OSPAR COMMISSION

Impacts of microbiological contamination on the marine environment of the North-East Atlantic

Monitoring and Assessment Series

2009

OSPAR Convention

The Convention for the Protection of the Marine Environment of the North-East Atlantic (the "OSPAR Convention") was opened for signature at the Ministerial Meeting of the former Oslo and Paris Commissions in Paris on 22 September 1992. The Convention entered into force on 25 March 1998. It has been ratified by Belgium, Denmark, Finland, France, Germany, Iceland, Ireland, Luxembourg, Netherlands, Norway, Portugal, Sweden, Switzerland and the United Kingdom and approved by the European Community and Spain.

Convention OSPAR

La Convention pour la protection du milieu marin de l'Atlantique du Nord-Est, dite Convention OSPAR, a été ouverte à la signature à la réunion ministérielle des anciennes Commissions d'Oslo et de Paris,
à Paris le 22 septembre 1992. La Convention est entrée en vigueur le 25 mars 1998.
La Convention a été ratifiée par l'Allemagne, la Belgique, le Danemark, la Finlande, la France, l'Irlande, l'Islande, le Luxembourg, la Norvège, les Pays-Bas, le Portugal, le Royaume-Uni de Grande Bretagne et d'Irlande du Nord, la Suède et la Suisse et approuvée par la Communauté européenne et l'Espagne.

Acknowledgement

This report has been prepared by Ms Monique Pompepuy, Ms Soazick Le Guyader, Mr Martial Catherine, Mr Jean Claude Le Saux, Mr Michel Joanny and Mr Patrick Camus.

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Executive Summary

Microbiological quality of coastal waters have been improving in 1997 – 2006 and around 95% of bathing waters falling within the scope of EU legislation met mandatory quality standards in 2006. Limited information prevents an overall assessment of trends in water quality in shellfish areas, but there are examples of improvement following better urban waste water treatment. Continued efforts are needed to further reduce microbiological contamination and improve risk management.

Microbiological contamination is a health risk concern

Microbiological contamination in the marine environment can occur in all marine biota anytime sewage from human or animal origin is discharged to coastal waters. Bacteria and viruses from humans and animals, mainly attached to fine particulate matter, can affect bathing water quality and can accumulate in filter feeding shellfish. Gastroenteritis and Hepatitis A are the most important microbial diseases transmitted to humans through shellfish. Contaminated water can also transmit diseases to bathers. Impacts of microbiological pollution depends on weather (rainfall and light), turbidity and hydrodynamics.

Diffuse sources are difficult to manage

Sources include treated and untreated sewage discharges from land or ships and animal excrement (e.g., from wildlife and farm animals in coastal catchments), especially through storm water discharges. Bathers, pets and contaminated marine sediments also contribute. The difficulty in achieving mandatory quality standards for bathing waters, in some cases despite sewage treatment, shows that diffuse pollution is a problem which is difficult to manage.

EU legislation is in place to help minimising reducing microbiological pollution

Since the QSR 2000, European legislation has been reinforced to address the sanitary risk to humans. This has been achieved by revising quality standards for bathing waters and shellfish growing areas, as well as requiring better urban waste water treatment. The Water Framework Directive and the Marine Strategy Framework Directive are also driving improved microbial water quality.

Improvement of water quality has been significant but legal targets are still not fully met

Achieving mandatory water quality standards under the Bathing Water Directive has been a slower process than initially envisaged. The original target of 1985 was not achieved, and even by 2006 around 5% of bathing waters in the OSPAR area do not comply with prescribed standards. There is much less progress in achieving the stricter, non-binding guiding quality values. However, the outbreak of diseases in waters complying with legal bacteriological standards suggests that current indicators are not adequate to detect viruses and to provide full control of risks.

Improvement of risk management through a range of tools and approaches is needed

OSPAR should promote actions in the EU under existing EU legislation to improve detection of pathogens in seawater and seafood and the assessment of associated risks through expanded monitoring and development of suitable molecular tools, including modelling. OSPAR countries should fully identify and quantify sources of microbial pollution, further reduce faecal inputs to coastal waters, such as e.g. through better sewage collection and treatment and best practices of agricultural uses of sewage and manure, and implement early warning systems living up to latest technological standards.

Récapitulatif

La qualité microbiologique des eaux côtières s'est améliorée entre 1997 et 2006, date à laquelle environ 95% des eaux de baignade tombant sous le coup de la législation de l'UE sont conformes aux normes de qualité. Les informations disponibles sont limitées et ne permettent pas une évaluation d'ensemble des tendances de la qualité des eaux dans les zones à mollusques et à crustacés mais on relève certains exemples d'amélioration à la suite d'un meilleur traitement des eaux usées urbaines. Il est nécessaire de poursuivre les efforts afin de réduire encore plus la contamination microbiologique et afin d'améliorer la gestion des risques.

La contamination microbiologique pose un risque pour la santé

La contamination microbiologique dans le milieu marin peut se présenter dans tout organisme marin chaque fois que les eaux usées d'origine humaine ou animale sont rejetées dans les eaux côtières. Les bactéries et les virus humains et animaux, fixés en général à la matière en suspension à granulométrie fine, peut affecter la qualité des eaux de baignade et peut s'accumuler dans les filtres d'alimentation des mollusques et crustacés. La gastroentérite et l'hépatite A sont des maladies microbiennes transmises à l'homme par les mollusques et crustacés. L'eau contaminée peut également transmettre des maladies aux baigneurs. Les impacts de la pollution microbiologique dépendent des conditions météorologiques (précipitations), de la turbidité et des hydrodynamiques.

