International Association for Food Protection WEBINAR

Impact of Water Use and Reuse in Food Production and Processing on Food Safety at the Consumer Phase: Focus on the Fish and Fishery Products Sector

Organized by IAFP's Water Safety and Quality PDG, International Food Protection Issues PDG, and Seafood Safety and Quality PDG

Moderator: Leon Gorris, Food Safety Futures
Past Chair of Water Safety & Quality PDG

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Food and Agriculture Organization of the United Nations

SUSTAINABLE DEVELOPMENT GOALS

Development of international scientific advice on water (re-)use and food safety

Dr Kang Zhou

Food Safety Officer
Food Systems and Food Safety Division
Food and Agriculture Organization of the United Nations (FAO)

Background on safety and quality use of water in food at the FAO

- Many Codex documents make reference to the use of **portable** or ‘**clean**’ water

Challenge

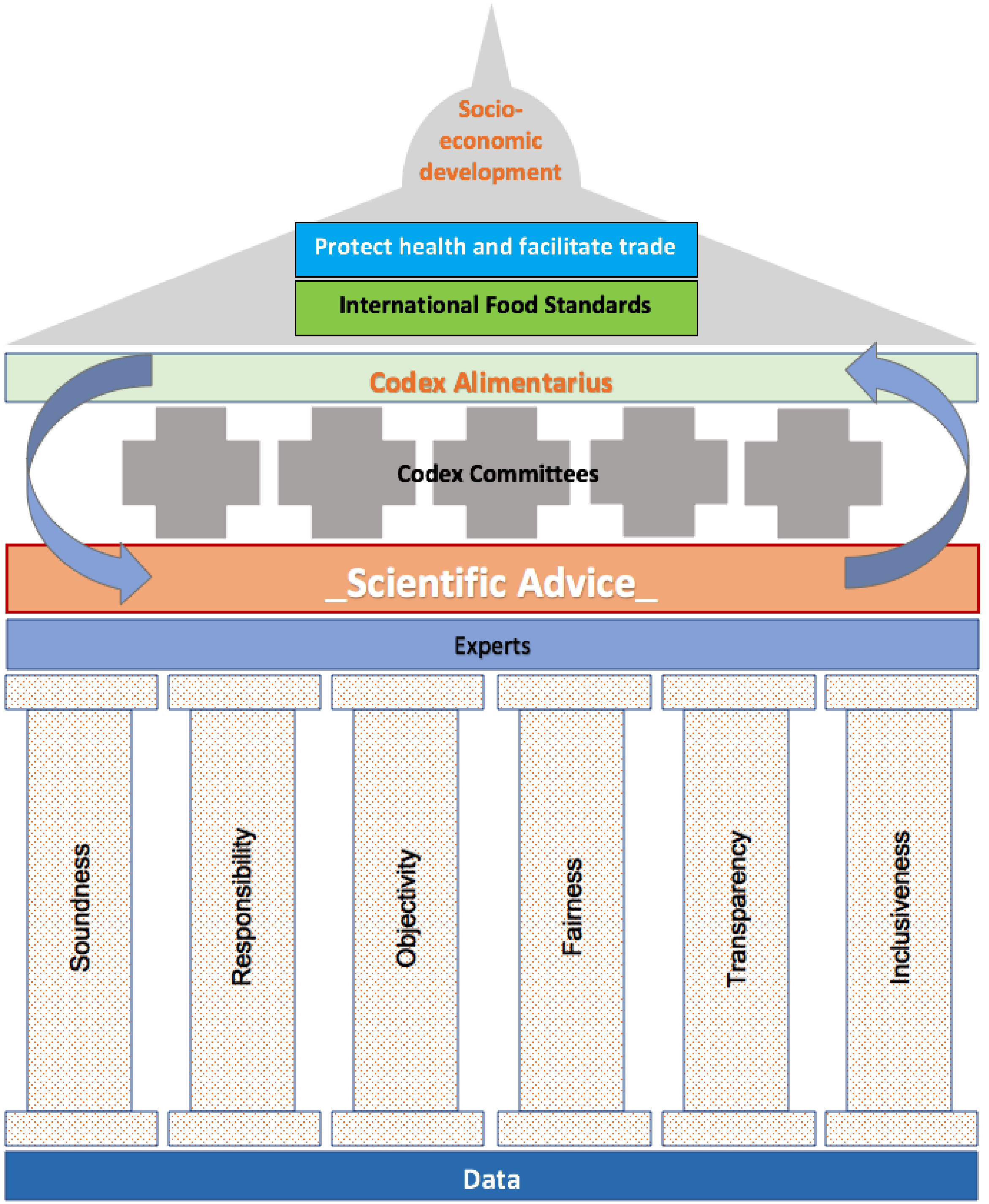
How to turn the Codex current definition clean water “*water which does not compromise the safety of food in the context of its use*” into operational guidance/target for water use and re-use by food producers and processors

- Water is a **dwindling resource** worldwide and not all food producers and processors have access to safe water sources, or this access may be limited.

- Codex Committee on Food Hygiene (CCFH) noted the importance of water quality in food production and processing (48th session in November 2016), requested JEMRA to provide guidance processing water, in particular, “clean water” for irrigation water, clean seawater, and on the safe reuse of water

Joint FAO/WHO Scientific Advice Programme

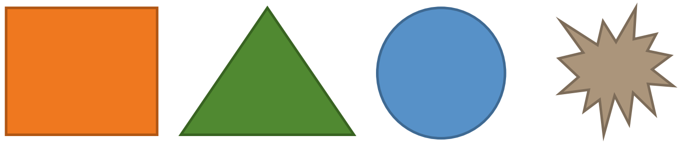
- **JEMRA**: Joint FAO/WHO Expert Meeting on Microbiological Risk Assessment
  - Established in 2000
  - Scientific advice on microbiological risk assessment
  - Expert meetings based on requests from Codex (CCFH) and as we deem necessary
- JECFA, JMPR, JEMNU, ad hoc

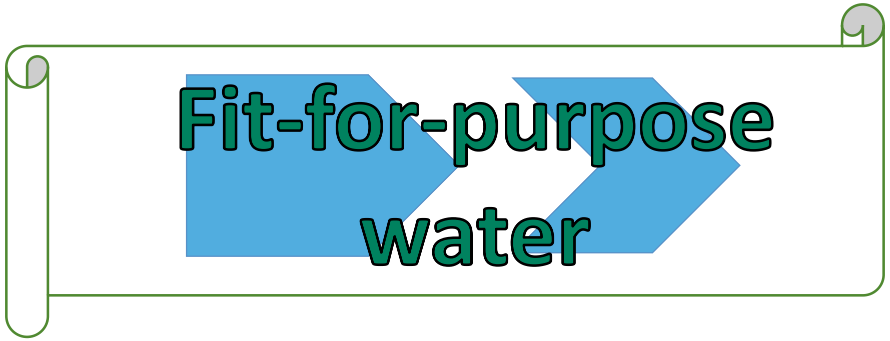


- Place a greater emphasis on a *risk-based approach to safe water* use.

- Instead of specifying use of potable water (or in some instances other water quality types) a risk-based approach and assessment of the *fitness of the water for the purpose* intended should be articulated.

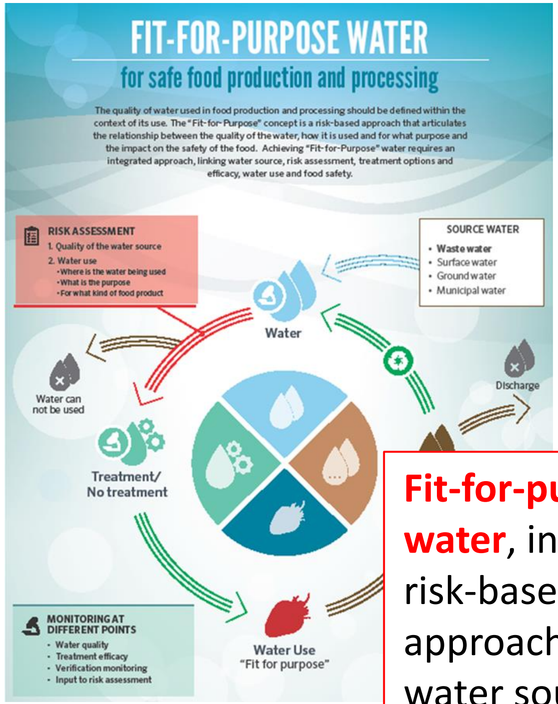
- One size does not fit for all.



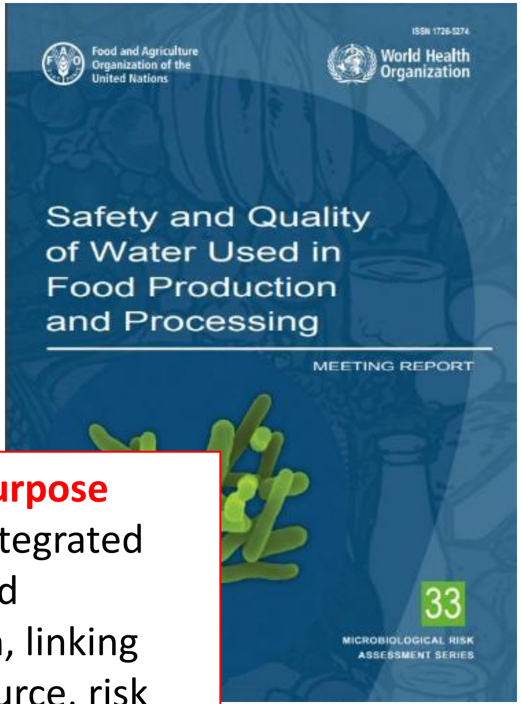


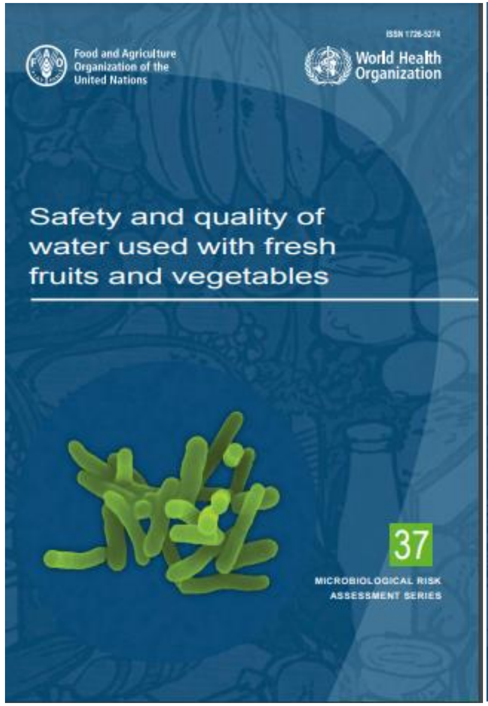
Pathway Forward

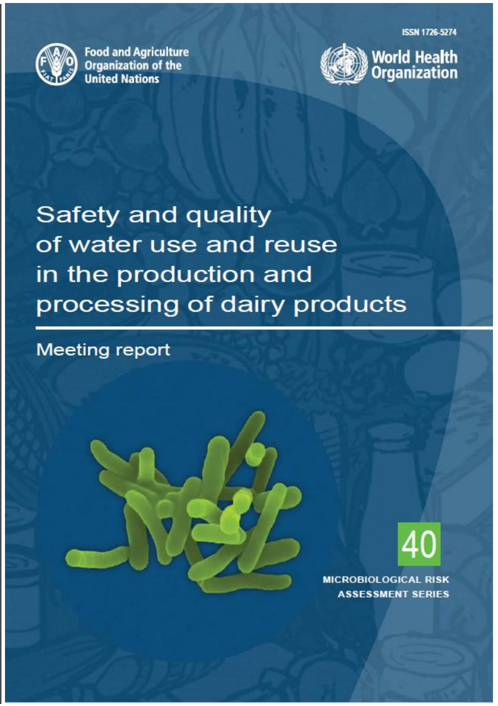
Workshop in **Honduras** to evaluate the decision tree and concepts from JEMRA, in October 2022

