Review paper
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HYGIENIC DESIGN AND OPERATION OF FLOOR DRAINAGE COMPONENTS

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Abstract

Drainage is a critical component affecting the hygienic performance of food production facilities intercepting and conveying fluids from a variety of sources whilst also providing a barrier function used to segregate areas and separate the internal environment from the sewer.

Drain components can be considered 'environmental surfaces' - with no direct food contact but with clear potential to act as a source of contamination. Studies indicate that drains are reservoirs for pathogenic bacteria, of particular concern is *Listeria*. Importantly drains are implicated as pathogen harbourage sites in both pre and post cleaning studies This in itself raises questions on persistency and cleaning efficacy. Soils include viscoelastic fluids that may be rinsed or viscoplastic fluids such as biofilms that cannot be rinsed. The degree to which a drain is cleanable depends to some extent on component design. Recent work on design aspects of drains has been undertaken by the European Hygienic Engineering Design Group (EHEDG).

In this article consideration is given to how features within the drain component itself might improve hygienic performance with regard to cleanability. Initial experiments are reported that highlight the role of component design and cleaning methodology. Conclusions suggestthe need for consideration of component design, risk assessment of the cleaning method and the need for cleaning validation and verification.

***Key words**: Food processing plant drainage, Environmental surface, Hygienic floor drainage, Linear channel, gully, Drain design, Drain cleaning, Validation and verification.*

1. Introduction

Drainage is a critical component that affects the hygienic performance of food production facilities. Floor drainage specifically provides three basic functions – interception, conveyance of fluids, and the ability to act as a barrier. Drain components have ample water supply, they accrete nutrients and provide an environment ideal for microorganism harbourage and growth. There are numerous examples of drainage installations that exhibit some capacity to be termed hazardous, often as a result of poor component design. Forthcoming output from EHEDG [10] promotes hygienic drain design. Translating this to hygienically safer factories ultimately depends on the cleaning regime. Some academic studies have focused on hygienic attributes of floor drains, and indicate varying performance with regard to pre and post clean microbial status (Swanenburg *et al.* [21]; Zhao *et al.* [24]; Warriner and Namvar [23]; Rotariu *et al.* [19] and Parisi *et al.* [18]). This article considers internal surface drainage focussing on features within the drain component itself and the cleaning regime.

2. Floor drain function

Within the food production facility, surface fluids present a hazard for which an appropriate risk assessment strategy can be devised. Fluids may be part of the cleaning process, or may originate from specific equipment discharge points, or be simply the result of accidental spillage. Floor drainage components cater for these situations through three core functions (Fairley [12]):

- Interception
- Conveyance
- Barrier capability

These functions are illustrated in Figure 1.

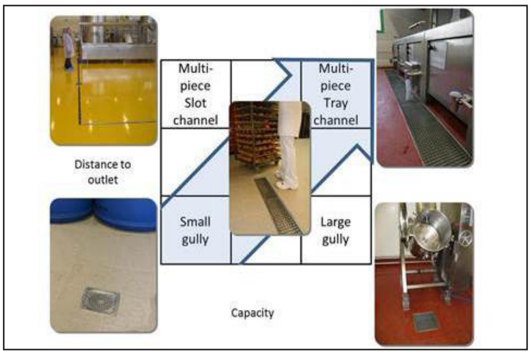


Figure1. Fluid interception and conveyance: conveyance is represented by the y axis. Interception is a function of conveyance and capacity and is represented by the arrow

The main categories of floor drainage; gullies and linear channels, differ in their performance of these functions. The property of interception can be related to the efficiency of surface fluid removal, a function influenced by the source: Point discharges can be most efficiently intercepted by a gully, often with a tundish or funnel component on the cover or grate to minimise splashing. In cases where large volumes of fluid discharge over a wide area, wide channel systems provide interception along their length and prevent bypass.

Conveyance relates to fluid movement or transport. Conveyance near the surface, as executed in a channel leads to simpler floor designs, removing joints and improving durability [2]. The minimisation of point gullies further reduces underground connection complexity with possible cost savings. While fluid conveyance across floors should be minimised it is clear that linear channels exhibit good conveyance attributes with the benefit of generally keeping the drainage invert higher than with a pure gully system. This is especially so in larger areas. This attribute is also useful in drainage retrofit schemes, where construction depths might be minimised with subsequently less disruption. Gullies on the other hand, convey only to the ongoing drain pipe.