Les sources diffuses sont difficiles à gérer

Les sources comprennent notamment les rejets d'eaux usées traitées et non traitées d'origine tellurique ou provenant de navires et d'excréments d'animaux (par exemple d'animaux sauvages ou d'élevage dans les bassins hydrographiques côtiers), en particulier dans les rejets d'eau pluviale. Les baigneurs, les animaux domestiques et les sédiments marins contaminés y contribuent également. Il est difficile de parvenir aux normes de qualité obligatoires pour les eaux de baignade, dans certains cas en dépit du traitement des eaux usées, car la pollution diffuse est un problème difficile à gérer.

La législation de l'UE est en place pour permettre de minimiser la pollution microbiologique

Depuis le QSR 2000, la législation européenne a été renforcée pour traiter des risques sanitaires pour l'homme. Ceci a exigé une révision des normes de qualité pour les eaux de baignade et les zones de production de mollusques et crustacés, ainsi qu'un meilleur traitement des eaux usées urbaines. La Directive cadre sur l'eau et la Directive cadre de stratégie marine conduisent également à une meilleure qualité microbienne des eaux.

L'amélioration de la qualité des eaux est significative mais les cibles juridiques ne sont pas encore complètement atteintes

Parvenir aux normes de qualité des eaux obligatoires dans le cadre de la Directive sur les eaux de baignade s'est avéré être un processus plus lent que prévu. La cible d'origine de 1985 n'a pas été atteinte et même en 2006 environ 5% des eaux de baignade dans la zone OSPAR ne sont pas conformes aux normes prescrites. Les progrès sont beaucoup plus lents lorsqu'il s'agit de parvenir à des valeurs plus strictes de qualité recommandées non contraignantes. Cependant, le fait que des maladies se déclarent dans les eaux conformes aux normes bactériologiques juridiques suggèrent que les indicateurs actuels ne parviennent pas à détecter les virus pour permettre de contrôler totalement les risques.

Il est nécessaire d'améliorer la gestion des risques grâce à une série d'outils et d'approches

OSPAR devrait promouvoir des mesures au sein de l'UE et dans le cadre de la législation européenne existante afin d'améliorer la détection des pathogènes dans l'eau de mer et dans les mollusques et crustacés et pour perfectionner l'évaluation des risques correspondants en étendant la surveillance et le développement d'instruments moléculaires pertinents, y compris la modélisation. Les pays OSPAR devraient déterminer et quantifier complètement les sources de pollution microbienne, réduire davantage les apports d'excréments aux eaux côtières (grâce par exemple à un meilleur recueil et traitement des eaux usées et à de meilleures pratiques quant à l'usage agricole des eaux usées et du fumier) et mettre en œuvre des systèmes d'alerte conformes aux toutes dernières normes technologiques.

1. Introduction

Microbiological pollution in the marine environment can occur when treated and untreated sewage discharges from land or ships and animal excrements reach the sea. Bacteria from humans and animals can affect water quality and marine biota. Impacts on bathing water quality and accumulation in filter feeding shellfish are of main concern.

The purpose of this report is to evaluate the impacts of microbiological contamination on the marine environment of the OSPAR area and the progress that has been made since the Quality Status Report 2000, which identified concerns and needs for action relating to microbiological contamination, and the effectiveness of measures since then.

Progress on reducing microbiological pollution and its impacts and effects on the quality of the marine environment is reported specifically since 1998 (the closing date for information taken into account in the Quality Status Report 2000). The assessment mainly relates to the coastal waters of Regions II, III and IV (Figure 1.1).

This report is part of a suite of assessments prepared under the OSPAR Joint Assessment and Monitoring Programme to evaluate impacts of human activities on the marine environment and contributes to the Quality Status Report 2010.

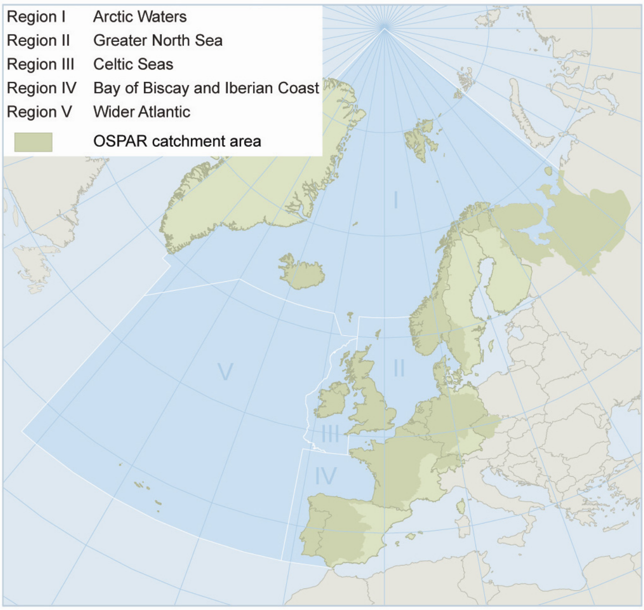


Figure 1.1: *OSPAR area and its Regions*

2. What are the problems?

What are the micro-organisms involved?

Human and animal pathogens (disease-producing bacteria and viruses) can be observed in recreational waters or in shellfish from time to time. The presence of micro-organisms such as norovirus (NoV), astrovirus, rotavirus, hepatitis A virus (HAV), and pathogenic bacteria (e.g., Salmonella, *Listeria monocytogenes*, Shiga-Toxin-Producing *Escherichia coli* (STEC), *Vibrio cholerae* and *Vibrio parahaemolyticus*) are reported in coastal waters. There is only little evidence of infection transmission by protozoan parasites via shellfish or coastal bathing waters.

The pathogens involved in recreational exposure and shellfish food borne diseases can be placed in two classes.

