Assuring the microbiological quality of draught beer

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16.1 Introduction

The need to assure draught beer quality is not new. In 1912, in the Journal of the Institute of Brewing, Mr. G.R. Seton noted that 'it is not possible to find a subject fraught with greater importance to the brewing trade than cellar management'. He further observed (Seton, 1912) that 'the national beverage, as it is served over the counter of many of the public houses in England today, has not the flavour and appearance commensurate with the care bestowed upon its manufacture in the brewery, a fact that often leads the public into the mistaken notion that the beers of today are inferior to those of our forefathers'. Obviously not a shrinking violet, Seton then hit home with 'it (is) difficult to understand why at the most critical point in its passage from the brewery to the consumer, viz., the public house, beer is allowed to be treated under conditions which are in direct antithesis to those strictly enforced in the brewery'.

So, some 102 years on, with draught beer now being (predominantly) a keg rather than cask offering, Mr. Seton's remarks still regrettably hold true. Perhaps, to quote Ecclesiastes, 'what has been will be again, what has been done will be done again; there is nothing new under the sun'. Whilst a long recognised issue, draught beer hygiene has received only sporadic attention over the years with publications in the 1950s on cask beer (Hemmons, 1954; Wiles, 1950) and, with the transition to keg, the comparative golden age in the 1970s and 1980s from the British School of Malting and Brewing (Casson, 1982, 1985; Harper, Hough, & Young, 1980; Hough et al., 1976). In the last 20 years or so, there have been occasional communications including a number from Germany (e.g. Ilberg, Schwill-Miedaner, & Sommer, 1995) although regrettably (for me) not in English. Inevitably the focus is on aspects of hygiene such as the impact of line composition (Thomas & Whitham, 1996), application of ATP bioluminescence to validate cleaning (Orive i Camprubi, 1996; Storgårds & Haikara, 1996), use of technology to extend line-cleaning frequency (Price, 2002), hygienic design, installation, and standards (Jurado, 2003), and possible the role of enzymes in treatment precleaning (Walker, Fourgialakis, Cerezo, & Livens, 2007). Finally 'dispense' has been covered, albeit with different emphasis, in two big books on brewing (Boulton & Quain, 2001; Briggs, Boulton, Brookes, & Stevens, 2004).

16.1.1 Global beer market

The worldwide beer market is increasingly contradictory. The Statistical Handbook from the British Beer & Pub Association (BBPA) (Sheen, 2013) has long been the

Brewing Microbiology. http://dx.doi.org/10.1016/B978-1-78242-331-7.00016-2

'go to' source of drinks industry data. This shows that since 2000, beer production in Europe has either declined (e.g. UK, Germany), has been flat (Italy), or has shown reasonable growth (Belgium, Spain). Similarly in North America, the market is static (Canada) or in decline (USA). In Africa there has been reasonable (South Africa) or appreciable (Nigeria) growth. In Australia, beer production between 2000 and 2011 has been flat. However, things are very different in the so-called BRIC countries of Brazil, Russia, India and China, where growth has been substantial and, in the case of China, extraordinary. Indeed, in 2000, China was slightly shy of the USA at 221 million hectolitres (hL) but by 2011 has romped away, more than doubling production to 490 million hL. This partly contributes to the pleasing statistic that global beer production has increased from 1391 million hL in 2000 to 1929 million hL in 2011.

16.1.2 Draught beer market—size of the cake

'Beer racked into kegs and served on draught is generally considered to be an optimal method to showcase the brewers' art' (Grossman, 2012). Given this, it is ironic that, in terms of packaging format, draught beer is the poor relation to bottle and can. The above BBPA Handbook reports 'draught sales' in 2011 for 25 of 42 leading countries. These 25 countries produce some 709 million hL of beer (37% of the global total) of which 18% (130 million hL) is draught. As noted in the Handbook, 'for some countries it is very difficult to obtain all necessary data' and consequently there is no sense of the draught contribution from 17 countries that include the aforementioned BRIC and other significant countries (e.g. South Africa, Ukraine, and Mexico). Accordingly, even if the draught contribution is only 1% or 2% (or more), the true total global draught volume is realistically way greater than the above 130 million hL. Indeed, over time, these figures may become more transparent, as in some countries draught beer is seen by consumers as being more aspirational than the small pack offering.

The top 10 countries cut by draught volume are detailed in Table 16.1 The proportion of the mix as draught beer varies widely, with the major players being Ireland

Table 16.1 Top 10 draught beer countries

Country	Production (000 hL)	Imports - exports	Universe (000 hL)	Draught (%)	Draught (000 hL)
USA	225,540	26,862	252,402	10	25,240
UK	45,694	2332	48,026	48	23,052
Germany	95,545	–7889	87,656	15	13,148
Spain	33,573	2151	35,724	28	10,003
Japan	54,470	72	54,542	18	9818
Czech Republic	18,181	–2598	15,583	42	6545
Ireland	8514	–1224	7290	61	4447
Australia	17,420	442	17,862	22	3930
France	15,910	2786	18,696	18	3365
The Netherlands	23,644	–11,503	12,141	26	3157

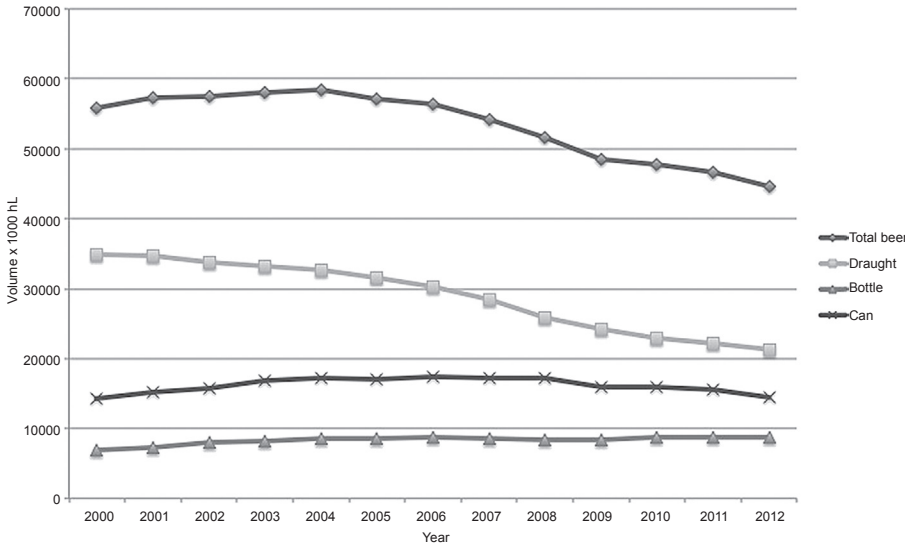

Figure 16.1 UK beer market 2000–2012.