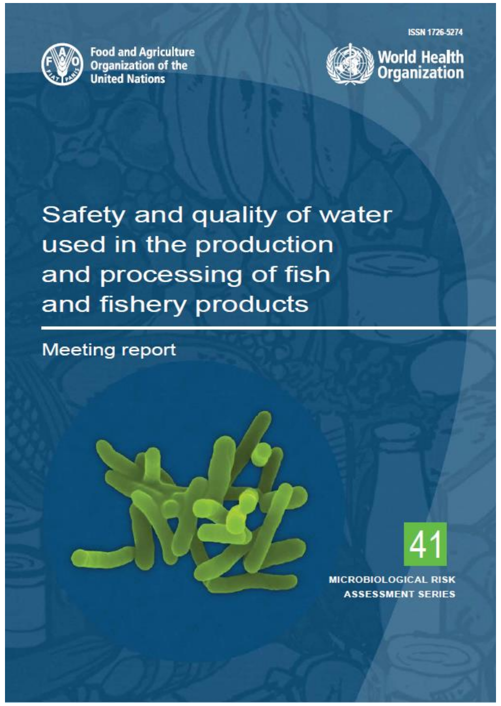


Fit-for-purpose water, integrated risk-based approach, linking water source, risk assessment, treatment options and efficacy, water use and food safety.





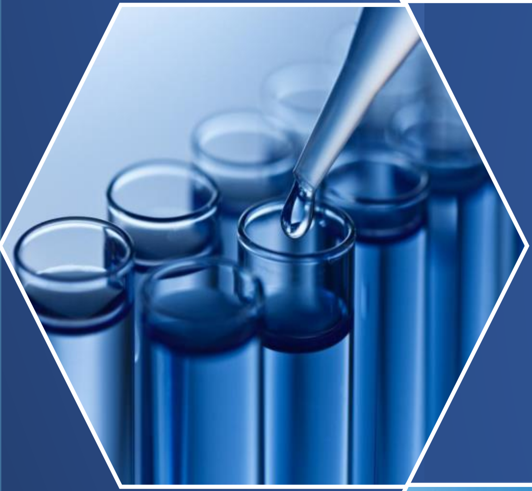




- 2017 meeting and infographic
- 2018 meeting 2019 report
- 2019 meeting 2021 report
- 2021 meeting 2022/2023 report

Codex Alimentarius – international food standards

- **General Principles of Food Hygiene (2022)**
- **Guidelines for the safe use and reuse of water in food production and processing (2023)**
  - Provide guidance for **food business operators** (FBOs) and **competent authorities** on the application of a risk-based approach for the use and reuse of water that is fit for purpose.
  - Provide practical **guidance and tools** (e.g. DTTs) and risk-based microbiological **criteria** as examples to help FBOs evaluate risks and potential interventions of water as part of their food hygiene system.
  - Annexes: **fresh produce**, **fishery products**, **dairy products**.



Risk-based, fit-for-purpose water (re)use approach for Fish and Fishery Products Sector

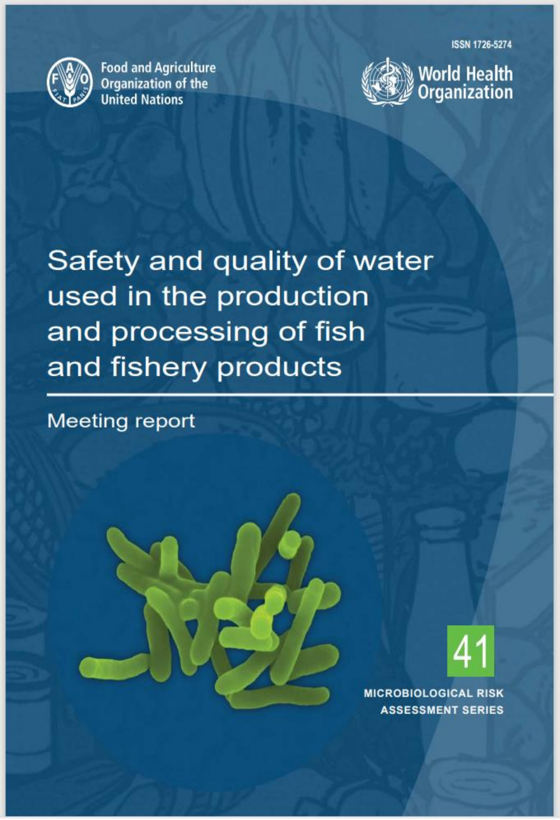
Yulie E. Meneses, Ph.D.

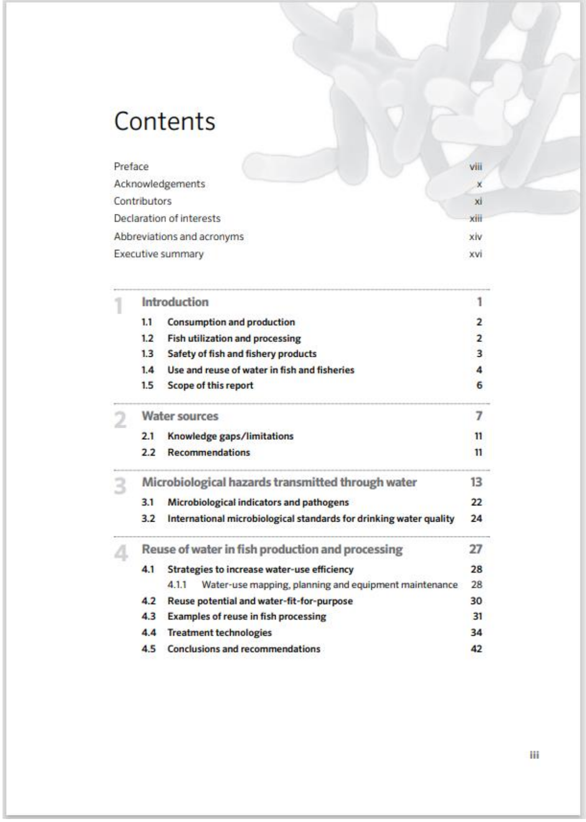
University of Nebraska Lincoln

Water for Food Daugherty Global Institute at the University of Nebraska

Produce Safety Alliance

Safety and Quality of water used in the production and processing of FFP: Meeting Report





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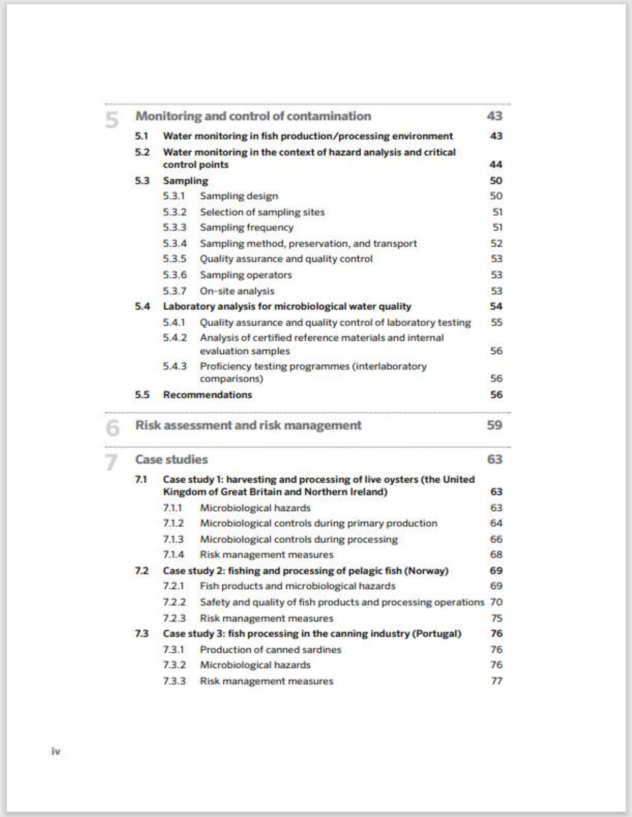

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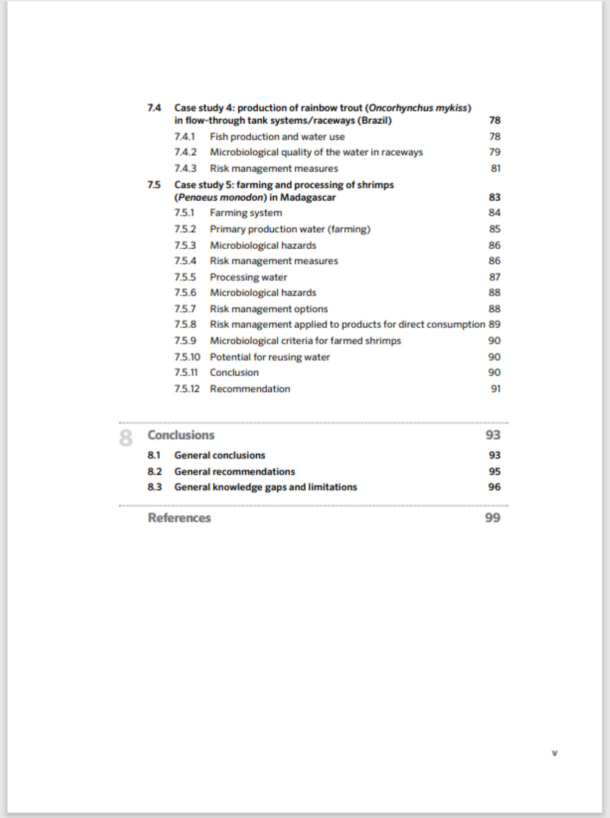

