Environmentally friendly cleaning operations

In a nutshell

Summary				
Best practice is to reduce the amount of water, energy and chemicals used during cleaning operations by: • implementing and optimising ‘Cleaning In Place’ (CIP) systems by optimal cleaning preparation (e.g. ice pigging), accurate design and configuration, measuring and controlling detergent temperature and concentration, using mechanical action appropriately, reusing final rinse water for the pre-rinse, recycling detergents, and by using real-time cleaning verification, • optimising manual cleaning operations by raising awareness, monitoring the energy, water and chemicals used, dry clean-up and cleaning of equipment as soon as possible after use, • minimising or avoiding the use of harmful chemicals by capturing and reusing cleaning agents and using less harmful and biological chemicals, • better production planning in order to avoid changes in the production process that require the equipment to be cleaned, • better plant design by improving the design of vessels, pipework, etc. so as to eliminate areas that detergent cannot reach or where fluid accumulates.				
Target activities				
All food and beverage manufacturing	Processing of coffee	Manufacturing of olive oil	Manufacture of soft drinks	Manufacture of beer
Production of meat products	Manufacture of fruit juice	Cheese making	Manufacture of bread, biscuits and cakes	Manufacture of wine
Applicability				
This best practice is applicable to all food and beverage manufacturers. However, some limitations may arise when substantial economic investment is needed in order to adopt more sophisticated cleaning systems.				
Environmental performance indicators				
• Cleaning-related energy use per unit of production (kWh/weight, volume or number of products) • Cleaning-related water use per unit of production (m3/weight, volume or number of products) • Cleaning-related water use (m3) per day • Cleaning-related waste water generation per unit of production (m3/weight, volume or number of products) • Cleaning-related waste water generation (m3) per clean • Mass (kg) or volume (m3) of cleaning product used per unit of production (weight, volume or number of products) • Share of cleaning agents (%) with an ISO Type I ecolabel[1] (e.g. EU Ecolabel)				

Benchmarks of excellence
N/A

[1] As part of the ISO 14000 series of environmental standards, the International Standards Organisation (ISO) has drawn up a subseries (ISO 14020) specific to environmental labelling, which covers three types of labelling schemes. In this context a ‘Type I’ ecolabel is a multi-criteria label developed by a third party. Examples are, at EU level, the ‘EU Ecolabel’ or, at national or multilateral level, the ‘Blaue Engel’, the ‘Austrian Ecolabel’ and the ‘Nordic Swan’.

Description

Cleaning operations can account for up to 70% of a food and beverage manufacturing site’s total water use and effluent volume (Environmental Technology Best Practice Programme, 1998), and are also responsible for a significant portion of a site’s energy consumption; In the dairy sector, for instance, more than half of a typical milk processing plant is devoted to cleaning equipment and pipes (Innovation Center for U.S Dairy, 2010).

This best practice describes how the best performing manufacturers implement environmentally friendly practices in their cleaning operations so as to reduce water and energy consumption or to use more environmentally friendly chemicals. Two types of cleaning should be considered here:

1. Cleaning processes during the preparation of raw materials prior to production, and;
2. Cleaning of production equipment between batches or recipes.

In both cases, the cleaning operations can be very intensive in their use of water, energy and chemicals.

Frontrunners implement this best practice in a number of ways, including:

- Implementing and optimising of Cleaning In Place (CIP) systems
- Optimising manual cleaning operations
- Minimising or avoiding the use of harmful chemicals
- Better production planning
- Better plant design

Implementing and optimising Cleaning In Place (CIP) systems

CIP is a hygiene technology widely used by larger food and drink manufacturers during scheduled cleaning and wash downs to remove surplus product and bacteria from vessels and pipework while minimising interruptions to the process.

Tamime (2008) defines CIP as:

The cleaning of complete items of plant or pipeline circuits without dismantling or opening of the equipment and with little or no manual involvement on the part of the operator. The process involves the jetting or spraying of the surfaces or circulation of cleaning solutions under conditions of increased turbulence and flow velocity.

CIP reduces water, detergent, heat and energy use during the cleaning process; promotes the use of chemicals with more desirable environmental characteristics and minimises production downtime which in turn cuts the food and packaging wastage associated with the starting up and slowing down of production. CIP is typically practised for the cleaning of production equipment, the second of the two purposes referred to above.

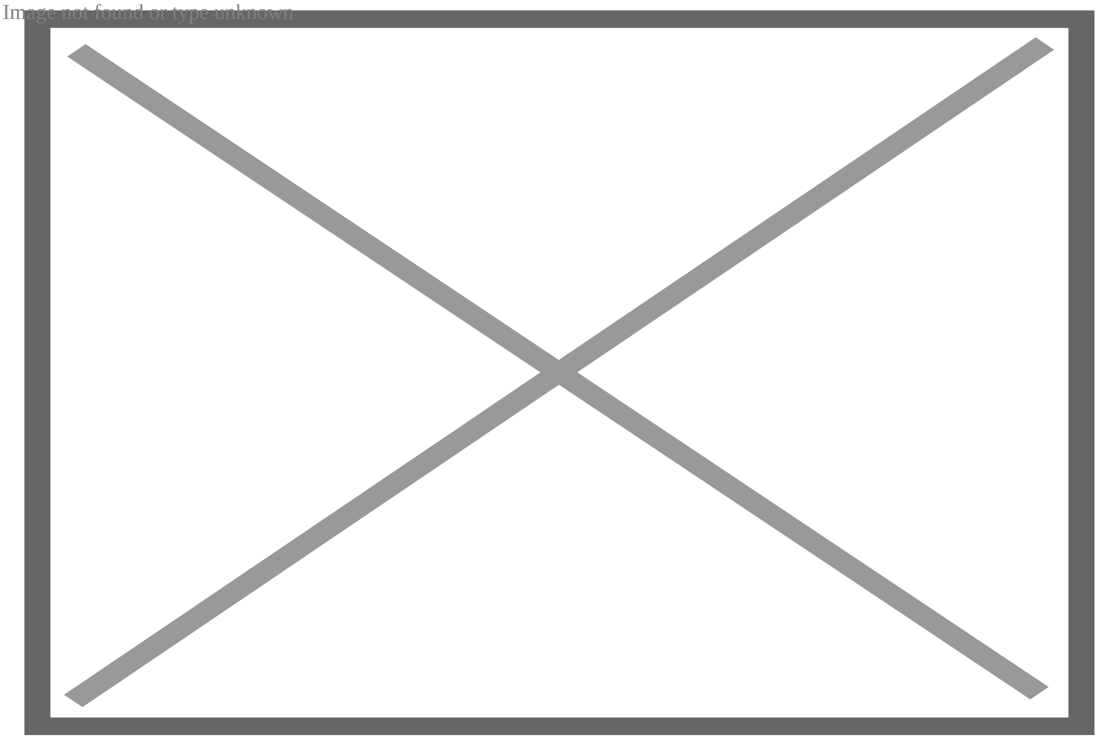
In fully automated systems, computer software can be used to coordinate the CIP cycle which typically involves detergent solution for cleaning, disinfectants and sterilisers, other additives such as ozone (see below) or a ‘pig’, an object which dislodges solid material prior to cleaning (Product Sustainability Forum, 2013a).