The first class includes environmental pathogens that normally spend a substantial part of their life cycle outside human hosts, but which when introduced to humans cause disease with a measurable frequency. Among them vibrios (*V. cholerae*, *V. parahaemolyticus*, *V. vulnificus*) are common in marine environmental infections, especially in countries where climatic conditions allow them to proliferate (Southeast US coast, South America and Asian countries), while few cases are reported in Europe, especially in warm summers.

The second class relates to enteric pathogens which are non-native micro-organisms, discharged into the sea by raw or insufficiently treated waste waters during epidemics in the population. Most of the time they have been excreted by sick people living on coastal watersheds, but they may be present in the intestines of healthy humans or in the animal population. Among them viruses (especially Noroviruses and HAV) are the chief concern in shellfish-borne diseases, while bacterial infections (salmonelloses, typhoid fever) have decreased due to sanitary control measures set up over the past century. A recent example of control measures is Regulation EC 854/2004 which sets out requirements for sanitary surveys of shellfish production areas and improvements in shellfish depuration technology.

Recently, new methods based on molecular techniques have become available for the detection of pathogens in the environment including emerging micro-organisms. Quantitative Polymerase Chain Reaction (PCR), gene probes, DNA fingerprinting techniques can now detect human enteric pathogens in seafood and seawater. The major interest in developing and using such techniques is that they have been shown to be rapid, sensitive, specific and cost-effective. Traditional methods of detection and enumeration of pathogens are time-consuming, monospecific and cannot afford adequate protection to public heath. Those new techniques allow to address risk assessment due to the dispersion of human pathogen in the sea.

What are the sources of microbiological pollution of coastal waters?

In most of the polluted areas, the river and sewage outfalls discharging to the estuaries or marine bays have high levels of bacteria and viruses. Different sources of contamination are currently identified on sites where bathing activities are present or shellfish are farmed (Figure 2.1):

- Sewage discharges including sewage outfall, combined sewer overflows and storm water discharges. The type of treatment applied to sewage waters plays an important role in the faecal load discharged into marine waters (physical, biological or tertiary treatments).
- Sewage network failures: many storm water events could contribute to this pollution and could trigger persistent faecal contamination even during dry weather.
- River discharges and possible run-off from agricultural activities.
- Other specific discharges could also come from ships, wild birds, bathers, sediments or other diffuse urban sources such as seagulls, dogs or cats.

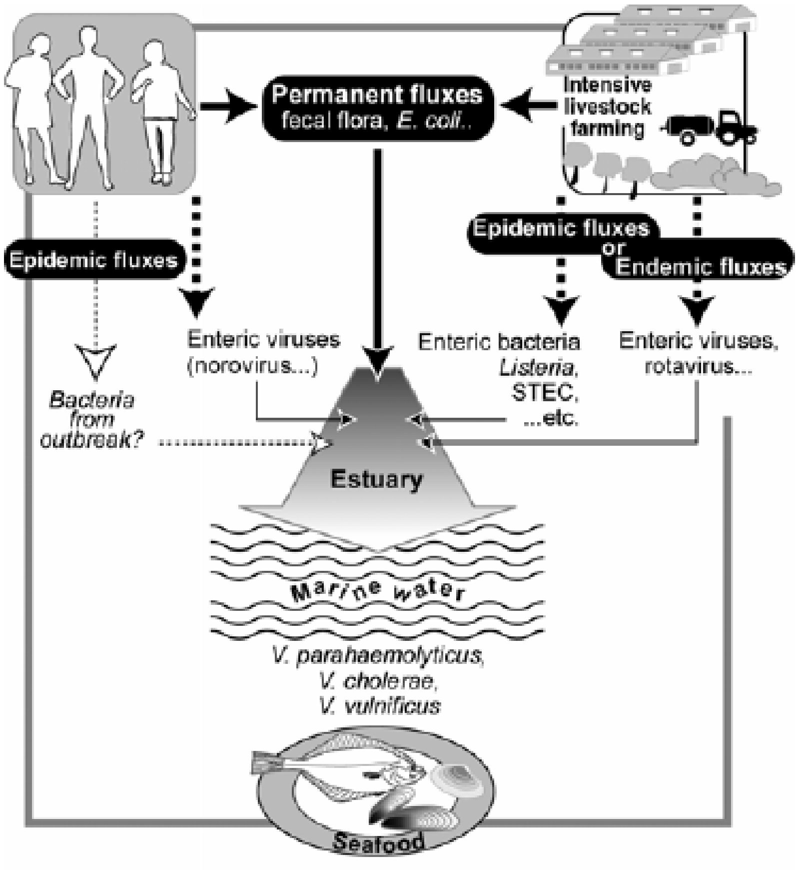


Figure 2.1 *Origin and pathways of microbiological contamination of marine waters.(Pommepuy* et al., *2005)*

A recent review of the impact of rainfall on microbiological pollution, identified point source intermittent discharges as one of the major sources of shellfish contamination (Lee *et al*., 2003). These discharges can result from

- heavy localized intense storms that result in a rapid flushing of stored material and associated contaminants from within the sewerage system, and;
- periods of heavy rain that may overload sewerage infrastructure.

The highly contaminated first flush from combined sewer overflows or storm tank overflow may pass in a few tens of seconds. As currently observed, the combined sewer overflows receive rainfall water, untreated wastewater and runoff during high precipitation events - all sources of faecal contamination – and can seriously impact bathing waters or shellfish areas (Lequette *et al.*, 2006). These events are of the utmost importance given the persistence of micro-organisms in the environment (see Table 2.1). Moreover a recent publication suggests that the specific binding of viral particles to the oyster digestive tract will increase the difficulty of removing viruses from contaminated oysters during depuration processes (Le Guyader *et al.*, 2006 and 2007b).