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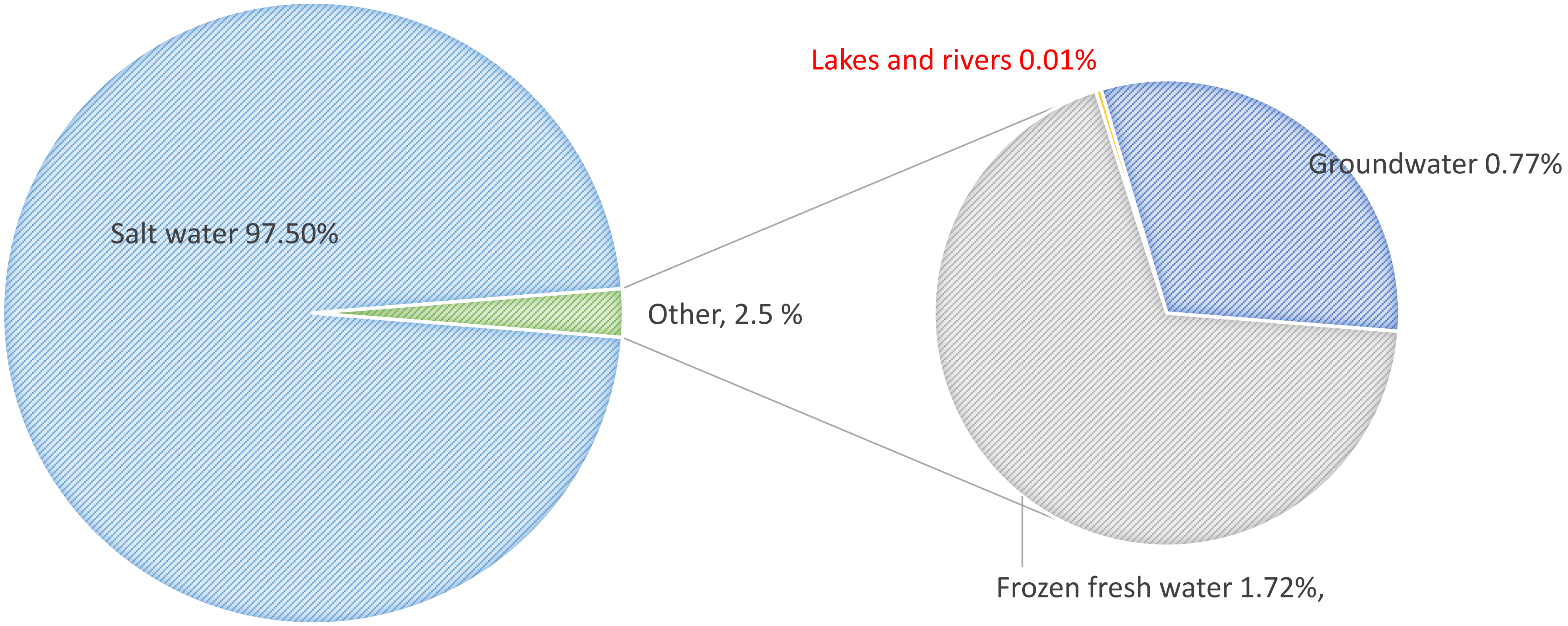
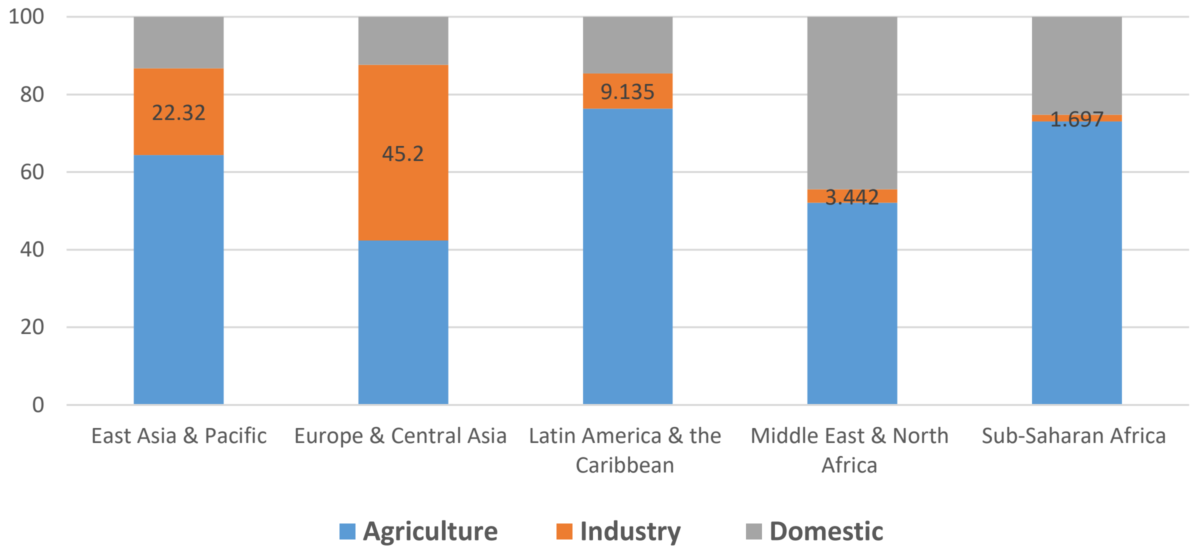
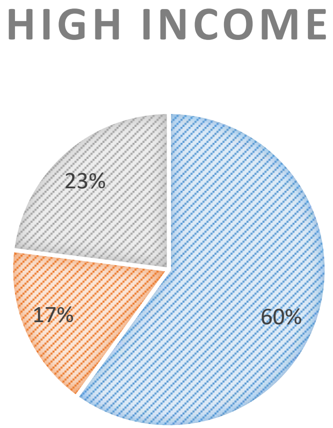
Global water resources

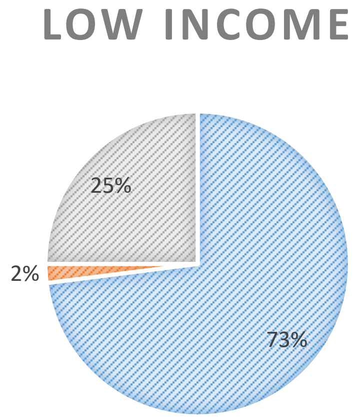


Source: United Nation World Water Development Report, 2003

Share of freshwater withdrawals by sector (%)

