DANISH TECHNOLOGICAL INSTITUTE

Report

8 December 2022
Proj.no. 2008770
Version 6
AGLK/MT/EMMP/KSOR/TJAN

Project: Cleaning with less water

Evaluation of microbial risk when using process water for cleaning (pre-rinse)

Anette Granly Koch, Karen Sørensen og Emma Bilsted Petersen

Summary

Aim

The aim of this report is to collect information for risk analysis if process water is to be used for pre-rinse. And to prepare small initial generic risk analyses on the food safety if process water from different sources is to be used for pre-rinse in the daily cleaning in the meat industry.

Conclusion

In conclusion, process water can be used for pre-rinse. However, care must be taken to document that the use will not affect food safety, shelf life or the quality of the cleaning process (microbial or ATP results). Therefore, a risk analysis must be made in each case describing the water source, storage, and intended use, as part of the basis for decision making.

The basis of decision making when applying the use of process water for cleaning purposes includes the following activities:

- Cost benefit analysis – business case
  - Water prices, including heating costs
  - Wastewater treatment costs
  - Estimated technology investment incl. distribution and CIP-costs
- Theoretical risk analysis (microbial, chemical, physical)
  - Regulatory barriers (legislation, customers)
  - Describe water quality
  - Describe intended use
    - Initial cleaning (floors, conveyers, equipment, stable, etc.)
- Baseline study – microbial, visual, chemical
  - Water quality from the source process
  - Water quality demand and environment in the place of reuse
- Design the process water treatment (technology partner)
  - Treatment steps to obtain the water quality demanded
  - Distribution system layout
- Evaluate the process
- Microbial analysis of the new process (the surfaces after cleaning)
- Update the risk analysis
- Monitoring water quality
  - How and where?
  - Online measuring versus lab analysis
- Update the cost benefit analysis – business case

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Introduction

Aim

The aim of this report is to collect information for risk analysis if process water is to be used for pre-rinse. And to prepare small initial generic risk analyses on the food safety if process water from different sources is to be used for pre-rinse in the daily cleaning in the meat industry.

Background

It is estimated that 30% to more than 50% of the 'cleaning water' is used for initial cleaning, when organic material is removed in slaughterhouses. Water is essential in cleaning operations and is required for rinsing off gross soils before cleaning as well as removing detergents after cleaning. Furthermore, water is the primary solvent for the chemicals used during cleaning. Large quantities of water are used for cleaning equipment during production, and not least the final cleaning and disinfection. Only potable water/drinking water can be used for these purposes, as stated in the legislation.

Reuse of process water can reduce the volume of used potable water, but treatment of the process water is necessary to meet the legal standards for water quality, that is "Fit for purpose" (DRIP, 2016).

Process water can be used in the food industry instead of potable water if it does not pose a risk of contaminating the end products. The quality of the reused water (process water) must be like potable water unless the company can demonstrate that there is no risk to food safety of the final product, which should be accepted / approved by the competent authority (Europa-Parlamentets og Rådets forordning (EF) nr. 852/2004 af 29. april 2004 om fødevarehygiejne, kap. VII stk. 3).

This report is a risk-based discussion on the water quality needed for cleaning in different areas in meat factories. The suggestions on the use of process water for cleaning refers only to the step "pre-rinse with water". In all other sanitation steps, water of drinking water quality shall be used. This must be ensured by the management of the cleaning process (e.g., special colour for cleaning hoses using process water).

In some cleaning processes, water is already recirculated, e.g., in machine washing equipment and tools or in CIP (Cleaning In Place). This is possible due to conditions in the individual cleaning steps that prevent microbial hazards from occurring, e.g., temperature and pH of the water containing the cleaning agent.

Water of drinking water quality is used in various processing steps in the meat industry. These include cleaning intestines, chilling autoclaved cans, rinsing robots, cooking, chilling heat-treated products, rinsing carcasses with hot water, etc. This water might be reused in the same process or other processes. The reuse demands water treatment technologies to different extents. For each case, a risk analysis must be made as the demand depends upon:

- The specific product – where in the process line, the intended use
- The technology used for water treatment and storage
- The time – production time, storage of water for reuse

- Aesthetics – smell, visual appearance

Examples on reuse of process water

- Cleaning intestines.
  Intestines are cleaned using several rinsing steps. For the final rinse of beef tripes and omasums, hot water (82-85°C) is used. And from pig slaughtering, for the final rinse of trays carrying plucks/intestines, 82°C hot water is used. This water can be used for the first pre-rinse removing faecal matter. Then several steps follow where potable water is used and finally a rinse using hot water. The water might also be used for pre-rinse of conveyer belts and trays before rinse and final disinfection with hot water. The water is kept in the same process, and the number of bacteria in the hot water (last rinse) is negligible compared to the high number of the same hazards in the intestines before the rinse.

- Hot water for heating sausages.
  In a hot dog stand, hot water is reused the entire day to heat the sausages. The water is kept at a temperature that inactivates vegetative bacteria and virus. However, proteins, colour, fat, flavour, and spores are concentrated in the water during the day. Based on a risk analysis, no chemical nor microbial risks have been identified, as the heated meat product is of high microbial quality, and no chemical hazards are added to the water from the sausages. Furthermore, the high temperature ensures no propagation of bacteria during the day. Water is always dumped after one day's use.

- Decontamination of carcasses with hot water.
  The water is filtrated to remove large particles, followed by flocculation for removal of small particles. The high temperature of 75°C inactivates vegetative bacteria. Spores are not inactivated. The water is kept in a closed system.

Examples of reuse of brine

- Curing by injection.
  Fresh brine is produced regularly with total counts below 1 cfu/ml and at temperatures below 5°C. During the day, brine is recirculated, and fresh brine is added. The total count in the recirculated brine is lower than the count found in the meat used in the process. The microbes added to the brine are the same as found in the meat. The low temperature in the brine reduces growth. Protein and fat are concentrated; however, it is the same quality as found in the meat used in the process.

In the DRIP project, best practice to minimise water consumption and wastewater emissions at slaughterhouses were listed. For cleaning, the following was suggested (DRIP, 2016).

Technologies described to reduce water consumption in the cleaning process (DRIP, 2016):

- Apply dry cleaning on areas and floors before washing (dry scrape, sweep up and/or vacuum solid materials) (PPI, 2002; UNEP, 2008).
- Reuse final rinse cleaning water from the previous day for initial rinse on the next day (UNEP, 2008).

- Standardisation of cleaning procedures with rational use and use of water meters at inlet and outlet (section/process) (Kist et al., 2009).

Technologies described to reduce water consumption in cleaning process (DRIP, 2016):
- Install high pressure, low volume spray or jet nozzles with low wear, e.g., hardened stainless steel (PPI, 2002). Have been tested in this project, see the Catalogue of ideas (Bildsted Pedersen, 2022).
- Use mechanical washers for tubs, cutting boards and trays (PPI, 2002).
- Use floor machines to clean large flat areas (e.g., floors) (PPI, 2002).
- Use time-controlled flow systems (hand wash stations and tool sterilisers) (UNEP, 2008).
- More ideas are presented in the catalogue of ideas (Bildsted Pedersen, 2022).

Legislation

Cleaning procedure

Legislation on the quality of water used for cleaning is not clear. The legislation states that cleaning and disinfection must ensure that hygiene is acceptable, and food is not contaminated (kap. 19.1, VEJ nr. 9866 af 27. juni 2022, Vejledning om fødevarehygiejne). The Danish legislation states that only water of drinking quality must be used for cleaning in the food industry (Europa-Parlamentets og Rådets forordning (EF) nr. 852/2004 af 29. april 2004 om fødevarehygiejne). Further reading in Appendix 1 (in Danish).

The EU regulation (EC) 852/2004 on the hygiene of foodstuffs states that there must be an adequate supply of potable water, which is to be used whenever necessary to ensure that foodstuffs are not contaminated. However, it also says that recycled water used in processing or as an ingredient is not to present a risk of contamination. It is to be of the same standard as potable water, unless the competent authority is satisfied that the quality of the water cannot affect the wholesomeness of the products in its finished form (Holah, 2012). This suggests that food manufacturers could promote sustainable water use if they can safely reuse water instead of potable water.

Reuse of water for food processing is also discussed by the Codex Alimentarius Commission (1999). Some general guidelines are presented, and as examples on the reuse of water in meat and poultry processing these topics are discussed:

- Reuse of cooking or chilling water used for packaged ready-to-eat products.
- Recirculation of water used to wash raw meat and poultry products.
- Use of reconditioned water.

