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Bivalve depuration: fundamental and practical aspects

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Cover photographs:
Clockwise from top left: Horizontal bivalve depuration plant in Goro, Italy (courtesy of Acqua&Co S.r.l.); depuration system in La Rochelle, France, operating vertical bins and horizontal tanks including a protein skimmer unit (courtesy of Acqua&Co S.r.l); bivalves on display at a fish shop in Rome, Italy (FAO/A. Lovatelli); post-depuration bivalve sorting and packing operations taking place in a separate area of a depuration plant in Ferrara, Italy (courtesy of M.GI.B. S.r.l.).

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Preparation of this document

World bivalve production and consumption has increased significantly during the recent years, going from a combined total for wild catch and aquaculture of approximately 10.7 million tonnes in 1999 to 14 million tonnes in 2006 (FAO fishery statistics). Likewise, the development of freight by air and sea and preservation techniques have enabled consumers, in different parts of the world, to enjoy eating bivalves that were produced in distant waters. Such developments in distribution and trade have in turn led to emerging challenges for consumer protection, particularly in relation to the safety of bivalves from pathogenic micro-organisms. Several species of bivalves are preferably consumed live or raw (e.g. oysters), or lightly cooked (e.g. mussels) which make them a high risk food product category requiring proper control measures to eliminate or reduce to acceptable levels potential biological, chemical and physical hazards. Furthermore, the distribution of frozen raw products also markedly extends the period of time over which contaminated batches may be consumed.

While the best approach to the production of safe shellfish is to grow them in, and/or harvest them from, areas subject to no external sources of pollution, truly unpolluted shellfish growing waters are very rare. Sourcing shellfish from areas with relatively low levels of pollution, followed by the use of depuration, will ensure that the risk of illness from faecal contaminants will be as low as can be practically achieved without thorough cooking. It enables the removal of microbial contaminants from light or moderately contaminated bivalves and thus increases the availability and supply of safe and nutritious bivalves. Furthermore, it enables the industry to meet the legal requirements of many countries which have made depuration of bivalves mandatory under specific circumstances.

However, effective depuration depends on the operation of the systems to a number of recognized principles which are intended to maximize biological activity of the bivalves while enhancing the separation of any excreted contaminants from the seawater in which bivalves are located and to prevent their re-uptake. It is also necessary to operate the centres within which the systems are located according to recognized standards of food hygiene. Without these measures, the operations can actually increase the level of contamination of individual batches or cause cross-contamination from one batch to another. Depuration will also not yield effective or consistent removal of all types of contaminants and operators need to know the limitations of the process.

This document was prepared to provide guidance to the bivalve industry on the construction, operation and monitoring of depuration systems and processes. It is mainly targeted at new operators or those with limited experience, as well as fishery and public health officers who deal with the bivalve industry. This is of particular importance for several developing countries, where the bivalve industry is expanding quickly with the aim of winning an ever larger share of the bivalve international market.

The document is divided into chapters intended to lead the reader from a consideration of the public health problems associated with bivalve molluscs, through the principles of the depuration process to more detailed considerations of the construction and operation of a depuration centre, including the application of the international principles of Hazard Analysis Critical Control Point (HACCP). Finally, there is a short section on checks to undertake in the case of problems being encountered.

This document is part of three FAO technical publications dedicated to bivalve aquaculture. The first volume of this series entitled "*Hatchery culture of bivalves: A practical manual*" (FAO Fisheries Technical Paper No. 471) was published in 2004 and is now available in Arabic, Chinese, English, French and Spanish. The second volume entitled "*Installation and operation of a modular bivalve hatchery*" (FAO Fisheries Technical Paper No. 492) was published in 2006 and is available in English.

The present document was prepared under the overall coordination of Alessandro Lovatelli, Fishery Resources Officer (Aquaculture), Aquaculture Management and Conservation Service (FIMA). The chapter on HACCP was prepared by Lahsen Ababouch, Chief, Fish Utilization and Marketing Service (FIIU).

Abstract

Bivalve molluscan shellfish concentrate contaminants from the water column in which they grow. These contaminants may then cause illness to humans when the bivalves are eaten. For microbial contaminants, the risk is enhanced by the fact that these shellfish are often eaten raw (e.g. oysters) or relatively lightly cooked (e.g. mussels). Limiting the risk of illness depends partly on sourcing the shellfish from areas in which such contaminants are at relatively low levels. The risk may be reduced further by appropriate treatment following harvest.

Depuration (purification) is a process by which shellfish are held in tanks of clean seawater under conditions which maximize the natural filtering activity which results in expulsion of intestinal contents, which enhances separation of the expelled contaminants from the bivalves, and which prevents their recontamination. Depuration was originally developed as one of a number of means to address the problem of a large number of shellfish-associated outbreaks of typhoid (caused by the bacterium *Salmonella typhi*), which caused illness and death in many European countries and in the United States of America at the end of the nineteenth century and beginning of the twentieth century.