An innovative new ‘ice pigging’ method using ice slurry has recently been rolled out with significant environmental and productivity benefits. This method involves using crushed pumpable ice as a semi-solid object to clean pipes. Rather than flushing food pipes and tanks with liquid water (prior to the use of detergents such as caustic soda), the ice slurry is driven through the system which is far more efficient in mechanically recovering residual product. In effect, the ice scrapes the pipes and tanks and recovers useable food product, rather than the organic material being lost in the effluent. The ice pigging method has the huge advantage that the ice can be driven throughout the system, around bends, through narrow diameters, across heat exchangers, etc. whereas standard pigs can only be used across straight pipes. However, ice production is an energy intensive process, requiring about 9.15 kWh per 50 kg pig, even if more efficient techniques are under development. Nevertheless, the water and product savings achieved with the ice-pigging method counterbalance the higher energy consumption (Carbon Trust, 2015).

The method was piloted in 2011-12 by the manufacturers Premier Food and General Mills with funding from Defra (UK Department for the Environment, Food and Rural Affairs) and has been proven to work in the manufacture of various foods including dairy products, curry sauces, sausages and tomato purees. Ice pigging is commercialised and is especially used in the water industry. However, many other sectors in the food and beverage manufacturing sector could benefit from the implementation of this cleaning technique.

CIP is nothing new in the food and beverage industry but many companies, conscious of the risks associated with failure (i.e. contamination of product), tend to factor a high level of contingency into their CIP programmes, over-using water and energy and wasting product. CIP programmes in the food and beverage sector are traditionally composed of multiple steps. The initial rinse with water serves a mechanical purpose in physically dislodging as much of the food product remaining (although as discussed below this step is less effective than the ‘ice pigging’ method). The hot alkali solution (typically caustic soda – i.e. sodium hydroxide) is designed to kill microbes and remove the remaining COD. The system is flushed again with water to remove the caustic soda and sometimes an acid wash (typically nitric or hydrochloric acid) is used, especially in the dairy sector, to remove unwanted minerals such as calcium, before a final post-rinsing with water (Figure 1).

Figure 1: Conventional cleaning steps in the CIP process in the dairy industry



Source: Paul et al. (2014)

The best performing companies therefore seek to optimise CIP systems and maximise savings without compromising function. Ways to optimise CIP include the following (Environmental Technology Best Practice Programme, 1998; WRAP, 2012):

- *Optimising process design and configuration* - simple systems use the vessel to be cleaned as a detergent reservoir whilst the more complex are multi-channelled with tanks for detergent, pre and post rinses, and sometimes disinfectant;
- *Optimising control and measurement of detergent temperature and concentration* – for instance, by installing automatic dosing systems.
- *Optimising the application of mechanical action* (e.g. wiping, rubbing, brushing, flushing and high-pressure jets) to improve the effectiveness of the cleaning.
- *Use of real time cleaning verification* - i.e. monitoring critical parameters (e.g. temperature, chemical concentration) and indicators of effectiveness in removing soil (e.g. turbidity, surface cleanliness, flow) in real time allows adjustments during the cycle to ensure efficiency while avoiding the temptation to ‘over clean’ and thus waste energy, water and chemicals. The monitoring is typically done by fitting electrode conductivity sensors in the process pipe work, although a verification system that uses a coloured chemical to detect the organic contamination indicative of ineffective cleaning has also been recently developed (Thonhause GmbH, 2014, pers.comm.).

- *Re-use of final rinse water for pre-rinse and recycling of detergent* – the recirculated detergent must be filtered to avoid the need to dump dirty detergent solution regularly down the drain.
- Use of *turbidity detectors* to recover product from pipework prior to cleaning.
- Use of *spray devices* designed to clean effectively with the minimum volume of water.
- *Regeneration of caustic soda – the ‘Green CIP’ method* (see below)

- *Ice pigging* (see above and achieved environmental benefits)

Optimising the resource efficiency of manual cleaning operations

Small and medium-sized manufacturers may not have the resources to implement sophisticated automated systems like CIP, but scope exists to improve resource efficiency of manual cleaning operations in many low-cost or freeways including (Environmental Technology Best Practice Programme, 1998):

- staff training and awareness-raising;
- better monitoring of the consumption of water and energy used in cleaning;
- water pressure controls and water-efficient spray nozzles for hoses;
- improved chemical formulations and application;
- cleaning of equipment as soon as possible after use to prevent wastes hardening
- regular servicing and maintenance - to identify and rectify faulty, inefficient or leaking equipment;
- dry clean-up – i.e. manual removal without waste water from the floor and machinery prior to cleaning (which ultimately lowers the organic concentration of effluent)

Frontrunners in the food and beverage manufacturing sector will also plan their manual cleaning programme to better match particular machinery or types of soil with the correct cleaning methodology and materials. This can significantly impact on the quality, speed and cost of cleaning (Bailey, 2013). Traditionally, facilities are cleaned by a group of cleaners following an intuitive and simple 'sequential method':

1. remove debris to another area,
2. rinse surfaces,
3. apply detergent,
4. rinse again,
5. finish with sanitiser.