In general, Codex Alimentarius describes that no raise in the level of contaminants must take place, and that the water must be free of pathogens.

The current Danish regulation for potable water sets the minimum standard for water quality and composition (Bekendtgørelse om vandkvalitet og tilsyn med vandforsyningsanlæg – BEK nr. 1068 af 23/08/2018 opdateret version BEK nr 2361 af 26/11/2021). The requested microbiological standard for water quality is listed in Table 1.

Table 1. Requested microbiological standard for potable water (Bekendtgørelse, 2021).

Parameter	Limit in potable water	Ref[2)]
Coliform bacteria	Not detectable in 100 ml	Bilag 1c
Escherichia coli (*E. coli*)	Not detectable in 100 ml	Bilag 1a
Aerobic colony count, 22°C	200 cfu/ml	Bilag 1c
Enterococci	Not detectable in 100 ml	Bilag 1a
Clostridium perfringens, incl. spores[1)]	Not detectable in 100 ml	Bilag 1c

[1)] Only test if there is a risk of surface water (overfladevand) in the drinking water. Indicator for pathogens, e.g., *cryptosporidium*

[2)] Where in BEK nr 2361. Bilag 1a=microbial parameter. Bilag 1c= indicator organisms

cfu = colony forming units.

The step for approval to reuse water

If food business operators wish to reuse water, they must demonstrate, that there is no risk of contaminating the final products, which should be accepted / approved by the competent authority. This must be described in an application and contain this information:

- Where does the water come from?
- What is the quality of the water?
- Where should the water be used?
- What quality must the water have?
- How is the water treated to achieve the quality needed?
- How is the water stored before use?
- How is the control of the reused water (self-control program, monitoring quality, validation, verification, cleaning of the new water reuse system, etc.)?
- Can the water be contaminated with substances that might cause a risk?
- Etc.

Preliminary literature study on the reuse of process water for cleaning

A limited number of scientific papers on the reuse of process water are available. Most papers focus on how to treat wastewater. For example, the review by Bustillo-Lecompte & Mehrvar (2015) describes the characteristics, treatments, and management of wastewater in the meat industry.

Requirements to quality of process water for reuse

Mavrov et al. (2001) investigated the possibilities of treating process water from vapour condensate in a milk processing company, and chiller shower water from a sausage production to comply with the requirements of boiler make up water and warm cleaning water. These water types are in industrial settings typically produced by treating drinking water to the required composition, with less salts and minerals than the raw drinking water. Mavrov et al. (2001) showed that it was possible to use another source of water than potable water for such purposes (Table 2). However, it was not defined, in which cleaning purposes the treated process water was to be used.

Table 2. Requirements (selected parameters for treated low-contaminated process water for reuse in various areas of application (Mavrov et al., 2001)).

Parameter	Boiler make-up water[1)]	Warm cleaning water	Drinking water
pH	-	6.5-9-0	6.5-9.0
E. conductivity, µS/cm	<40	<200	<2000
COD, mg O_2/l	<10		$KMnO_4$ < 5 mg/l
TOC, mg O_2/l	<4	<4	<4
Ca^{++}, mg/l	<0.4	<1	<400
Colony forming units/1 ml	-	<100	<100[2)]
Escherichia coli/100 ml	-	Not detectable	Not detectable
Coliform bacteria/100 ml	-	Not detectable	Not detectable

[1)] Circulation boilers with operating pressure <68 bars.

[2)] In Denmark, the requirement is 200 cfu/ml.

Guidelines on recycling water

Avula et al. (2009) describe that according to the USEPA (2004), reconditioned water is allowed to replace potable water in the chilling step (products are not described) in certain predetermined ratios based on a percentage of reduction of microorganisms and improvement in light transmission values of reconditioned water. The water can also be reused for moving heavy solids in eviscerating troughs, scalding tanks, feather flow aways, picker aprons and for washing the picking room floor. In these cases, the authors recommend that the establishment monitors the quality of reused chiller overflow water by analysing coliforms, *Salmonella,* and *Staphylococcus aureus.* The guidelines on the quality of reconditioned water are listed in Table 3.

Furthermore, Avula et al. (2009) state that the basis for approving the use of recycling water requires:

1) Approval of reconditioning equipment and conditions for use.
2) Reconditioned process water must be treated and stored to obtain at least a 60% reduction in total microbial count, and the reduction in coliform bacteria (*E. coli* or *Salmonella* sp.) must be within 60% ± 10%. NB: this is a low reduction compared to the work conducted in the Danish DRIP project. 60% reduction in microbes is less than 1 log reduction, and if high numbers are found in the process water, this might not be enough.
3) Light transmission of treated water must be at least 60% of that of fresh water (drinking water quality) used in the process meaning that the water must not be too coloured or turbid.
4) Water that has been in contact with raw products may not be used on "ready-to-eat products".
5) Process water that has never contained human waste and has been treated by an onsite advanced wastewater treatment facility may be used on raw products, except in product formulation, and throughout the facility in edible and inedible production areas, if measures are taken to ensure that the quality of water meets the requirements (USDA, FSIS, 1999 cf. Avula et al., 2009).

Table 3. Reconditioning guidelines for chiller water (USEPA 2004 cf. Avula et al., 2009).

Reduction in microorganisms (%)	Light transmission (%)	Volume of reconditioned water to 1 l of fresh water
60	60	1.75
70	70	1.50
80	80	1.35
90	80	1.25
98	80	1.10

Reconditioned water is allowed to replace potable water in the chilling step in certain predetermined ratios based on a percentage of reduction of microorganisms and improvement in light transmission values of the reconditioned water.

USDA sanitation standards for re-use of water

The Sanitation Performance Standards Compliance Guide (USDA) describes that:

- water, ice, and solutions (such as brine, liquid smoke) used to chill or cook ready-to-eat products ***may be reused for the same purpose***, provided that they are maintained free of pathogenic organisms and faecal coliform organisms and other physical, chemical, and microbial contamination that have been reduced to prevent adulteration of the product.

- water, ice, and solutions used to chill or wash raw products ***may be reused for the same purpose***, provided that measures are taken to reduce physical, chemical, and microbial contamination so as to prevent contamination or adulteration of the products. Reused water, which has come into contact with raw products, may not be used on ready-to-eat products.

- Reconditioned water that has never been in contact with human waste and has been treated by an onsite advanced wastewater treatment facility may be used on raw products, except in product formulation, and throughout the facility in edible an inedible production area, provided that measures are taken to ensure that this water meets the criteria for potability of the water supply.

- Any water that has never contained human waste and is free of pathogenic organisms may be used in edible and inedible product areas, provided it does not contact edible product. For example, such reused water may be used to move heavy solids, flush the bottom of open evisceration troughs, or to wash antemortem areas, livestock pens, trucks, poultry cages, picker aprons, picking room floors and similar areas in the establishment.

The USDA guidelines on the reuse of water (cf. Jaffe) describes that the technology used must ensure:

- Total plate count: 500 cfu/ml or less.
- Total coliform: zero.
- Faecal coliform: zero.
- Turbidity: 5 NTU or less (NTU = Nephelometric turbidity units).

In Table 4, examples of water reuse and control analysis recommended by USDA are shown. Daily and weekly analyses are recommended depending on the intended use and the specific analysis.

Table 4. Guidelines (USDA) for controlling the quality of water for reuse

Reuse step	Analysis	Frequency	Action level
Chilling water reuse	Total plate count	daily	>500 cfu/ml[a)]
	Total coliform	weekly	positive
	Faecal coliform	weekly	positive
	Turbidity	weekly	>5 NTU
Cooking water	Total plate count	daily	>500 cfu/ml
	Gas forming anaerobes	weekly	positive
	Total coliform	weekly	positive
	Turbidity	weekly	>5 NTU
Chiller overflow water reuse	Total coliform	weekly	positive
	Faecal coliform	weekly	positive
	Salmonella	weekly	positive
	Staphylococcus aureus	weekly	positive
Condenser or compressor water reuse	Total plate count	weekly	>500 cfu/ml
	Total coliform	weekly	positive
	Faecal coliform	weekly	positive
	Turbidity	weekly	No samples >5 NTU
Reuse water to flume chicken feet (paws)	Total coliform	weekly	positive
	Faecal coliform	weekly	positive
	Salmonella	weekly	positive
	Staphylococcus aureus	weekly	positive
Reuse water to be used to wash livestock pens, trucks, poultry cages, and similar areas	Total coliform	weekly	positive
	Faecal coliform	weekly	positive
	Salmonella	weekly	positive
	Staphylococcus aureus	weekly	Positive
Reuse water from an advanced wastewater treatment facility	Total plate count	daily	>500 cfu/ml
	Total coliform	daily	positive
	Faecal coliform	daily	positive
	Turbidity	daily	>5 NTU
	Total organic carbon (TOC)	daily	>100 mg/l
	Physical analysis	daily	
	Chemical analysis	daily	
	Heavy metals	once a year	See legislation

a) In the Danish DRIP project, we have a limit at 200 CFU/ml.