Depuration is effective in removing many faecal bacterial contaminants from shellfish. As currently commercially practised, it is less effective at removing viral contaminants such as norovirus and hepatitis A. It is not consistently effective, or is ineffective, in removing other contaminants such as naturally occurring marine vibrios (e.g. *Vibrio parahaemolyticus* and *Vibrio vulnificus*), marine biotoxins (such as those causing paralytic shellfish poisoning PSP, diarrhetic shellfish poisoning DSP and amnesic shellfish poisoning ASP) or heavy metals or organic chemicals.

Effective depuration requires the shellfish to be properly handled during harvest and pre-depuration transport and storage. It also requires proper design and operation of the depuration systems to meet the requirements identified above for removal and separation of contaminants. Likewise the establishments in which the system or systems are located need to be operated to good levels of food hygiene in order to prevent cross-contamination between, or recontamination of, different batches of shellfish.

This document is intended to provide a basic introduction to the public health problems that can be associated with shellfish consumption and to provide guidance as to how a depuration centre, and the associated systems, should be planned and operated. It also includes guidance on the application of Hazard Analysis Critical Control Point (HACCP) plans and associated monitoring. The document is intended to be of use to members of the shellfish industry with no or limited experience in the area and to fishery and public heath officials who may be involved in providing advice to the industry. Supplementary material may be found in the publications given in the bibliography.

Keywords: marine aquaculture, bivalve depuration, pathogenic micro-organisms, faecal contamination, food hygiene, oysters, clams, scallops

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Acronyms

ABS	Acrylonitrile-Butadiene-Styrene
AOAC	Association of Analytical Communities
ASP	amnesic shellfish poisoning
ATCC	American Type Culture Collection
AZP	Azaspiracid
BP	British Pharmacopeia
CAC	Codex Alimentarius Commission
CAC/GL	Codex Alimentarius Commission/Guidelines
CAC/RCP	Codex Alimentarius Commission/Recommended Codes of Practice
CCMAS	Codex Committee on Methods of Analysis and Sampling
CCP	Critical Control Points
CEFAS	Centre for Environment, Fisheries and Aquaculture Science
CI	Cyclic Imines
CRL	Community Reference Laboratory
CRM	Certified Reference Material
DA	Domoic Acid
DAP	Defect Action Plan
DPD	diethyl phenylene diamine
DSP	diarrhetic shellfish poisoning
EC	European Commission
EDTA	Ethylene Diamine Tetraacetic Acid
ETCP	Effluent Toxicity Control Program
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FC	Faecal Coliform
FCV	Feline Calicivirus
GBP	British Pound
GRP	Glass-Reinforced Plastic
HACCP	Hazard Analysis Critical Control Point
HDPE	High Density Polyethylene
HMSO	Her Majesty's Stationery Office (United Kingdom)
IFREMER	Institut français de recherche pour l'exploitation de la mer
INIAP	Instituto Nacional de Investigacao Agroria e das Pescas (Portugal)
INRH	Institut National de Recherche Halieutique (Morocco)
IPIMAR	Instituto de Investigacao das Pescas e do Mar (Portugal)
ISO	International Standards Organization
MMGB	Minerals Modified Glutamate Broth
MPN	Most Probable Number
MTEC	Membrane Thermotolerant *Escherichia coli* Agar
NCTC	National Collection of Type Cultures
NLVs	Norwalk-like viruses
NSP	neurotoxic shellfish poisoning
NSSP	National Shellfish Sanitation Program (USA)
NTU	Nephelometric Turbidity Units
PAHs	polynuclear aromatic hydrocarbons
PCBs	polychlorinated biphenyls
PSP	paralytic shellfish poisoning
PTX	Pectenotoxins
PVC	Poly Vinyl Chloride

RFID	Radio Frequency Identification
RIVO	Institute for Fisheries Research (Netherlands)
RNA	Ribonucleic Acid
SG	Specific Gravity
SRSVs	Small Round Structured Viruses
STX	Saxitoxin
TBGA	Tryptone Bile Glucuronide Agar
TNTC	Too Numerous To Count
USDA	US Department of Agriculture
USFDA	US Food and Drug Administration
UV	Ultraviolet
UVPS	Ultraviolet Power Supply
W	Watt
WHO	World Health Organization of the United Nations
YTX	Yessotoxins

Glossary

Aquaculture	Aquaculture, with respect to this Guide, is the raising of bivalve molluscs from the juvenile state under controlled conditions.
Batch – harvested	Shellfish harvested on the same day and from the same area (if classification is necessary, of the same class).
Batch – depurated	Shellfish that have been depurated through the same cycle of the same depuration system.
Bivalve mollusc	Any marine or freshwater mollusc of the class Pelecypoda (formerly Bivalvia or Lamellibranchia), having a laterally compressed body, a shell consisting of two hinged valves, and gills for respiration. The group includes, among others, clams, cockles, oysters and mussels.
Classification of bivalve mollusc harvesting areas	A system for grading harvesting areas based on levels of bacterial indicator organisms in the surrounding seawater (using faecal coliforms in the US) or the shellfish themselves (using *E. coli* within the EU).
Clean seawater	Seawater from any source where harmful microbiological contamination, substances and/or toxic plankton are not present in such quantities as may affect the health quality of fish, shellfish and their products (Codex Alimentarius Code of Practice).
Coliform	Gram negative, facultatively anaerobic rod-shaped bacteria which ferment lactose to produce acid and gas at 37 °C. Members of this group normally inhabit the intestine of warm-blooded animals but may also be found in the environment (e.g. on plant material and soil).
Control (verb)	To take all necessary actions to ensure and maintain compliance with criteria established in the HACCP plan.
Control (noun)	The state wherein correct procedures are being followed and criteria are being met.
Control measure	Any action and activity that can be used to prevent or eliminate a food safety hazard or reduce it to an acceptable level.
Corrective action	Any action to be taken when the results of monitoring at the critical control point indicate a loss of control.
Culling	The process of separating dead or broken shellfish (and other species) from the live, intact shellfish.
Critical Control Point	A step at which control can be applied and is essential to prevent or eliminate a food safety hazard or reduce it to an acceptable level.
Critical limit	A criterion which separates acceptability from unacceptability.
Deviation	Failure to meet a critical limit.