The ability to create a barrier that prevents fluid bypass may be important at specific locations, such as doorways. As such, drainage layout may be part of the wider scheme of segregation or zoning within the facility as illustrated in Figure 2 (Fairley ibid).

The barrier concept importantly extends to the function of the floor drain providing an interface between the factory and the sewer. This is normally effected thought the incorporation of a foul air or water trap as shown in Figure 3. Such devices used to be separate to the gully - normally implemented by a 'P' trap in the pipe. Provision in the gully improves access but presents also a 'loose' part to manage. The good functioning of the barrier concept is crucial in the design of any drain in a food production area. It is clearly a physical barrier between hygienic areas, suitable for regular environmental cleaning, but also a closed, hidden and underground area, less suitable for cleaning and most likely highly contaminated. Sewer collection pipes can only be accessed for periodical cleaning as far as the applied cleaning system reaches (e.g. by high pressure hosing).

2.1 Internal floor drainage - a key component of hygienic design

It is well recognised that drainage is an essential component of effective hygienic operation. Global initiatives such as the Global Food Safety Initiative - GFSI [14] and European Economic Community legislation (EC 852 [8]) highlight the requirement for adequate drainage. EC 852 /2004 [8], stipulates general hygienic requirements for all food business operators. It states that 'drainage should be adequate for the purposes intended' and designed to avoid the risk of cross-contamination. It explicitly acknowledges Good manufacturing Practices (GMP) such as flow direction in open systems which must be from clean to contaminated areas. The importance of environmental factors is further underpinned in BS EN ISO 22000 [5], where the principles of the prerequisite programme (PRP) are considered key components of hygienic operation. Here, consideration must be given to measures for controlling food safety hazards from the operating environment. Aspects include layout, services

Figure 2. A common position for floor drainage

Figure 3. Gully with removable foul air trap with connection to on-going drainage and sewer

(including waste), potential for cross-contamination and cleaning and sanitising.

For wet areas or areas that undergo wet cleaning, the drainage infrastructure clearly forms part of the operating environment. Its components can be considered 'environmental surfaces' – with no direct food contact but potential to act as a source of contamination. Recent studies (Parisi *et al.* [18]) indicate drains are reservoirs for pathogenic bacteria. Importantly drains are implicated both pre- and post- cleaning (Rotariu [19]).This in itself raises questions on persistency and cleaning efficacy. The cleaning method can be seen as critical: high pressure jets may cause cross-contamination through aerosols, manual cleaning can produce 'ballistic droplets'. Equipment, procedure and methodology selection must be made in context of risk assessment. Ideally the eventual process should be validated and verified.

2.2 Floor drainage as a contamination source

Given that the floor drain is a receptor of fluids from processes, cleaning or accidental spills, it is hardly surprising that drain components harbor bacteria. Some studies highlight the drain as the most significant environmental site for microorganisms (Swanenburg *et al.* [21]). Even during cleaning, the removal of the foul air trap - which may clog if gross particulates are not removed, causes free circulation of air between a highly contaminated sewer system and the production area.

Swanenburg *et al.* [21] studied salmonella in pig slaughter houses noting the highest incidence (61%) in the drain. In dairy plant research Parisi *et al.* [18]) found *Listeria* spp. in 6.8% of food samples, 11.3% of product contact surfaces and 40.6% of floor drains. In their study of smoked fish processing plants Rotariu *et al.* [19] established the frequency for drain contamination as 75% *Listeria* spp. and 63% *L. monocytogenes*.

Listeria especially has received wide attention due to its ability to survive and grow at low temperature (Chan and Wiedmann [7]), with consequent adverse effects in the ready-to-eat food sector. Listeria is furthermore noted for its capacity to establish biofilm as it readily adheres to surfaces, including stainless steel (Swaminathan *et al.* [20]).