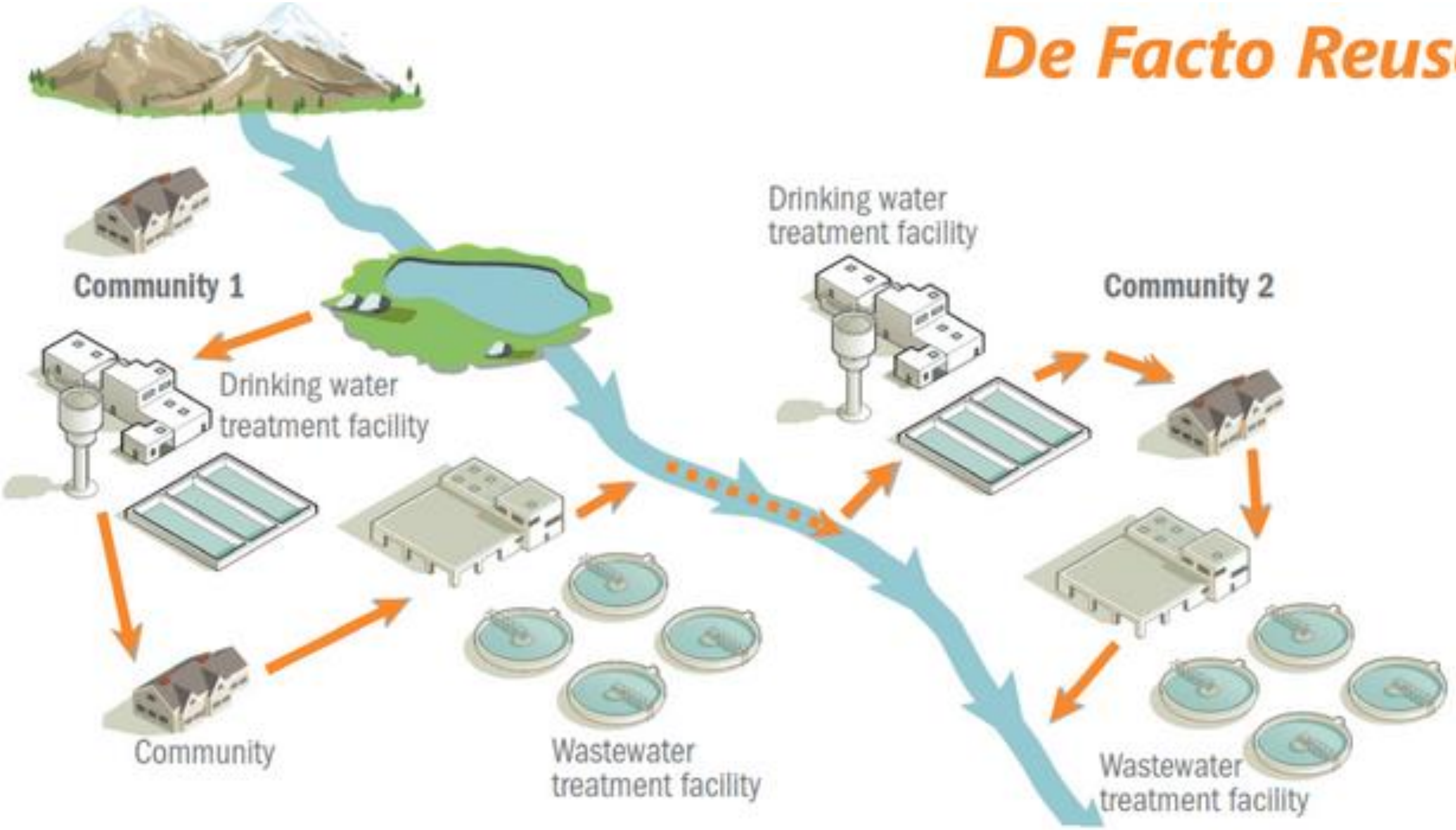






Source: World Bank, 2015

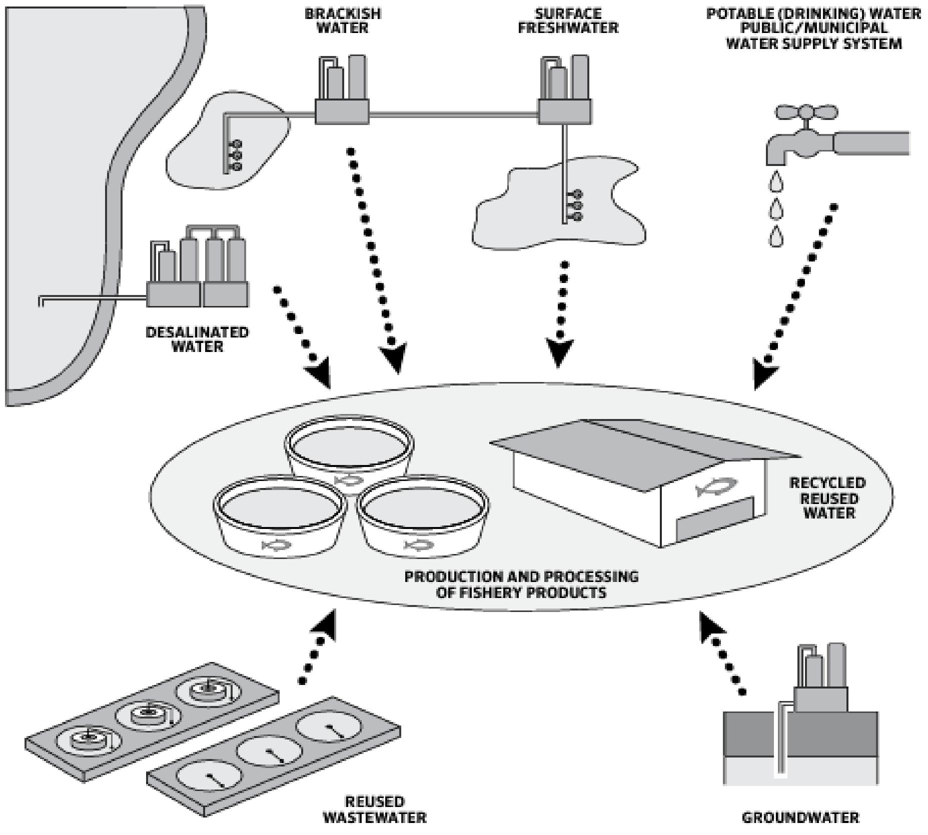
De Facto Reuse



Source: AWWA Potable Reuse 101

Water sources and use in the production and processing of fish and fishery products

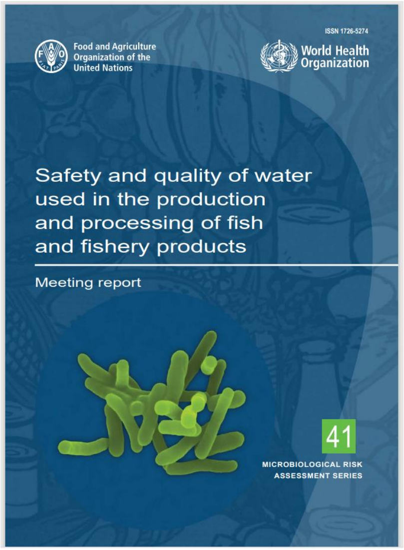
Sources



Source: ritacortez_illustration

Uses

- Rearing or harvest
- Ingredient
- Transport/convey products
- Wash
- Cool down
- Cook
- Clean and sanitize
- Make ice



Minimization of water consumption

<u>Internal strategies</u>

- Initiatives such as behavioral change → 25%
- Recycling (without reconditioning treatment) → 30%
- Monitoring → 60%

<u>Reconditioning and reuse > 90 %</u>

Initial steps

- Mapping water use
- Determining water quality and quantity

Water quality, requirements for use

Water used as ingredient or water that comes into direct contact with food or food contact surfaces should be of potable quality. With a few exceptions, the use of non-potable water is allowed during handling and processing, as long as its use does not compromise the safety of the product(s). (FAO and WHO, 2020c).

↓

Fit-for-Purpose

Water Quality

- Important factors to consider

Quality of water source

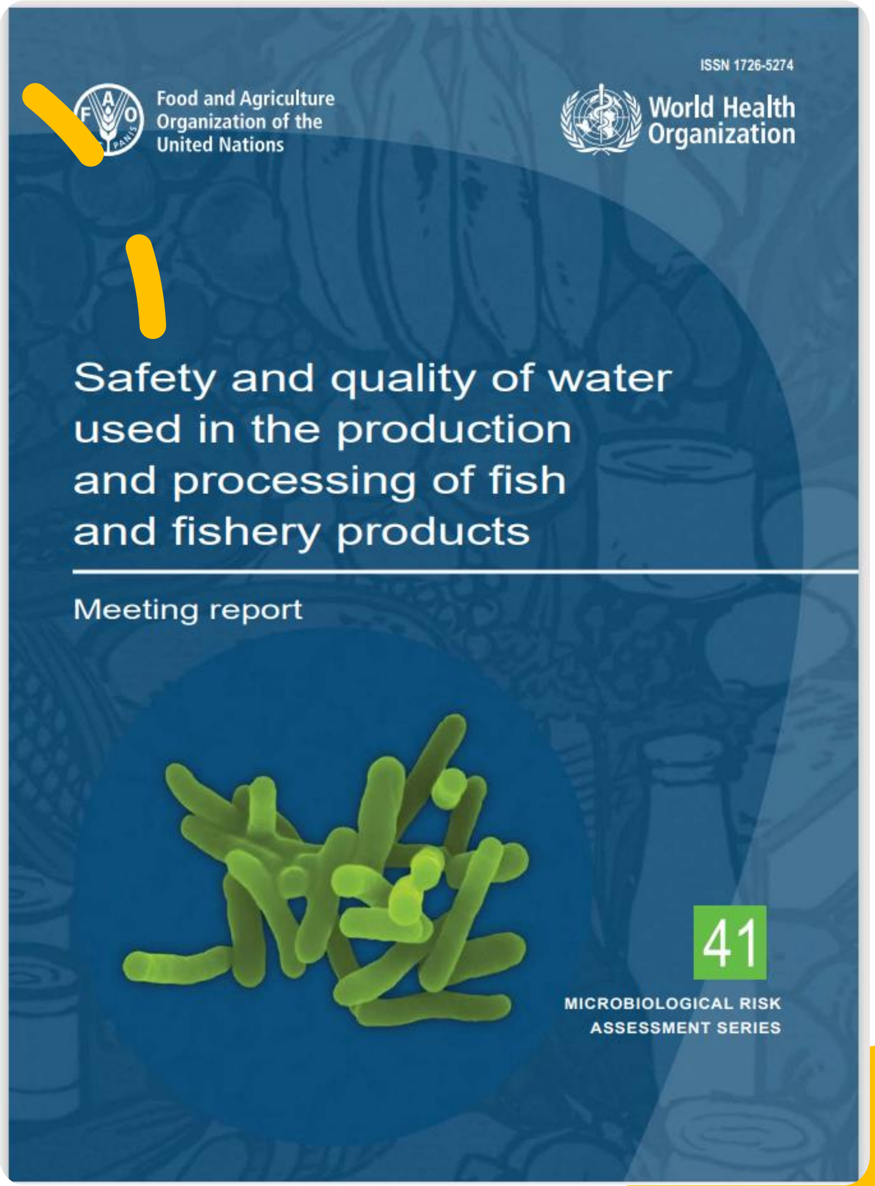
Characterization

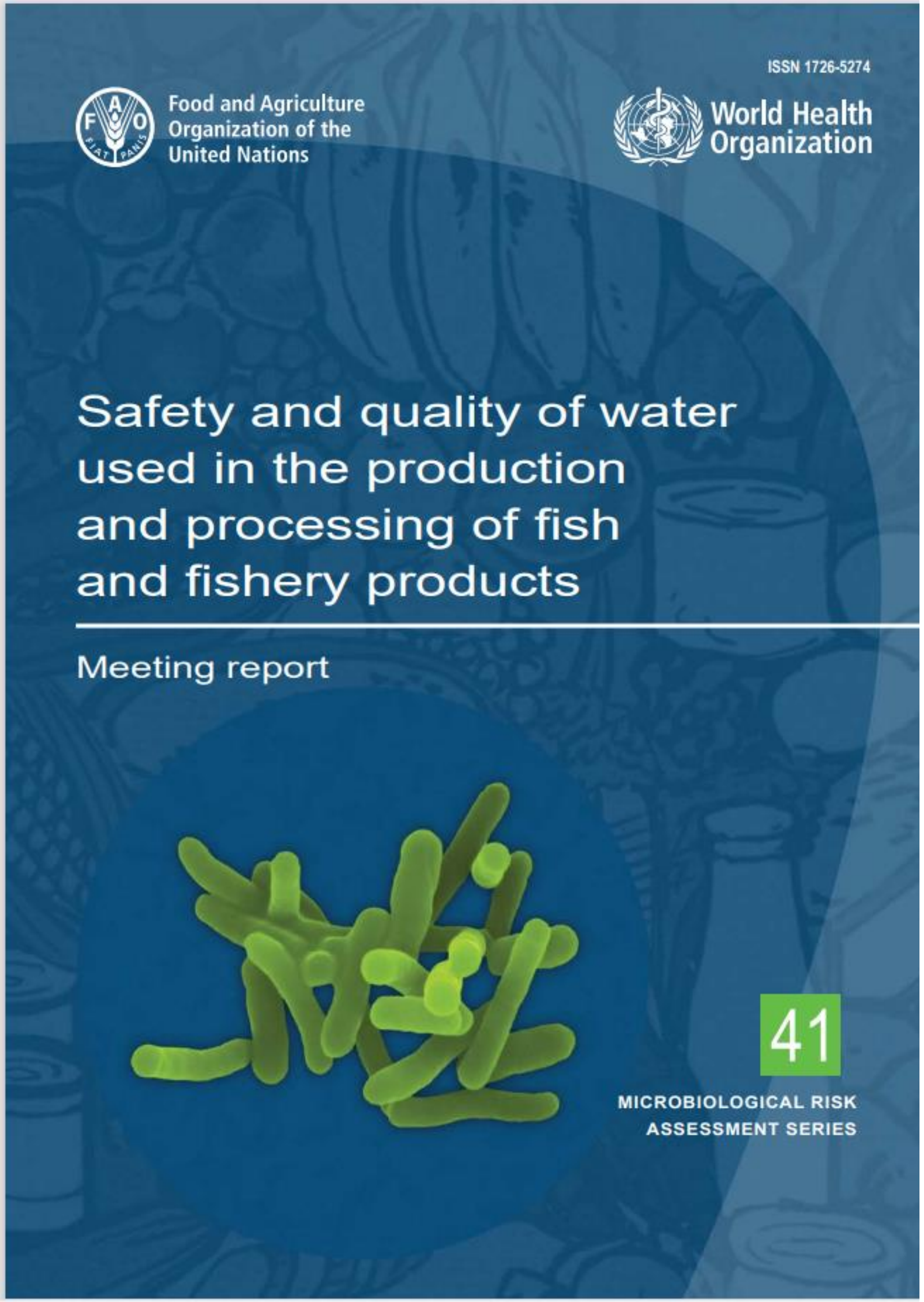
Assessment of the risks

Verification

- Focus on microbiological hazards

Good understanding of the microbial hazards helps to inform **treatment methods** and **health-based targets**





Water Quality

- Fish and fishery products have been associated with infections and intoxications mediated by viruses (principally norovirus and Hepatitis A), bacteria (principally Vibrio spp. and Salmonella spp.), protozoans (principally Giardia sp. and Cryptosporidium sp.), and helminths (principally Anisakis spp.)