Different technologies can be used to treat water before reuse. The choice of treatment depends on the first use of the potable water and the intended use in the next step. In the Guideline by Campden, an overview of different technologies for appropriate water treatment for specific hazards are listed (Holah, 2012). A copy of this overview is shown in Appendix 2.

In the Danish DRIP project, the limit for total viable count was set to 200 cfu/ml as the limit for potable water. In the USDA, 500 cfu/m is suggested.

Guideline on HACCP analysis

In Guideline no. 70 by Campden (Holah, 2012), the reuse of potable water for food processing operations is discussed. The guideline gives examples on how hazard analysis and risk assessment can be used to determine the necessary re-conditioning of potable water from its first use in the food processing operation, to allow it to be reused in a second food processing operation in lieu of potable water.

The steps used in the HACCP are (Holah, 2012):

- Preparatory stage 1: Obtain management commitment.
- Preparatory stage 2: Define terms of reference/scope of the study.
- Preparatory stage 3: Select the water reuse assessment team.
- Preparatory stage 4: Describe the first use of water.
- Preparatory stage 5: Identify the intended use.
- Preparatory stage 6: Construct flow diagrams.
- Preparatory stage 7: On-site confirmation of flow diagram.
- Stage 8.1: List the potential hazards (microbiological, chemical, physical).
- Stage 8.2: Conduct a hazard analysis.
- Stage 8.3: Identify appropriate control measures.
- Stage 9: Determine operational prerequisites (OP's).
- Stage 10: Establish control or operating limits for each OP.
- Stage 11: Establish a monitoring system for each OP.
- Stage 12: Establish a corrective action plan.
- Stage 13: Verification.
- Stage 14: Establish documentation and record keeping.

Reuse of water from CIP cleaning

During the Danish project DRIP, different projects have shown how water can be treated and safely used in other processes. At Carlsberg, a water treatment system was built to collect water from the brewing processes and to reuse it for rinsing cans before filling them with product. During the project, all biological, chemical, and physical hazards were identified. The quality needed of the water for reuse was defined, and therefore an advanced water treatment system was established in a building outside the factory. The system consists of the following steps with a theoretically high impact on microbial hazards:

- Anaerobic degradation of organic matter.
- MBR (membrane bioreactor)/UF (ultrafiltration):
  - Bacteria: 6 log.
  - Virus: 6 log.
  - Protozoa: 6 log.

- RO (reverse osmosis):
  - Bacteria: 4-6 log.
  - Virus: 4-6 log.
  - Protozoa: 4 log.
- UV:
  - Bacteria: 5 log (3-40 mJ/cm^2).
  - Virus: 5 log (>60 mJ/cm^2).
  - Protozoa: 5 log (>40 mJ/cm^2).

This gives an overall log reduction of 15 log, and due to the use of ClO_2 treatment on top of this there is an additional 2 log reduction.

The treatments will also reduce the chemical hazards. For example, special UV lamps can be used to oxidise the most complex chemical compounds. E.g., wastewater from hospitals or ground water pesticides (www.ultraaqua.com).

The suggested parameters to control the water quality are:

Parameter	Critical limit	Frequency
Conductivity (Ms/CM)	≥ 300	In-line
Turbidity (NTU)	1	In-line
pH	7-10.5	In-line
Temperature (°C)	<20	In-line
COD or TOC (mg/l)	<25 or lower	In-line
Nitrate (mg/l)	50	Weekly
Nitrite (mg/l)	3	Weekly
Phosphorus (mg/l)	<2	Weekly
Aerobic plate count (22°C, cfu/ml)	200	Weekly
Escherichia coli	None in 100 ml	Weekly
Aerobic spores	None in 100 ml	Weekly

Ref: (Truelstrup Hansen, slides from presentation, 2022).

This water treatment system is very advanced and expensive but produces treated process water that is suitable for all steps in the cleaning process. In the following part of this report, a risk-based discussion is made on the use of different water sources just for pre-rinse. The first part is a description of the microbial effect of the different steps in cleaning and disinfection.

Cleaning in general

All items that come into contact with food must be effectively cleaned and sanitised. This is process including several steps that removes food waste, dirt, grease and destroys food-borne pathogens.

There is no demand to which procedures must be used to ensure that the premises and equipment are kept in a clean and sanitary condition. Food businesses may use a combination of procedures and methods to meet the requirements.

The typical steps in daily cleaning in a food production setting are:

- Prepare for cleaning (clean-up).

- Scrape away meat/food residues (dry scraping).
- Pre-rinse (soak materials with water (variable temperatures is used fx 45°C-55°C* depending on the type of food residues) (must this water be potable?), maybe flush and scrub to remove loose dirt and food particles (coarse cleaning).
- Rinse with potable water.
  The water must be 55°C* to dissolve fat and avoid denaturation of protein.
- Soak with soap (wash with hot water (60°C*) and detergent).
- Rinse with clean potable water (55°C*).
- Disinfection (cold or lukewarm sanitisers as directed on the label).
- Rinse with clean potable water (cold).
- Air drying (allow benches, counters, and equipment to air dry. The most hygienic way to dry equipment is in a draining rack). Often powerful fans are used in the production area.

*) the water temperature in the steps above may vary and will depend on the food matrix to remove and the recommendation from the supplier of soap and disinfectants.

The use of process water discussed in this report is only intended for the pre-rinse step. So, four steps of using potable water alone or in combination with soap and disinfectants are performed after the initial pre-rinse (soaking).

The microbial effect of the different steps during cleaning

Studies performed by DMRI have shown that a large part of the bacterial load on surfaces and equipment are removed during pre-rinse (Figure 1). A multi needle injector was contaminated with an emulsion of meat, blood, and starch. The set-up was left overnight in the cold processing environment. The equipment was cleaned the next day using the generic cleaning procedure. After pre-rinse, the microbial load was reduced from 7 log cfu/ml to 3 log cfu/ml. The microbial level was not further reduced after using an enzyme-based cleaning product. The microbial load was reduced to around the detection limit after disinfection with sodium hypochlorite (Rasmussen, 2010).

In contrast, results from another experiment (Figure 2) have shown that pre-rinse does not reduce the number of bacteria if meat and bacteria was left on a surface for a long period. The lactic acid bacteria *Lactobacillus brevis* was grown in a cooked meat emulsion on the surface of metal plates for 13 days at 10°C. After the incubation period, the surfaces were cleaned using an alkaline detergent containing chlorine followed by disinfection with sodium hypochlorite. The bacterial number was reduced after the use of the alkaline detergent (Petersen & Koch, 2020).

Based on the results from these experiments, it can be difficult to make a conclusion on how many bacteria the pre-rinse removes from the surfaces. Sometimes water is enough to remove food residues including bacteria, and in other cases soap is needed to remove food residues and bacteria. However, it can be concluded that the combined effect of pre-rinse and soap + rinse reduces the bacteria to an acceptable level. And depending on how efficiently these two steps are performed, the surfaces can be almost without bacteria before disinfection. But if small food residues are still present on the surfaces, disinfection + rinse is needed to bring down the bacterial number to an acceptable level.

One important difference in the two studies is the time used for contaminating the surfaces. The results might indicate that for freshly contaminated surfaces (one production day), the pre-rinse removes a lot of bacteria together with the food residues whereas for the long-term contamination (biofilm might be produced), pre-rinse is less effective as soap is needed to remove the biofilm containing bacteria.