As such, the question is raised on *Listeria* persistency. *L. monocytogenes* has been termed transient or endemic, with strains becoming established on non-contact surfaces such as drains (Warriner and Namvar, [23] and Rotariu *et al.* [19]). Zhao *et al.* [24] focussed on *Listeria* in poultry plants - commenting on the importance of drains: "Floor drains in food processing facilities are a particularly important niche for the persistence of *Listeria* and can be a point of contamination in the processing plant environment and possibly in food products". Meanwhile Carpentier *et al.* [6] conclude that the low number of cells resisting detachment or disinfection is progressively eliminated with robust cleaning and disinfection. The authors suggest that surface based populations were constantly renewed in their study site.

As well as suggesting the floor drain as a major site for colonization Parisi *et al.* [18]) note that drains serve as a presence indicator and thus suggest monitoring. Equally Swanenburg *et al.* [21] note that drains are not normally considered critical control points but suggest that, as a source, they are evidently important. This highlights the role of cleaning validation and verification.

2.3 Cleaning effect

That cleaning and disinfection does not remove all surface borne micro-organisms is understood, a 1 log reduction is cited as an overall performance (Carpentier *et al.* [6]). However the role of validation and verification is highlighted by various studies that indicate the variability in pre and post clean microbial status. Rotariu *et al.* [19] noted an absence of drain disinfection measures in a number of premises observed. But even when sanitation measures were implemented the effect appears negligible – indeed prevalence in the drain being sometimes worse post-control measures (49.6% and 54.2%), where presumably bacteria may have concentrated in the drain following removal from the floor.

Similarly, Berrang and Frank [3] cite studies where bacteria have been detected in floor drainage even after extensive plant sanitation. The presence of *Listeria* is given by Gudbjörnsdóttir *et al.* [25] for meat, poultry and seafood plants – in each case as measured on

Table 1. Frequency of *Listeria* spp (L. spp), and *L. monocytogens* (L. m) in floors and drains from selected facilities (Adapted from Gudbjörnsdóttir *et al.* [25])

Facility type	In process L. spp (L.M) %	After cleaning L. spp (L.M) %
Meat processing	28.2 (7)	10.9 (6.5)
Sample size	71	46
Poultry processing	74.1 (40.7)	66.7 (22.2)
Sample size	27	9
Seafood processing	26.7 (26.7)	19.8 (18.7)
Sample size	75	91
All	34.7 (20.8)	19.9 (15.1)
Sample size	173	146

floors and in drains during process and after cleaning - though specific methodology of cleaning is not given. The authors summarize that *Listeria* was detected in 11 of the 13 plants analyzed and the specific and overall incidence of *Listeria* spp. and *L. monocytogenes* is given in Table 1. Of importance the authors found variation in the presence L.M. between different plants, ranging from 0% - 52.2% after cleaning and from 0% to 50.0% during processing.

2.4 Soils in drains

Floor drains receive fluids from a variety of sources including process waste, cleaning and disinfection and accidental spills. Goode *et al.* [26] define fouling as the ´unwanted build up of material on a surface, noting underlying processes that might be usefully considered with respect to the floor drain:

- Crystallization – for example cooled surface fouling by salts, fats and waxes
- Particulate deposition – sedimentation fouling
- Biological growth and chemical surface reactions
- Corrosion

They refer to earlier work that categorizes deposit types within three broad ranges (Fryer and Asteriadou [13]):

Type 1: Viscoelastic or viscoplastic fluids that can be rinsed from a surface.

Type 2: Microbial and gel-like films such as biofilms that cannot be rinsed

Type 3: Solid-like cohesive foulants formed during thermal processes that cannot be rinsed.

Drains are likely to be subject to type 1 and 2 foulants.

With regard to microorganism biofilm fouling the authors note adhesive and cohesive properties are combined. It is likely therefore, when coupled with poor drain component design, the microbial hazard may perpetuate.

2.5 Floor drainage issues in practice

Generally, two main issues give rise to hygienic concern: issues related to installation, and in particular the floor-to-drain interface, and issues related to the component design itself (Fairley [12]). Here, the latter is considered.

Where hygienic considerations apply stainless steel is the preferred material choice for drainage component manufacture, grades 304 and 316 are most often utilised but, in any case, components should be passivated, post-fabrication, to minimise corrosion potential. Components are often fabricated by non-drainage-specific companies. In basic form Linear channels especially can be easily fabricated, as can simple 'box' type gullies. It is estimated that more than 200 suppliers fabricate drainage components in the European Union (EU) alone (ACO [1]), the vast majority of which are primarily fabrication companies with no specific expertise in drainage. Consequently, there is huge variation in how floor drains are fabricated; examples are shown in Figure 4.