- Pathogen occurrence and distribution are affected by:
  - Indigenous prevalence
  - Contamination from land by sewage and agriculture
  - Catchment characteristics
  - Human populations and their lifestyles
  - Water and wastewater uses and treatment
  - Medical interventions

Water fit-for-purpose

To mitigate these health risks, the use of water in the production and processing of fishery products should be subject to a risk-based approach covering the whole water system

- ✓ Source
- ✓ Characterization (quality and quantity)

Intended use

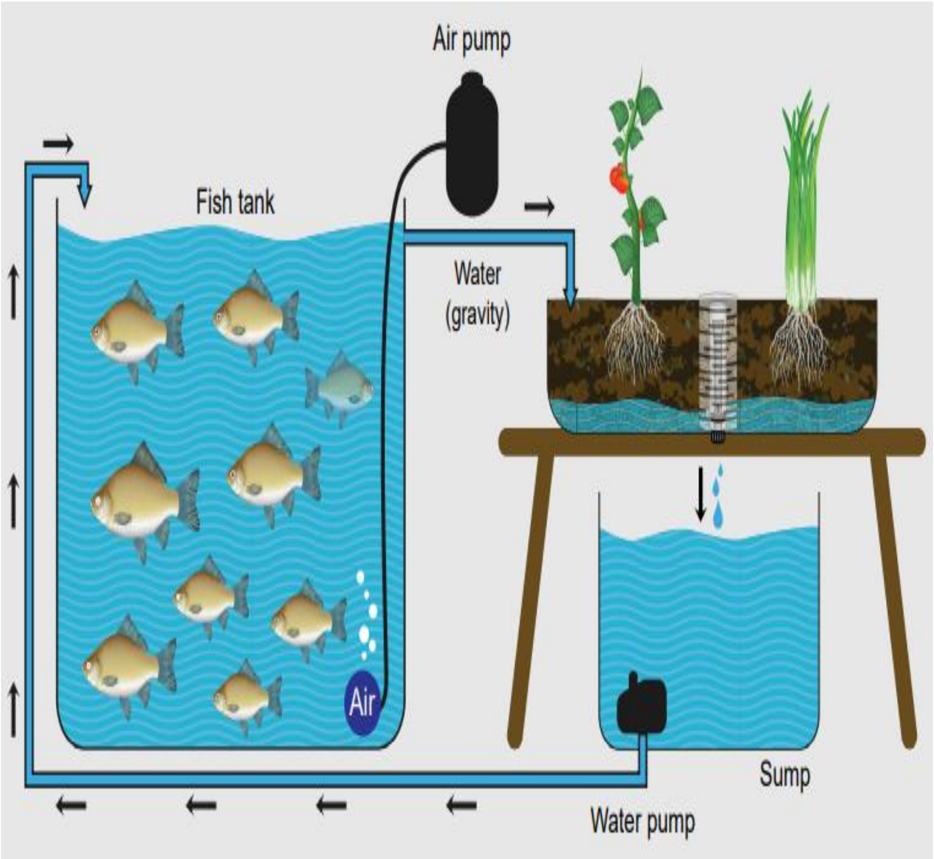
Sanitary surveys/profiling
Hazard analysis and critical control point (HACCP)-based approach such as water safety plans (WSPs)

↓

Water fitness and the likelihood of contamination in the production and processing system

Water fit-for-purpose

Product	Canned fish	Sardines	Fish	Canned anchovies	Shrimp
pH	6.13–7.14	6.5–6.9	5.5–9.2	NA	NA
COD (mg/L)	1 147–8 313	6 000–15 767	110–1 722	16 984	1 200–2 300
BOD_5 (mg/L)	463–4 569	2 122	43.85–890	7 060	720–1 100
TN (mg/L)	21–471	NA	10.8–102	1 152	45–77
TP (mg/L)	13–47	56.8	0.058–16.4	NA	18–71
TSS (mg/L)	324–3 150	NA	60–940	4 621	122–872
Conductivity (mS/cm)	4.73–24.8	NA	NA	160	NA
Reference	Cristóvão et al. (2015)	Duarte et al. (2015)	Ferraciolli et al. (2018)	Corsino et al. (2016)	Anh et al. (2011)



Source: FAO. 2014. *Small-scale aquaponic food production. Integrated fish and plant farming.* FAO Fisheries and Aquaculture Technical Paper No. 589. Rome, FAO. https://www.fao.org/3/i4021e/i4021e.pdf

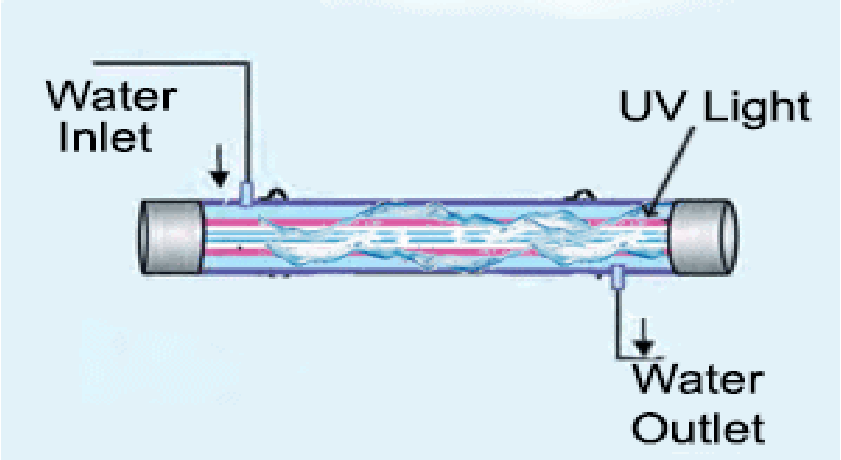
Reconditioning treatments- Chemical methods

Reconditioning treatment = Required water quality characteristics

Method	Application	Pollutant removal (%)	Advantages	Limitations
Chlorine	Disinfection	NA	Low cost Widely available Simple testing of free residual	Organic matter reduces efficiency Potential hazardous by-product
Ozone	Disinfection Impurities removal	COD: 59.8	Short contact time No harmful residues	High energy demand
Peracetic acid	Disinfection	NA	Not inhibited by high organic load Effective in low concentration	Corrosive (equipment) Increase BOD and COD in the effluent

Reconditioning treatments-Physical methods

Method	Application	Pollutant removal (%)	Advantages	Limitations
Membranes	Removal of impurities and microorganisms	> 95	Allow recovery of by-product Absence of residual toxicity	High investment cost Microbial survival is possible
UV light	Disinfection	NA	Absence of residual toxicity	UV-dose difficult to determine Require low turbidity in wastewater



Reconditioning treatments- Biological methods

Treatment	Application	Removal	Advantages	Disadvantages
Aerobic bacterial		COD: 98.1% BOD5:99.6%	Efficient removal of COD, BOD Easy to build up and operate Low investment	Require energy for aeration Inefficient in P, N removal Generate carbon dioxide
Anaerobic bacteria		BOD_5: 95%	Less affected by organic loading Generate biogas as byproduct	Require large space Inefficient in P,N removal Require long treatment period
Microalgae	Degrade organic nutrients		Efficient in P, N removal Synthesize lipid, protein and starch	High cost of biomass harvesting Less efficient in COD removal
Yeast		COD:41%	Tolerate high COD Generate enzyme like lipase, amylase	Require longer biodegradation period Less resistant to exterior contamination
Vermifiltration		COD: 96% TN: 21.57% TP: 43%	Low cost No energy requirement Generates no sludge	Low removal of TN and TP

Reconditioning treatments- Biological methods

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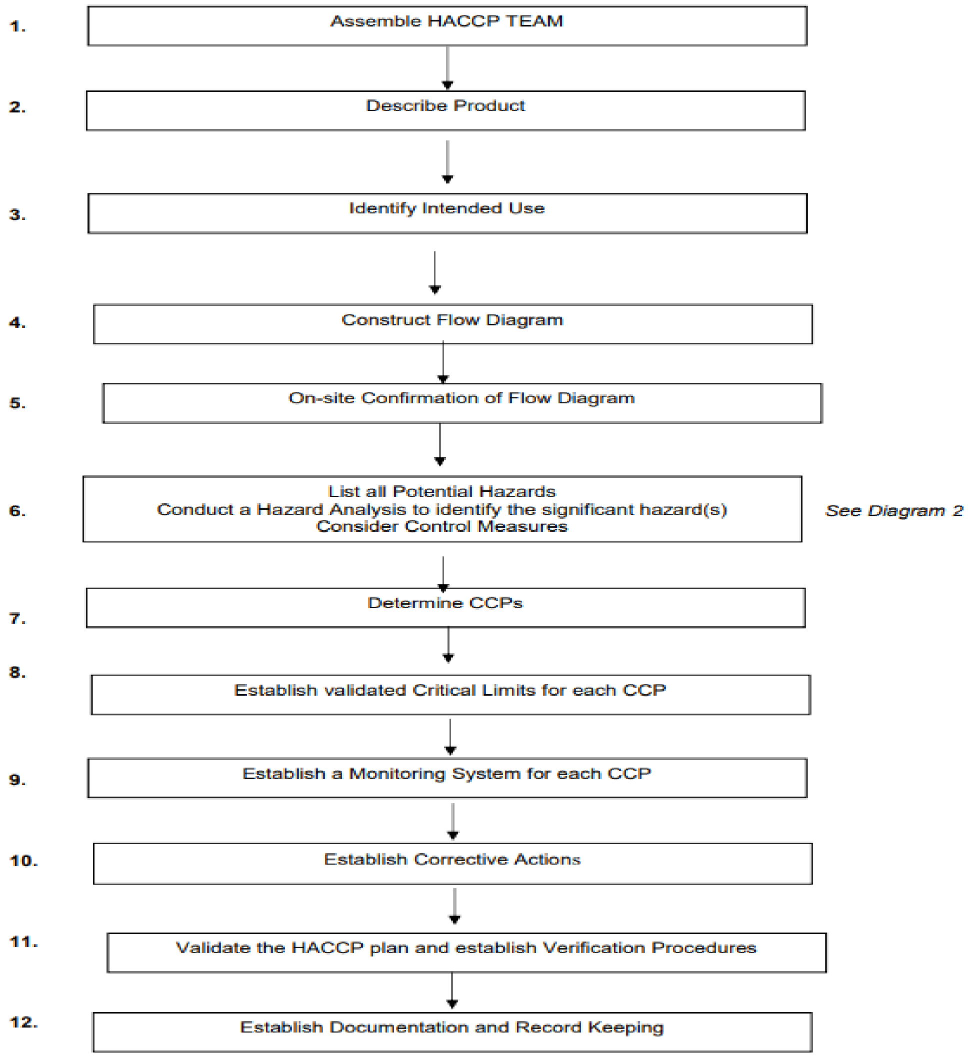
Vermifiltration		COD: 96% TN: 21.57% TP: 43%	Low cost No energy requirement Generates no sludge	Low removal of TN and TP

Following HACCP Principles



A water monitoring plan should consider the following aspects:

- ✓ Monitoring objectives
- ✓ Deviation from a critical limit should be detected as quickly as possible to allow prompt corrective action
- ✓ Monitoring frequency
- ✓ Monitoring location
  - Sampling
  - Laboratory analysis

Source: FAO & WHO. 2011. Codex Alimentarius. General principles of food hygiene, CXC 1-1969. Rome, FAO.

