Keeping it clean

Balancing cost and best practice in brewery operations

It is a long time since I carried out an audit at Whitbread's Cheltenham Brewery – to be told by a foreman that he comes in every Saturday morning in his own time, strips down the mains and gives them 'a good scrubbing with a stiff brush'. Since those days, much has changed – both in the market place and brewing companies' approach to beer quality and hygiene.

By **Paul Buttrick**
Beer Dimensions

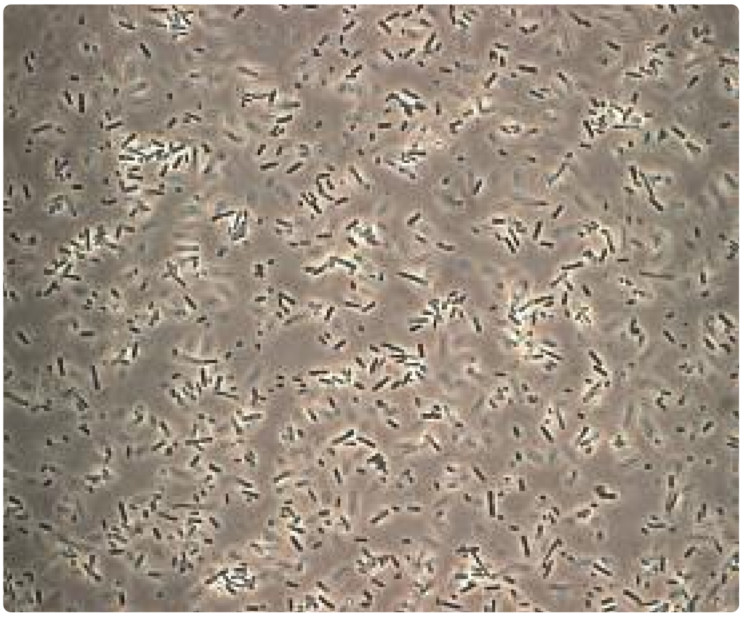

Figure 1: Beer spoilage microorganisms – what no brewer wants to see under the microscope!

Photo: Abhi Banik & David Quain, ICBD, Heriot-Watt University

Let us begin by taking a look at some of the drivers:

- The move to off-trade beer and longer supply chains, including export, requires higher quality standards.
- The rising cost of raw materials and competitive nature of national and global trade, forces companies to innovate, improve quality and reduce costs.
- Environmental concern has grown, accompanied by spiraling costs of energy, water and effluent disposal.
- New market trends are forcing companies to change their approach. Tunnel and flash pasteurisation was the answer to everything as long as reasonable beer hygiene was achieved up to the BBT/bottle/can, but consumers have been told about 'double cold filtered' fresh tasting beer which has not been pasteurised.
- The capital and running cost of tunnel pasteurisers has led to many companies using of flash pasteurisation and sterile filling techniques for small packaged beer.

Detergents

Up to a decade ago, the cleaning budget was a significant part of a brewery's costs, however, since then, the proportion associated with the cost of chemicals has reduced. Budget control was focused on ensuring chemicals were not used over recommended strength, or cleaning was 'overdone' in terms of frequency and choice of chemicals. With less than 10% of cleaning costs due to chemical purchase, the emphasis has changed and more attention is being paid to other areas such as water, effluent, energy use and maintenance (Fig 1).

Caustic soda still accounts for about 60% of all chemicals used. It is a by-product of chlorine manufacture which is used in making PVC. Demand for plastics has fallen, production capacity in Europe has reduced, leading to a 54% cost increase from £280 to £430 per dry tonne in 2007. Phosphoric acid has the best detergency properties of the commonly used acids. The demand for calcium phosphate rock has increased due to demand for fertilisers to increase yields of food grain and biofuels, this has driven up the cost of merchant grade