Table 2.1 Persistence of micro-organisms in the environment. The persistence is measured with the T90, which is the time observed for a 90% decrease of the concentration of the bacteria or virus. The table gives examples of literature data on T90 in estuarine and marine waters. (Decimal reduction time is expressed in hours: minimum-maximum according to depth and intensity of light and turbidity) In Pommepuy et al., 2006.

Pathogen	Seawater		Estuarine water	
	18 – 22°C	4 – 5°C	18 – 22°C	4 – 5°C
Listeria innocua	5 – 45	54 – 89	6 – 24	57 – 96
Listeria monocytogenes	22 – 39	-	80	-
Escherichia coli	5 – 35	67 – 81	96 – 500	120 – 235
Salmonella. tyohi	33 – 84	33 – 79	-	-
Salmonella panama	13 – 72	108 – 316	15 – 34	96 – 144
Poliovirus-1	10 – 72	158 – 170	-	-
F+RNA	60 – 76	-	-	-
Hepatitis A virus	72 – 672	-	-	-
Astrovirus	384 – 432	648 – 720	-	-

What are the concerns associated with microbiological pollution?

Microbiological pollution and its impacts is dependant on the weather (amount of rainfall), climate (temperature, intensity of light) and environmental conditions such as turbidity and amount of organic matter. Faecal indicator bacteria die off much faster in warm clear water (with increased sunlight) than in cold turbid waters which is less well penetrated by sunshine..

The release of faecal micro-organisms and pathogens into the marine environment through sewage outfall and polluted rivers is of concern from a recreational standpoint and a threat to important shellfish-growing areas. The health risk is dependent on the infectious dose and the human sensibility to micro-organisms (age- or immunity-dependent). Some pathogens are highly dangerous for humans even at low concentrations (hepatitis A virus, *E. coli* O157:H7, *V. cholerae*), while others need to be ingested in high concentrations to be harmful (*Vibrio parahaemolyticus*), or, although highly infectious, are not very dangerous (norovirus).

Risks have recently been estimated from epidemiological data and indicator concentrations in surface waters (Lopez-Pila & Szewyk, 2000). The minimum risk bathers are exposed to can be estimated from a dose response relationship for rotavirus and the ratio of faecal coliform/rotavirus in water. Because the probability to become infected by a single infectious unit is relatively high, the authors of the study considered the rotavirus model as being very sensitive to assess the illness load. Assuming that a bather ingested 100 ml water, the risk was estimated to be of 1.6:1000, if the mean value of lognormal distribution was 100 *E. coli* per 100 ml (95% percentile value: 6300 *E. coli* per 100 ml). However, based on risk assessment models, maximum risks were estimated to be 1.3 infections per 100 swimmers. The risk assessment was also applied to viral contamination of shellfish. An average virus exposure of 6 plaque forming units (PFU) per 60g of shellfish would lead to a risk estimated to be 31:1000. The rotavirus risk varied from 15:1000 to 540:1000 depending whether the shellfish was depurated or not.

Since a few years, viral zoonoses have become more evident. Unusual rotavirus strains in humans suggest that animal transmission and co-infection of environmental samples by different strains may enhance genome re-arrangements and re-assortiment. The recent diagnosis of hepatitis E virus (HEV) infections in non-travellers in developed countries raised the question of the source of infection. Molecular studies, which demonstrated similarities in the sequence of strains among animals (swine, pigs) and humans, and the detection of HEV in sewage in different countries suggest that humans may be infected through contact with effluents of animal origin. The zoonose risk can widely be extended to other micro-organisms. Thus, *E. coli* O157:H7 is a model of emerging pathogen. Intensive livestock farming and the selective pressure on micro-organisms to successfully survive in the environment have led to a horizontal transmission and accumulation of virulent factors.

Exposures of humans to pathogens in the aquatic environment for example during recreational activities may result in diseases. Susceptible populations (younger, immune deficient or older populations) may have a higher risk of contracting severe illnesses.

The World Health Organisation (WHO) is actively involved in the protection of human health providing guidelines and epidemiological reviews in this field. A link between gastroenteritidis, acute febrile respiratory illness, ear infections and generally minor self-limiting illnesses and faecal-contaminated water is clearly demonstrated. In most cases the primary disease symptoms are diarrhoea, vomiting and acute respiratory infections.

More serious or fatal diseases were less frequently reported. A few illnesses are triggered by protozoan parasites (see e.g. amoebic meningoencephalitis, septicemia, typhoid, leptospiriosis), some of which may lead to sequelae (renal disease, cardiac and nutritional disorders). Reviews covered different pathogens, especially bacteria (*Campylobacter jejuni*, *E. coli* O157, *Helicobacter pylori*, *Legionella* spp., *Mycobacter avium, Shigella* spp., *Vibrio vulnificus*), parasites (*Giardia*, Mycosporidia, *Naegeria fowleri, Schistosoma* spp.) and viruses (adenovirus, coxsackievirus, echovirus, Hepatitis A virus, Hepatitis E virus). However, only few cases have been reported in Europe, which mostly related to recreational activities in monitored areas.

The link of infectious diseases to the consumption of raw shellfish like oysters, mussels, cockles and clams has long been identified. Bacterial diseases such as cholera and typhoid fever were the first to be suspected of being linked to consumption of contaminated shellfish. Viral outbreaks associated with contaminated shellfish consumption were first suggested more than 50 years ago. Initially, the analysis of outbreaks was mainly based on epidemiological data and symptoms in patients (Richards, 1987). The development of molecular biology, and thus the ability to detect low levels of enteric viruses in shellfish, has provided more accurate assessment of shellfish as a path for disease transmission. Despite the fact that many enteric viruses can be detected in human faeces, only HAV and NoV have been clearly identified as infectious agents in consumed shellfish.