Framework, a holistic approach for water reuse

Drivers, challenges and SOLUTIONS

Environmental

Water management

Economical

Cost based on true value of water

Regulatory

Need for guidelines and risk-based approach

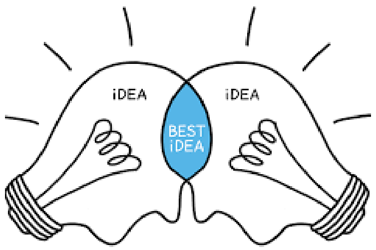
Technological

Holistic evaluation of proposed treatments

Social

Communication between scientist, media and consumers

Industry & Academia



Applied research in collaboration with industry

"Anyone who can solve the problems of water will be worthy of two Nobel prizes - one for peace and one for science."

John F. Kennedy

Thank you!

Yulie E. Meneses, Ph.D.

Bringing the fit-for-purpose approach for fish and fishery products into operation

Water (re)use case studies

Carlos Campos

Jacobs

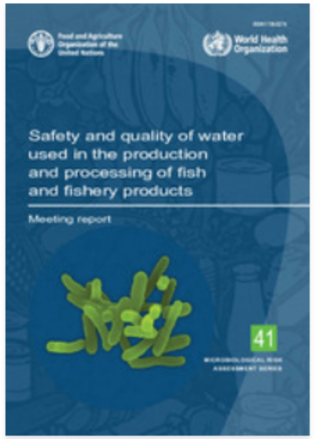
Challenging today.
Reinventing tomorrow.

International Association for Food Protection

Safety and quality of water used in the production and processing of fish and fishery products: meeting report

Microbiological Risk Assessment series 41

27 March 2023 | Report



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Overview

In 2020, the 43rd Session of the Codex Alimentarius Commission approved the "Development of Guidelines for the Safe Use and Reuse of Water in Food Production" proposed at the 51st Session of the Codex Committee on Food Hygiene. To support this work, JEMRA was asked to provide scientific advice on sector-specific applications and case studies for determining appropriate and fit-for-purpose microbiological criteria for water sourcing, use and reuse in fish and fishery products from primary production to retail.

This report presented the outcome from the JEMRA meeting, which includes the: Situation analysis concerning water use and reuse in the production and processing of fish and fishery products, analysis of case studies for different risk-based water use and reuse processing scenarios and species, water quality monitoring and the use of non-culture based microbiological methods, recommendations concerning the safety and quality of water used in fish production and processing, and critical research gaps and policy developments.

More information

- Microbiological Risk Assessment series

WHO TEAM

Joint FAO/WHO Expert Meetings on Microbiological Risk Assessment (JEMRA),
Nutrition and Food Safety (NFS),
Standards & Scientific Advice on Food Nutrition (SSA)

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World Health Organization & Food and Agriculture Organization of the United Nations

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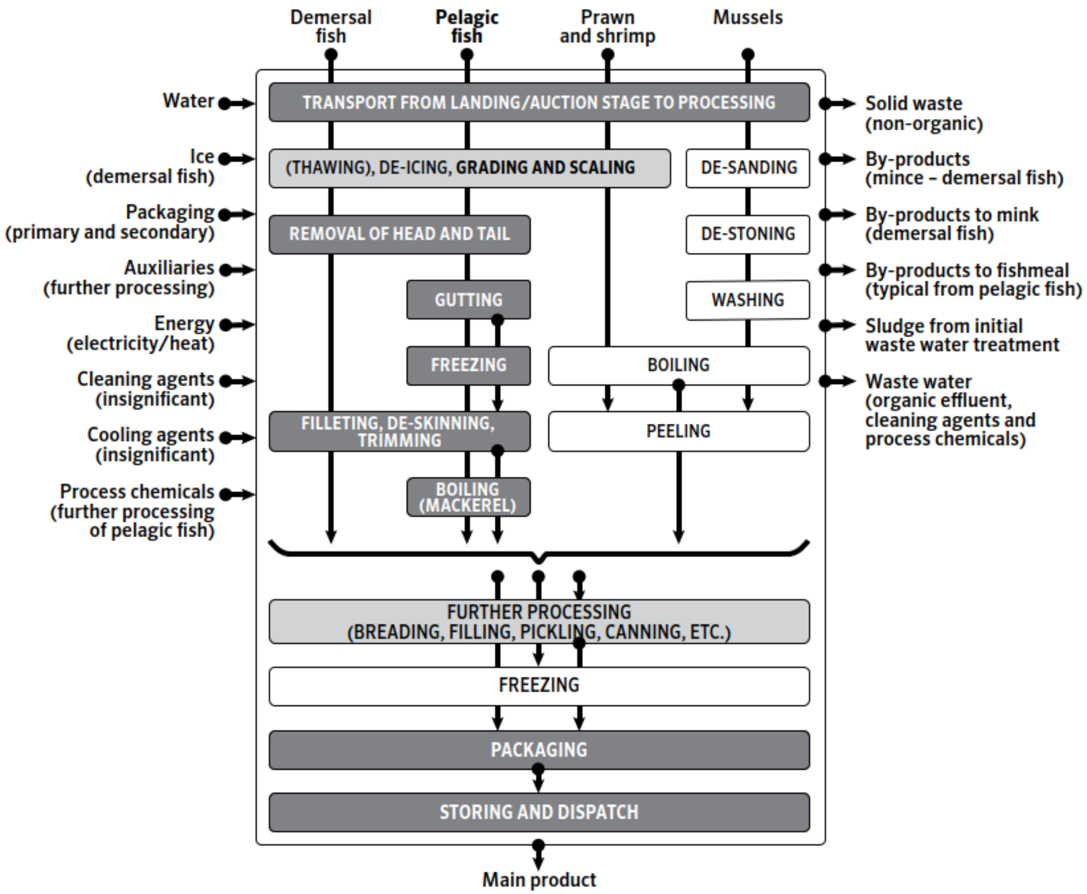
The importance of cleaner production in the fish and fisheries sector

FIGURE 5 Flow chart of fish and shellfish processing steps used by the industry in Denmark. Demersal fish include codfish and flatfish; pelagic fish include herring and mackerel



Source: Thrane et al. (2009)

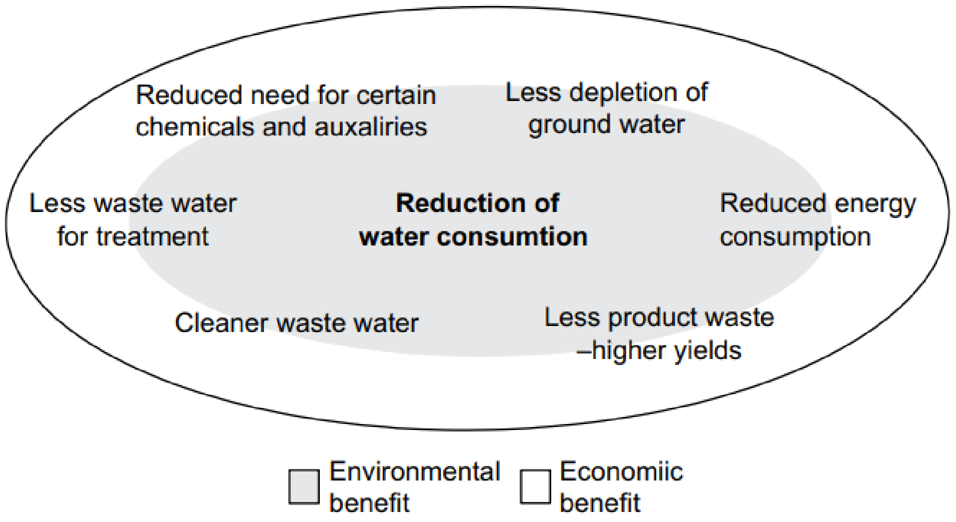


Fig. 4. Environmental and economic benefits related to reductions in water consumption.

Case studies

Clean water is essential to produce safe shellfish

- Shellfish are filter-feeding organisms; they strain the surrounding water through their gills which trap and transfer food particles to their digestive tract.
- If the water is contaminated with pathogens, these are also consumed as food. Because shellfish pump large quantities of water through the gills each day, pathogen concentrations in shellfish can reach hazardous levels.
- If shellfish containing pathogens are eaten raw or partially cooked, illness may result.
- It is important that shellfish be harvested from approved harvesting waters.

Norovirus outbreaks linked to oysters sign of water pollution: shellfish group

Marsha Taylor, B.C. Centre for Disease Control epidemiologist, said norovirus contaminates foods

The Canadian Press
May 3, 2018 5:20 PM

Oysters contaminated with norovirus in British Columbia have become a costly problem and the issue magnifies a broader failure to keep oceans clean, says the provincial shellfish growers association.

Source: https://www.summerlandreview.com/news/norovirus-outbreaks-linked-to-oysters-sign-of-water-pollution-shellfish-group-4156153

Sanitary controls of shellfish produced for human consumption

- Sanitary surveys combined with microbiological monitoring of shellfish growing areas and, if necessary, post-harvest treatments, help protect shellfish consumers.

- Sanitary surveys evaluate factors that influence the sanitary quality of a growing area. These include:
  - Sources of pollution (animal wastes from agricultural land, wastewater treatment plants, surface-runoff)
  - Microbiological quality of the water and shellfish
  - Hydrographic characteristics of the growing area.

- Sanitary controls focus on growing areas because these determine much of the end-product safety/quality.