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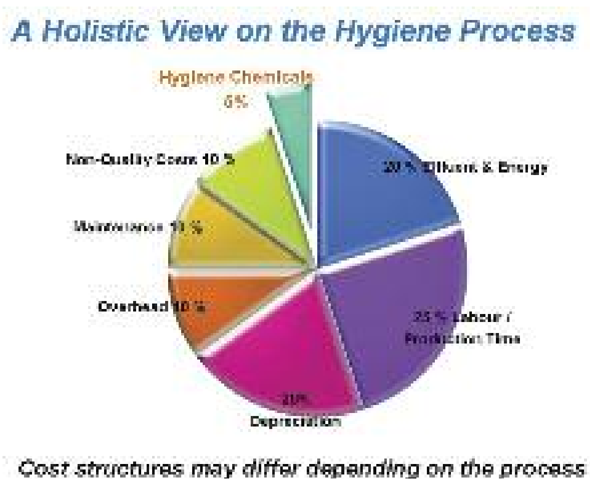


Apportioning brewery cleaning costs

Photo: Ecolab (UK) Ltd

TOP: Fig 2 CIP equipment in a modern plant – these tanks are at Quinn's packaging facility at Elton near Warrington.

ABOVE: Fig 3: Chlorine dioxide generation equipment for disinfection of rinse liquors

Photo: Prominent Fluid Controls Ltd

"There has been a lot of interest recently in the use of chlorine dioxide for cleaning water and tank disinfection. It has the advantage that there is residual biocidal activity after dosing, and pipework and plant surfaces are protected against biofilm growth."

phosphoric acid from €345 per tonne in January 2007 to €1733/tonne in June 2008. Sulphuric and hydrochloric acids are not used in the UK because of their corrosive properties, but blends using nitric acid have been employed for sometime. Apart from the base chemicals, the price of specific additives such as EDTA has also gone up by 20–40% due to increased demand and limited supply.

Current trends for tank cleaning Acid based pressure cleaning is standard practice for bright beer tanks, with top pressure CO_2 atmosphere and tank pressure retained. Traditionally hot caustic solutions of 2–4% have been used for cleaning 'rough beer tanks' But the ancillary cost of these cleans has lead to changes in approach. Current best practice points to the use of a 'sacrificial' pre-rinse of caustic (at 1–2%) to remove soil from tanks, followed by a main acid clean (at 1%) Acids have the advantage that they do not react with residual CO_2 to form carbonates and diminish the effectiveness of the detergent. Acid cleaning is used more generally with a separate disinfectant cycle, but the major suppliers are recommending the use of combined compatible detergent/disinfectant, saving time, energy, water and effluent from operating a single stage process. (Fig 2)

Disinfectants

In discussing brewery hygiene, we should talk about disinfecting since sterilisation means the complete kill of all microorganisms that might be present, while disinfection is a declared kill rate of the majority of present organisms (that is 99.99%) Various disinfectants have been used over time, some were corrosive and tainted beer (for example sodium hypochlorite and iodophors), others had detrimental effects on beer quality (quaternary ammonium compounds on beer foam). The use of heat - hot water and steam are still used on more complex equipment such as keg racking lines.

The disinfectant of choice, due to its effectiveness and non toxic residue was and in many cases still is PAA - peracetic acid used at 100–300 ppm. It has remained a preferred agent, despite its potentially dangerous, explosive and corrosive nature. It had the added advantage that it was not necessary to rinse residues from tanks before refilling. This is an interesting point since European legislation requires PAA residues to be rinsed from plant, whilst it has 'non rinse approval' from the FDA in the United States.

There have been more recent disinfectant developments with the use of a new generation of 'per-acids' and active oxygen free agents organic/fatty acids such as glycolic acid.