In Europe the most common illnesses associated with bivalve mollusc consumption are gastroenteritis (NoV, *Salmonella, Vibrio paraemolyticus*) and hepatitis caused by HAV. Other gastro enteric viruses, (astroviruses and parvoviruses), parasites such as *Crypstosporidium* and bacteria (*E. coli* O157:H7, *Shigella*, *Plesiomonas*, *Listeria*) have also occasionally been detected in shellfish or in shellfish related outbreaks although their true epidemiological significance is not clear.

3. What has been done?

EU efforts to ensure clean bathing and shellfish waters go back to the 1970ies. The directives dealing with bathing waters (1976) and shellfish waters (1979) have been revised and updated in 2006 and linked-up with the Water Framework Directive (2000/60/EC) and more recently with the Marine Framework Directive (2008/56/EC). The new directives require EU Member States to identify the pressures and impacts of activities on water quality and to design a programme of measures in this case to ensure compliance with the microbial standards in areas devoted to bathing or shellfish activities. To comply with the Bathing Water Directive (2006/7/EC), EU Member States have implemented monitoring programmes for indicators of water quality in bathing .

In the case of the production of live bivalve molluscs, Annex II of Regulation (EC) 854/2004 sets out criteria for official food controls which require the classification of production areas and the monitoring of those classified areas. In general, all production areas should be monitored for their *E. coli* content as indicator for faecal pollution and classed A, B or C depending on the observation results (Table 3.1). The level of pollution determines how bivalve molluscs need to be processed before they can be placed on the market.

An important requirement of EU legislation is that official control monitoring plans should be performed according to scientific principles. Point A.6 of Regulation EC 854/2004 requires that:

If the competent authority decides in principle to classify a production or relaying area, it must:

(a) make an inventory of the sources of pollution of human or animal origin likely to be sources of contamination for the production areas;

(b) examine the quantities of organic pollutants which are released during the different periods of the year, according to the seasonal variations of both human and animal populations in the catchment area, rainfall readings, waste-water treatment, etc.;

(c) determine the characteristics of the circulation of pollutants by virtue of current patterns, bathymetry and the tidal cycle in the production area;

and

(d) establish a sampling programme of bivalve molluscs in the production area which is based on the examination of established data, and with a number of samples, a geographical distribution of the sampling points and a sampling frequency which must ensure that the results of the analysis are as representative as possible for the area considered.

All this data are gathered to provide an efficient 'sanitary survey' of all the European shellfish growing areas.

Table 3.1: Criteria for the classification of live bivalve molluscs harvesting areas under Regulation (EC) No. 854/2004, (EC) No. 2074/2005, (EC) No. 1021/2008 and (through cross-reference) Regulation (EC) No. 853/2004 and Commission Regulation (EC) No. 2073/2005 on microbiological criteria for foodstuffs.

Classification	Microbiological standard per 100g of bivalve mollusc flesh and intra-valvular liquid	Treatment required
A	<230 *E. coli*/100g of flesh and intra-valvular liquid	None
B	90% of live molluscs from these areas must not exceed the limits of a five-tube, three dilution MPN[1] test of 4 600 *E. coli*/100g of flesh and intra-valvular liquid. In the remaining 10 % of samples, live bivalve molluscs must not exceed 46 000 *E. coli*/100 g of flesh and intra-valvular liquid.	Purification, relaying in class A or treatment by an approved method (sterilization, heat treatments)
C	Live molluscs from these areas must not exceed the limits of a five-tube, three dilution MPN test of 46 000 *E.coli*/100g of flesh and intra-valvular liquid	Relaying for a long period or treatment by an approved method (sterilisation, heat treatments)

[1] Most Probable Number test specified in ISO 16649-3

In parallel, relevant international measures and codes of practice have been developed by international organizations. International expert committees report on the health risk due to recreational activities or shellfish consumption (www.fao.org; www.who.int).

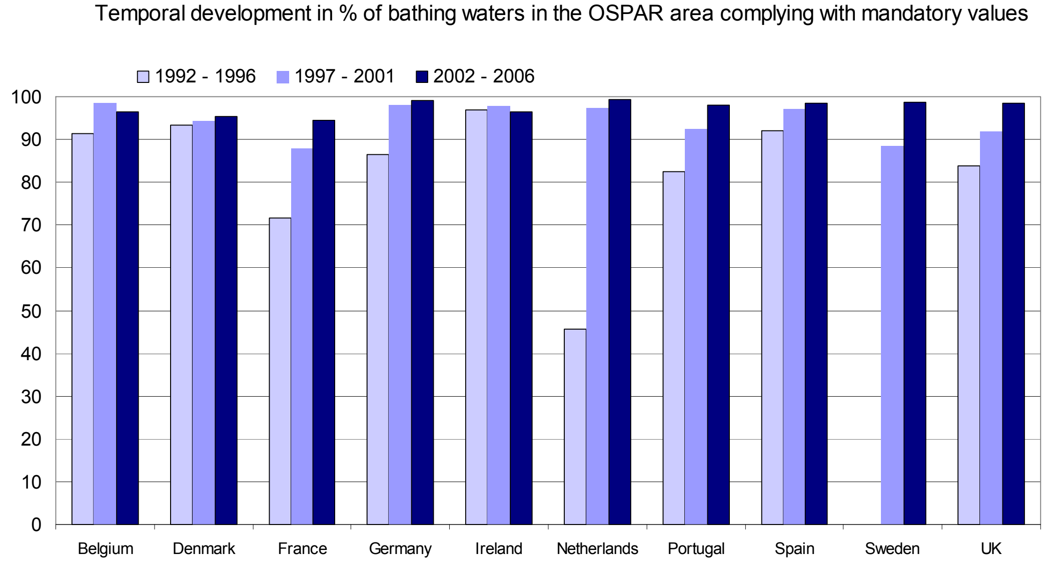
OSPAR countries have developed monitoring program to identify the status and the trend of each water bodies concerned either by bathing or shellfish farming and harvesting activities.