(61%), the United Kingdom (48%) and the Czech Republic (42%). For a wide variety of reasons (see PEST analysis in Quain, 2007), the UK market is in decline in terms of both total volume and the proportion of draught beer (which uniquely includes the 'cask' category). Indeed, between 2000 and 2012, the decline in draught beer (13.5 million hL) outperformed the total decline (11.4 million hL) in the UK beer market. As shown in Figure 16.1, draught beer has declined year on year, whereas small pack volumes over this period have either been flat (can) or, in the case of bottle, grown. Further analysis (Figure 16.2) shows that both draught lager and draught ale have lost more than 5 million hL, although this is more damaging for ale, as this accounts for some 65% of the volume in 2000, whereas with lager the loss is 29%. Stout has also been less robust, losing some 40%, with cask losing 30%. The different rates of decline are surprisingly linear (Table 16.2), which encourages extrapolation. Indeed, should the current trends continue, then the draught beer volumes will fall to 15 million hl around 2017. This would have a dramatic impact on keg ale, with its share falling from 14.4% of 21.5 million hL in 2012 to an estimated 3.6% of 15 million hL in 2017. Both stout and cask would increase slightly, with lager winning out with its market share moving to 71% (Table 16.2).

16.2 Draught beer quality

Cost and quality are indelibly linked. In the case of draught beer, poor or 'so-so' quality coupled with high purchase price are two of many drivers for consumers to switch from the on-trade to drinking beer in small pack at home. Regrettably, quality issues are all too common with draught beer, which, in the consumer's eyes, reflects badly

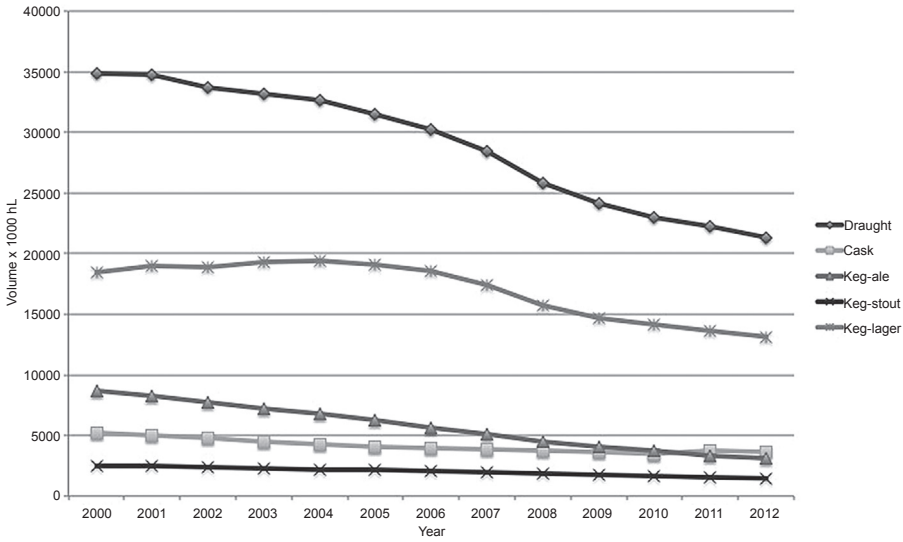

Figure 16.2 UK draught beer market 2000–2012.

Table 16.2 Draught beer category mix, 2012–2017 (estimated)

	2012	2017	Linear regression (2000–2012)
Keg lager	61.6%	70.9%	$Y = 0.494x + 3741$ $R^2 = 0.9250$
Keg ale	14.4%	3.6%	$Y = 0.3724x - 5047$ $R^2 = 0.9611$
Keg stout	6.9%	7.3%	$Y = 0.1019x + 1231$ $R^2 = 0.9789$
Cask	17.3%	18.3%	$Y = 0.0679x + 69$ $R^2 = 0.7823$

on the brand or the account. Although mostly subliminal, beer quality is assessed by consumers' 'eyes, nose and throat' (Bamforth, 1998), although consumers are increasingly adept at picking up things that are not (in their experience) right! This may include 'temperature', particularly as brand owners and retailers talk-up 'cold' dispense. In the case of flavour and aroma, this may not hit the heights of 'diacetyl', 'phenolic' and 'lactic' but may well spot 'vinegar' or simply be described as 'off'. Appearance, though, is a little more straightforward, especially if the beer is either fobbing or flat. Although perhaps not strictly in scope, beer in the wrong branded glass is also a fault and undermines the 'quality' offer. In terms of clarity, issues are invariably more obvious in lager and ales, in which haze readily confirms a problem. That said, clarity is not a good measure of compromised quality *ex* dispense with

Table 16.3 Draught beer dispense—simple versus complex

Variable	Simple	Complex
Container	Keg (20 L)	Primarily keg (20–100 L) but resurgence in large volume (unpasteurised) 'tank' beer (2.5–10 hL)
Keg cooling	Keg cooler	Cellar (12 °C) or cold room (4–6 °C); chilled supply chain can be an option
Line	Single	Many (4–14) bundled together in an insulated 'python'
Line age	New	Up to 10 years or more
Line length/ID	1–4 m/ID ≈ 6 mm	5–120 m ID ≈ 6 mm; require a FOB detector
Line cooling	None	Wide bore lines circulate cold water or glycol python—*ex* icebank or glycol remote cooler/chiller in cellar/cold room
Cooling at the point of dispense	None	'Extra cold' products require trim cooling via underbar icebank flash coolers or 'pod' heat exchangers. Trace cooling an option in fonts
Line cleaning	None—line is disposable	Required regularly—recommended frequency varies (reflects storage and dispense temperature). Performed in-house or via third-party service providers

wheat beers, dark ales, stouts, porters and— in the growing 'craft' category—unfined and unfiltered beers.

Whatever the packaging format, a combination of hygienic practices and processes ensures that, on leaving the brewery, beer is fit for purpose and its quality assured. Accordingly it is a reasonable deduction that any quality defects in a glass of draught beer are a consequence of the 'dispense' process from container to tap. However, at its simplest, beer dispense (e.g. directly from a cask or a home 5 L mini-kegs) is both straight forward and without complexity. However, this is not the norm for beer dispense, which is increasingly complex and can be performed over substantial distances from container to tap. This and the need for end-to-end cooling, together with the trend for installing more taps than are commercially sustainable, have resulted in draught beer dispense in the UK and elsewhere being overly complicated. Table 16.3 details the void between a simple, commercial dispense system for low-volume accounts (<50 hL p.a.) against the many variables involved in standard accounts (large and small) in countries where draught beer is a significant contributor to the beer market. In terms of complexity, Table 16.3 can be even further developed to include an overlay of hardware detail that includes numerous snap-in connectors, flow restrictors, a FOB (foam on beer, see 16.4.4) detector, a tap spout (which may or may not be removable), and beer line, which (parking age!) could be stainless steel or mid-density polypropylene either 'as is' or lined with nylon or other finishes.