Chlorine Dioxide

There has been a lot of interest recently in the use of chlorine dioxide for cleaning water and tank disinfection. Chlorine dioxide is a non-chlorinating oxidative biocide. It has the advantage that there is residual biocidal activity after dosing, and pipework and plant surfaces are protected against biofilm growth. One of the main reasons that brewers have a resistance to using chlorine dioxide is the risk of tainting their beer. However, unlike with chlorine, there is no substitution on activated C-H bonds to form trihalomethanes, or with phenolic compounds to form medicinal tasting chlorophenol. The main breakdown compounds of chlorine dioxide are chlorite and chloride which have no flavour contribution at low levels. Chlorine dioxide is very stable in acidic solutions, but above pH 9.5 will break down into chlorate and chlorite. Chlorite itself has biostatic activity which contributes to continued protection of a system. Chlorine dioxide can be dosed directly as an aqueous solution at the point of use, but this is an expensive option. Prominent Fluid Controls Ltd recommend generating it using hydrochloric acid and sodium chlorite using specifically designed equipment (Fig 3).

The equation for forming ClO_2 from hydrochloric acid and sodium chlorite is:

$$5NaClO_2 + 4HCl \; = \; 4\,ClO_2 + NaCl + 2H_2O$$

Maximum allowable levels in drinking water vary; it is 0.5 ppm in the UK and 0.2 ppm in Germany. Because of its non tainting properties chlorine dioxide is beginning to be used as a final rinse plant disinfectant, usually at 2 ppm. Although chlorine dioxide has very good biocidal properties, it is claimed by some to be less effective against beer spoilage organisms than peracetic acid in plant which is not perfectly clean – In debates like this, only time and experience will tell.

Ultra violet systems for water

Easily installed UV systems at 'point of use' have been successfully used for many years to ensure process water in breweries has been free of microbiological contamination. It has had mixed reviews from users, with detractors having issues mainly resulting from

Table 1: Comparing cleaning devices

Type	Volume flow m^3/hr	Pressure at head	Time/bursts etc	Total water volume to drain
Rotary jet head	9	5	35	$1.2m^3$
Fixed sprayball	18	2	60	$4.5m^3$

feed water quality; namely, the water must be clear (<5 NTU), have suspended solids <10mg/l and be substantially free from iron and manganese. Older breweries with non-stainless steel water pipes have had problems and filter systems are required up stream to ensure the UV light can perform its task. The use of UV disinfection is only effective at the point of irradiation; there is no residual effect, so a periodic disinfection of water systems by other means is still necessary.

Ozone as a disinfectant

Ozone is considered a viable alternative to chlorine dioxide or water and rinse liquor disinfection (I reported on the Esazon from Esau & Hueber in the *Brewer and Distiller International* in November 2007). It is an excellent biocide and leaves no residue. There are, however, general concerns from some over its handling and safety which need to be addressed before it will be more widely accepted.

Ways of making cleaning more cost effective

Water usage and effluent charges are a significant part of cleaning costs, so, using a 500 hl FV as an example, we will look at how the choice of cleaning head can affect overall efficiency and costs. It is purely a paper exercise as a first step towards deciding what sort of process and cleaning device to choose. As with any project, overall costs for purchasing, installing, maintaining and operating a piece of equipment must be taken into account. This means that every decision will be made according to individual plant circumstances and money available. Two types of cleaning device will be considered:

1) A high pressure, low flow rotary jet spray head (Fig 4)
(in this example figures are quoted for a Toftejorg TJ20G rotary jet head)

2) A low pressure high flow thin-wall spray-ball (Fig 5)

FVs have a thick ring of adhered yeast at the top of the vessel, which will take more effort to remove, as well as on the bottom cone and general yeast in the body.

As can be seen from Table 1 (opposite) the spraying time is about half and the water and effluent volume is about one third for the rotary jet example compared to the thin walled spray ball. As an example, with water costing at £0.8/m^3 and effluent at £1.70, the total saving on one tank clean is in the order of £9.37. A brewery cleaning 50 tanks a week would make savings of £23,437 a year.