4. Did it work?

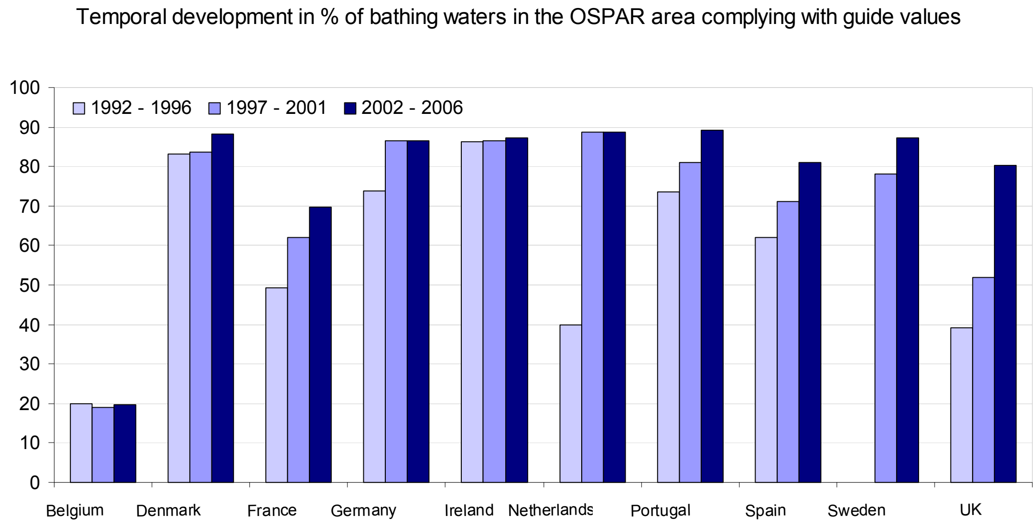
4.1 Trends in the bathing water quality in OSPAR coastal waters

The quality of EU bathing waters has improved in 1997 – 2006 in terms of compliance with the mandatory standards laid down in the Bathing Water Directive (2006/7/EC). However, improvement was slower than initially envisaged. The original target of the preceding 1976 Bathing Water Directive was for Member States to comply with the standards by the end of 1985. This was not achieved, and even by 2006 around 5% of bathing waters still do not comply with the mandatory quality standards. Nevertheless the improvement in OSPAR countries has been significant in the last 15 years (Figure 4.1A).

Yet, the rate of achieving the (non-mandatory) quality guide values has been much lower in OSPAR countries than that for the mandatory standards (Figure 4.1B). This is probably because countries would need to invest considerably more for sewage treatment works and the control of diffuse pollution sources to achieve the guide values.



A



B

***Figure 4.1**: Development of percentage compliance of bathing waters of OSPAR countries with mandatory (A) and guide (B) quality values of the Bathing Water Directive in 1992 – 2006. Data source: European Commission; annual compliance reporting of EU Member States; http://www.eea.europa.eu/*

Member States have invested significant amounts of money to move towards the prescribed standards. The implementation of the Urban Waste Water Treatment Directive (91/271/EC) has also contributed significantly to the general improvement of surface water quality including bathing waters. However, in some cases the installation of sewage treatment works did not result in 100% compliance with bathing water quality standards because of diffuse pollution which still remains a source of microbiological and other contamination..

In addition, for some of the parameters listed in the directive a robust, analytical methodology has not been yet developed. Therefore compliance with the mandatory standards which focus on faecal coliforms as indicators for microbiological contamination does not necessarily mean that there is no risk to human health. In fact, a number of studies have shown that the concentration of faecal streptococci in bathing water is a more useful indication of the likelihood of illness than faecal coliforms (*e.g.,* Cabelli, 1983 and Kay *et al.*, 1994). There is a guide value in the directive for faecal streptococci (100 per 100ml) but recent scientific studies found there was a significantly increased risk of gastroenteritis when enterocci (previously named faecal streptococci) count was greater than 40 per 100ml. That means that reaching the guide value does not necessarily protect totally human health. The proposed revised Bathing Water Directive (COM (2002) 581) has introduce a higher health standard than the old directive thereby reducing likelihood of illness.

4.2 Trends in the shellfish water quality in OSPAR coastal waters

Very little information exists on the trends in shellfish water quality. Only limited compilations of data are available (e.g., Charting progress – An integrated assessment of the state of UK seas – www.defra.gov.uk) on location and percentage of quality waters (A, B and C according EU regulation). Therefore no report was done concerning the possible improvement or degradation of the production areas.

In France, a sanitary survey from the national microbiological monitoring network REMI demonstrated a stability of the shellfish areas classification (wwz.ifremer/envilt/fr). When the Urban Waste Water Treatment Plant Directive (91/271/EEC) was implemented a real improvement of shellfish quality was observed. Since then, no real improvement or degradation has been observed in recent years on shellfish quality (e.g. Bay of Morlaix Figure 4.2). Moreover, the REMI survey demonstrated the sensibility of production areas to meteorological events and to related diffuse pollution.