However, this has the following disadvantages:

- the team can only work as fast as the slowest member
- the team lacks the flexibility to respond to short-term needs
- an area or piece of equipment may be unnecessarily cleaned 'because it is on the schedule'
- some areas or equipment may be left for too long before they are cleaned with the result that contamination builds up and food particles may be harder to remove.

Frontrunners, especially those with extended or continuous production, use a more flexible approach called 'cluster cleaning' and 'event cleaning' which balance food safety with economy, equipment is cleaned when necessary and not before. The staff involved in cluster cleaning have clearly defined roles, each waiting for the right time to complete their part of the process quickly and efficiently, and without impeding any other cleaner. By this approach, each area of production is cleaned as soon as it falls idle, reducing plant downtime and increasing profitable production time. With event cleaning the process is further refined, with surfaces examined frequently by an experienced operative, to assess the scheduled clean time using pre-set criteria. Only then, if needed is the surface cleaned. Event cleaning is best suited to ancillary surfaces (e.g. guard rails, packaging and wrapping machinery, air conditioning units, corridors, and door or wall touch-points). These advanced cleaning methods can potentially cut labour costs by up to 15 % compared to traditional sequential cleaning regimes (Bailey, 2013).

Minimising or avoiding the use of harmful chemicals

Chemicals such as chlorine, quaternary ammonium compounds, bromine or iodine based products are routinely used to maintain the hygiene of food manufacturing sites. However, these are often potentially hazardous in combination with organic residues (Canut & Pascual, 2007). Moreover, to work safely and effectively, such chemicals typically require large volumes of water and often high temperatures. Then, when cleaning is complete, further treatment with significant associated environmental impact is often needed to clean up any effluent.

Frontrunner companies therefore seek to minimise or avoid the use of such chemicals in a number of ways:

- capturing and re-using cleaning agents (Environmental Technology Best Practice Programme, 1998), as evidenced in the Taw Valley Creamery example below
- using less harmful cleaning chemicals
- using electrochemical activation (WRAP, 2012)
- using biological cleaning agents.

All these approaches can be applied to both manual and automated cleaning systems (e.g. CIP). Two examples of these are described below.

Re-using cleaning agents - A team of French and Canadian technologists have pioneered the regeneration of caustic soda used in CIP, a technology called 'Green CIP' that enables the re-use caustic soda (Utilities Performance, 2014, pers.comm.). Rather than the initial rinse with cold water (see Figure 3.6), in this method the pipes and tanks are flushed through with hot alkali as a first step resulting in a liquid very high in organic matter. The used caustic soda is then passed into the Green CIP process in which a clay-based reagent is used to separate the alkali from the solids which forms a sludge. The Green CIP is not a mechanical process (using membranes or centrifugation), but a 'soft process' of coagulation and flocculation paralleling that in a standard wastewater treatment plant.

The sludge from the Green CIP is sufficiently clean to be spread on farm land as a fertiliser or even fed to animals. Crucially, the effluent from the caustic soda flush does not need to be 'cleaned up' in an expensive waste water treatment plant before being discharged to the municipal drains. Importantly, unlike with a standard wastewater treatment plant which requires a neutral pH, the Green CIP process can function at any pH enabling the cleaning up and regeneration of both alkali, and where necessary, acid effluent. The caustic soda regenerated in the Green CIP process can be re-used multiple times, and tests indicate that the regenerated caustic soda is more effective than virgin alkali in its task of removing solids.

The Green CIP process has already been used by:

- **Actalis** a multinational dairy products maker in a 30,000 tonnes per year capacity plant making mozzarella and ricotta cheese in Buffalo, New York state, USA – since 2006
- **Danone** in its 'Yoplait' plant on the French island of Réunion in the Indian Ocean – since 2012

Utilities Performance Group has now worked with a PhD student in northern France to collect more technical data on the Green CIP process to prove its safety, effectiveness and environmental performance before industrial scale up on the European continent. Green CIP has been successfully used by manufacturers making dairy products (yogurt, cream, and ice cream), meat products, soups, chocolates and alcoholic and non-alcoholic beverages.

Using less harmful cleaning chemicals - The use of ozone as a cleaning agent is a particularly promising technique (Canut & Pascual, 2007; OzoneCIP Project, 2007) which does not produce any harmful residues. The highly oxidative, and thus anti-microbial, properties of ozone (O_3) are well-established. Ozone in water solution can destroy the cell membrane of pathogens by oxidising the phospholipids and lipoproteins and has the advantage of itself quickly breaking down into harmless oxygen. Ozone is effective against a wide range of microbes including bacteria, yeasts, moulds, viruses and spores (Khadre et al., 2001). The incorporation of ozone-enriched water in CIP - and other cleaning processes - has the advantage over traditional disinfectants that no residues are left and the ozone is applied cold. This reduces the volume of water necessary to rinse detergents from the plant and the energy associated with heating the water. Ozone can also be used in dry settings (Environmental Technology Best Practice Programme, 1998). As a result ozone is increasingly being used by frontrunners in a number of subsectors (especially winemaking).

Better production planning

Better production planning and scheduling so as to minimise the number of discrete cleaning episodes needed between product changeovers will also offer significant time, environmental and financial savings. This includes improving demand forecasts in order to avoid abrupt changes in production requiring the equipment to be cleaned. Cleaning at non-optimum times is likely to result in larger amounts of food waste given that the process would not have come to an end, and therefore more residual food is likely to be present in the production equipment. This would also result in increased use of water and detergents to eliminate the larger amounts of residual food that need removing.