16.3 Microbiology of draught beer

As noted above, keg beer leaving the brewery is fit for purpose in terms of the distribution chain and subsequent retail. Microbiologically such beer is 'commercially sterile' in that the microbial loading is very low or barely detectable (e.g. <1 colony/L) and accordingly will not grow to any noticeable level during the product shelf life or beyond. However, dispensed beer is not commercially sterile and contains a diverse mixture of yeast and bacteria that are derived from the dispense system. The loading in beer *ex* dispense varies widely, reflecting system hygiene but also the subtleties of sampling and testing. As a rule of thumb, data from commercial accounts suggest good-quality beer to typically contain around 1000 colonies (or 'colony-forming units') per millilitre of beer. Loadings can, of course, be much lower (<100/mL) or substantially higher (>10,000/mL) (Boulton & Quain, 2001; Quain, 2012; Storgårds & Haikara, 1996). A survey in Germany (Ilberg et al., 1995) found that the total count exceeded 10^3/mL in 81% of tested accounts, with an alarming 10^5–10^6/mL being observed.

Given the worldwide scale of draught beer and the spotlight on food safety, it is surprising that there is only one set of standards that covers drinks dispense. The DIN (Deutsches Institut für Normung) is the International Organisation for Standardisation (ISO) body for Germany and is responsible for DIN 6650 ('Dispense Systems for Draught Beverages'), published in seven parts, the headlines of which have reported elsewhere (Jurado, 2003). Specifically, part six of the standard (Deutsches Institut für Normung, 2006) covers 'requirements for cleaning and disinfection', whilst generic for draught beverages (e.g. beer, wine, water, carbonates, etc.) provides a guideline for microbial loading. Here 'a typical guideline value for a positive result with respect to microbial contamination would be 1000 colony-forming units per millilitre (cfu/mL), a value of more than 50,000 cfu/mL being considered unacceptable. If the count is 10,000 or higher, cleaning is necessary'.

Although relatively inhospitable to microorganisms, beer is vulnerable to spoilage by a selection of bacteria and yeasts. With changes in technology and product composition, microbial suspects come and go, but the usual suspects (Bokulich & Bamforth, 2013) remain Gram-positive bacteria (*Lactobacillus* and *Pediococcus*), Gram-negative acetic acid bacteria (*Acetobacter, Gluconobacter*) and wild yeasts (*Saccharomyces, Brettanomyces* and less so *Pichia, Candida*). Specifically, there have been relatively few publications (mostly from the UK) on the microflora found in draught beer. Broadly, over a 50-year period, Table 16.4 (yeast) and Table 16.5 (bacteria) confirm the general picture of contaminants against a backdrop of evolving methods of microbial identification, market decline and switch from cask to keg packaging with the associated reduction in the availability of oxygen.

In terms of damage to product quality, archetypal indicators of draught beer microbiological spoilage include turbidity/haze, acidification (lactic and acetic acids), phenolic aromas (medicinal, 'barnyard'), diacetyl/butterscotch and super attenuation. Other less common markers include 'eggy' sulphury aromas (hydrogen sulphide), fruity characters (esters and higher alcohols) and 'sweaty socks' (short-chain fatty acids). It is ironic that unless these are characteristic of the (special) beer type or style, such indicators will (almost) never be found by consumers in bottled or canned beer

Table 16.4 Yeast genera identified in draught beer 1950–2012

	Wiles (1950)	Hemmons (1954)	Hough et al. (1976)	Harper et al. (1980)	Casson (1985)	Quain (2012)
Yeast genus						
Brettanomyces			✓	✓	✓	✓
Candida	✓	✓				
Debaromyces			✓	✓		
Hansenula			✓	✓	✓	
Kloeckera	✓	✓	✓	✓	✓	
Pichia	✓	✓	✓	✓	✓	
Rhodotorula		✓			✓	
Saccharomyces	✓	✓	✓	✓	✓	✓
Torulopsis		✓	✓	✓	✓	

Table 16.5 Bacterial genera identified in draught beer 1965–2013

	Ault (1965)	Hough et al. (1976)	Harper et al. (1980)	Casson (1985)	Quain (2012)	Bokulich and Bamforth (2013)
Bacterial genus						
Acetobacter	✓	✓	✓	✓		✓
Gluconobacter	✓		✓			✓
Lactobacillus	✓			✓	✓	
Obesumbacterium		✓	✓	✓		
Pediococcus					✓	
Zymonomas		✓	✓	✓		

but will experience them periodically in draught beer. It is this simple point that should drive a step change in attitude to the protection of draught beer quality.

Less well lauded is the potential impact of dispense on the concentration in draught beer of biogenic amines, which are natural compounds that are widespread in foods and beverages. The likes of tyramine and histamine are derived from the decarboxylation of the amino acids histidine and tyrosine by lactic acid bacteria and wild yeasts. Whilst levels in beer are typically not a concern, ingestion of high levels of biogenic amines can be associated with headaches, heart palpitations, and other allergy-like responses (Loret, Deloyer, & Dandrifosse, 2005). More directly alarming are reports of two individuals being treated with the antidepressant (a MO inhibitor) phenelzine sulphate who were hospitalised with hypertensive crisis on consuming a glass of draught beer in Ontario, Canada (Shulman, Tailor, Walker, & Gardner, 1997; Tailor, Shulman, Walker, Moss, & Gardner, 1994). As biogenic amines are detoxified

by monoamine oxidase (MO) in the gut, patients treated with phenelzine (which inhibits MO) are vulnerable to overconsumption of tyramine, etc. A survey of 98 beers showed that four of the 49 'tap' beers had elevated levels of tyramine (26–112 mg/L), whereas the remaining beers *ex* tap together with the 49 bottled or canned beers contained <10 mg/L. With the brand associated with hypertensive events having the highest concentration of tyramine, the working hypothesis (Shulman et al., 1997) was that 'the cause of high tyramine levels in tap beer is the contamination of the lines from keg to the tap with bacteria capable of converting tyrosine to tyramine'.

With one exception, the above observations have seemingly triggered little in the way of follow-up. One report (Diel, Herwald, Borck, & Diel, 2009), however, reiterates the higher average loading of histamine in commercial draught beers than bottled. Tellingly, this work connects the dispense system hygiene directly with histamine concentration such that 'mechanically cleaning of the tap and the storage devices reduces histamine concentration up to 35% and combined mechanical and chemical hygienic prevention (by) 93%' (Diel et al., 2009).