Figure 4. Poor drainage component design – metal to metal contact, gaps, sharp corners, non-drainable areas

Specification of components that meet appropriate standards - Euronorms or their regional counterparts - ensures compliance with a number of criteria, not the least of which are load bearing capacities, as drains can be subject to large point loads from hard wheels. However, even when the provisions contained in component standards are adopted, these are not necessarily aligned with best hygienic practice: for example, the standard BS EN 1253 [4] permits the design of gullies with a sump that is not readily drainable. Furthermore hydraulic testing permits the use of 20 mm water head over the grating. The consequence in practice, should design hydraulic load occur, would be for substantial pooling on floor, as indicated in Figure 5, with clear potential for motile pathogens to migrate from colonised areas in the drain (Fairley [11]).

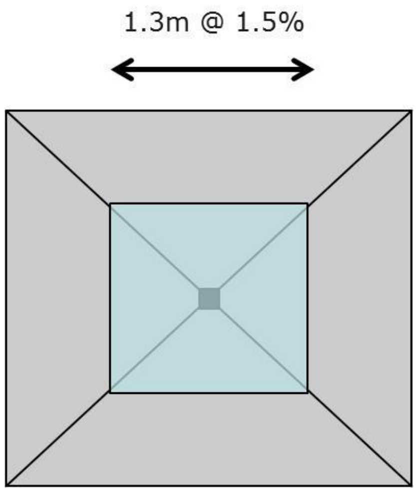


Figure 5. Extent of pooling at design hydraulic load as tested to BS EN 1253 [4]

It thus becomes necessary to supplement general standards with further guidance. In the case of the floor gully, many of the design aspects of European Hygienic Engineering Design Group (EHEDG) guidance documents, particularly Document 13 [9], may be economically incorporated in product design as indicated in Figure 6. Generally achievable with current widely available production technologies are:

- Continuous welding of joints
- Radiused corners
- Drainability

All of these elements might affect in in-situ hygienic performance; it might be argued that their absence might further facilitate initial microbial adhesion, promote localised sedimentation, or settling of lipids. However this is a question of degree - fouling can be expected even with better design. Of greater importance is the effect of such features on cleanability.

Figure 6. Section image of gully at floor interface demonstrating radius corners

2.6 Cleaning drains

The selection of cleaning and disinfection chemicals, cleaning utensils and choice of whether to use a manual, foam, or combined cleaning process will depend on the assessments made in the operational prerequisite programme (O-PRP), as part of the HACCP system. Further consideration must be given to effect of the chosen chemicals and utensils on:

- The floor materials
- Drain materials
- The hygiene operator
- The receiving environment

It is suggested that a full risk assessment is made of the methodology with consideration of the points made.

Cleaning is generally considered to be a combination of four factors:

- Time
- Temperature
- Chemicals
- Mechanical effort/kinetic energy

Goode *et al.* [26] suggested a typical process in cleaning and, although given with regard to CIP, the structure might be modified to account for the types of soil and likely cleaning methodology required for drains and is presented in Table 2.

Table 2. Generic drain cleaning processes. Shaded rows are additions to Goode *et al.* [26]

	Process	Comment
1.	Pre-rinse to remove loosely bound soil and product.	Low pressure
2.	Removal of gross debris – either at sediment basket located in terminal floor drain or along linear channel.	Rotariu *et al.* [19] note that drain clogging may itself cause contamination.
3.	Removal of lipids	Dry wipe gross deposits before emulsification can occur
4.	Detergent phase (alkali or acid); to remove the fouling layers. However the detergent phase is often a result of the combined action of floor and environmental cleaning. In practice the applied foam or gel is flowing by gravity to the drain, where chemical action takes place.	Consideration of contact time. May be chosen exclusively or in combination with manual cleaning
5.	Manual cleaning	May be chosen exclusively or in combination with chemical cleaning
6.	Intermediate rinse; to remove chemical and remaining soil.	Low pressure
7.	Sanitization/disinfection step (chemical and/or thermal); to kill viable microbes and restore the hygienic condition of the system.	Requires assessment of soil removal as presence may inhibit disinfection step.
8.	Final water rinse	Low pressure
9.	Use of sanitizer blocks in drain	Rotariu *et al.* [19] study suggests this may help prevent re-colonization.