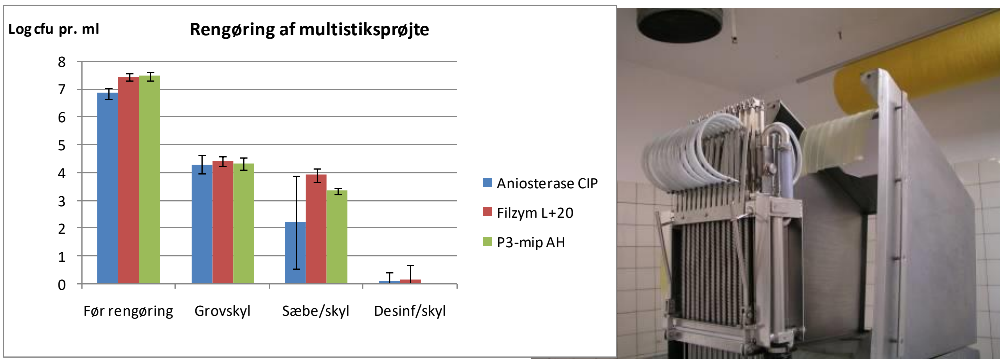

Figure 1. Reduction in aerobic count during cleaning of the injection manifold in a multi needle injector. Different types of enzyme soap and alkaline soap were used.

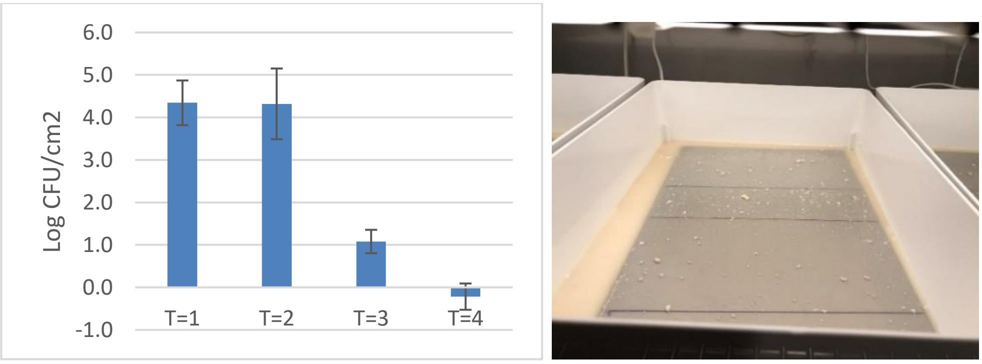

Figure 2. *Lactobacillus brevis* grown in a cooked ham emulsion on the surface of a metal plate (n=3) for 13 days at 10°C. T1 = before cleaning; T2 = after rinse; T3 = after alkaline soap + rinse; T4 = after disinfection (sodium hypochlorite) + rinse (Petersen & Koch, 2020).

Characterization of different process water sources for reuse

The following process water sources might be suitable for treatment and use in the first part of pre-rinse (soaking). The usability will depend on available volume, need of treatment before use, storage conditions, establishment of pipelines, tanks, pumps, etc.

<u>Meat processing</u>

In meat processing, water used for heating and chilling is most often discarded. This water might be suitable for pre-rinse in the meat processing department (raw meat handling, mince production, curing etc.). Possible water sources are:

- Autoclaves (hot water).

- Cooking cabinets (hot water, chilling water).
- Water from sous vide cooking.
- Chilling water from soup production.
- Other water sources where limited microbial contamination has taken place.

Slaughterhouses

At the slaughterhouses, much water is used to clean and disinfect robots during slaughtering, due to the demand of cleaning equipment between carcasses. This water might be collected, treated and used for pre-rinse (soaking). In this analysis of microbial risk, the water is intended to be used in the same part of the slaughter line or up-stream after some water treatment to avoid spread of pathogens and spoilers.

- Equipment at the "unclean" part of slaughterhouses, and their suitability as process water sources for pre-rinse water
  - Rotastic (high blood loads in water).
  - Rectastore (parts of water flow high in blood, larger part is without blood).
  - Scalding tank (skoldekar) (water quality very low, high load of manure and dirt).
  - Dehairing (very high load of blood, high load og bristles).
  - Flaming/singeing (no water).
  - Whipping line (high volume, acceptable water quality).

- Equipment at the "clean" part to pre-rinse in the clean area of slaughterhouses, and their suitability as process water sources for pre-rinse water
  - Bung handler (water quality acceptable).
  - Chest opener (high load of blood, clotted lumps must be dissolved).
  - Belly opener (water quality acceptable).
  - Pre-score machine (Friskærer) (high fat load, no blood).
  - Splitter (high volume, water quality acceptable).
  - Intestine tray washer.
  - Others?
- The water consumption for cutting and deboning is not high during the production, thus, it is not included in this report.

During cleaning – recirculating and not upstream use

During cleaning, the largest amount of water is used during pre-rinse to soak materials and to remove materials from equipment, conveyers, and floors. If this water can be collected and treated to "fit for purpose" quality, it might be suitable for recirculation in some areas/equipment for example:

- Nozzles at conveyer belts.
- Washing machines (boxes, trays, Vemag trolley, others).
- Intestine tray washer.
- CIP cleaning procedures (dairy, DRIP results).
- Trucks washing (water from rinse after disinfection, but take care for livestock diseases).
- Others?

An overview is given in the next table.

Equipment at the "unclean" part of slaughterhouses, and their suitability as process water sources for pre-rinse water

✓: Small/minor
✓✓: Medium
✓✓✓: Large/high

	Volume	Microbiological load	Particle load	Organic load (blood)	Other
Rotastic	✓✓	✓	✓	✓✓✓	
Rectastore	✓✓	✓	✓	✓✓✓	
Scalding tank	✓✓✓	✓✓✓	✓✓✓	✓✓✓	
Dehairing	✓✓✓	✓✓✓	✓✓	✓✓✓	
Whipping line	✓✓✓	✓✓	✓✓	✓✓	

Equipment at the "clean" part of slaughterhouses, and their suitability as process water sources for pre-rinse water

✓: Small/minor
✓✓: Medium
✓✓✓: Large/high

	Volume	Microbiological load	Particle load	Organic load (blood)	Other
Bung handler	✓✓	✓✓	✓✓	✓✓	
Chest opener	✓✓	✓✓	✓✓	✓✓ (both dissolved and clotted blood)	
Belly opener	✓✓	✓✓	✓	✓✓	
Pre-score machine	✓✓	✓✓	✓	✓✓	Dissolved fat
Splitter	✓✓✓	✓✓	✓✓	✓✓	
Intestine tray washer	✓✓✓	✓✓	✓✓	✓✓	Contains detergent

More detailed specification of the water qualities can be found in Sørensen & Koch, 2020a+b.

Collection and storage of process water for pre-rinse

Collection of water

The water for pre-rinse (soaking) must be collected during the day to ensure that enough water has been collected for use in the first part of the cleaning process. Therefore, tanks big enough to store the water must be built, and a pipeline must be installed to transport the water. The costs of such installations must be considered as a part of the initial investigation as well as the establishment of cleaning systems for the entire set up.

On top of that, risk of pathogen growth during storage must also be considered. As a starting point, it does not seem acceptable to have pathogens in process water for pre-rinse, even though small amounts of pathogens can be detected in the meat handled in the department. Considering food safety, recirculation of pathogens will increase the risk of unintended cross contamination of the final products.

Growth or concentration of biological agents must be avoided during storage of water for reuse, e.g., by storage at temperatures above 65°C or storage at <=5°C for a maximum of 24 hours. Also, the risk of propagation of legionella must be prohibited (lung infection).

Chemical hazards such as allergens must be considered. But it seems that if a factory handles allergens, then the cleaning procedure used is capable of removing these agents. However, the risk of cross contamination of raw material or other ingredients used in allergen free products must be considered.

Visual appearance must be acceptable due to aesthetics and technical reasons. If employees are supposed to work in a hygienic way in food processing, the surroundings must support this behaviour, which includes the use of water for sanitation or process water.

For technical reasons, solids and particles must be removed to avoid filters, tubes, and nozzles to be blocked.

Growth during storage of water

To estimate a storage time with a limited risk of increase of pathogens in the process water, the growth of bacteria was predicted with CombasePredictor. The fastest growth at 5-50°C and pH 7 or 7.5 are shown in Table 5.

The predictions show that the water should not be stored for more than 1-2 hours if bacteria are expected to be found in the water, and no control of temperature is used. If water is stored for a longer time, a water treatment step will be needed, e.g., UV to inactivate bacteria prior to use .

If water is to be stored for a longer time, temperatures below 5°C or above 60°C are recommended.

Table 5. Predicted time for 1 log growth at 5-50°C and pH 7 or 7.5 (CombasePredictor). Only the fastest growing bacteria at the different temperatures are shown.