16.3.1 Biofilms

In the real world, microorganisms in aqueous environments exist in complex communities of diverse microorganisms that attach to surfaces, creating a multi-layered, heterogeneous, multicellular organism or biofilm. The usual rules of phenotypic and genotypic behaviour gleaned from the pampered world of pure cultures in the laboratory simply do not apply in the real world of biofilms. Driven by pressing commercial issues such as chronic medical infections and industrial biofouling, there has been an explosion of worldwide research activity to better understand and ultimately manage (or better still, control or eliminate) biofilm attachment and growth. Biofilm formation involves five steps of reversible attachment, irreversible attachment, microcolony formation, maturation and dispersion. Furthermore, there is cell-to-cell communication (quorum sensing) within genera, which triggers a collective response to environmental stimulus across the population. Biofilms protect themselves against the wider world by laying down an outer slime layer (extracellular polymeric substance) consisting of glycoprotein. Additionally, microorganisms in biofilms are markedly more resistant to antibiotics, disinfectants, ultraviolet (UV) light and other antimicrobials. Nutrients and metabolic byproducts circulate through the biofilm, which over time becomes thicker and more established. In addition biofilms disperse and establish new sites of attachment via the seeding of free-floating planktonic microorganisms or from the flow-related shedding or sloughing of biofilm 'towers' or 'mushrooms' into multicellular fragments. It is generally recognised that quantitatively the loading of microorganisms in a biofilm outnumbers many-fold the planktonic loading. Consequentially measurement of loading in the aqueous phase (e.g. dispensed beer) is likely to be the tip of the microbial iceberg.

Although it is beyond the scope of this chapter to hone in further on the fascinating details of biofilms, there are scores of available review articles. A good place to start is a (relatively thin) book, The Biofilm Primer (Costerton, 2007), by the 'grandfather' of biofilm microbiology, William 'Bill' Costerton. Closer to home and from a brewing perspective, there are much (shorter) reviews by Quain and Storgårds (2009), Livens

and Pawlowsky (2009) and Mamvura, Iyuke, Cluett, and Paterson (2011). In passing, the fascinating subject of cell-to-cell communication has been demonstrated in bacteria isolated from brewery process biofilms (Priha, Juvonen, Tapani, & Storgårds, 2011).

16.3.2 Biofilms in draught beer dispense

The impact of poor hygienic practices on dispense systems is hard to miss. Visible signs of microbiological colonisation are apparent in FOB detectors, tap orifice plates/diffuser, and those parts of the line can be examined outside the python bundle. Although regular line cleaning is the key player in the armoury of hygiene assurance, dispense systems are innately unhygienic such that post cleaning they recontaminate over time (and require cleaning once more).

Whilst the formation of biofilms is the obvious consequence of poor hygiene, there is little in the public domain about them in the context of dispensed beer. Arguably the only studies that quantify attached microorganisms in dispense lines are Thomas and Whitham (1996) in a study on-line composition, Fielding, Hall, and Peters (2007) on the use of ozone as a line cleaner, and Walker et al. (2007), who evaluated the use of enzymes as line cleaning pretreatment.

Hitherto unpublished work (Quain, 2012) focussed on the impact of line cleaning on the attached sessile and planktonic microorganisms in a beer dispense rig mimicking a commercial system in complexity, hardware, throughput, and length. In outline, the system was infected with a microbial soup (sourced from trade samples *ex* dispense), allowed to stand and then cleaned using a proprietary caustic cleaner. The attached and free microbial loading was monitored before and after cleaning using standard methods for beer microbiology together with biofilm washing and recovery from short segments of beer line.

Figure 16.3 clearly shows the impact of line cleaning and the subsequent recontamination of the line and beer. It is noteworthy that cleaning does not completely clean the system, as both anaerobic and aerobic microorganisms are found on both the surface and in the beer immediately after cleaning. For clarity, the data are the average of the results from two lines, sampled after the dispense system 'void volume' was dispensed and, during recontamination, flushed weekly with a total of 25 L of beer (phased to reflect weekly trading pattern). Although an extreme demonstration, the final loading of attached anaerobes and aerobes was *ca*. 2.2×10^6 cfu/cm^2 and 1×10^6 cfu/mL in the beer.

16.3.3 Sources of contamination

On installation, dispense lines are rarely cleaned and therefore commence working life in an unhygienic state. That said, new installations are not the norm, and beer dispense lines can be in place for a decade or more. Accordingly the primary and ongoing source of external contamination is from either end of the line, that is, the tap or keg coupler. Both are subject to unhygienic practices that result in microbial contamination, particularly at the tap end where the ambient temperature is more supportive of growth. A further route, although quantitatively less significant, is the continual seeding during dispense from 'commercially sterile' beer containing an inevitably low

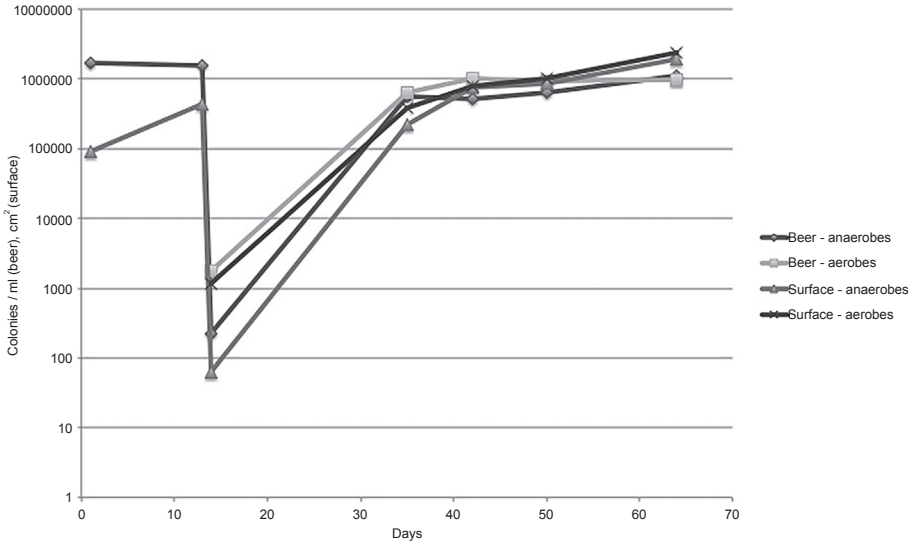

Figure 16.3 Pre/post line cleaning—impact on attached and free microorganisms (aerobes and anaerobes).

level of background microorganisms. This is of course more significant from unfiltered beers such as wheat beers and, to a lesser extent, cask beers.

16.4 Managing the microbiological risk

There is little debate that line cleaning is the key parameter in the assurance of draught beer quality. Whilst the tap and the keg coupler are clearly contributors to dispense system hygiene, they receive comparatively little attention, and what there is (i.e. spout cleaning), can exacerbate the problem.

16.4.1 Line cleaning

On the face of it, line cleaning is a straightforward process involving the regular use of proprietary (usually) caustic-based cleaners to remove biofilms from surfaces. Inevitably and regrettably, it is not that simple; rather, too many tunes can be played, with consequent damage to system hygiene and beer quality.