Another example is better planning in production plants where allergen free foodstuffs are produced, as well as regular products. In these cases, planning production shifts so that the allergen free products are scheduled first which reduces the need for thorough cleaning when moving the non-allergen-free equivalent which would otherwise be required to avoid cross-contamination. This would result in reduced use of both water and detergents. This approach can also be generalised to non-allergen-free food stuff. Optimised production planning can allow the next batch of ingredients to be used as a cleaning agent, ensuring that there is no need for specific cleaning operations and risk of contamination between different batches.

Better plant design

Improving the design of vessels, pipework, etc. so as to eliminate areas that detergent cannot reach or where fluid accumulates will reduce cleaning time as well as saving water, chemicals and energy (Figure 2).

The use of different materials in the construction of processing equipment also facilitates cleaning. An example of this comes from the UK beer producer **Adnams** which reduced water use below the industry average, in part by using stainless steel in brewery construction which can be cleaned with less water (Product Sustainability Forum, 2013c).

Figure 2: Designs for efficient cleaning

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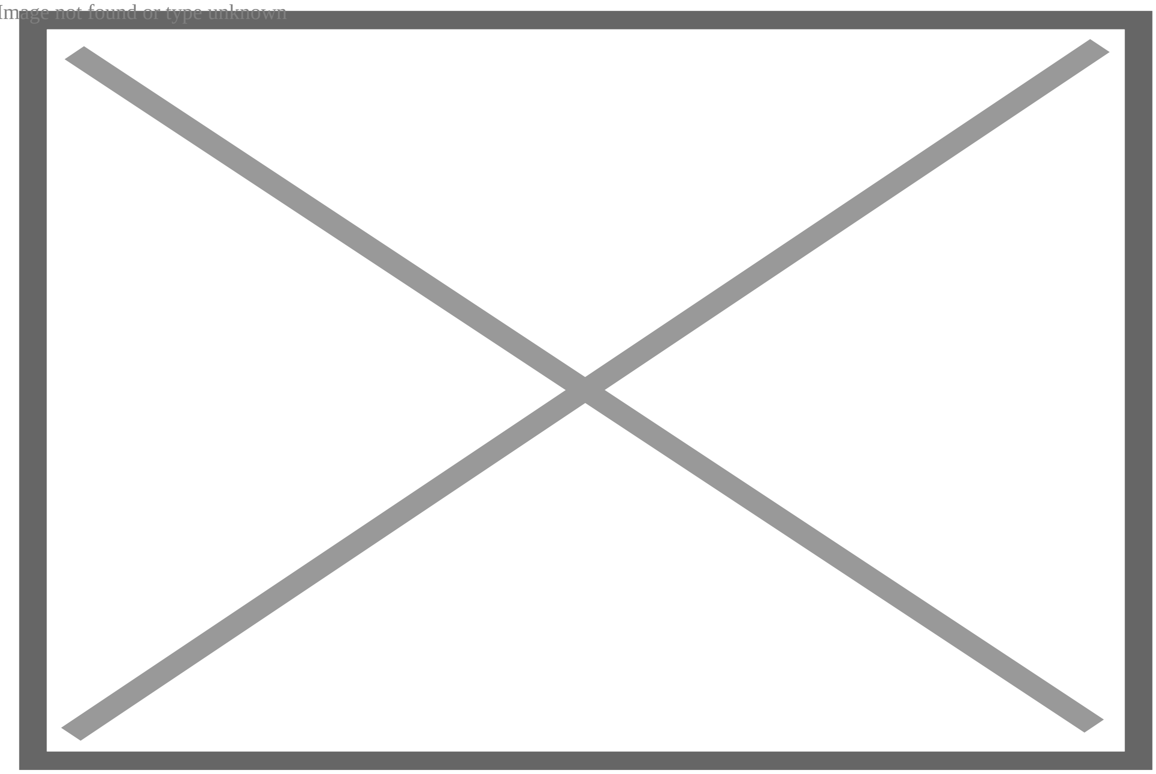

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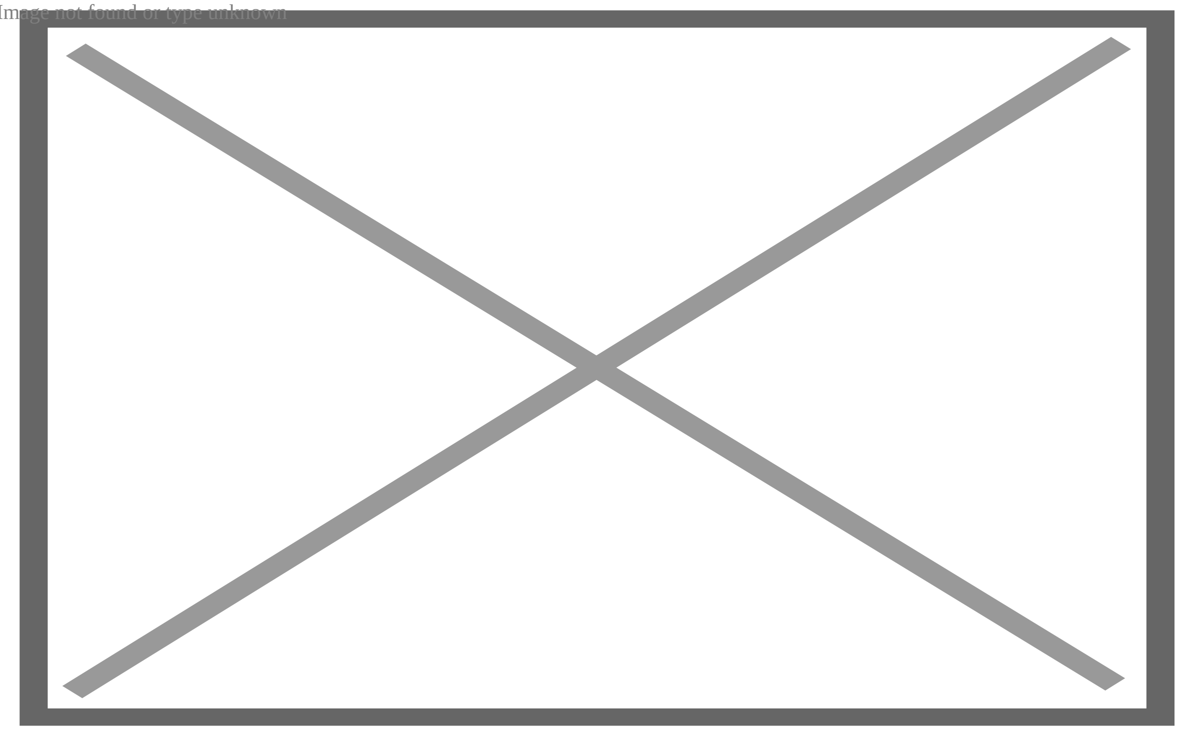