2.7 Environmental considerations

Whilst necessary for hygienic operations, cleaning processes must be assessed with consideration of the environment. Matuszek [17] cites the industry as being a major water consumer and user of chlorine derivatives in cleaning and sanitization, Goode *et al.* [26] similarly notes the need to lessen both the impact of cleaning on the environment and on water use. However positive environmental impacts also exist: Gracey *et al.* [15] comment on 4 mm drain screens in UK slaughterhouses to prevent the discharge of effluent containing nerve tissue greater than 1g - possibly the infective dose for BSE. With regard to fats, recent work on the problem of accumulating fats in sewer systems indicates the substances are metallic salts of free fatty acids – where the metal calcium might be released form concrete pipework (He *et al.* [16]), the deposition mechanism is facilitated further by free oils present in many wastewater discharges. Thus the suggested dry lipid removal stage prevents emulsified fats entering the system causing harm further downstream. Notably, downstream effects may well impact negatively, with blockage causing back up or possibly 'regurgitation', as highlighted by Gudbjörnsdóttir *et al.* [25].

2.8 Mobilization

The act of cleaning open equipment, including drains, may well provide the primary mechanism for cross-contamination: Parisi *et al.* [18]), Swanenberg *et al.* (2001) and Gudbjörnsdóttir *et al.* [25] suggest the floor drain might impact the processing environment as a result of aerosol formation in cleaning - specifically the use of high pressure. Work by Berrang and Frank [3] studied *Listeria* mobilisation from the drain by inadvertent water spray during cleaning operations, with subsequent potential to transfer to food contact surfaces.

Campden BRI undertook to study the spread of droplets and aerosols resulting from the use of a high pressure hose on floors and drains, as indicated in Figure 7.

From the data generated it can be seen that such cleaning activities enable the spread of contamination from the floors and drains over a considerable distance and

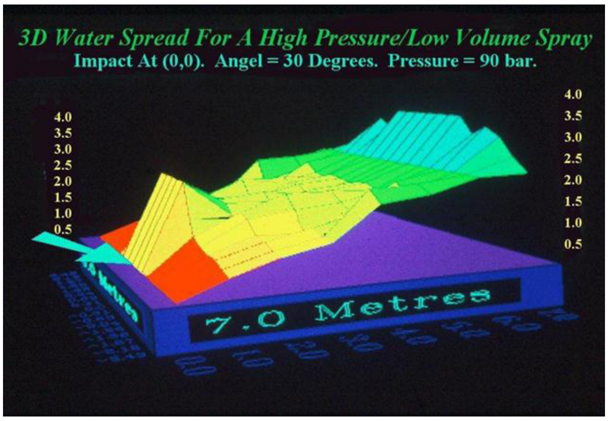


Figure 7. Spread of droplets and aerosols resulting from the use of a high pressure hose on floors and drains (Source: Campden BRI)

to a height where subsequent deposition of the aerosols could cross-contaminate food contact surfaces. Similarly, Smith (personal communication 2013) has used the term 'ballistic droplet generation' to refer to the potential impact of brushes and other manual cleaning tools on contamination spread. Aerosols and droplets are not the only mechanisms for possible contamination transfer, simple splashing also needs to be considered. Rotariu *et al.* [19] list issues associated with, amongst others, mid-shift wet cleaning, and report that 17 of 23 companies undertook such processes.

Clearly method, material and execution affects risk of contaminant spread – drain cleaning should therefore be considered as a necessary element of the operational pre-requisite programme.