Depuration cycle The depuration process from the point at which the shellfish are immersed in the seawater and all of the conditions for depuration process are in the correct range until the time when depuration is ended, e.g. by draining the tanks. If conditions go out of range then the cycle must be identified as starting again for the purposes of the depuration period.

Escherichia coli A species of bacterium that is a member of the faecal coliform group (see below). It is more specifically associated with the intestines of warm-blooded animals and birds than other members of the faecal coliform group. Traditionally, *E. coli* produce indole from tryptophan at 44 °C. Now determined on the basis of the possession of β-glucuronidase activity.

Faecal coliforms Coliforms (see above) which can produce their characteristic reactions (e.g. production of acid from lactose) at 44 °C as well as 37 °C. Usually, but not exclusively, associated with the intestines of warm-blooded animals and birds.

Flow diagram A systematic representation of the sequence of steps or operations used in the production or manufacture of a particular food item.

Geometric mean The geometric mean of a series of N numbers is the N^{th} root of the product of those numbers. It is more usually calculated by obtaining the mean of the logarithms of the numbers and then taking the antilog of that mean. It is often used to describe the typical values of a skewed data set such as one following a log-normal distribution (see below).

Growing or harvesting area Brackish and marine areas approved for the production or harvesting of bivalve molluscs either by natural growth or by aquaculture destined for human consumption. The growing areas may be approved as production or harvesting areas for bivalve molluscs for direct consumption, or they may be approved as production or harvesting areas for bivalve molluscs for either depuration or relaying (Codex Alimentarius Code of Practice).

HACCP A system which identifies, evaluates, and controls hazards which are significant for food safety.

HACCP plan A document prepared in accordance with the principles of HACCP to ensure control of hazards which are significant for food safety in the segment of the food chain under consideration.

Hazard A biological, chemical or physical agent in, or condition of, food with the potential to cause an adverse health effect.

Hazard analysis The process of collecting and evaluating information on hazards and conditions leading to their presence to decide which are significant for food safety and therefore should be addressed in the HACCP plan.

Hepatitis A virus A 27nm diameter virus that contains RNA as its nucleic acid. It is transmitted by the faecal-oral route and although most infections are inapparent or mild feverish episodes, it can cause inflammation of the liver resulting in jaundice.

Live bivalve molluscs Bivalve molluscs that are alive immediately prior to consumption.

Log-normal distribution	A log-normal distribution is one in which the logarithms of the values have a normal (bell-shaped) distribution. Environmental monitoring data for many bacteria follow a log-normal distribution.
Monitor	The act of conducting a planned sequence of observations or measurements of control parameters to assess whether a CCP is under control.
Norovirus	Noroviruses are small, 27 to 32 nm diameter, structured RNA viruses which have been implicated as the most common cause of nonbacterial gastroenteritis outbreaks. (They were formerly called Small Round Structured Viruses [SRSVs] and Norwalk-like viruses [NLVs]).
Percentile	The *pth* percentile of a series of observations (measurements) is the value such that *p* percent of the observations fall at or below it. Thus the 95th percentile is the value below which 95 percent of the observations fall.
Potable water	Water of sufficient quality as to be safely used for drinking, whether it is used for that or another purpose. It should at least conform to WHO Guidelines (WHO, 2004) and may need to meet requirements in local legislation.
Production area	Any sea, estuarine or lagoon area, containing either natural beds of bivalve molluscs or sites used for the cultivation of bivalve molluscs, and from which live bivalve molluscs are taken.
Relay area	Any sea, estuarine or lagoon area with boundaries clearly marked and indicated by buoys, posts or any other fixed means, and used exclusively for the natural purification of live bivalve molluscs.
Relaying	The removal of bivalve molluscs from microbiologically contaminated growing area to an acceptable growing or holding area under the supervision of the agency having jurisdiction and holding them there for the time necessary for the reduction of contamination to an acceptable level for human consumption (Codex Alimentarius Code of Practice).
Step	A point, procedure, operation or stage in the food chain including raw materials, from primary production to final consumption.
Validation	Obtaining evidence that the elements of the HACCP plan are effective.
Verification	The application of methods, procedures, tests and other evaluations, in addition to monitoring to determine compliance with the HACCP plan.