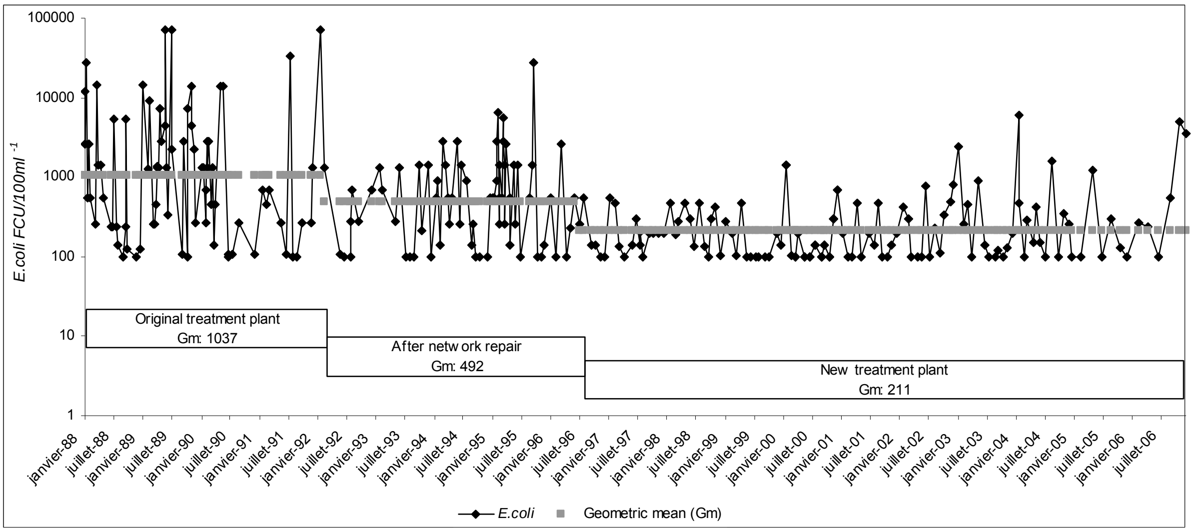


Figure 4.2 *Effect of setting up equipment on shellfish quality, Morlaix, France. Ref. REMI network, Ifremer data: wwz.ifremer.fr/envlit/*

The current controls have been effective at reducing the risk of bacteriological illness to minimal levels. However, despite the legal controls shellfish outbreaks are currently reported by the "Rapid Alert System for Food and Feed" (www.ec.europa.eu/food/food/rapidalert/archive_en.htm), the « Foodborne Virus in Europe network » (www.eufoodborneviruses.co.uk) and the « Eurosurveillance » network www.eurosurveillance.org.

The European regulation on microbiological criteria for shellfish quality stipulates legal control based on the traditional bacterial indicators (*Escherichia coli*). However *Escherichia coli* indicator does not perform well for viruses, the main micro-organism involved in shellfish associated outbreaks in Europe. Thus many outbreaks, even recently have been associated with shellfish fully compliant with legal bacteriological standards. In some outbreaks, multiple strains of a single virus such as NoV can be detected indicating sewage or faecal contamination. Analysis of shellfish events leading to shellfish-related outbreaks has confirmed this hypothesis, and when environmental data are available, sewage-related contamination is often demonstrated.

5. What do we do next?

Disposal of sewage sludge from waste-water treatment has increased in Europe due to the ending of sewage sludge disposal at sea in the 1980s and the requirements for minimum levels of treatment under the Urban Waste Water Treatment Directive (91/271/EEC). Progress has to come with the current horizontal EC legislation regulating all water bodies and all food commodities established by the Water Framework Directive (2000/60/EC) and Marine Strategy Framework Directive (2008/51/EC), and by the new EU food safety regulations.

Reduction of faecal inputs to the coastal areas. Microbial contamination in coastal areas is not a fatality. Recent studies carried out on water quality demonstrated the possibility to determine the main sources and to list the critical points in the catchments thus enabling targeted management actions to improve bathing water quality. Hydrodynamical models when applied to microbiological contaminants, even if they need further development and have to be validated by data bases, may be helpful in case of unclear pollution situations. Thus, they can contribute to make choices to limit the contamination of the coastal environment and to prioritise the impact of pollution sources (Lequette et al. 2006).

Therefore, the new legislation evolves from a rather "close" approach, where criteria are fixed for both spatial and temporal scales, to a more dynamic deductive prevention strategy, where for example shellfish production areas are considered by their complexity and inherent variations. However, the regulation does not provide the methodology to set up and run monitoring plans and deal with data treatment. This would need a great deal of coordination among competent authorities and official laboratories as well as collaborative work with research and development institutions in order to develop appropriate harmonisation tools for use in the EU territories. However, an EU working group chaired by the European Community Reference Laboratory for monitoring bacteriological and viral contamination of bivalve molluscs has recently considered these issues. A guide to good practice for microbiological monitoring has been developed to assist competent authorities and scientific institutes responsible for implementing these requirements (downloadable from www.crlcefas.org.).

Risk management involves different measures to ensure consumer protection and a sustainable development of coastal activities. This requires enforcing the strict application of regulations. Effective regulation and measures are also necessary in managing the location of sludge storage sites and their containment, catchment sensitive farming approaches in relation to spreading of sewage sludge (including in exclusion and buffer zones), and sludge treatment such as sludge pasteurisation. It is assumed that long-residence-time treatment-lagoons, microfiltration and optimised UV plants currently offer the best options for significant reductions in pathogens in continuous discharges. Studies suggest that more than 90% of the catchment-derived faecal indicator flux is due to diffuse source pollution (Kay *et al.,* 2007). The same authors underline the lack of operationally useful and empirical modelling approaches which could solve the problem.

Different strategies have been proposed to manage the risk. The conventional approach is to determine a better indicator than faecal coliforms or *E. coli* for quality standard purposes. Thus, bacteriophages, adenoviruses, *Clostridium* and enterococci have been proposed. But the relationship between pathogen and any indicator has not been demonstrated yet.