Of all the variables, line-cleaning frequency is the most damming. Whilst there is no universal rule of thumb, different markets (Table 16.6) recommend the best practice for line cleaning ranging from 7days (UK) to 21–28 days (Canada). This reflects temperature, typically that of the supply chain, container storage and beer dispense. Whatever the recommendation, long-term issues arise when best practice frequencies are relaxed because of concerns over time, beer losses, and word of mouth assurances ‘that it will be fine’. Then, to make matters even worse, in the absence of any significant consumer complaint, line-cleaning frequency drifts further out and becomes the

Table 16.6 Line cleaning best practice by market

Market	Frequency	Storage (°C)	Dispense (°C)	Reference
UK	7 days	11–13	2–12	Profit through quality (2009)
USA	14 days	3		Brewers Association -Draught beer quality manual (2011)
Canada	21–28 days	1–5	1–5	Draught – technical guidance on dispensing (2007)
Australia	7 days	0–10	−0.5–3	Draught beer dispense systems installation guidelines (2009)
Spain	>28 days	Ambient	2–4	—
Ireland	21 days	7–9	2–6	—

new norm. Indeed, it is estimated that in the UK anywhere between 10% and 80% of accounts fail to meet best practice standards. This is despite insight from a high street retailer that shows that accounts grow volume (and profit) when cleaning every 7 days and only marginally every 14 days (Quain, 2007).

Building on this, other variables that get in the way of effective line cleaning include cheap, cheerful, and nonoptimised cleaning solutions (with compromises on strength, surfactants to reduce surface tension, sequesterants, and chelators to bind calcium, etc.), water (cold or hand hot, hard versus soft), and, most importantly, whether the process is essentially static or involves movement as mechanical action.

Operationally the efficacy of manual line cleaning is strongly influenced by knowledge, skill, and understanding. If frequency and other 'corners are cut', the hygiene of the lines and consequently beer quality will be compromised. An effective route around this is the use of line cleaning service providers, which is increasingly common in the UK and a standard approach in Europe.

Although there are a number of best practice manuals around the world (Table 16.6), by far the most exhaustive guide to the assurance of draught beer quality and dispense hygiene is the Brewers Association 'Draught Beer Quality Manual' (2011) with additional resources at http://www.draughtquality.org. Although obviously USA-centric, this manual, through great attention to detail, contains a host of best practice recommendations that should, and do, translate to other markets. For example, quarterly line cleaning with phosphoric acid to remove oxalate and scale, cleaning solutions at 20–43 °C, and use of an electric recirculating pump for caustic (and acid) cleaning as the preferred method for nearly all systems.

Of course line cleaning mirrors cleaning in place (CiP) processes in breweries in particular and the food industry in general. For successful cleaning, four parameters (Boulton & Quain, 2001) are required—time, temperature, chemical action, and mechanical action. Although debatable, basic line cleaning broadly delivers on time, temperature, and chemical action but at its simplest fails to include any significant mechanical action. Indeed in the UK, line cleaning typically consists of four steps: (i) chasing beer out of the line by flushing with water, (ii) filling with cleaning detergent, (iii) allowing to stand for 30 min and moving (pulling a pint or two) halfway, and

(iv) flushing with water before replacing with beer. Given this, it seems a reasonable conclusion to draw that the introduction of mechanical action through recirculation would, at a stroke, improve the efficacy of the process, particularly with regard to the removal of biofilm and penetration into nooks and crannies and difficult-to-clean places. Additionally, mechanical action would be expected to add further value in the removal of dead microorganisms from surfaces, thereby reducing favourable sites for fresh colonisation and biofilm development.

For many, line cleaning is a chore performed reluctantly at the end of a long trading session. Accordingly there have been a number of innovations looking to improve the process such as the automation of line cleaning (16.5.1) or technologies that are claimed to slow biofilm growth and enable the frequency of cleaning to be reduced (16.5.3). Furthermore the long-held view (noted above) that line cleaning results in costly beer losses through flushing has been increasingly challenged, through management or technology, so that beer in the line is dispensed from the line before cleaning.

16.4.2 Taps and spouts

The tap/faucet is rife for contamination through a variety of routes, including human interaction and handling, air and the general environment. Furthermore, taps are not necessarily hygienically designed, and the inclusion of orifice plates, restrictors or diffusers, sparklers and flow straighteners adds sites for microbial colonisation. Accordingly, as shown in previous studies, the tap is a comparatively rich source of contamination (Harper et al., 1980; Hough et al., 1976; Orive i Camprubi, 1996; Storgårds & Haikara, 1996).

Not surprisingly, the management of this hygiene issue varies depending on the market. In the UK, tap spouts or nozzles fall into two categories: removable (either plastic or stainless steel) or a one piece as part of the tap, which are cleaned *in situ*. Removable spouts, which are either 'straight through' or containing diffusers and straighteners, are cleaned via a peculiar daily ritual. At the end of a day's trading all removable nozzles (and any internal plasticware) are soaked in (usually) carbonated water overnight. The next morning they are rinsed and returned (hopefully) to the mother tap. Given that they are effectively soaked in beery water overnight at bar temperatures, it should be no great surprise that this process effectively exacerbates, not minimises, contamination. With this in mind, it is easier to appreciate why the tap is one of the primary contenders for dispense system contamination.

The many practitioners of the soda water steep anecdotally believe that this approach has antimicrobial properties, which improves the hygiene of nozzles and orifice plates, sparklers, etc. Unpublished work (Board, 2010) based on accounts in Edinburgh confirms that this approach does not add value and makes things worse. Indeed a more effective approach (confirmed by Board, 2010) that is gaining traction from particularly regional Brewers in the UK is soaking the spouts in hot water (from the coffee machine) followed by air-drying. That said, the best practice recommendation in the UK (Long, 2003) is that 'beer dispense nozzles should be soaked in food-grade cleaner after each session'.

In the USA, a very different approach is recommended to assure the hygiene of the tap. Here the Brewers Association (2011) takes a very different stance and, as best practice recommended, as part of the 14-day cleaning cycle 'all faucets should be completely disassembled and cleaned'. Intuitively this will add (hygienic) value and should be a best practice aspiration in all markets for draught beer.

16.4.3 Keg coupler

As a potential 'seat' of dispense contamination, the keg coupler gets a less bad press than the tap (Harper et al., 1980; Hough et al., 1976; Storgårds & Haikara, 1996). However, the intimate connection between keg and coupler suggests that this interface is worthy of greater attention, especially as the cellar environment is not usually a place where hygienic best practice is found. Here, on changing containers, keg couplers are likely to be placed on the floor and other surfaces prior to being reconnected. In reality, and although a good idea, treatment of the keg head with antimicrobial sprays or wipes before connection is regrettably very unlikely.

Inevitably the Brewers Association (2011) has this covered. The recommendation here is that every 14 days that 'all keg couplers or tapping devices should be scrubbed clean' and every 3 months that keg couplers should completely disassembled and hand cleaned. That said, although the logic is undeniable, it would be very interesting to get a sense of real-world take-up in accounts in the USA on the practicalities of this, together with tap disassembly and cleaning.

16.4.4 FOB detector

A newer and arguably major contender in the dispense hygiene stakes is the FOB detector, which is present worldwide in all reasonably complex dispense systems. The 'foam on beer' detector's role is to minimise the risk of foam entering the beer dispense line when the container is empty or is being changed. The mechanism is essentially a float control, which in the absence of beer falls and blocks the beer inlet. On connecting a new container the fob detector is bled hygienically to drain and then filled with beer enabling dispense to recommence. As to naming, in addition to 'foam on beer', FOB detectors are also variously known as cellarbuoy, beer saver, FOB-stop, 'froth on beer', 'fobbing pot' or, less exotically, beer monitor.