The case for using rotary spray heads on bright beer tanks is less compelling, because pre-rinsing is less, soil removal is not required, cleaning times are shorter and water requirements similar. Savings in water and effluent using a rotary spray head cannot justify a decision to replace spray balls with rotary spray heads. As with most debates, advocates of retaining fixed spray balls, contend that the spray-ball gives better drenching/coverage and outlet pipe cleaning on scavenging than low volume devices. The cost of a spray-ball at say £300 is significantly less than the more sophisticated jet device purchased for £1500 – £2000

Recovery of rinse liquors

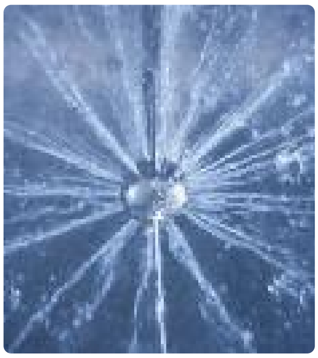
Final rinse water from cleans are often recovered to a CIP pre-rinse tank. Effluent from a pre-rinse will go to drain. To do this requires the addition of a pre-rinse collection tank and extra plant and control equipment. This all adds to the capital required, but is increasing necessary as environmental awareness and costs escalate.

'Single use' cleaning systems

'One shot' cleaning systems which were popular in the 70s and 80s, used lower chemical concentrations than recovery systems but water and effluent cost increases has contributed to their demise.

Use of technological monitoring

With the use of PLC and SCADA systems, monitoring cleans has become easier. Simple timers were used originally, these were backed up later with conductivity probes used to measure chemical concentrations to determine switchovers from chemicals to rinses and vice versa. Pressure switches can be used to monitor flow.



LEFT: Fig 4: Spray pattern from a high pressure low volume rotary jet.

ABOVE: Fig 5: Spray pattern from a low pressure high volume thin walled spray ball.

Photo: Alfa Laval Ltd

Flow meters can measure that flow delivery to cleaning heads and from scavenge are balanced and working properly.

How often should cleaning be carried out?

A good question – It remains best practice to clean fermentation vessels after every fill, but bright