Temp.	Lag time	1 log growth	Bacterium
5°C	20 hours	37 hours	*Brochotrix*
10°C	9 hours	16 hours	*Brochotrix*
15°C	5 hours	9 hours	*Brochotrix*
20°C	4 hours	7 hours	*Brochotrix*
25°C	3 hours	5 hours	*E. coli; salmonella*
30°C	2 hours	3 hours	*E. coli; salmonella*
35°C	2 hours	3 hours	*E. coli; salmonella*
40°C	3 hours	3 hours	*Salmonella*
45°C	3 hours	4 hours	*C. perfringens*
50°C	3 hours	4 hours	*C. perfringens*
55°C	Some bacteria might grow, prediction is not possible		
>60°C	Inactivation of bacteria depending on time/temperature		

Growth of legionella in water systems is avoided at temperatures below 20°C and above 50 °C (www.SSI.dk).

Water quality for pre-rinse

Pre-rinse

The step pre-rinse can be split up into two parts. But often it is just one step as there is no effect of soaking before flushing:

- Soak surfaces (loosen meat residues).
- Rinse (remove meat residues).

Microbial estimates

This section discusses how the use of process water (not potable water quality) might affect food safety. In the discussion, microbial, chemical, and physical qualities of the process water are compared to the surfaces to be soaked and the effect of the cleaning process.

In Tables 6, 7, and 8, different estimates are shown on how the process water might change the number of bacteria in meat residues on the surfaces. The numbers illustrate that using process water low in microbial load will have a minor effect on the number of bacteria on the surfaces to soak. Whereas using water higher in microbial contamination will make the surfaces more contaminated and therefore put on more pressure on the effect of the following cleaning compared to the use of potable water.

Based on the examples, it is suggested that potable water might be exchanged with process water at the pre-rinse step. But the process water used for soaking in the pre-rinse step must always be at least 2-3 log lower than the level of contamination on the surfaces to pre-rinse (soak) and free of pathogens.
On top of that, risk assessments on all possible contaminations in the process water must be made. Which hazards can be introduced in the area to clean: specific pathogens, allergens or chemical hazards, and physical hazards? One suggestion is to make sure no new hazards are introduced to the area to clean, and one possibility might be to only use water from the same production line – meaning taking water upstream from the clean part to the more unclean part of the process line. This, however, opens the discussion of whether cleaning is a part of the process

or a separate part. Cleaning companies argue that cleaning and disinfection are the first part of food processing (and not a separate one or end of production), as clean surfaces are fundamental for quality and food safety in any food production. Today cleaning and disinfection is an important GMP procedure in all food companies and not described as a process step in the production line.

In the following part of this report, cleaning and production are considered two separate processes.

Table 6. Estimated effect of process water on surface contamination. Added water per cm^2 surface is estimated to 1 ml. These numbers must be used together with the amount of water used for pre-rinse/soaking.

Surface contamination	Process water contamination	Contamination after soaking
1 cfu/cm^2	100 cfu/ml	101 cfu/cm^2
10 cfu/cm^2	100 cfu/ml	110 cfu/cm^2
100 cfu/cm^2	100 cfu/ml	200 cfu/cm^2
1,000 cfu/cm^2	100 cfu/ml	1,100 cfu/cm^2
10,000 cfu/cm^2	100 cfu/ml	10,100 cfu/cm^2
100,000 cfu/cm^2	100 cfu/ml	100,100 cfu/cm^2
1,000,000 cfu/cm^2	100 cfu/ml	1,000,100 cfu/cm^2

Green colour: acceptable change.
Red colour: not acceptable change.
Yellow colour: maybe not acceptable.

The example in Table 6 shows the effect of using water with a bacterial number below the quality of drinking water. This is an acceptable process in all places in the food industry where microbial contamination will be higher than 1-10 cfu/cm^2 before cleaning is initiated.

Table 7. Estimated effect of process water on surface contamination. Added water per cm^2 surface is estimated to 1 ml. These numbers must be used together with the amount of water used for pre-rinse/soaking.

Surface contamination	Process water contamination	Contamination after soaking
1 cfu/cm^2	1,000 cfu/ml	1,001 cfu/cm^2
10 cfu/cm^2	1,000 cfu/ml	1,010 cfu/cm^2
100 cfu/cm^2	1,000 cfu/ml	1,100 cfu/cm^2
1,000 cfu/cm^2	1,000 cfu/ml	2,000 cfu/cm^2
10,000 cfu/cm^2	1,000 cfu/ml	11,000 cfu/cm^2
100,000 cfu/cm^2	1,000 cfu/ml	101,000 cfu/cm^2
1,000,000 cfu/cm^2	1,000 cfu/ml	1,001,000 cfu/cm^2

Green colour: acceptable change
Red colour: not acceptable change
Yellow colour: maybe not acceptable

Table 8. Estimated effect of process water on surface contamination. Added water per cm^2 surface is estimated to 1 ml. These numbers must be used together with the amount of water used for pre-rinse/soaking.

Surface contamination	Process water contamination	Contamination after soaking
1 cfu/cm^2	10,000 cfu/ml	10,001 cfu/cm^2
10 cfu/cm^2	10,000 cfu/ml	10,010 cfu/cm^2
100 cfu/cm^2	10,000 cfu/ml	10,100 cfu/cm^2
1,000 cfu/cm^2	10,000 cfu/ml	11,000 cfu/cm^2
10,000 cfu/cm^2	10,000 cfu/ml	20,000 cfu/cm^2
100,000 cfu/cm^2	10,000 cfu/ml	110,000 cfu/cm^2
1,000,000 cfu/cm^2	10,000 cfu/ml	1,010,000 cfu/cm^2

Green colour: acceptable change
Red colour: not acceptable change
Yellow colour: maybe not acceptable

In the following part of this report, examples are given of risk analysis on the use of process water for pre-rinse.

Example 1
Reuse of water from heating/chilling cabinets (meat processing)

Sources of process water for pre-rinse

The water collected comes from:

- Autoclaves
- Cooking cabinet – hot water
- Cooking cabinet – chilling water
- Sous vide cooking vessel – hot water (55-70°C)

Premise: The water is collected directly from the autoclave, cooking cabinet or sous vide vessel with no contact to floors or other environmental parts outside the autoclave or cooking cabinet.

Flow chart for re-use

In Figure 3, an illustration of the intended process is shown.

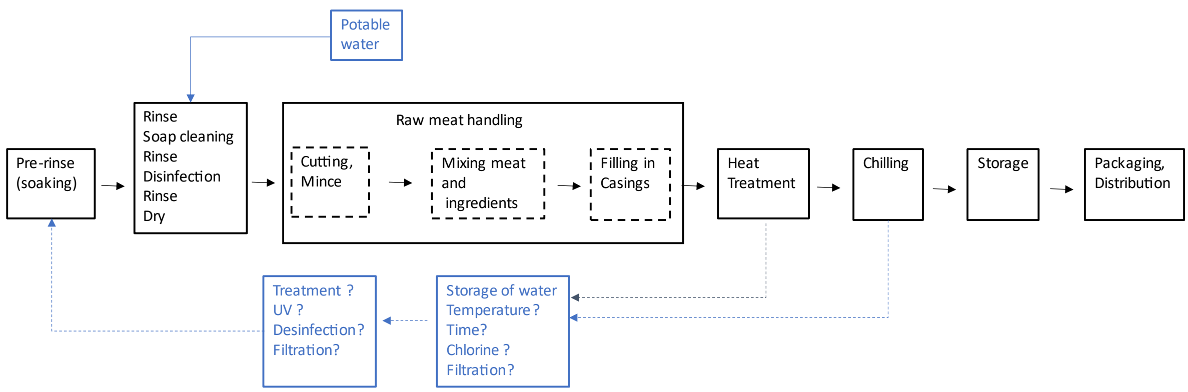

Figure 3. Production line for cooked meat products. Collection of water from the heating process for use in pre-rinse.

Microbial load of process water from heating and chilling

The water has been part of a cooking process. Therefore, the microbial load is expected to be low. Best guess is (premise: water is collected without contamination from the surroundings):

- Aerobic count: <1-2 log cfu/ml.
- Aerobic spores: <1-2 log cfu/ml.
- Anaerobic spores: <1-2 log cfu/ml.
- Pathogens: Maybe some spores.
  - Almost all survive 72°C/a few survive 121°C.
- Spoiler: Maybe some spores.
  - Almost all survive 72°C/a few survive 121°C.
- Virus: Maybe.
  - Some survive up to 100°C.
- Protozoa: Maybe.
  - Most are inactivated at 72°C but some survive up to 80°C.

Heating is one of the procedures used to disinfect water for reuse.
The expected microbial numbers are therefore comparable to microbial numbers for potable water.

Chemical load of process water

In autoclaves, chemical agents are used. These chemicals are approved by the authorities for technical use in food processing, meaning that small residues will not harm the consumer if by mistake they do contaminate food.