Anecdotal evidence together with personal observation suggests that FOB detectors are a potent reservoir of system contamination (see for example Figure 16.4). Although FOB detectors are typically located in the cellar or storage area at temperatures (Table 16.6) from cold (12 °C) to very cold (3 °C), they provide an early visual indication of dispense system contamination. Although a generalisation, this is most likely a reflection of the poor cleanability of FOB detectors (especially the upper surfaces) during a manual cleaning without any recirculation or mechanical action.

Remedial action is straightforward and as recommended by the Brewers Association (2011) 'draught beer quality manual' such that every 14 days 'all FOB-stop devices should be cleaned in line, and cleaning solution vented out of the top' and every three months 'all FOB-stop devices should be completely disassembled and hand-cleaned'.

Figure 16.4 Contaminated FOB detector.

16.5 Innovation

Arguably the simplest and most effective 'innovation' to assure dispense hygiene and beer quality is to wholeheartedly apply best practice principles as exemplified in the Brewers Association (2011) manual. Such an innovation would not be exciting or indeed glamorous, but if applied correctly, universally and sustainably, it would achieve a step change (or more) in hygiene and quality. Although there will always be a cohort of enlightened on-trade/on-premise individuals and companies who 'get it' and do buy into best practice, regrettably the majority simply will not. Irrespective of the market and its trading complexities, changing the mindset and culture is a long, uphill struggle involving education, training and commitment.

Whilst the churn of bar staff and misplaced focus on profit (at the expense of quality) will always challenge improvement, there are encouraging signs that the take-up of education and training is on the up! In terms of self-help there are a number of best practice manuals (e.g. Brewers Association) on beer dispense that cover generic and local practices (Table 16.6). Similarly with training, there are short and long, face-to-face or online, opportunities to step change knowledge and competency (see reference to 'Suppliers of dispense training and education'). Accordingly, the more enlightened accounts and retail chains have 'cellar champions' who lead and train colleagues on hygienic practices and other means to assure draught beer quality.

In the last decade or so, there has been a significant amount of investment in dispense innovation through technology above and below the bar (McCrorie, 2014; Quain, 2006). Much has focused on the cold dispense platform with innovations in cooling technology and consumer communication, but perhaps more effort and diversity has been expended in developments that can contribute to beer quality. Many of these are outlined below. Whilst laudable and welcomed, many 'quality' innovations focus on the bottom line but frequently lack independent testing. Accordingly, claims on performance and benefit are from the manufacturer and lack independent validation.

16.5.1 Line cleaning—automation

One of the smarter innovations in dispense technology was the introduction of the disposable line with small-volume integrated systems. Regrettably, though, this is not an option for the vast majority of accounts worldwide, in which regular line cleaning is a routine 'fact of life'. As outlined above (16.4.1), manual line cleaning is, for many, a chore, although on the face of it, automation of line cleaning should be a winner! Potent arguments about reducing wastage, saving time, enhancing health and safety, and improving beer quality through more effective line cleaning (with mechanical action) should be a door opener. However, although this is tried and tested technology from a number of established suppliers, automated line cleaning has yet to take off in the UK. Indeed, Buttrick (2006) estimated that about 4% of UK accounts have adopted this technology, and concluded that there was any one of a number of factors preventing significant take-up in the on-trade. However, he noted that if barriers to entry (inevitably understanding and education) could be lifted, then 'automated line cleaning equipment could be as common as glass cleaning machines are now'.

Whilst cost and (comparative) complexity of integrated automated systems may have hindered take-up, the use of portable line-cleaning approaches has found increasing application, especially by line-cleaning service providers. As with plumbed-in automatic systems, portable approaches also achieve potentially better hygiene, through the added involvement of mechanical cleaning through turbulence and liquid flow.

16.5.2 Line-cleaning solutions

A cleaning solution designed to clean beer lines will be fit for purpose only when it is used at the appropriate frequency. Relaxing the frequency of line-cleaning will result in a greater cleaning challenge, and consequently cleaning may or may not be as successful as is expected or required. Attempts to make up infrequent cleaning by extending line-cleaning time or using at a higher concentration is poor practice. Such 'pickling' or 'bottoming out' both damages and ages the surface of the line (Casson, 1985; Walker et al., 2007) and provides more places for microorganisms to hide and colonise.

Innovation in line-cleaning solutions is a fertile area in which, on a regular basis, another formulation comes along which is claimed to deliver better cleaning capability. However any independent evidence to support such claims is typically non-existent. Furthermore it is surprising how 'tunes' are played with the composition of line-cleaning solutions, especially with regard to claims for the concentration of components. Bizarre

claims for products that are 'caustic free' merely replace sodium hydroxide with potassium hydroxide. Surprisingly, given the risk of flavor active taints (chlorophenol, chloramines), sodium hypochlorite remains a popular inclusion in alkaline cleaners in the UK. However in the USA, the Brewers Association (2011) manual is unequivocal in saying 'never use solutions that contain any amount of chlorine for line cleaning'.

As ever with successful innovation, a clear benefit typically makes a difference, and enhances take-up and acceptability. Although not necessarily new, a new category of line cleaner with colour indicator technology adds real benefit to the user. These cleaners change colour in response to oxidation of organics (*aka* biofilm) (see McCrorie, 2012). This provides a 'control loop' of sorts such that if the cleaning solution is no longer violet or purple but 'discoloured' or yellow/green, this indicates that it is oxidised. On return to the parent colour, the cleaner has done its work and is no longer removing biofilm. Furthermore, the (lack of) colour is useful in determining when the cleaning agent has been fully flushed from the dispense system.

More innovative but less successful innovations in line cleaning include novel approaches such as the use of ozone, chlorine dioxide and peracetic acid. Although these are well-accepted approaches in (brewery) CiP disinfection, none have made an impact on dispense line cleaning, although, pleasingly, ozone has at least been evaluated under controlled conditions (Fielding et al., 2007).

16.5.3 Line cleaning—extending the frequency

In terms of novel innovation, in the last 10 or so years there have been a number of devices that typically are installed in the cellar and wrapped around a short length of line usually leaving the keg. These emit a constant or varying sonic signal which is believed to delay the rate of biofilm build up in the line and, because the line stays cleaner for longer and recontaminates more slowly, it can be cleaned less frequently without risk to quality. These do not clean the line but inhibit or slow down the growth of contaminants. The sell-in is about reducing the number of cleans and consequently saving time, effort, and money. Whilst prone to a plethora of quasi-scientific descriptions about radio frequency and electromagnetic fields, these technologies seem to have stuck inasmuch as the suppliers are still in business some 10–15 years later.