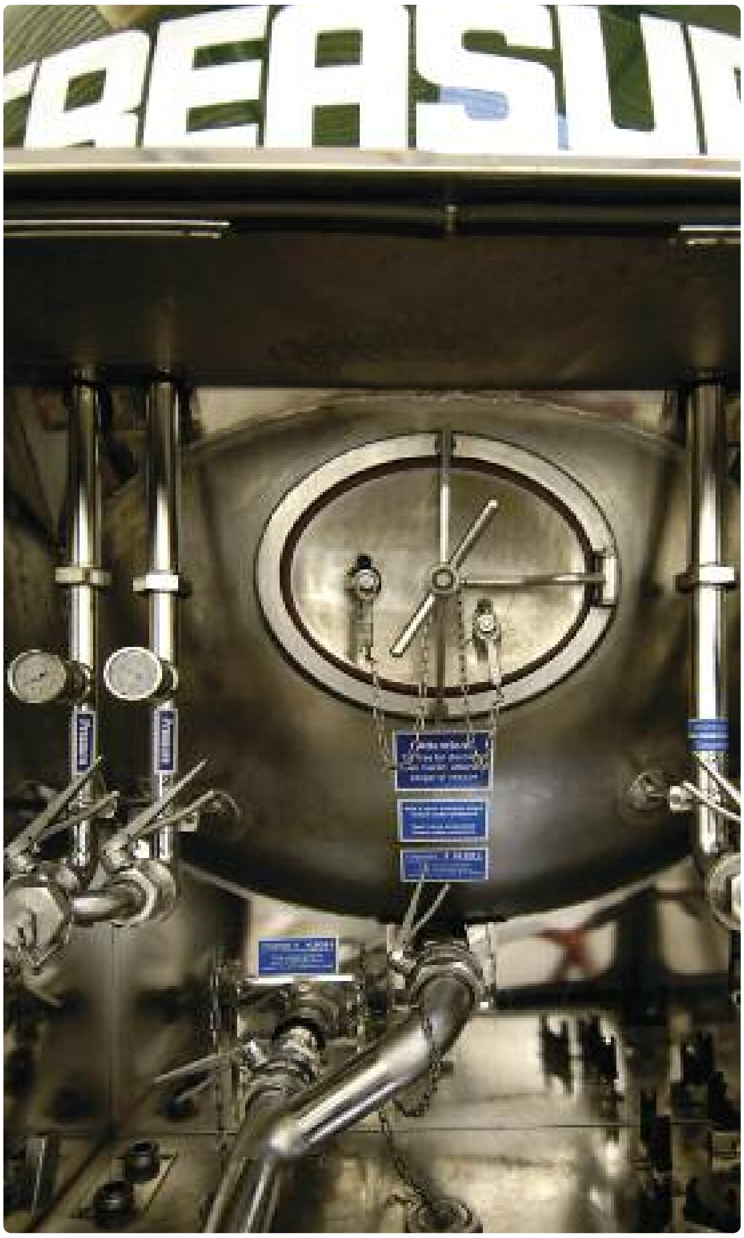


Fig 6: General view of the back of a beer tanker, showing beer, CIP and top pressure connections.
Photo: Treasure Transport Services Ltd –

"Taking and analysing in-process samples is carried out by most companies. It has an advantage that, as long as the sampling method is sound, what is in the beer cannot be disputed."

beer and mains cleans are often delayed for longer. Bright beer tanks, if microbiological control is backed up by a pasteuriser are sometimes not always cleaned every use. Some breweries which run 24 hours a day have stopped cleaning kegging lines on a daily basis, instead only stopping 'mid week', or even waiting until the end of the production week.

How to check the effectiveness of a clean

In an automated brewery, there is no longer the time and easy option to check visually that cleaning is being carried out correctly. Tanks are often huge with no easy access for visual inspection, and valve matrices and manifolds make it difficult. Another problem is that plant can look clean and bright, but may not be sterile and any cleaning problem could and is most likely not to be where you are looking. Having said that, a quick look into a tank and view with a torch can show gross problems such as staining, scaling and possibly missing (those that may have dropped off) spray heads. Feeling a surface with the hand is useful, the rough surface under a tank door can indicate protein scale which may be missed on quick visual inspection.

Standard microbiological methods for check cleaning effectiveness

Standard methods have involved swabbing, rinse liquor testing and beer testing using standard microbiological techniques. A few remarks on each is worthwhile:

Swabbing

This was common when tanks were small and all areas easily accessible, however, large tanks and automated plant have made swabbing almost impossible, except on dismantled smaller individual plant items to help pinpoint problem areas.

Rinse Liquors

Taking and analysing rinse liquors replaced swabbing in larger plants A potential issue with rinse liquors is that they only come from where the spray reaches, an inadequate or defective spray pattern can give good but false results.

Beer testing

Taking and analysing in-process samples is carried out by most companies. It has an advantage that, as long as the sampling method is sound, what is in the beer cannot be disputed. What is important is the interpretation of the results and whether the microbes found are beer spoilage organisms or fast or slow growing. Results from aerobic samples get different responses – some say – OK no need to worry too much, it is a sign of less than ideal hygiene, but the beer will not spoil. A significant downturn in anaerobic results is more likely to cause excitement and immediate action.

Management of brewery hygiene

The management of hygiene in the brewery is key to consumer satisfaction and helps to ensure that returns are kept low. Few things for a brewery team are worse than when beer in the trade is receiving complaints on flavour that is linked to poor microbiological quality. There is no 'quick fix', and depending on where a problem has started, putting it right for the consumer can take weeks especially with extended supply chains.
For this reason, it is vital that sampling and analysis is properly structured, with a choice of frequency, sample size and type of analysis (aerobic and anaerobic) set to cover the greatest risks. Knee jerk reactions from problems sometimes result in a scattergun approach with an excessive sampling regime remaining, or conversely, financial axe swinging results in holes in the procedure with risks increased.

Photo:3M Ltd

A quality review by the people responsible for the beer and plant, with any remedial actions noted for feed-back, has in the past, been a management review, but with flatter structures, there is much to be gained by the people actually doing the work, learning, working with suppliers and getting satisfaction from solving their own problems.