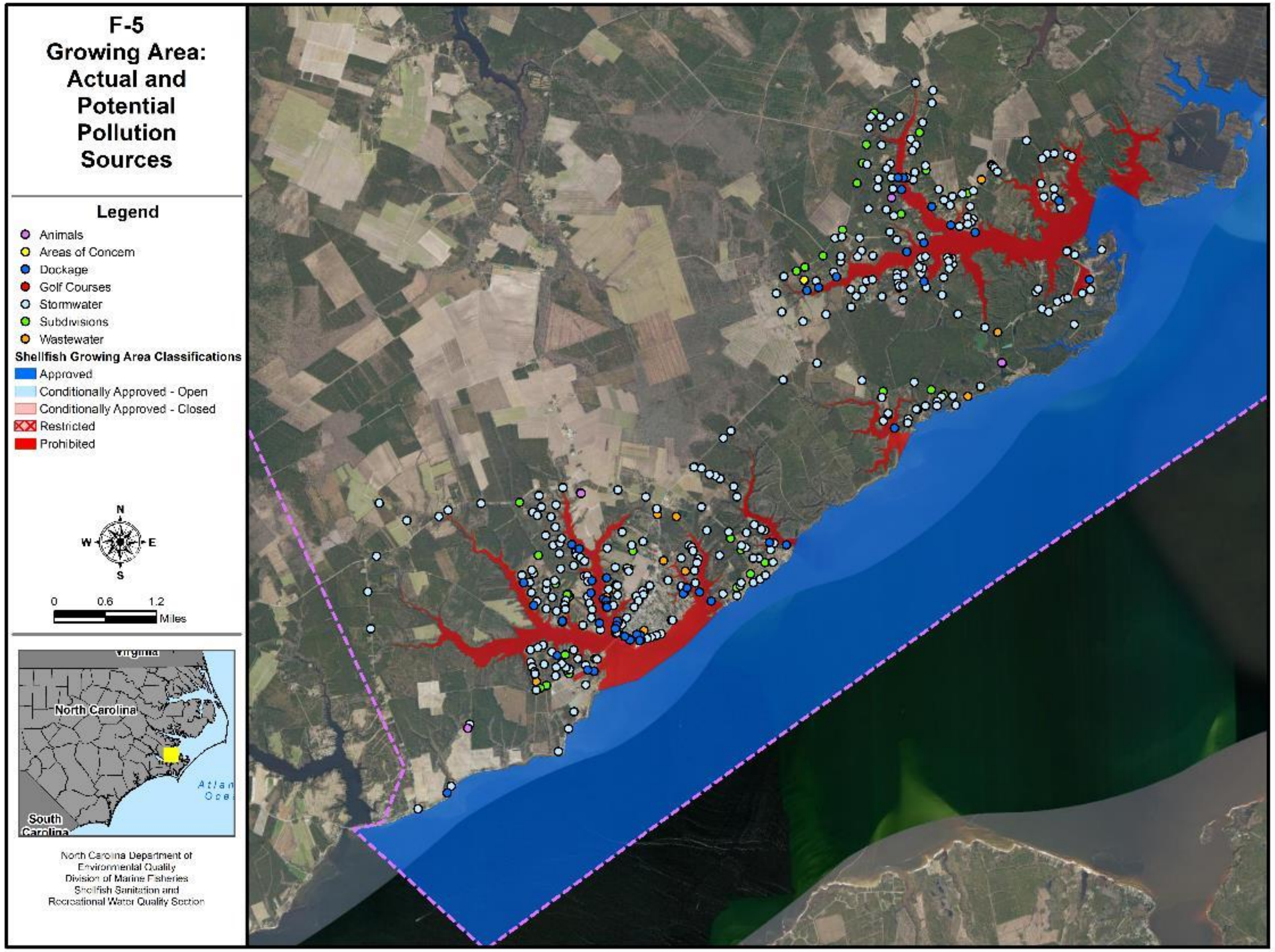
- Regulatory monitoring programs use fecal indicator bacteria.

TABLE 7 Criteria for classification of shellfish production areas in the European Union

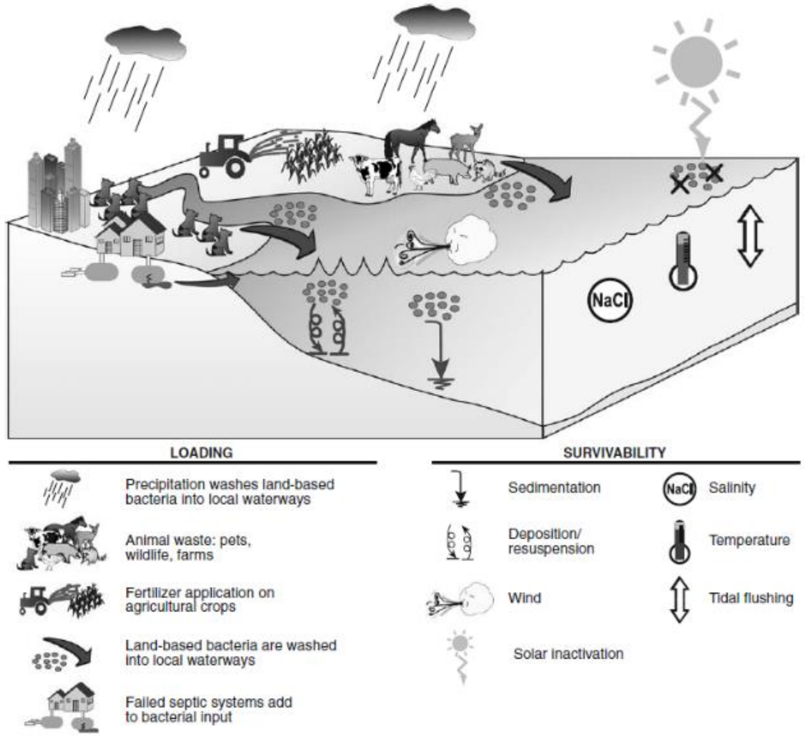
CLASS[a]	MICROBIOLOGICAL STANDARD[b]	TREATMENT REQUIRED
A	Samples of live bivalve molluscs from these areas must not exceed, in 80% of samples collected during the review period, 230 *E. coli*/100 g of flesh and intravalvular liquid. The remaining 20% of samples must not exceed 700 *E. coli*/100 g of flesh and intravalvular liquid.[c]	None
B	Live bivalve molluscs from these areas must not exceed, in 90% of the samples, 600 MPN *E. coli*/100 g of flesh and intravalvular liquid. In the remaining 10% of samples, live bivalve molluscs must not exceed 46 000 MPN *E. coli*/100 g of flesh and intravalvular liquid.[d]	Purification, relaying or heat treatment by an approved method
C	Live bivalve molluscs from these areas must not exceed 46 000 *E. coli* MPN/100 g of flesh and intravalvular liquid.[e]	Relaying or heat treatment by an approved method

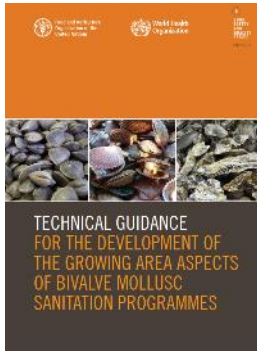
Sanitary profiling of shellfish growing areas

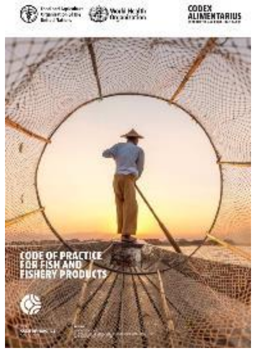
Source: https://storymaps.arcgis.com/stories/946ba7399b2248578b01a86ea720adbb



Pollution: All Sources







Post-harvest treatments: depuration and relaying

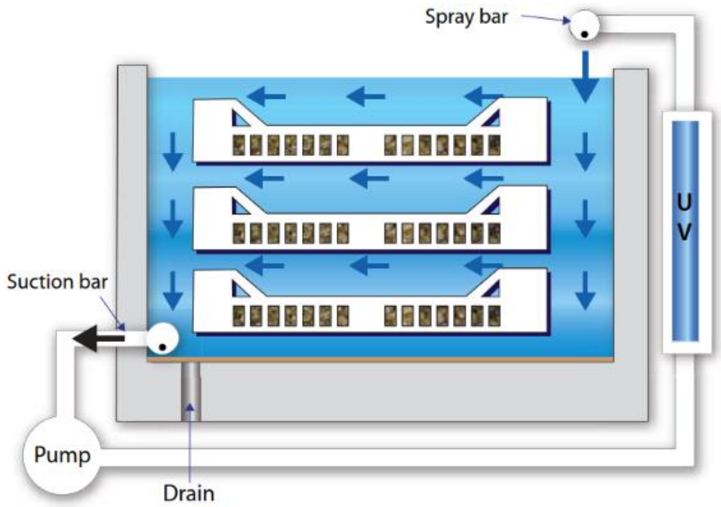
- Shellfish are depurated by placing them in tanks with clean seawater such that the animals undertake their normal pumping activity and excrete contaminants in their feces.

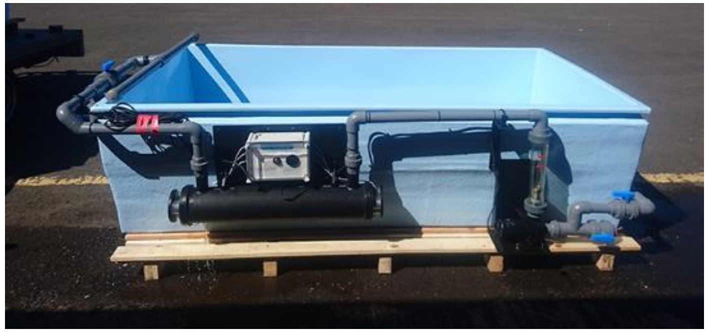
- Depuration is used to remove contaminants from lightly/moderately contaminated shellfish.

- Seawater is disinfected prior to depuration to prevent re-contamination. Water is then recycled through the system to allow aeration of the water.

- Shellfish loading, salinity, dissolved oxygen, temperature and turbidity determine process efficacy.

- In relaying, the shellfish are transferred from a contaminated/closed growing area to an approved growing area. This purification process also uses the natural ability of the animals to cleanse themselves.





Source: https://www.toddfishtech.com/bivalve-purification-systems/

Risk management of norovirus in oysters

- The microbiological hazards of greatest concern in relation to shellfish are viruses (norovirus, Hepatitis A) and vibrio bacteria.
- Routine monitoring of norovirus in shellfish is not legally required at present.
- Interim measures have been implemented in some countries to control the norovirus risk.
- EFSA considers that microbiological criteria for norovirus in oysters are useful for validation and verification of HACCP and can be used as additional control to improve risk management in growing areas.
- Depuration at elevated temperatures can significantly reduce norovirus in shellfish.
- Relaying followed by depuration at elevated temperatures over several days can reduce norovirus concentrations to background levels.