There has been some attempt to validate the performance of some of these devices (Godfray, 2005; Price, 2002), although both of these publications are comparatively slight with little corroborating data. However, a hitherto unpublished study (Quain, 2008), independently evaluated a 'magnetic field' technology in a protracted and detailed paired trade trial of a number of products in three accounts over 16 weeks with and without the technology. The conclusion from this study, based on microbiological and beer analytical data, was that the frequency of line cleaning could be decreased from 1 to 4 weeks without threat to product quality.

So there is some tentative evidence that one of the 'sonic' approaches does indeed disrupt the microbiology of commercial dispense systems and delivers the opportunity to relax line-cleaning frequency. As ever, with such work, it poses more questions and hopefully provokes other technology providers to take the brave step of independent testing.

Biofilm research is, of course, focused on larger issues than draught beer dispense, notably the twin challenges of chronic medical infections and industrial biofouling. From this there can be related and transferable leanings that may underpin and support some of the approaches described here. Of possible relevance are insights into the 'electrocidal effect' (Del Pozo, Rouse, Mandrekar, Steckelberg, & Patel, 2009) or 'antimicrobial fields' (Giladi et al., 2008, 2010) in biofilms. In the former, long-term exposure (up to 7 days) to low-intensity direct current from 20 to 2000 microamperes reduced the bacterial biofilm load *in vitro*. Building on this, the use of low-intensity alternating electric fields of high frequencies (antimicrobial fields) has an inhibitory effect on the growth of pathogenic bacteria, including *Staphylococcus aureus* and *Pseudomonas aeruginosa in vitro* (Giladi et al., 2010) and *in vivo* (Giladi et al., 2008) with mice with a *P. aeruginosa* lung infection.

Less exotic but easier to sell-in and comprehend is enhanced end-to-end cooling in which the product is kept unambiguously cold, which then allows the frequency of line cleaning to be confidently decreased to 4 weeks without threat to product quality (see 'SmartDispense' in McCrorie, 2014). Importantly this 'cold approach' includes the FOB detector, which is considered to be an important source of microbial recontamination (see Section 16.4.4). Keeping the FOB cold together with re-engineering its hygienic design and performance are important 'game changing' additions in the assurance of total system hygiene.

16.5.4 Line composition

At 20 or so metres long, the beer line provides a substantial surface area for microbial colonisation (Table 16.3). Accordingly, the composition of the line has become an increasingly fertile ground for innovation directed at preventing the attachment and growth of biofilms. This is not new with Casson (1985) and Thomas and Whitham (1996) evaluating the adhesion of microorganisms to different plastics. These studies have informed developments in beer dispense line tubing which, these days, are dominated by medium-density polyethylene (MDP) and, increasingly, nylon-lined MDP multilayer barrier tubing. The sell-in here is that MDP is more susceptible to biofilm attachment than nylon. Other innovations include (for one manufacturer) the inclusion of a 'specially selected antimicrobial in the inner nylon layer' and for another 'a coating which releases silver ions gradually, protecting the inner surface of the tubing where microorganism growth is likely'. More recently, a new generation of barrier layer lines has been introduced which are significantly less permeable to gases and consequently reduce the egress of carbon dioxide or the ingress of oxygen. These lines are also marketed in reducing the growth of yeast and bacterial biofilms. Such developments are likely to continue, prompted by acceleration of interest in materials research and surface engineering to control adhesion and biofilm formation (Gu & Ren, 2014).

16.5.5 Data logging

Like automatic line cleaning, data logging technologies would be anticipated to add real value in terms of understanding key success parameters and diagnostics such as

volume, flow rate, throughput, temperature, and, to the case in point, line cleaning. Again the technology is available, successful, and increasingly sophisticated in providing real-time insight. Many large pub groups use data logging to reconcile delivered stock against dispensed volume of beer. Data logging has also found application in the assurance of dispense temperature and to minimise associated volume losses through fobbing. The technology clearly also lends itself to troubleshooting and, in response to throughput, identifying the 'hot spot' on the bar and, where appropriate, rationalising the number of branded fonts. Clearly wonderful, insightful stuff! However, the benefits of this technology have been diluted by a mindset that data logging is a 'spy in the bar' with a special focus on reconciliation of sales and sourcing of products. This, allied with controversy over accuracy of volume data and ensuing disputes between retailers and tenants, has ensured that the focus on benefit to hygiene and product quality has been well and truly lost.

16.5.6 ATP bioluminescence

The use of real-time hygiene testing with ATP bioluminescence has truly made a difference in the assurance of cleaning operations in the brewing and wider food industry (Boulton & Quain, 2001). Its application to validate line cleaning has been a mixed success (Orive i Camprubi, 1996; Storgårds & Haikara, 1996) and although used seemingly regularly in dispense development work, it has never really taken off as a routine in-trade test. This reflects two major issues that need to be resolved with a view to using ATP bioluminescence in line-cleaning validation and product testing *ex* tap: namely, improving sensitivity and detecting lower levels of ATP and, more importantly, robustly compensating for the high background levels of ATP in beer.

References

Ault, R. G. (1965). Spoilage bacteria in brewing. *Journal of the Institute of Brewing*, *71*, 376–391.

Bamforth, C. (1998). *Beer – tap into the art and science of brewing*. New York: Plenum Press.

Board, C. (2010). *A study of hygiene practice regarding beer dispense tap nozzles*. Available from http://www.bar-tech.co.uk/wp-content/uploads/2012/11/Charles-Board-Nozzle-Thesis.pdf. Accessed 11.04.14.

Bokulich, N. A., & Bamforth, C. W. (2013). The microbiology of malting and brewing. *Microbiology and Molecular Biology Reviews*, *77*, 157–172.

Boulton, C., & Quain, D. (2001). *Brewing yeast and fermentation*. Oxford: Blackwell Publishing.

Brewers Association. (2011). *Draught beer quality manual* (2nd ed.). 1–82.

Briggs, D. E., Boulton, C. A., Brookes, P. A., & Stevens, R. (2004). *Brewing science and practice*. Cambridge: Woodhead Publishing.

Buttrick, P. (2006). Automated beer line cleaning. *Brewer and Distiller*, *2*(8), 25–27.

Casson, D. (November 1982). Beer dispense lines. *The Brewer*. 447–453.

Casson, D. (November 1985). Microbiological problems of beer dispense. *The Brewer*. 417–421.

Costerton, J. W. (2007). *The biofilm primer*. Springer-Verlag: Berlin, Heidelberg.

Del Pozo, J. L., Rouse, M. S., Mandrekar, J. N., Steckelberg, J. M., & Patel, R. (2009). The electricidal effect: reduction of *Staphylococcus* and *Pseudomonas* biofilms by prolonged exposure to low-intensity electrical current. *Antimicrobial Agents and Chemotherapy*, *53*, 41–45.

Deutsches Institut für Normung. (2006). *DIN 6650-6 Dispense systems for draught beverages—Part 6: Requirements for cleaning and disinfection*.