Source: Environmental Technology Best Practice Programme (1998)

Environmental benefits

Three main benefits resulting from the use of environmentally-friendly cleaning operations have been identified. Water can be saved through the use of CIP systems, electrochemical activation (ECA) and by replacing this with other chemicals such as in 'Green CIP' methodologies. Such cleaning methods also result in significant reduction of energy use; for example, this can be done by switching to lower temperature methods. Chemical usage can be reduced through the use of ECA and CIP systems, this can also be achieved by re-using such detergents.

In addition, certain forms of environmentally-friendly cleaning, notably CIP, have the added benefit of reducing the wastage of food - both raw materials and end products - and packaging associated with the starting up and slowing down of production.

Best reported water savings

The South African brewing company **SABMiller** trialled a new CIP system which uses ECA instead of detergent and disinfectants at its 'Chamdor' brewery. The result was an 83% reduction in water use (WRAP, 2012).

In 2007 **Kraft Foods** – now part of the multinational food and beverage conglomerate **Mondel?z International** – implemented an optimised CIP system, along with other innovations such as the re-use of production waste water, at its Vegemite factory in Australia. The project reduced overall water use by 39%, with the optimised CIP alone cutting annual water consumption by 11.8 million litres with the equivalent reduction in waste water needing to be treated (EPA Victoria, n.d.).

The 'Green CIP' method which has been used by **Actalis** and **Danone** results in up to 50% water savings by replacing the use of water with that of a hot alkali for initial pipe flushing (Utilities Performance, 2014, pers.comm.).

Best reported energy savings

According to the **Innovation Center for U.S. Dairy** more than half of an average[1] milk processing plant's annual energy use of 27,500 million BTUs (British Thermal Units)[2] is devoted to cleaning equipment and pipes to meet necessarily stringent sanitation standards. In 2010-11, the Center began piloting a new lower temperature cleaning technique which cuts fuel and greenhouse gas emissions by 15%, uses less rinse water, and produces less alkaline effluent (Innovation Center for U.S Dairy, 2010).

In addition to the substantial water savings noted above, **SABMiller**'s ECA system at the 'Chamdor' brewery cut energy use by 98% (WRAP, 2012).

The use of biological agents instead of traditional detergents can lower the energy consumption associated with cleaning. Recent work in Ireland, for instance, has identified several enzymes extracted from fungi as potentially suitable for environmentally friendly CIP in the dairy industry. Lab tests showed that the enzymes removed industrial-like milk fouling deposits from stainless steel at the relatively low temperature of 40°C (versus conventional CIP methods which use caustic-based cleaning solutions such as 0.5 to 1.5% sodium hydroxide at 70-80°C). The researchers report that, when scaled up, the enzymatic CIP procedure would cut energy consumption, decrease chemical usage and reduce the requirement for pH neutralisation of the resultant waste prior to release (Boyce & Walsh, 2012). Similar findings, again in the dairy sector, are reported from experiments carried out in India with enzymes derived from bacteria (Paul et al., 2014).

Within the Italian wine sector, the use of ozone in a non-CIP system is being promoted. The following advantages have been reported (Tebaldi, 2014, pers.comm.):

- no residues are left;
- the consumption of water used in the cellar is lowered and the parameters of wastewater are improved (NB the company also recovers washing water enabling it to save up to 80% of the water used to wash bottles)
- toxic chemical sanitisers are no longer required reducing risks to human and environmental health;
- energy savings in all phases of sanitisation;
- time and personnel costs savings, as to sanitise a bottling system takes only a few minutes;

- reduction in waste; and,
- resistant microbial strains are not produced.

The ‘Green CIP’ method which has been used by **Actalis** and **Danone** results in a reduction on energy consumption by up to 50% because (Utilities Performance, 2014, pers.comm.):

- waste water treatment is no longer required, and
- the pipes are no longer cooled down with the initial cold water flush and thus no longer need heating up again when production resumes after cleaning (this also saves time which is critical from a financial perspective).

Best reported chemicals savings

SABMiller’s ECA system at the ‘Chamdor’ brewery cut the cost of the chemicals by 99% (WRAP, 2012).

Coca-Cola realised similarly substantial chemicals savings after introducing ECA to the CIP system at its Atlanta Beverage Base Plant (ABBP) in the USA, reducing chemicals usage by 84%. CIP had already cut water use during cleaning by 1,500 gallons per cleaning cycle (WRAP, 2013b).

The German brewer **Gutmann** has been working to optimise CIP at its facility lowering the use of caustic detergent by 30% and acid detergent by 24% (GEA Brewery Systems GmbH, 2010). The optimisation also realised an 18% saving in water use and substantial savings in electricity consumption (Figure 3).