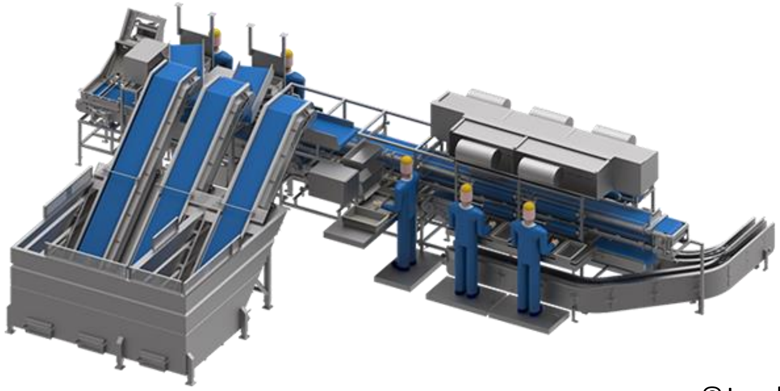
Fish products and hazard controls

- Pelagic fish are commonly processed to produce fish fingers, fish balls and fish cakes.

- The fish are placed in tanks containing refrigerated seawater shortly after capture to maintain high fish quality during on-board storage and transportation, and to delay bacterial spoilage.

- In processing plants, the fish are transported on conveyor belts, washed with potable water, sorted and processed through filleting or trimming machines, before packing and finalizing the product. Along the production line, the fish are exposed to surfaces, production waters and handled by trained workers.

- HACCP systems implemented in freezer/factory vessels may be less stringent than those implemented land-based processing units.

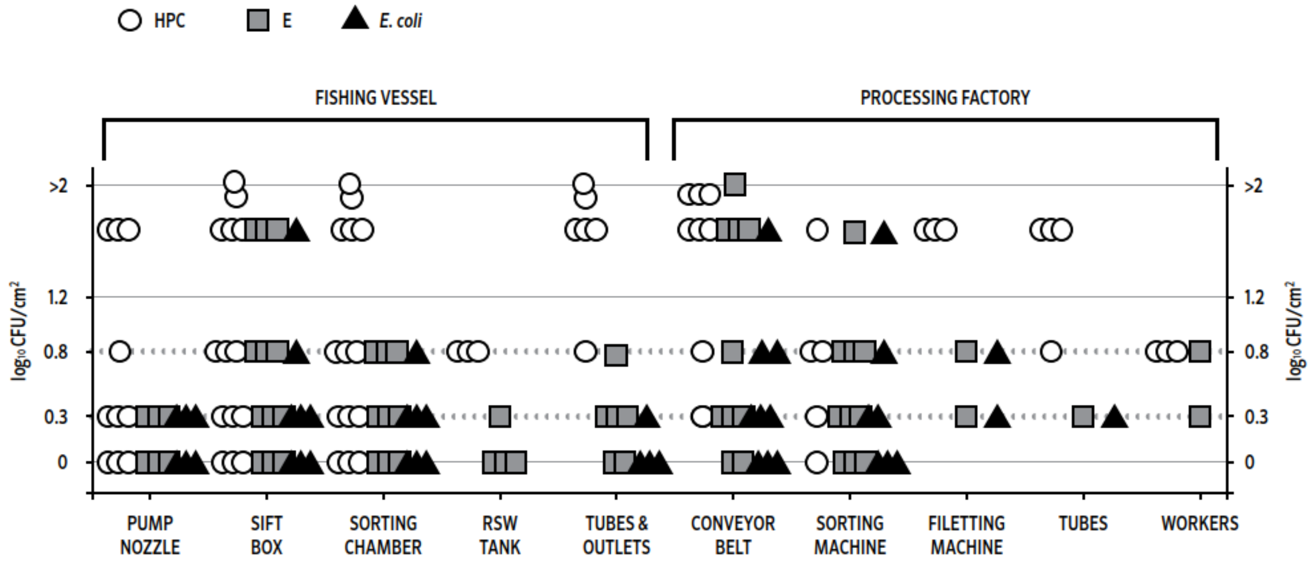


Product safety and quality in processing factories and vessels

- Cases of human illness have been associated with cross-contamination during handling and processing, improper conditions of storage and preparation/reheating of the product.

- Studies have assessed the microbiological conditions of fresh fish, surfaces and production water along the production and processing chains against quality, hygiene and safety parameters.

FIGURE 10 Median concentrations of heterotrophic plate count, *Enterobacteriaceae* and *E. coli* in samples collected from surfaces in fishing vessels and processing facilities



HPC – heterotrophic plate count (quality parameter)
E – Enterobacteriaceae (hygiene parameter)
E. coli – *Escherichia coli* (hygiene parameter)

Controlling microbial contamination in the processing chain

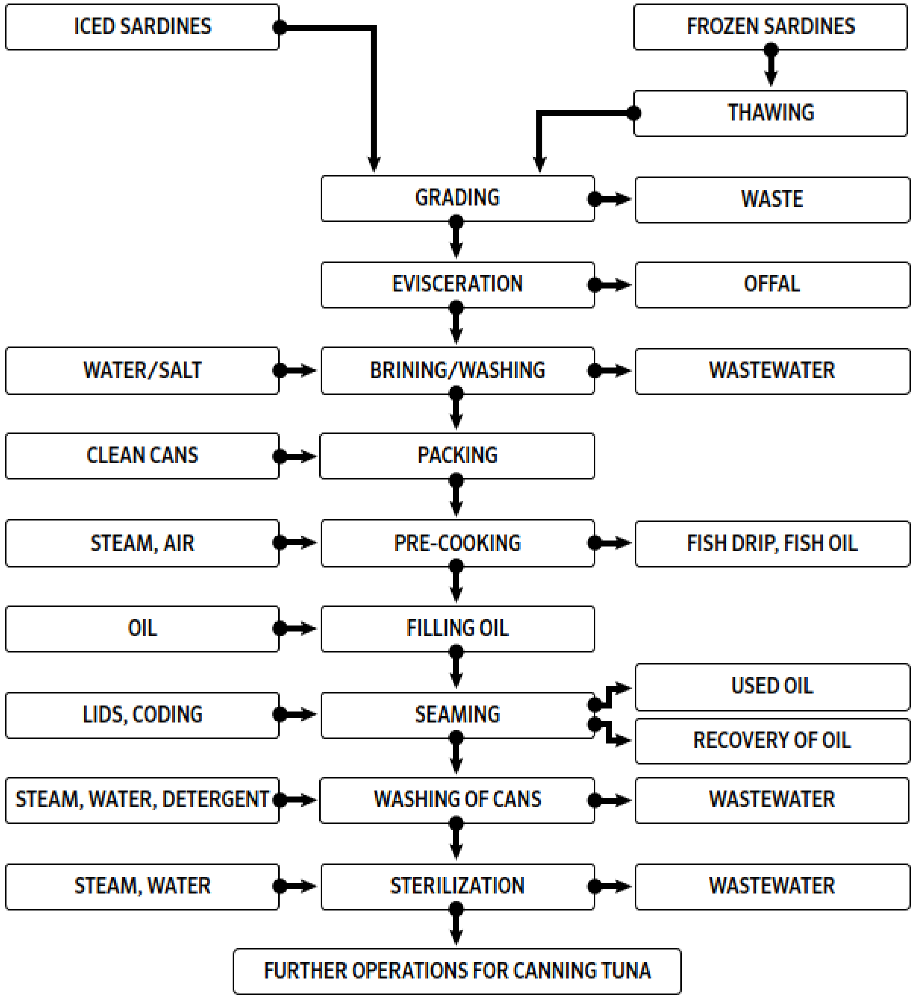
- Risk assessments show the importance of controlling microbial contamination throughout the pelagic fish processing chain, from catching and handling to processing.

- There is scope to improve the hygiene conditions of fish held in processing factories and onboard freezer/factory vessels.

- On-board pumping has been found to increase bacterial contamination of fish gills and skin.

- Contamination risk can be reduced by:
  - Maintaining constant sub-zero temperatures during storage
  - Proper recirculation and good hygiene practices in refrigerated water systems
  - Reduction of fish densities in tanks.

Production of canned sardines in oil



- Large volumes of water used in cleaning, washing, cooling, thawing, and ice production and removal.
- Critical operations include seaming, sterilization and sanitation of cooling water.
- These operations generate large quantities of wastewaters with high content of organic matter, salts, oil and grease.
- Challenges associated with large variations of wastewater produced between fish processing operations, type of raw material processed, and compliance with effluent emission limits.

Fish canning: control of microbiological hazards

- Fish canning has been implicated in low numbers of cases of food poisoning.
- The most important microbiological hazards are botulism, histamine poisoning and staphylococcus enterotoxin poisoning.
- Thermal processes must ensure the inactivation of *C. botulinum*. Canning is typically conducted at a sterilization temperature of 121.1°C. At this temperature, the D121.1 value for this pathogen is 0.1–0.23 minutes.
- Regulation (EC) No. 2073/2005 prescribes maximum values for histamine in fish products. For fish species associated with a high amount of histidine (e.g., tuna, mackerel, sardines), the mean value is ≤100 mg/kg of histamine and the maximum value is 200 mg/kg.
- In commercial operations, retail or trading organizations commonly impose a maximum concentration of 50 mg/kg.

Fish canning: control of microbiological hazards

- Regulation (EC) No. 852/2004 requires food manufacturers to implement HACCP, with specific requirements for manufacture of heat-processed products:

  - Any heat treatment is to raise every part of the product to a given temperature for a given period of time and to prevent the product from becoming contaminated during the process.
  - FBOs must check regularly the main relevant parameters (e.g., temperature, pressure, sealing and microbiology), including the use of automatic devices.
  - The process should conform to an internationally recognized standard (e.g., for pasteurization or sterilization).

- Fish canning operators are required to examine each step of the manufacturing process and monitor the physical, chemical and biological hazards that could affect the safety and quality of the product(s).

General conclusions from the case studies

- There are many opportunities for water reuse in the fish production and processing industry.
- Sanitary surveys and risk assessments are important to determine the safety of water for (shell)fish production and the likelihood of product contamination.
- To maintain the sanitary quality of fish on vessels and in processing factories, measures must be applied to limit contamination, avoid temperature rise and control any cross-contamination from capture.
- Canning processes should comply with internationally recognized standards for the control of physical, chemical and biological hazards.
- Further research needed to determine the relationships between water quality parameters in fish production and processing environments, pathogen infectivity and health effects on fish producers/processors and consumers.

Thank you

Full report: https://www.who.int/publications/i/item/9789240066281

Summary report: https://cdn.who.int/media/docs/default-source/food-safety/jemra/jemra-microbiological-water-quality-fishery-products-summary-report.pdf?sfvrsn=1516dd87_7&download=true

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