Diel, S. D., Herwald, M., Borck, H., & Diel, F. (2009). Histamine in beer. In V. R. Preedy (Ed.), *Beer in health and disease prevention* (pp. 317–326). Academic Press.

Draught – Technical guidance on dispensing. (2007). Brewers Association of Canada, 1–12.

Draught beer dispense systems installation guidelines. (2009). Brewers Association of Australia and New Zealand, 1–17.

Fielding, L. M., Hall, A., & Peters, A. C. (2007). An evaluation of ozonated water as an alternative to chemical cleaning and sanitisation of beer lines. *Journal of Food Service*, *18*, 59–68.

Giladi, M., Porat, Y., Blatt, A., Shmueli, E., Wasserman, Y., Kirson, E. D., et al. (2010). Microbial growth inhibition by alternating electric fields in mice with *Pseudomonas aeruginosa* lung infection. *Antimicrobial Agents and Chemotherapy*, *54*, 3212–3218.

Giladi, M., Porat, Y., Blatt, A., Wasserman, Y., Kirson, E. D., Dekel, E., et al. (2008). Microbial growth inhibition by alternating electric fields. *Antimicrobial Agents and Chemotherapy*, *52*, 3517–3522.

Godfray, M. (January 2005). A system for reducing the occurrence of biofilm in beer dispense systems. *Brewer and Distiller*, 30–32.

Grossman, K. (2012). Draught beer. In G. Oliver (Ed.), *The Oxford companion to beer* (pp. 297–299). Oxford University Press.

Gu, H., & Ren, D. (2014). Materials and surface engineering to control bacterial adhesion and biofilm: a review of recent advances. *Frontiers of Chemical Science and Engineering*, *8*, 20–33.

Harper, D. R., Hough, J. S., & Young, T. W. (January 1980). Microbiology of beer dispensing systems. *Brewers' Guardian*, 24–28.

Hemmons, L. M. (1954). Wild yeasts in draught beer 1. An exploratory survey. *Journal of the Institute of Brewing*, *60*, 288–291.

Hough, J. S., Young, T. W., Braund, A. M., Longstaff, D., Weeks, R. J., & White, M. A. (June 1976). Keg and cellar tank beer in public houses – A microbiological survey. *The Brewer*. 179–183.

Ilberg, V., Schwill-Miedaner, A., & Sommer, K. (1995). Mikrobiologische Probleme an Schankanlagen. *Brauindustrie*, *80*, 992–995.

Jurado, J. (2003). Hygienic design, installation, and maintenance standards for draft beer dispense: German progress and North America's challenge. *Technical Quarterly of the Master Brewers Association of the Americas*, *40*, 271–279.

Livens, S., & Pawlowsky, K. (March 2009). Quality in dispense. *Brewers' Guardian*, 34–35.

Long, D. E. (2003). Hygienic management of cellars and cleaning of beer dispense lines. *British Beer and Pub Association*. Technical Circular No. 379.

Loret, S., Deloyer, P., & Dandrifosse, G. (2005). Levels of biogenic amines as a measure of the quality of the beer fermentation process: data from Belgian samples. *Food Chemistry*, *89*, 519–525.

Mamvura, T. A., Iyuke, S. E., Cluett, J. D., & Paterson, A. E. (2011). Soil films in the beverage industry: a review. *Journal of the Institute of Brewing*, *117*, 608–616.

McCrorie, C. (July 2012). New developments in CIP technology. *Brewer and Distiller International*, 12–19.

McCrorie, C. (May 2014). Recent advances in beer dispense technology. *Brewer and Distiller International*, 13–17.

Orive i Camprubi, M. (1996). Hygiene monitoring in draught beer dispensers. Edinburgh: *European Brewery Convention Monograph* XXV, 173–185.

Price, A. C. (2002). An evaluation of the efficacy of the BLM 2000 device for maintaining beer dispense line cleanliness. *Technical Quarterly of the Master Brewers Association of the Americas*, *39*, 133–137.

Priha, O., Juvonen, R., Tapani, K., & Storgårds, E. (2011). Acyl homoserine lactone production of brewery process surface bacteria. *Journal of the Institute of Brewing*, *117*, 182–187.

Profit through quality – a guide to cellar management and beer dispense. (2009). *British beer and pub association*. BIIAB and Cask Marque. version 3, 1–78.

Quain, D. (2006). Innovation in beer dispense – both below and above the bar. *Brewer and Distiller*, *2*(8), 1–5.

Quain, D. (2007). Draught beer quality – challenges and opportunities. In *Proceedings of the 31st Congress* (pp. 791–801). Venice: *European Brewery Convention*.

Quain, D. (2008). *An independent report on the application of BeerSaver technology in the assurance of beer hygiene in the on-trade*. Available from http://www.cambridgescientificsolutions.com/wp-content/uploads/2012/02/BeerSaver_ICBD_report_CSS_V1.pdf. Accessed 12.04.14.

Quain, D. (2012), Unpublished work.

Quain, D., & Storgårds, E. (2009). The extraordinary world of biofilms. *Brewer & Distiller International*, *5*, 31–33.

Seton, G. R. (1912). Cellar management. *Journal of the Institute of Brewing*, *18*, 389–406.

Sheen, D. (2013). *Statistical handbook*. London: Brewing Publications Limited.

Shulman, K. I., Tailor, S. A. N., Walker, S. E., & Gardner, D. M. (1997). Tap (draft) beer and monoamine oxidase inhibitor dietary restrictions. *Canadian Journal of Psychiatry*, *42*, 310–312.

Storgårds, E., & Haikara, A. (1996). ATP bioluminescence in the hygiene control of draught beer. *Ferment*, *9*, 352–360.

Suppliers of dispense training and education – Micro Matic Beer Dispense Institute (http://www.micromatic.com/draft-keg-beer-edu/dispense-institute-cid-85.html), Siebel Institute of Technology (http://www.siebelinstitute.com/courses-a-programs/courses-in-english/courses/details/212-siebel-institute-draught-master-program) and Cask Marque (http://cask-marque.co.uk/index.php/training-courses/cellar-management-training) Accessed 17.08.14.

Tailor, S. A. N., Shulman, K. I., Walker, S. E., Moss, J., & Gardner, D. (1994). Hypertensive episode associated with Phenelzine and tap beer – a reanalysis of the role of pressor amines in beer. *Journal of Clinical Psychopharmacology*, *14*, 5–14.

Thomas, K., & Whitham, H. (1996). Improvements in beer line technology. Edinburgh: *European Brewery Convention Monograph* XXV, 124–137.

Walker, S. L., Fourgialakis, M., Cerezo, B., & Livens, S. (2007). Removal of microbial biofilms from dispense equipment: the effect of enzymatic pre-digestion and detergent treatment. *Journal of the Institute of Brewing*, *113*, 61–66.

Wiles, A. E. (1950). Studies of some yeasts causing spoilage of draught beer. *Journal of the Institute of Brewing*, *56*, 183–193.