In cooking cabinets and sous vide vessels, no chemicals are used. If chemicals are used, they are food grade as they are in direct contact with food.

Organic materials will be present from spoiled cans, spoiled cooked meat products, broken sausages, fat, and protein from surfaces, etc.

Preservatives like salt, organic acids, and nitrite will be present from spoiled cans, spoiled cooked meat products, broken sausages, fat, protein, and carbohydrates from surfaces, etc.

Allergens from ingredients might contaminate the water from spoilt cans, packages or products.

Physical load of process water

Physical hazards like plastic, metal, bone etc. might be found in the water. Physical hazards are unwanted, but not a hazard to humans.

Intended use of process water

The water might be used for pre-rinse (soaking) of:

- Floors in areas handling raw meat, mince, etc.
- Equipment in areas handling raw meat, mince, etc.

Practical evaluation is needed – can it be handled with one water source for floors and another for equipment's? Probably not. Therefore, water treatment to "fit for purpose" in the entire surrounding will most probable be the best solution.

The process water from the cooking cabinet, sous vide vessels or autoclaves are low in bacteria – but some bacteria and spores are expected to be found. Chemicals, preservatives, allergens, and meat residues are to be expected.

Microbial load of areas to pre-rinse

The microbial load of meat and ingredients for meat processing might be high. Best guess is:

- Aerobic count: 4-7 log cfu/g.
- Aerobic spores: <1-3 log cfu/g (spices maybe 6 log cfu/g).
- Anaerobic spores: <1-3 log cfu/g (spices maybe 4-5 log cfu/g).
- Pathogens: <1-3 log cfu/g.
- Spoiler: 3-6 log cfu/g.
- Virus: Maybe.
- Protozoa: Maybe.

Chemical load of areas to pre-rinse

Organic material (meat, fat, flour, spices, milk, soya, etc.) will be present from meat formulation.

Preservatives like salt, organic acids, and nitrite will be present from the meat formulation.

Allergens might be present form meat formulation.

Physical load of areas to pre-rinse

Physical hazards like plastic, metal, bone etc. might be found in the area to clean. Physical hazards are unwanted but not a hazard to humans.

Discussion on microbial risk

The microbiological contamination of process water from autoclaves and cooking cabinets is much lower than what is expected to be found in meat residues and mince from handling raw meat and ingredients during meat processing (before heat treatment).

The aerobic total count is expected to be 4-6 log higher in the mince/residues to be removed than in the process water from the heating/chilling cabinet.

The difference in spore load is expected to be smaller, ranging from no difference to a few log cfu lower in the process water from the heating/chilling cabinet.

Pathogens (not spores) are not expected to be found in the process water as the heating process is used to eliminate pathogens. But presence due to contamination from the surroundings might occur. Attention to collection and storage of the process water from the heating/chilling cabinet is important.

Spores from spoilt cans or products might be found in the water. The number is expected to lower (maybe not much lower) than what can be found in the meat formulation from raw meat and ingredients like spices, proteins (meat, vegetables), starch etc.

The prevalence of virus and protozoa is also expected to be much lower, if present at all, in the process water from the heating/chilling cabinet compared to the raw meat/mince.

Discussion on chemical risk

No harmful chemicals are used during production of meat products. However, it is also important to consider if the water quality would be harmful to the equipment in the factory. Too much salt might be harmful to the equipment and surfaces (rust, iron oxidation).

Ingredients from the products (meat, spices, allergens, if used) will be present in the process water, but the concentration is expected to be low and lower than in the mince where they are used. If products with and without allergens such as milk, soya etc. are produced in the same factory, cleaning systems must be in place to clean properly between the different productions to avoid cross contamination with for example pork in chicken products or milk in products free of milk etc.

The same argument can be made for preservatives, for example nitrite. Small residues of nitrite will cause discoloration in nitrite-free products. Therefore, proper cleaning between the productions of products with and without nitrite must exist.

Discussion on physical risk

The aim of pre-rinse is to remove solids like meat, fat, bone, plastic etc. The number and concentration of residues in the process water will be much lower compared to the areas to be pre-rinsed.
Using process water for pre-rinse is not expected to increase the number and concentration of residues on the surfaces before soap is added in the cleaning process.

However, solids must be removed to avoid clotting of tubes, pipes, and nozzles.

Suggested analyses before start of using process water for cleaning in the meat processing department

The following investigations are suggested to be made before starting to use process water from the heating/chilling cabinets for initial pre-rinse (soaking):

- How can enough water be collected and stored without microbial growth and without pathogens?
  - Storage time, storage temperature, disinfection (UV, chlorine, others), filtration (avoid clotting of nozzles).
  - How easy is it to collect water, transport and store it?
- Survey on the microbial contamination of the water intended to be used.
  - total aerobic count, aerobe and anaerobe spores, pathogens.
- Decide whether a filtration (macro, micro, nano or RO) or water disinfection technology, e.g., UV, is needed to avoid the spread of bacteria (pathogens, spoilers) – for inspiration see: "Water Catalogue for Use of Treated Process Water in the Meat Industry" (Sørensen, Koch, Kaas-Larsen et al 2020).
  - If e.g., UV or chlorine treatment is added on top of the heating, then two disinfection steps are used to reduce microbes. Chlorine might not be suitable if acidic soap and disinfection are used. Another issue is the ongoing work of reducing the use of chlorine due to unwanted environmental issues.

- Measure the effect of cleaning with process water. For example, ATP test can be used to measure residues after cleaning and combined with microbial test of total count to verify that the hygienic status is acceptable – no change to the current situation (baseline).

Suggestion for further research

The cleaning test set-up used in this project are used to test the effect of different chemicals and methods on the visual and microbial effect on cleaning.

This system is suggested for test of the use of process water from cooking cabinets or sous vide vessels or autoclaves in pre-rinse. The aim will be to investigate if this process water with organic contamination and a low microbial load can be used without affecting the quality of the cleaning and disinfection. The results from the test where "contaminated" water (microbes, organic residues etc.) is used for pre-rinse will be compared with results from tests where potable water is used. Water supply (tank, pump, pressure) for the cleaning system must be modified to use water that is not from the water pipes with potable water.

In summary: use of process water from cooking cabinets for pre-rinse:

Microbial risk

Process water: < 200 cfu/g, no pathogens except maybe some spores
Area to pre-rinse/soak: $10^{4\text{-}6}$ cfu/cm^2.

Cleaning effect of pre-rinse: microbe is reduced by 0 to 3 log cfu (DMRI test shown in Figure 1 and 2).

Cleaning effect of soap + rinse + disinfection + rinse: microbe is reduced by 4 log cfu (DMRI test shown in Figure 1 and 2).

In conclusion, if the microbial contamination of water is <200 cfu/ml, and the water originates from heating the same kind of products as produced in the processing area to clean, then no microbial risk is identified.

An increased load of spores in the water will not affect the safety as the survival or growth is already handled in the process by preservatives, storage temperature and heat treatment.

Other risks

Chemicals: only chemical additives from the meat heated can be expected and food grade chemicals added to water.

Allergens: Allergens from meat residues in the process water will spread to surfaces during pre-rinse. However, these allergens are the same as added to the products. Care must be taken not to re-contaminate with allergens. But if different allergens are handled in the same process line, this is expected to be dealt with in cleaning and separation of production time. One risk might be if water is collected for longer periods when products with different allergens are produced.

Example 2
Reuse of water from slaughterhouse – treated water from robots approved for use in the dehairing machine

Source of process water for pre-rinse

A slaughterhouse has a water treatment system installed for reuse of water from equipment at the clean slaughter line for use in the dehairing machine. The process is approved by the Danish authorities. The process chart is shown in Figure 4.

The water is collected during the production day. The water not used in the dehairing machine is only at a low volume. However, if more water is collected for treatment in the water treatment system, this can be upgraded by more treatment and used in cleaning.

Discussion for use at pre-rinse

The process water from the equipment at the clean slaughter line is treated, so the microbial load is comparable to potable water. The chemical load is not comparable with potable water nor the physical quality, due to particles. However, all residues are from slaughter animals treated in the slaughterhouse. Furthermore, the risk analysis concluded that the water could be used without any hazards to the fresh pork produced. After dehairing, the surfaces of the carcasses are further treated by singing/flaming bringing the bacterial number at the rind down to a low number.

Without further analysis, this water should be suitable for pre-rinse in the unclean area of the slaughter line – marked with blue in Figure 4.

Care must be taken to avoid clotting of nozzles.