2.9 Validation

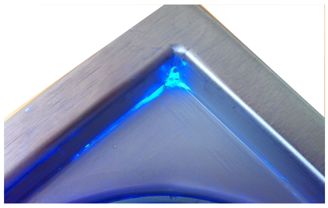
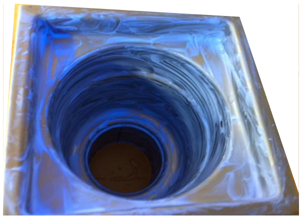
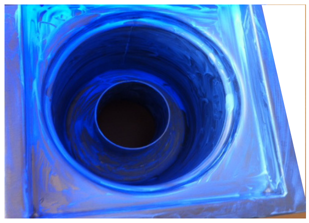
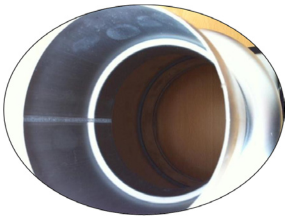
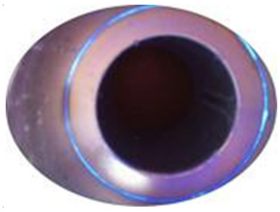
The Rotariu *et al.* [19] study indicated the presence of bacteria both pre- and post- cleaning, in conclusion they recommended monitoring effectiveness. Timmerman [22] notes validation is defined as 'obtaining documented evidence that cleaning and/or disinfection processes are consistently effective at reaching a predefined level of hygiene', and goes on to suggest that around 80% of all cleaning operations in the industry are not validated or documented.

As previously mentioned – complete contaminant removal is unlikely, or may be prohibitively costly with respect to benefit. It is therefore necessary to understand residue types and limits, and selection of analytical method (Timmerman ibid).

As a precursor to a full consideration of drain component cleanability, ACO and Vikan undertook a provisional assessment of newly incorporated hygienic features with a drain gully comparing the 'hygienic' component with a gully with no direct hygienic consideration in its design. Key findings are presented in Table 3. For these simple experiments an ultra violet sensitive lotion was used to coat internal surfaces. The lotion was left for one and eighteen hours to represent Type 1 and Type 2 soils respectively (Fryer and Asteriadou [13]). Removal methods included only low pressure water rinse and manual cleaning.

The work to date indicates further consideration of drain cleaning validation is necessary. Soil type, cleaning method and component design affect results. The impact of component design appears significant - especially where complete access is more problematic - as with the underside of the gully. This then raises the question of which part of the floor drain system should be validated: floor drain systems have been described as enabling interception, conveyance and provision of a barrier. Systems vary widely from smaller single point gullies to multi-piece structures with corners, some use gratings and promote access others are formed from a slot. The barrier provision is most important at point of discharge to the ongoing drain and ultimately the sewer. Here the integral foul air trap is intended to prevent odor.

Table 3. UV lotion based comparison of drain gully with hygienic features vs. conventional fabrication

Method	Hygienic features	Convetioal fabrication	Comments
Low pressure rinse of Type 1 soil			Smooth radius corners assist in rinse removal of UV lotion when left for 1 hour only
Low pressure rinse of Type 2 soil			Type 2 soils – UV lotion left for 18 hours, does not allow rinse only cleaning. Manual cleaning methods must be employed.
Manual cleaning of underside			Removal of Type 1 soils was not possible by rinse or manual cleaning alone from the gully underside, indicating chemical cleaning may provide further benefit.

The optimal cleaning procedures in relation to the efficiency of the barrier system have to be evaluated and validated in further studies. With regard to factory hygiene however its performance is not known.

3. Conclusions

- Floor drains provide for interception and conveyance of a variety of fluids in a food processing environment. Critically the drain often performs as a barrier function – segregating areas and separating the internal environment from the sewer.

- A drain might be considered an environmental surface and has capacity to act as a contamination source especially during cleaning.

- Drains are subject to soils that also present opportunity for biofilm formation.

- Drains are known to be common harborage sites for bacteria and of special concern is *Listeria*.

- Recent work by EHEDG will promote hygienic consideration in drain component design. Hygienic design features are compared with more conventional drain fabrication techniques through simple experiments using UV sensitive lotion and application of low pressure rinses and manual cleaning.

- Results indicate that whilst type 1 soils might be removed by rinsing when the component is designed hygienically, type two soils require additional manual cleaning.

- Furthermore, the less accessible parts of the drain remained soiled even after manual cleaning supporting the use of chemical cleaning. Prior to cleaning it is suggested gross solids and fats are removed from the drain as far as possible.

- A risk assessment should be made of the cleaning methodology.

- These results together with results from other studies which report pathogen presence in drains pre and post cleaning suggest a strong case for drain cleaning validation and verification where hygienic operation is required.

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