Service and Support

Service and support from suppliers differ widely, with some customers contracting almost full time support from their chemical suppliers – it could be said to be outsourced. Other arrangements involve less frequent visits which probably includes a quick check of the plant and chemical strengths. Most good chemical suppliers offer advice and assistance in improving cleaning efficiency and costs. I would personally be wary of derogating responsibility for plant cleaning. Yes, it may release staff for core activities, but the loss of knowledge and experience from the production team, in my opinion leaves a brewery exposed to higher risk and increased costs in the long run. It is better for brewery staff to become more knowledgeable and work with the supplier to increase quality and reduce overall cost on a partnership basis.

Supplier support in improving operations

Ecolab has introduced a concept called 'Advantis', which was developed to help customers improve their cleaning operations. An example of this is where a traditional 80oC caustic detergent clean is followed by a disinfection cycle on a bottle filling machine. A cleaning time of two hours was reduced to about 40 minutes by using a specifically formulated detergent and disinfectant combination used at 40oC. The change resulted in increased production time, savings in water effluent, energy and chemical usage.

The challenge of managing the logistics and quality of a beer tanker operation across large areas of the country and beyond can be addressed by partnering a specialist company which has full responsibility for beer delivery, maintenance and cleaning of tankers. It is a 'ring fenced' operation which can be managed without brewers losing control. Treasure Transport Services Ltd has a fleet of 40 road tankers ranging from 25 to 180 brls capacity and has transported beer for over 50 years. In 2005 it invested in a purpose built PLC controlled tanker cleaning facility at its base in Grantham, Lincolnshire. It is able to clean tankers according to customers' needs and does residual chemical and rapid bioluminescence swab checks from the tanker outlet to confirm cleaning is to the required standard. (Fig 6)

The move to sterile beer packaging

Retrospective sampling, growing up plates and broths etc, have helped improve beer microbiological quality immensely and problems with bright beer in trade are now thankfully rare. The 'summer' problems with cask beer are reduced but not unknown. With bright beer, the almost universal use of pasteurisation has allowed brewers to sleep better at night, however more marketing focus on unpasteurised sterile filled small and large pack beer is forcing brewers to up their game in beer hygiene throughout the brewery. Improved disciplines and standards for unpasteurised beer had to be introduced, to ensure small pack beer stayed in good condition throughout its shelf-life. The recent trend has been for tunnel pasteurisers to be replaced with flash pasteurisers and sterile filling, there is still an upstream safety net, but risks are bound to be higher and sense dictates that overall microbiological quality and sampling regimes must be higher focus.

Fig 7 left: Clean-Trace bioluminescence probe for sampling swabs and rinse liquors. Photo: 3M Ltd

Fig 8 above: Hand held luminometer showing swab probe sample being analysed.

Rapid microbiological techniques

An issue with retrospective sampling is that results are historical, things can get a whole lot worse in the time it takes to analyse results. Ideally, beer should be 'passed' as fit for sale before it leaves the brewery, also it is good to feel comfortable that brewery plant is clean and sterile before use.

With small pack and export beer, there are only two alternatives:

a) analyse the packaged beer and release it to trade, hoping that previous results demonstrate that all should be well.
b) hold stock at the brewery / warehouse until the results show the beer has passed its tests. Boddingtons beer for export was sterile filtered and forcing tests had to pass muster before it was allowed out of Strangeways Brewery.

Market changes and business needs have encouraged the development of rapid techniques for plant checking and beer analysis, based on biotechnology and bioluminescence.

How do rapid checks work?

All living organisms contain ATP (adenosine triphosphate) used as an energy source within the cell. The structure of ATP was first established in 1935, but it was not until the 1990s that ATP was used in production situations for rapid assays.