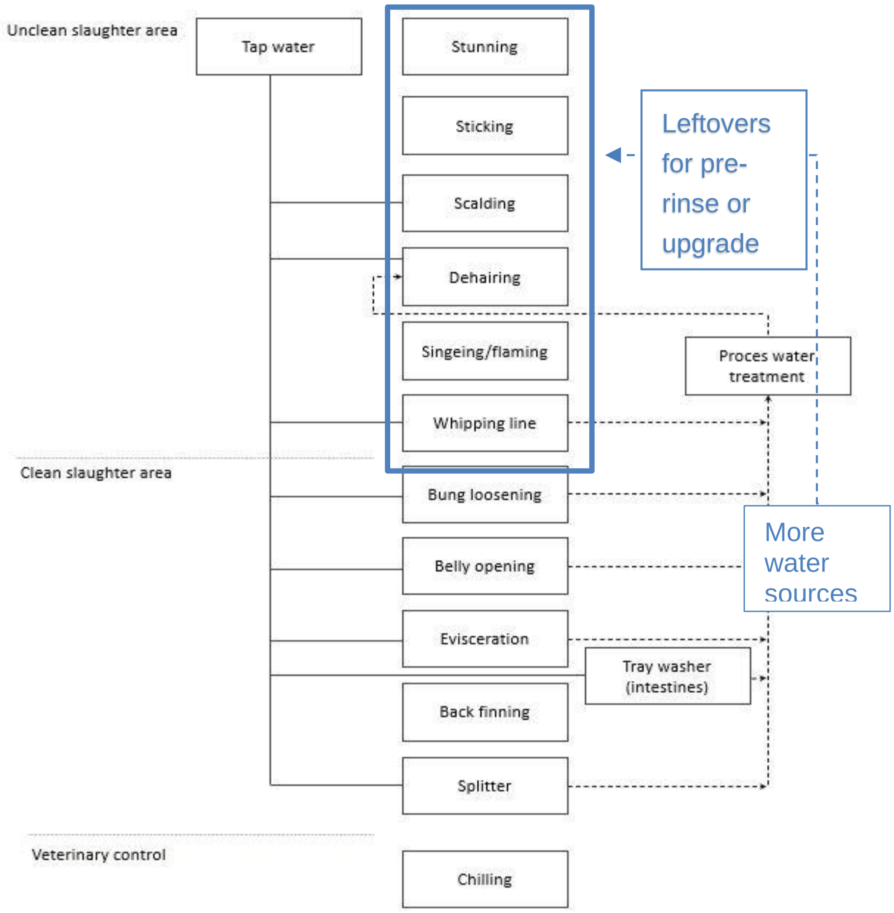

Figure 4. Flow chart slaughter line. Slaughter processes indicating water consumption for rind treatment **(permitted use, DRIP)** using treated process water in the dehairing machine. Collection and treatment of process water for use in the dehairing machine is marked with dotted lines. The **areas (floor and equipment) intended to be pre-rinsed with treated process water** are marked in blue.

Reuse of water from slaughterhouse – for pre-rinse in pig stable and pig trucks

Source of process water for pre-rinse

- Baseline studies on water sources have not been performed to locate water for pre-rinse in stable and/or trucks. Some ideas might be: Collect process water from the entire slaughter line and clean it to fit for purpose quality and use it for pre-rinse only.
- Collect all process water from the slaughter line and clean to the same quality as potable water regarding microbes, chemicals, and physical hazards (DRIP, Carlsberg case).
- Collect water from washing machines running all day, e.g., box/tray washing machine, gambrel washer, Christmas tree washer, intestine trays washer.
- Reuse during cleaning – conveyer belts, Vemag trolleys, and trucks.

Flowchart

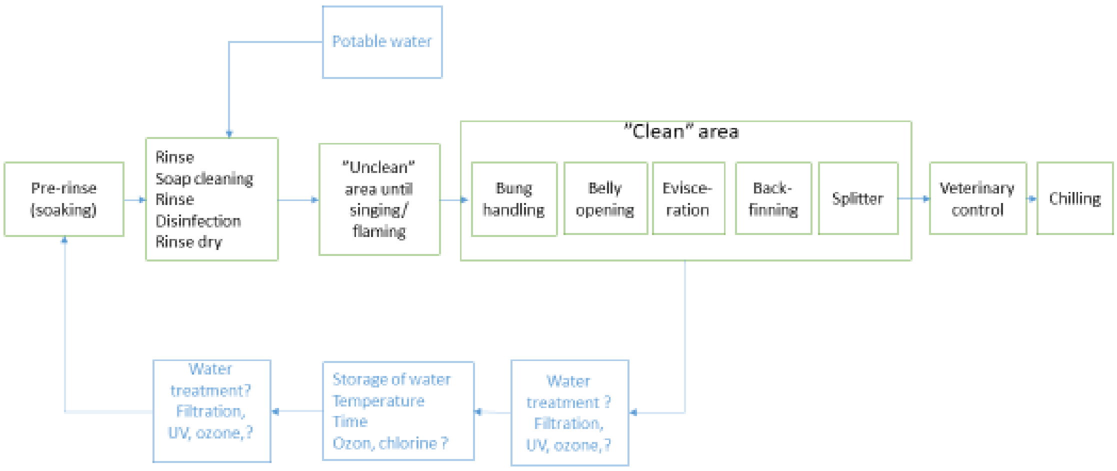

Figure 5. Slaughter line. Collection of water from robots at clean slaughter line for treatment and subsequent use for pre-rinse at the clean slaughter line. During cleaning pre-rinse (soaking) and rinse can be just one operation. Here the requirements to water treatment might be higher.

Microbial load of process water from "clean" slaughter line

Low if it is from the water treatment system used in the dehairing machine. The threshold values are in preparation during the ongoing validation of the system.

High if no water treatment is used. But probably in the same numbers as for the equipment to pre-rinse in the same area.

Chemical load of process water

Organic material (meat, fat, bone, blood, faeces, saliva, etc.) will be present from the slaughtering process.
Lactic acid might be used for decontamination of equipment.
Grease (smørefedt) from machines is food grade.
Other?

Physical load of process water

Physical hazards like plastic, metal, bone etc. might be found in the area to clean. Physical hazards are unwanted but not a hazard to humans.

Intended use of process water	Pre-rinse at "clean laughter line".
Microbial load of areas to pre-rinse	The microbial agents on the surfaces and in the water will be comparable to each other but might differ in numbers. Microbial load on the "clean" slaughter line: • Aerobic count: 4-7 log cfu/cm^2. • Aerobic spores: medium? log cfu/ cm^2. • Anaerobe spores: medium? log cfu/ cm^2. • Pathogens: low-medium? log cfu/ cm^2. • Spoiler: medium? log cfu/ cm^2. • Virus: Yes, number and concentration are to be found. • Protozoa: Yes, number and concentration are to be found.
Chemical load of areas to pre-rinse	Chemicals at the clean slaughter line: only food grade (lactic acid, oil/fat/grease) Organic material (faeces, blood, meat, salivary, etc.)
Physical load of areas to pre-rinse	Physical hazards like plastic and metal etc. might be found in the area to clean. Physical hazards are unwanted but not a hazard to humans.
Discussion on microbial risk	If process water with the same number of bacteria is used to pre-rinse an area, no reduction in microbial load will be obtained. This will put on extra pressure on the next step in cleaning and is not recommended. It is recommended to treat with filtration, ozone, and UV as described above to obtain water with low microbial numbers.
Discussion on chemical risk	Antibiotic residues, lactic acid or oil is not believed to have negative impact on the pre-rinse process. Organic materials from fat, blood, bone and meat might affect the cleaning quality as this might clog the nozzles used. Furthermore, the purpose of pre-rinse is to remove organic matters. Therefore, some treatment to remove organic materials is needed.
Discussion on physical risk	Physical hazards like plastic and metal etc. might be found in the area to clean. Physical hazards are unwanted but not a hazard to humans. But they must be removed in order to avoid break down of the cleaning equipment.
Suggested analysis to be performed before starting to use process water for cleaning in the	The following investigations are suggested to be made before starting to reuse process water from robots at the clean slaughter line to perform the initial pre-rinse (soaking) in the same area: • How can water enough be collected and stored without microbial growth and without pathogens?

meat processing department

- o Water treatment before storage is necessary to reduce any microbial growth and to remove large organic residues.
- o Storage time, storage temperature, disinfection (UV, chlorine, others), filtration (avoid clotting of nozzles).