OSPAR should promote actions in the EU under existing EU legislation to improve detection of pathogens in seawater and seafood and the assessment of associated risks through which directly address the presence of targeted pathogens in the environment. This includes the following tools which OSPAR countries should further explore and validate:

Development of molecular tools: new genetic techniques provide the best tool to detect pathogens in the sea and seafood. Genetic data bases also must be expanded from existing data bases (GeneBank, etc.).

Risk assessment: quantitative information on pathogen concentration in the environment allows to better evaluate the sanitary risk in coastal areas. Promising advances in molecular detection point to the possibility to directly detect the presence of pathogens in the environment. Real Time PCR, gene probes or biosensors are already proposed to detect the pathogens in food. These methods applied to environment samples and added to genetic information on strains (genotyping, molecular characterization) would help to identify the danger from emerging pathogens. Kay *et al.*, 2007, underlined the lack of research and regulatory attention to the microbial pollution topic and noted the emergency policy imperative from the Water Framework Directive to understand and predict catchment microbial fluxes as the “challenge of the 21st Century”.

Implementation of warning systems: in the near future, alert systems based on gene chip technology will allow pathogens to be directly detected and help preventing contaminated water or seafood from being consumed. Expert systems for monitoring wastewater treatment plants are already available. They could be associated with neural networks to predict the wastewater inflow from sewage treatment plants or agriculture activities. These models calculate the hydraulic load and wastewater inflow which are able to reach the river and the coast when rainfall events occurred. Furthermore, in developed countries, information is already available on outbreaks of illnesses in the population. Associated with forecast information, salinity, STP failure and other factors, a warning system could lead to actual assessments of water quality in bathing or harvesting areas.

6. Glossary

Bacteria	Single-celled micro-organisms which can exist either as independent (free-living) organisms or as parasites (dependent upon another organism for life).
DNA	Deoxyribonucleic acid. One of two types of molecules that encode genetic information. (The other is RNA, Ribonucleic acid). In humans DNA is the genetic material; RNA is transcribed from it. In some other organisms, RNA is the genetic material and, in reverse fashion, the DNA is transcribed from it.) There are four nucleotides in DNA. Each nucleotide contains a base: adenine (A), guanine (G), cytosine (C), or thymidine (T).
Depuration	Term applied to the purification of shellfish, under controlled conditions. The process generally involves holding the shellfish in tanks of flowing seawater for periods of forty-eight to seventy-two hours.
Enteric (or faecal)	From intestine (human or animal).
Enteric viruses	Viruses such as astrovirus, rotavirus, norovirus (NoV), responsible for gastroenteritidis
Enteric bacteria	Bacteria such as *E. coli, Enterococcus, Listeria monocytogenes*, *Salmonella, … are or may be present in the intestines of humans and animals.*
E. coli	Short for *Escherichia coli*, the colon bacillus, a bacterium that normally resides in the human colon. Most strains of *E. coli* are harmless and live in the intestines of healthy humans and animals.
E. coli 0157 :H7	A major health problem. The Shiga-Toxins produced by *E. coli* 0157:H7 (STEC) can damage the lining of the intestine and is responsible for gastroenteritidis or in some cases more severe illness: hemorrhagic colitis, fatal infections in fragile people. About 20 000 cases of hemorrhagic (bloody) colitis (inflammation of the bowel) due to *E. coli* 0157:H7 occur each year in the U.S.).
Enterococcus	Formerly named *Streptococcus*. Another colon bacillus, that normally resides in the human colon. *Enterococcus* are harmless and live in the intestines of healthy humans and animals.
Hepatitis A virus (HAV) or Hepatitis E virus (HEV)	Enteric viruses responsible for liver illness.
Listeria	A group of bacteria capable of causing miscarriage (spontaneous absorption), stillbirth and premature birth and which can also cause serious and sometimes fatal infections in young children, frail or elderly people, and persons with a weakened immune system.
Noroviruses	Group of related viruses that cause acute gastroenteritidis, nonenveloped viruses single-stranded RNA. Noroviruses are named after the original strain "Norwalk virus" which caused an outbreak of gastroenteritis in a school in Norwalk, Ohio, in 1968. Several other names have been used in the past for noroviruses, (including Norwalk-like viruses, Caliciviruses; Small round structured viruses).

Parasite	An organism that lives in or on and takes its nourishment from another organism. A parasite cannot live independently.
Plage Forming Unit (PFU)	PFU is viral unit from a culture cell method (plages are formed after destruction of cells on the culture plates).
Polymerase Chain Reaction (PCR)	PCR is a molecular technique based on genome or part of genome amplification, that allows the analysis of any short sequence of DNA (or RNA) without having to clone it. PCR is used to amplify selected sections of DNA. It takes only a few hours and gives a qualitative value (positive or negative).
Real time PCR	Quantitative PCR method based on the amplification of the genome or a part of genome (RNA or DNA)
Salmonella (S.)	Genus name for a large number (over 2,500) of types of bacteria. Each type is distinctly identifiable by its specific protein coating. The types are otherwise closely related. Salmonella bacteria are rod-shaped, flagellated, Gram stain-negative and are known to cause disease in humans, animals, and birds (especially poultry) worldwide.
Vivrio cholerae	Marine bacteria responsible of gastroenteritis
Vibrio parahaemolyticus	Marine bacteria responsible of gastroenteritis (sporadic occurrence in Europe)
Vibrio vulnificus	Marine bacteria responsible of wound infections and gastroenteritis
Viruses	Small living particles that can infect cells and change how the cells function. Infection with a virus can cause a person to develop symptoms. The disease and symptoms that are caused depend on the type of virus and the type of cells that are infected

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New Court
48 Carey Street
London WC2A 2JQ
United Kingdom

t: +44 (0)20 7430 5200
f: +44 (0)20 7430 5225
e: secretariat@ospar.org
www.ospar.org

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