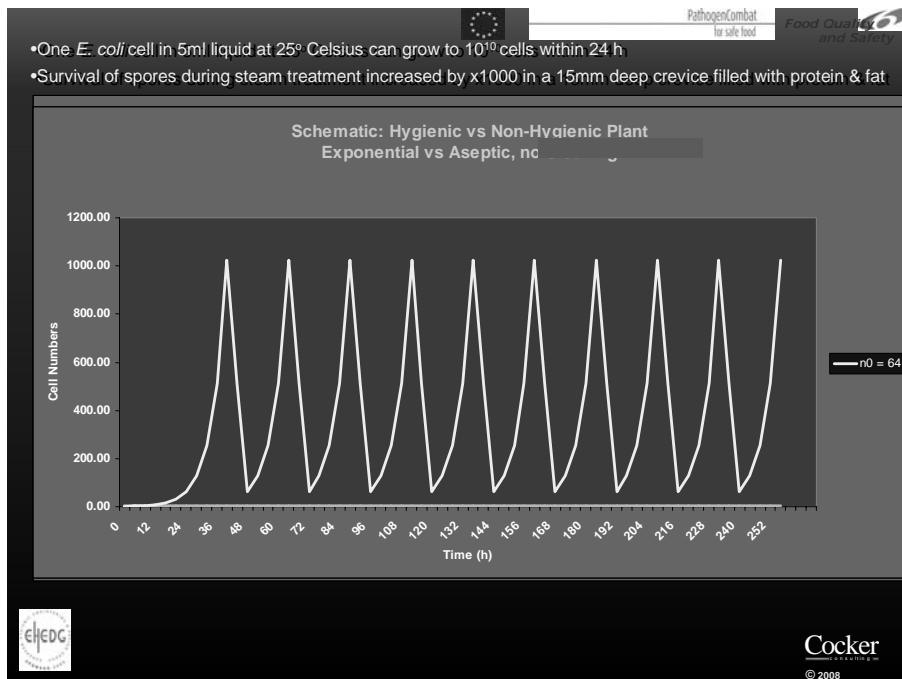
we all know from the biofilms that form on our teeth, mechanical force is needed to remove biofilms, once consolidation has taken place, and because of the kinetics of biofilm consolidation, the frequency of cleaning is crucial to maintaining control.

In the presence of nutrients, the growth-rate of microbes can vary from exponential down to apparent stasis, depending on nutrient sufficiency. The green curves in the following schematics represent a hygienic design, versus a non-hygienic design (yellow).





This can allow significant advantages to be gained from increasing levels of hygienic design, until ultimately for aseptic systems, the absence of contaminating microbes means that there is no growth of contaminants, and extremely long processing times are possible, without the need for cleaning or sterilization.



#### 4.2. Aerosol Formation

An appreciation of necessary hygienic design considerations for open systems requires some understanding of aerobiology, or the mechanisms by which microorganisms survive and spread whilst in the air. Even a drop of liquid falling from a pipette onto a lab bench generates a large quantity of micro-droplets. (Dimmick & Akers, 1969) The rate and intensity is proportional to the mechanical energy-flux. (Dimmick factor) In a food-processing environment, examples include high-pressure jets from cleaning, high-speed fans and high-speed slicers. Direct and reflected spray can carry microorganisms and nutrients a few feet away, but the associated aerosol can be copious and can spread much further. The finest aerosols have neutral buoyancy in the air and hang in the air for a very long time. This is why, for example, jet cleaning should never be performed in rooms where food or clean equipment is within reach of the aerosol cloud. It is also why high-speed, water-lubricated, slicer-blades can give problems like those at Maple Foods in Ontario. The spray and aerosol from the disc disseminates moisture, microbes and food, and there is ample time between cleaning shifts for multiplication. There were 22 deaths from *Listeria monocytogenes*) in this outbreak



High-pressure sprayers have been shown to become contaminated and to back-contaminate the water supply in food plants. (Carpentier, B. Proc. Food Hyg. Europe 2000 pp.41-43)

This phenomenon is supported by the finding that water-cooled high-speed dentist drills also suffer the same problem. (Appl. Env. Microbiol. 66 pp.6636)

EHEDG Document #13, Open Equipment, draws attention to the positioning of common sources of high energy, such as motor drives and fans, high-voltage insect traps and static components such as piping and cable trays. (Which can carry liquid to a point where it can contact such a device) The following image is taken from the EHEDG Trainer's Toolbox, which was developed using EU funding within the HYFOMA project.



The use of high-pressure sprays, especially those targeted near the floor or near drains with the intention of transporting food materials to the drain. It is easy to see how even the coarse, visible mist can spread contamination, let alone the invisible fine aerosol.



During PathogenCombat visits to Spanish food processors, it was found that for the ripening rooms of jamon iberico,



# Jamon Iberico



Image courtesy of Alan Friis, DTU



Both veterinarians and customer representatives (auditors) had demanded wet cleaning of the floor.

To prepare for this, the processor had to remove all the hams from the (very large) ripening rooms and then a ride-on floor scrubber/dryer was used. Unfortunately, this type of machine sucks the remaining fluid from the floor and exhausts it as an aerosol.