Figure 3: Electric power consumption per CIP process at the Gutmann brewery, Titting, Germany

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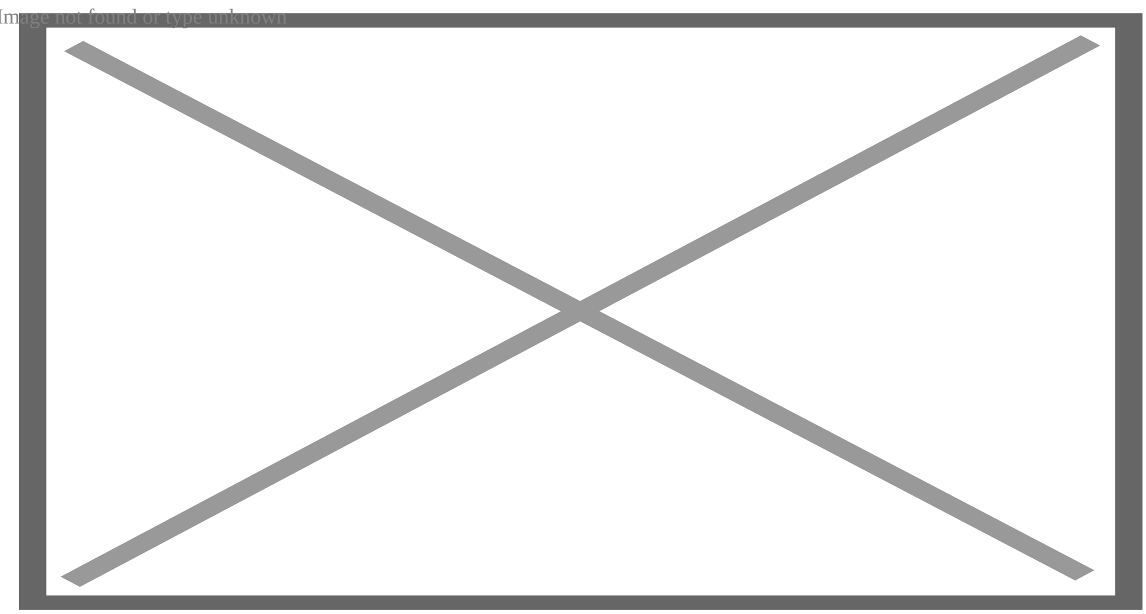


Source: GEA Brewery Systems GmbH (2010)

The **Taw Valley Creamery** in Devon, UK, achieved annual savings of 56 m^3 of 60% nitric acid and 2,750 m^3 of borehole water after starting to collect and re-use the acid and water used to clean an evaporator in the plant. A conductivity probe was fitted to monitor the recovered acid's strength and a flow meter fitted to control acid dosing for the next clean. As well as reducing chemical use, the innovation improved the performance of the effluent treatment plant (as it did not need to deal with the acid) and the consistency of the acid dosing process within the cleaning cycle. The payback period was just over a year (Environmental Technology Best Practice Programme, 1998).

The ‘Green CIP’ method which has been used by **Actalis** and **Danone** results in a reduction in caustic soda use by up to 90% because the same detergent can be re-used multiple times (Utilities Performance, 2014, pers.comm.).

Ice pigging method

There are a number of environmental savings offered by ice pigging (University of Bristol, 2014, pers.comm.: Carbon Trust, 2015):

- Reduction in food wasted – approximately 80% of the material stuck to the pipes which would have been lost to effluent is recovered and sold on
- Reduced water use during the cleaning process by replacing pre-CIP rinse and therefore reduced effluent production
- Reduction in BOD of effluent – which in turn reduces energy and chemical inputs in pre-treating effluent prior to discharge
- Reduction in the use of detergents (such as caustic soda) for cleaning pipes as far more of the food has been removed prior to use; the reduction in caustic soda use also reduces the problem of ‘saponification’ when the soda reacts with fat residues in the pipe

[1] ‘average’ defined here as processing 25 million gallons milk (c. 114 million litres) per year

[2] Approximately 29 million megajoules

Side effects

While CIP systems are generally efficient in terms of water and energy use, they can result in the discharge of highly-polluted effluents as well as relying on potentially toxic disinfectant chemicals which produce hazardous by products. The use of ozone or ECA in CIP may, however, reduce these impacts.

The use of a molecular sieve in ozone generators separates pure oxygen from other gases in the atmosphere. This prevents the generation of by-products, such as nitrogen oxides and other substances that can be very toxic or lead to uncontrolled or unknown reactions (Tebaldi, 2014, pers.comm.).

The use of ice pigging increases the energy use due to the ice production process. However, this is counter-balanced by the many environmental benefits of implementing such a method (Carbon Trust, 2015)

Applicability

This best practice is applicable to all food and beverage manufacturers. The purpose of cleaning is to safeguard the quality and safety of food and drink products so, any changes to cleaning regimes or techniques must ensure that all relevant standards continue to be met.

Cleaning systems need to be tailored to the individual situation since many factors must be considered including the design of the process, the scale, the type of product, available budget and so on. Not all the techniques and savings discussed above are universally available; for instance, CIP systems are not generally suitable for cleaning 'open' vessels (Environmental Technology Best Practice Programme, 1998).

For smaller manufacturers, substantial investment in the latest, most sophisticated technology may not be warranted by the relatively small financial savings available to them. For instance, the example of the brewer **Adnams** referenced above required the re-installation of pipework and tanks in a new material, stainless steel, which may be beyond the economic scope of smaller manufacturers. Similarly, retrofitting of plants to introduce CIP in the first place may not be feasible (WRAP, 2012).