- Survey on the microbial contamination of the water intended to be used
  - o total aerobic count, aerobe and anaerobe spores, pathogens.
- Decide whether a filtration such as belt filtration or membrane filtration (micro, ultra, nano or RO) or water disinfection technology, e.g., UV, is needed to avoid the spread of bacteria (pathogens, spoilers) – for inspiration see: "Water Catalogue for Use of Treated Process Water in the Meat Industry" (Sørensen, Koch, Kaas-Larsen et.al. 2020).
  - o Chlorine might not be suitable if acidic soap and disinfectants are used. Another issue is the on-going work on reducing the use of chlorine due to unwanted environmental issues.
- Measure the effect of cleaning with the treated process water. For example, ATP test can be used to measure residues after cleaning and combined with microbial test of total count to verify that the hygienic status is acceptable – no change to the current situation (baseline).
- Others ???

Suggestion for further research

The cleaning test set-up used in this project is used to test the effect of different chemicals and methods on the visual and microbial effect on cleaning.

This system is suggested to test the use of water from the treated process water produced for the dehairing machine or water of a comparable quality. The aim will be to investigate if this process water with organic contamination and a low microbial load can be used without affecting the quality of cleaning and disinfection. How will it affect the cleaning equipment during longer usage, can biofilm build up? The results from the test where "contaminated" water (microbes, organic residues etc.) is used for pre-rinse will be compared to results from tests where potable water is used. Water supply (tank, pump, pressure) for the cleaning system must be modified to use water that is not from the water pipes with pressure on.

In Table 9, an overview of the possible use of process water for pre-rinse is given.

Table 9. Requirements of the water quality used at step 2 in cleaning (**pre-rinse** with pressurised water) at the end of production or recirculation during processing.

		Requirements of the water quality		
Process step	Microbial load	Bacteria in general	Pathogens, viruses, nematodes, parasites	Chemical, visual
Trucks for animal transport, stable, Stunning, first cleaning of intestine	High, >> 8 log cfu/g	Total count must be below 5 log cfu/ml. Because: total count of less importance as the primary effect is to remove solid material	Free of pathogens, Free of virus, Free of nematodes, Free of parasites Because: Avoid spread to farmers (trucks). Avoid spread to the entire production of the day	60% light transmission compared to fresh water/ drinking water
Blood handling	Blood: Low/sterile Skin: high >>8 log cfu/g	No reuse of water but wash/rinse in a closed system like a dishwasher. CIP. Use water of drinking quality. Avoid growth and change or use water treatment regularly to avoid aesthetics/ unacceptable appearance.		
Slaughter line	Varies	Reuse is possible during processes in some equipment, e.g., scalding, dehairing – avoid growth and spread of pathogens. Use technologies that ensure microbial drinking water quality.		
Handling fresh meat, curing, mincing	3-4 log cfu/g	Use water of microbial drinking water quality. If small organic materials can be documented not to have a negative impact on the cleaning process, they can be accepted		
Production of processed meat	Varies Low after heat treatment. High in mince preparation	Use water of microbial drinking water quality OR use water treatment. Most important to demonstrate the cleaning effect and ensure that pathogens are not propagated.		
Process water not in direct contact with food	-	Reuse of water might be possible. Risk analysis in each case is necessary.		
High care areas	Low	Only use water of drinking quality (microbial, chemical, physical)		

Conclusion

In conclusion, process water can be used for pre-rinse. However, care must be taken to document that the use will not affect food safety and shelf life. Therefore, a risk analysis must be made in each case describing the water source, storage, and intended use.

The work to be done includes:

- Cost benefit analysis – business case
- Theoretical risk analysis (microbial, chemical, physical)

    - Regulatory barriers (legislation, customers)
    - Describe water
    - Describe intended use
        - Initial cleaning (floors, conveyers, equipment, stable, etc.)
- Baseline study – microbial, visual, chemical
    - Water from the process
    - Water and environment in the place of reuse
- Design the process (technology partner)
- Evaluate the process
- Microbial analysis of the new process (the surfaces after cleaning)
- Update the risk analysis
- Monitoring water quality
    - How and where?
    - Online measuring versus lab analysis
- Cost benefit analysis – business case

References

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Links:
Sanitation Performance Standards Compliance Guide (USDA)
Sanitation Performance Standards Compliance Guide | Food Safety and Inspection Service (usda.gov)

SSI.dk (Legionella i varmt brugsvand): https://www.ssi.dk/-/media/arkiv/subsites/infektionshygiejne/retningslinjer/roga/legionella-i-varmt-brugsvand.pdf

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Appendix 1

Legislation

References to legislation on cleaning and the reuse of water. No translation of Danish to English.

Vejledning om fødevarehygiejne (VEJ nr. 9866 af 27. juni 2022)

19. Rengøring og desinfektion i fødevarevirksomheder

19.1 Rengøring og desinfektion

Virksomheden skal gøre rent og desinficere så ofte, at hygiejnen er forsvarlig, og at fødevarerne ikke bliver forurenet. For at sikre dette, bør virksomhederne udarbejde en plan for rutinemæssig rengøring.

En sådan rengøringsplan kan f.eks. beskrive:

- Hvad virksomheden skal gøre rent (lokaler, inventar, kølefaciliteter, ventilation, transportmidler, redskaber mv.).
- Hvor ofte virksomheden skal gøre rent (hyppighed/frekvens).
- Hvilke rengørings- og desinfektionsmidler, virksomheden skal benytte og til hvad (produkter, dosering og brugsanvisning).
- Hvordan virksomheden skal rengøre/desinficere (metode for påføring og holdetid).

Europa-Parlamentets og Rådets forordning (EF) nr. 852/2004 af 29. april 2004 om fødevarehygiejne kapitel VII
Vandforsyning 1. a)

Der skal være forsyning af drikkevand i tilstrækkelig mængde, som skal anvendes, når det er nødvendigt for at sikre, at fødevarerne ikke forurenes.

B 2. Anvendes der vand, som ikke er af drikkevandskvalitet, til f.eks. brandslukning, fremstilling af damp, køling og lignende formål, skal det cirkulere gennem særskilte behørigt identificerede ledningssystemer. Dette vand må ikke have nogen forbindelse med drikkevandssystemerne eller mulighed for tilbagestrømning til disse.

3. Vand, der genbruges til forarbejdning eller som ingrediens, må ikke udgøre en risiko for kontaminering. Det skal være af samme standard som drikkevand, medmindre den kompetente myndighed er blevet overbevist om, at vandets kvalitet ikke kan påvirke de færdige fødevarers sundhed.

Bekendtgørelse om fødevarehygiejne BEK nr. 497 af 23/03/2021

Kapitel 20.

Genbrug af vand

§ 41. Fødevarevirksomheder, som ønsker at genbruge vand, kan gøre dette, såfremt betingelserne i bilag II, kapitel VII, punkt 3, i hygiejneforordningen er opfyldt.

Stk. 2. Uanset stk. 1, kan sidste hold skyllevand genbruges til forskyl af samme fødevarekategori, uden at virksomheden forelægger risikovurdering, på betingelse af at genbruget sker i en kontinuerlig proces.

Other references:

Forordningen om fødevarehygiejne, EF 852/2004, bilag II, kapitel VII, artikel 3.

Bekendtgørelse om fødevarehygiejne, BEK 1354, 2017, Kapitel 19, §39).

Virksomhedens almindelige egenkontrol skal omfatte overvågning og styring af vandbehandlingsanlægget og det behandlede vands kvalitet.

https://www.foedevarestyrelsen.dk/Selvbetjening/Vejledninger/Hygiejnevejledning/Sider/10--Vand-i-fødevarevirksomheder.aspx

Appropriate water treatment for specific hazards (Holah, 2012)

Hazard	Treatment											
	Filtration	Membrane filtration	Ion exchange	Reverse osmosis	Flocculation/ precipitation	Activated carbon	pH correction	Heat	Chlorine	Chlorine dioxide	Ozone	UV
Bacteria		X						X[1]	X[2]	X[2]	X[2]	X[1]
Viruses		X						X	X	X	X	X
Protozoa		X						X	X[3]	X[3]	X[3]	X[3]
Algal toxins						X						
Suspended particulates	X	X										
Organic residues						X						
Salts		X	X	X								
Heavy metals					X							
Salinity			X	X								
Acidity/alkalinity							X					
Colour/odour/taste						X						

1 only effective against spores at elevated temperatures or UV intensities and extended contact times
2 not effective against spores at concentrations likely to be used in water treatment
3 at higher concentrations and/or contact times, particularly for *Cryptosporidium*