# GL13 Open Equipment Vacuum Floor Washers



We recommended against using the floor scrubber or wet cleaning. The ripening-rooms have an ambient relative humidity of around 40%, so it was counterproductive to add water. Instead, we recommended using a sheet of material under each row of ham frames, rolling this up when it was time to clean. It could be recyclable, reusable or disposable. If reusable, it could be cleaned elsewhere, without the need to move all the hams out of the room and then move them back again.

For moisture-management, it is recommended to implement a “dry floor” policy. This means:

- Removing waste at source and spiriting liquid waste straight to drain
- NO rubber boots or aprons
- Normal safety shoes
- NO boot-washers at production
- Hoses & mops locked during production
- Rubber blades with scoops and bins only, for the removal of waste that falls to the floor.
- Good ventilation
- Controlled wet cleaning where necessary, for example, use of impregnated wet wipes.

Whilst this discussion is focused on liquid aerosols, it would be misleading to draw attention away from dust and solid aerosols, for example from building work or other sources of dust.

4.3. In the meat, poultry, fish and dairy industries, poorly-controlled sources of moisture include:

- All chilled equipment in process areas
- Freezers and chill rooms
- Overhead chiller units
- Product itself (especially chilled)
- Non-insulated pipes and tanks
- Ice
- Process water
- Washing fluids
- Vapour from internal combustion engines (battery versions OK)
- Traffic
- Drafts
- Boot-washers at entrances

A significant moisture-source was the movement of lift-trucks between areas. This should be avoided as far as possible, by use of roller- and belt-conveyers, passing via “windows” form one room to another, and split at the door, so that the rooms and conveyers can be isolated for cleaning and when product is not being transported.

PathogenCombat  
for safe food

Food Quality  
and Safety

# GL 34 Integration

## Walls, Openings & Transfer-Zones



Image courtesy of Kupan  
([info@kupan.com](mailto:info@kupan.com))

Control floor traffic between zones, especially where temperature and humidity differ

EHEDG

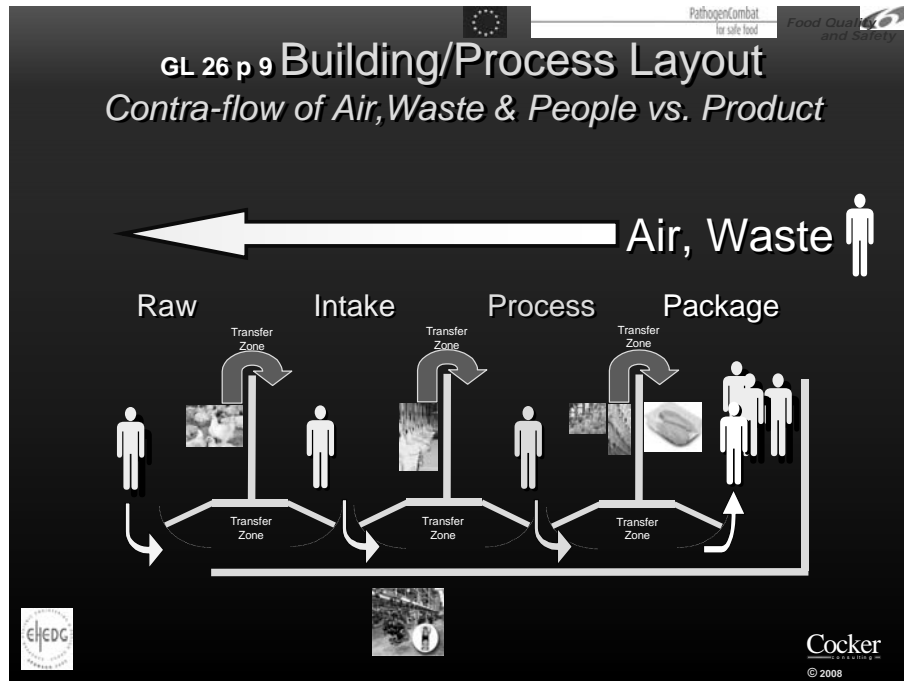
Cocker  
© 2008

Note that the conveyer above is also covered, effectively making it a “closed” part of the system, unaffected by the surroundings until opened.

#### 4.4. The Role of correct Integration

Humidity control and many other factors important for food safety often broke down once the layout and flow of products, people, equipment, materials and waste products became disrupted, This could have happened because of poor initial planning and/or because of badly planned expansions of production. There should be a systematic, sequential flow of product in one direction, with air, waste and people running counter to this. In the PathogenCombat visits, it was almost always the case that we were led through the process from beginning to end, dirty to clean. Many other visits have been the same.

The slide below is a schematic of the correct flows. The example is illustrated with respect to a poultry plant, as an example where the beginning of the process is very contaminated, and the visitors (yellow group) have just passed though from the live bird intake, via slaughter and evisceration.



The last Integration topic re-emphasizes that food safety requires a holistic approach. A forgotten aspect in many plants was the Maintenance Department, where equipment, clothing and people that find their way into processing areas (note the hairnets) were not handled in a hygienic fashion.