Economics

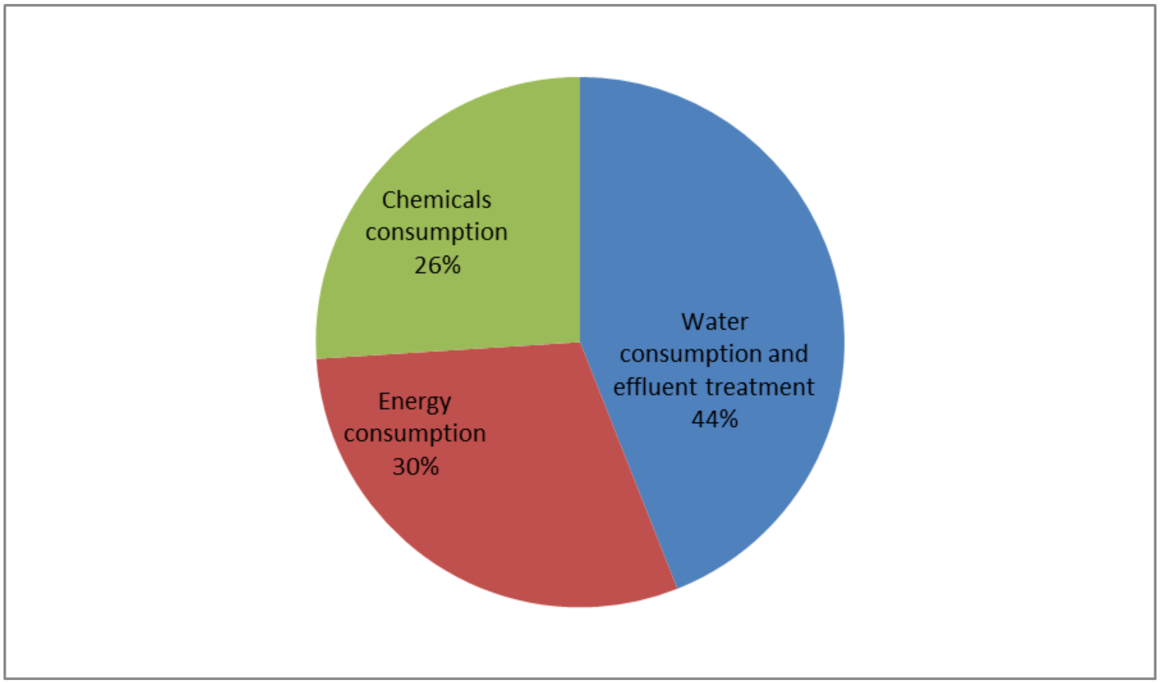
General points

Advanced cleaning techniques, especially CIP, offer manufacturers several economic benefits including:

- cutting the considerable costs of downtime (see below)
- cutting the cost of energy, water, chemicals and effluent treatment
- cutting the cost of food waste which might otherwise have arisen during production interruptions
- reduction of labour requirements.

Excluding labour costs and lost product costs, Figure 6 shows the typical breakdown of cleaning costs, suggesting that opportunities to cut water should be a priority.

Figure 6: Costs associated with cleaning at a food and drink manufacturing plant



Source: Environmental Technology Best Practice Programme (1998)

CIP requires substantial upfront investment in both new equipment and in the training of staff on the new and often complex systems. The project discussed above to install a CIP system at **Kraft**'s Australian 'Vegemite' factory took a reported four years and AUD 3.2 million of investment (approximately EUR 2.3 million), although due to the large production volume, the payback period in this case was relatively short at just three years (WRAP, 2013).

Optimised control of CIP

Once CIP systems are installed, however, improvements can be relatively inexpensive and yield significant further gains. According to The Brewers of Europe, Vienna's **Ottakringer** brewery optimised its CIP to lower chemical in the effluent 'without significant investment' (The Brewers of Europe, 2012). Less recently, **Coors Brewing Ltd** upgraded its CIP at its Burton-on-Trent plant in the UK with programmable logic controller (PLC), variable speed pumps and updated software allowing CIP operations to be customised in terms of time, volume, pump speed and chemical dosage. The changes saved GBP 42,000/yr (about. EUR 50,000) in chemical, water, effluent and electricity costs. Further improvements to road tanker CIP cut an additional GBP 3,000/year (about EUR 3,750). Within 41 months the investment had been recouped (Envirowise, 2006).

Substantial savings from environmentally friendly cleaning are available in other subsectors beyond brewing. For instance, the technology company Siemens claims that its 'SIMATIC PCS 7 system' for flexible and precise CIP, when installed in dairies, can reduce costs by up to 30% (Siemens, n.d.).

Ozone cleaning

Other forms of sustainable cleaning discussed above can also incur significant upfront costs. For instance, the **OzoneCIP Project** (2007) lists the following equipment as necessary for implementing an ozone-enriched CIP system whose costs will depend on the precise installations to be cleaned:

- gas feed preparation system,
- ozone generator,
- injector,
- reaction tank,
- dissolved ozone measurement device,
- ambient monitoring device,
- residual ozone destructor for the reaction tank and out-gassing system,
- control unit
- circulation pump.

However, the savings from the significantly reduced consumption of energy, water and chemicals - and potentially lower local costs and taxes associated with reduced effluent levels - may help offset these. In addition, the ozone equipment has relatively low maintenance costs (OzoneCIP Project, 2007).

The estimated cost of bottle washing is EUR 2 per cubic metre of water consumed, when this is carried out with chemicals (Tebaldi, 2014, pers.comm.). Table 5 shows the polluting power and volume of discharges over a year for a typical winery with an annual wine production of 20000 hl. Given that this process uses 8395 m^3/yr, switching to ozone would save EUR 16800 each year. Further knock-on savings would be available from avoiding the need to clean effluent prior to flushing it into the municipal sewage system which normally involves significant quantities of energy and disinfectant.

Table 5: Water consumption and pollution levels in a winery

Source: Adapted by Tebaldi from Farolfi (1995)

Similarly, the industrial scale use of biological cleaning agents, such as enzymes, in food and beverage manufacturing is not anticipated to be any more expensive than using traditional CIP chemicals such as sodium hydroxide or caustic formulated detergents and offers substantial energy and water-related cost savings (Boyce & Walsh, 2012)

Regeneration of caustic soda, 'Green CIP'

Installation costs for Green CIP equipment are broadly equivalent to those which a food and beverage manufacturer would otherwise have spent on building an on-site wastewater treatment plant. However, the regeneration of caustic soda offers substantial additional financial benefits as a result of (Utilities Performance, 2014, pers.comm.):

- shortening the downtime by between 5% and 20% due to a faster cleaning process, so increasing productivity and revenue accordingly
- the reduction in caustic soda requirements
- cutting energy consumption
- cutting water consumption
- lower taxes due to avoiding discharge of effluent to sewage plants
- subsidies for installing the equipment