ATP collected on a sample reacts with an enzyme called luciferase, which was originally extracted from the firefly, and produces an amount of light that can be measured. The light is measured in a luminometer and is expressed as Relative Light Units – RLUs. The amount of light measured is proportional to the level of contamination (that is ATP) in the sample. Because ATP is present in live and dead organisms, the measurement takes account of living contamination – yeast and bacteria, but also other debris. The technique can therefore be used to measure the overall sterility and cleanliness of a sample.

Using ATP bioluminescence does not provide a definitive measurement of the numbers or type of organisms present. but gives an excellent overall indication of the condition of the plant. Two techniques most often used are for swabbing a piece of plant, or checking rinse water after a clean to confirm it has been done correctly. It is increasingly being used as part of companies' HACCP systems, where rapid techniques used before plant is used, is a real time confirmation of contaminant free plant.

How is it carried out ?

One of the original companies producing equipment was Biotrace Ltd, which is now owned by the American company 3M. This is a multi-billion pound turnover business, and has interests in healthcare, highway safety and office products – including little yellow Post-its and Scotchbrite cleaning pads. The equipment is easy to use and tests can be carried out by trained brewery operatives. The first is a swabbing technique used to check plant is clean. A simple swab (Fig 7) is taken of a piece of plant, and any contamination extracted in a cell which is read on a luminometer. The luminometer is a hand held instrument (Fig 8), which, apart from giving a sample readout in RLUs can be programmed with sample plans and data collection to a PC. A similar sample probe is used to collect final rinse samples from CIP equipment. Experience and use has led to RLU levels which when achieved demonstrate a plant is clean and ready for use. This figure is approx 150 RLUs and figures of 151–300 are seen as a 'Caution' reading, and anything over 300 can be considered 'Fail', when recleaning and retesting should be carried out. The hand held luminometer device costs in the region of £2600, and sample swabs about £1.80p

Another company active in CIP and other brewing applications involving measurement of particles and luminescence is Cellfacts Instruments Ltd. The company is 'spin out' company from the University of Warwick and retains strong links with the University's Department of Biological Science. The ability to measure particles by number and size has been of interest to Cellfacts for some time and has included a whole range of brewing applications, including the brewhouse, fermentation/-conditioning and filtration. The application to CIP is important to a whole rage of industries including breweries.

How does it work?

The size and number of particles in a sample is measured by electrical flow impedance, they are then exposed to laser excitation which results in a fluorescence, the level of which indicates the viability of the cell. The instrument's measurements are manipulated using complex algorithms to give the concentration in particles in different size ranges, the number of cells and their viability.

In 2007 Cellfacts Instruments products were awarded a place on the Water Technology List for CIP equipment. This is a list of companies, managed by the Government's Defra and HM Revenue and Customs, which aims to help and encourage businesses save money by investing in products that reduce water usage. Because of cost and complexity, the instruments are better suited to the laboratory environment, although hand held 'plant use' versions are available. It would be interesting to see if the technology could be applied to rapid assessment of packaged beer before dispatch.

Many developments in brewing have come through the more exacting pharmaceutical environment. Pall Corporation has developed The 'Pallchek Rapid Microbiology System', also based on ATP bioluminescence, which is being used to check the cleanliness of bottling lines prior to production start up.

Legislation

There have been two recent pieces of legislation that will affect suppliers and users of chemicals. It is important that brewers know of these, and suppliers are aware of what needs to be done to comply.

1) REACH – Registration, evaluation and authorisation of chemicals (EC/1907/2006)
   The legislation came into effect on 1/6/2007 to streamline and improve the complex legislative framework with regard to chemicals in the EU.
2) Biocidal Products Directive 98/8/EC
   This Directive came into force in the EU in May 2000. Its aim is to provide a harmonised regulatory framework for placing biocidal products on the market, and ensure a high level of human and environmental protection. ■

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● Acknowledgements

The author would like to thank the following companies for their help in providing information for this article: Ecolab (UK) Ltd, Holchem Ltd, Sopura Ltd, Johnson Diversey Ltd,Alfa Laval Ltd Treasure Transport Services Ltd, Prominent Fluid Controls Ltd, 3M Ltd, Cellfacts Instruments Ltd

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