Operation type	Duration	Waters used		BOD_5	Equivalent population
	d	$m^3\ d^{-1}$	$m^3\ year^{-1}$	$kg\ d^{-1}$	n.
Cleaning of premises and equipment	30	20	600	4,8	99
Must defecation	3	3,6	10,8	104	3600
Cleaning of defecation tank	2	4,1	8,2	14,7	271
1st transfer	2	3,6	7,2	296	5466
Tank cleaning after 1st transfer	3	4,1	12,3	24,9	462
2nd transfer	2	4,1	8,2	46,7	865
Tank cleaning after 2nd transfer	5	2,4	12	6,7	123
Bottles washing	365	23	8395	0,4	10
Total water			9053,7		

Ice pigging

The cost of using ice pigging has not yet been determined since only a few sectors have been implementing this technique. However the process' inventor reports that the method offers food and beverage manufacturers significant financial savings (University of Bristol, 2014). These include:

- Of the food product which would previously have been lost in the effluent, 80 % can be recovered for sale. This can translate into huge savings depending on the value of the product being recovered. For instance, a factory making cream or butter might be able sell recovered product for up to EUR 2 per litre.
- Reduction in downtime during the CIP process from around 30 minutes to about 10 minutes, which translates into extra production time and substantially increased revenue.
- Reduced use of chemicals and water and their associated costs for supply and disposal.

A recent Carbon trust case study on the use of ice-pigging in the dairy industry demonstrated that the payback time for its installation in a custard-like product production line of batches of 500 litres is between 1.6 and 2.2 years. The calculations take into account the capital costs for the installation of the plant and also the operational ones (including increased energy consumption) (Carbon Trust, 2015).

Minimising or avoiding the use of chemicals

The cost of cleaning operations when avoiding or minimising the use of chemicals has been demonstrated not to generate extra costs for the company, compared to traditional cleaning (Lebensbaum, 2015 pers. comm.).

Driving forces for implementation

The opportunity to reduce costs, especially those associated with energy, cleaning chemicals, water and, above all, downtime, is likely to be among the greatest drivers for adoption of this best practice. An indication of the financial impact of downtime is given in Lea (2012) which reports that for one Italian snack food company production costs were EUR 3500 per hour. Emerson Industrial Automation (n.d.) puts downtime costs for the food and beverage industry at between USD 20000 (about EUR 15000) and USD 30000 (around EUR 23000) an hour. Higher estimates still have been reported, varying from USD 44000 (around EUR 34000) per hour to as much as USD 1.6 million (around EUR 1.2 million) per hour for some businesses (Marathon, 2010), although these higher figures may apply to non-food manufacturing.

With water, a double financial savings benefit can be gained in that manufacturers can not only cut the costs of water consumption but also those of treating waste water effluent prior to discharge to municipal sewage systems.

It should be borne in mind, however, that the 'true' value of water is typically underestimated in its monetary cost, so water prices are currently not yet thought to be a major motivating factor. Some companies nevertheless recognise that future water scarcity is likely to change this situation and, to hedge against such risks, are already assigning higher notional values to water when considering investment in new equipment (Nestlé, 2014, pers.comm.).

Regulatory compliance is also likely to play a role as manufacturers are legally required to 'clean up' effluent prior to discharge. Thus, any strategy to reduce the volume and toxicity of effluent is favoured. Local environmental enforcement agencies can also play a mentoring role in motivating best practice, with the innovations at the **Kraft Foods** 'Vegemite' factory in part encouraged by Environment Protection Authority Victoria (EPA Victoria, n.d.).

Voluntary agreements and initiatives have also been demonstrated to motivate the implementation of sustainable cleaning operations in the sector. A good example from the UK is the Food and Drink Federation's Federation House Commitment (FHC), a voluntary agreement sponsored by WRAP (Waste & Resources Action Programme). One signatory to FHC is **Tulip**, a British meat processor, which used 7.1% less water in 2011 than in 2010. Environmentally friendly cleaning delivered some of the water efficiency improvements, with 20m^3/day saved through amended cleaning-in-place systems. The company's goal is to cut water use by 15% by 2015 (Product Sustainability Forum, 2013d).

The need to maintain product quality and safety are additional drivers for minimising the use of water cleaning products which can sometimes be viewed as contaminants. This is certainly the case in the manufacture of dry products such as soluble coffee, chocolate powder, milk powder and so on (Nestlé, 2014, pers. comm.). In general, the best manufacturers seek to rapidly clean up water spillages, and ideally to avoid them in the first place so as to prevent the build-up of pathogens (Chilled Food Association, 2014, pers.comm.).

Product quality is also sometimes a driver for the adoption of novel cleaning methods. For instance, in Australia, ozone is used successfully on an industrial scale as an alternative to chlorine for disinfecting the oak barrels used for ageing the wine. The ozone is preferred not only for being more effective than chlorine at controlling certain microbial species that cause defects in the wines but also because it avoids the presence of substances such as trichloroanisol which cause cork taint problems (Canut & Pascual, 2007).

Reference organisations

The following companies have implemented different practices described in this BEMP:

- Actalis – introduced green CIP
- Adnams – incorporated a review of cleaning protocols within their equipment design

- Cantine Vini Armani – uses the O-TRE ozone generation system
- Casa Vinicola Canella – uses the O-TRE ozone generation system
- Coca Cola – uses Electrochemical Activation (ECA) in its CIP system instead of detergent and disinfectants
- Coors Brewing Ltd – developed a customisable CIP system.
- Danone – introduced green CIP
- Gutmann – undertook an initiative the lower caustic detergent use.
- Kraft Foods (Mondel?z) – Introduced an optimised CIP system
- ÖkoClean100- provider of green chemicals and green cleaning operations
- Ottakringer– Introduced an optimised CIP system
- SABMiller – uses Electrochemical Activation (ECA) in its CIP system instead of detergent and disinfectants
- Schneider Weisse
- Tenuta Pakravan Papi – uses the O-TRE ozone generation system
- Tulip – undertook a water reduction programme focussed on its cleaning processes
- Vini de Tarczal – uses the O-TRE ozone generation system

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