

Evaluating seawater quality objectives: Application to the Andalusian littoral

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ABSTRACT

The University of Cadiz (southern Spain) and the Andalusian Environmental Agency (AMA) have signed an agreement to draw up a proposal of quality objectives for Andalusian littoral waters in accordance with the classification of zones approved in the Andalusian Littoral Waters Quality Objectives Regulations (Decree 14/1996, 01-16-1996, BOJA no. 19, 02-08-1996). The present paper reviews different regulations (European Union, Spain and the United States) concerning seawater quality criteria and presents the quality criteria proposed by the University of Cadiz.

Key words: Quality objectives, littoral waters, legislation, Andalusia.

RESUMEN

Evaluación de los objetivos de calidad en agua de mar. Aplicación al litoral andaluz

La Universidad de Cádiz y la Agencia de Medio Ambiente Andaluza (AMA) han desarrollado un convenio cuya finalidad es la realización de una propuesta de objetivos de calidad para las aguas litorales andaluzas según la clasificación de zonas establecida en el Decreto 14/1996, por el que se aprueba el Reglamento de Calidad de las Aguas Litorales Andaluzas (BOJA n.º 19 de 8 de febrero de 1996). En este trabajo se hace una revisión de la normativa referente a los objetivos de calidad de las aguas marinas en la Unión Europea, España y Estados Unidos. Además, se recoge la propuesta de objetivos de calidad de aguas litorales realizada por la Universidad de Cádiz.

Palabras clave: Objetivos de calidad, aguas litorales, legislación, Andalucía.

INTRODUCCION

At present, there are approximately 70 000 chemicals in use or being distributed throughout the environment, and an additional 500-1 000 are added each year (Laws, 1993). Government agencies have an urgent need to establish water quality guidelines to deal with the large number of toxic chemicals that pollute groundwater and surface

water (seawater and freshwater). Consequently, there is also a need to develop standard methodologies and techniques for establishing those guidelines.

In Spain, the regional government of Andalusia has made a major effort to establish environmental regulations concerning seawater: the Environmental Protection Law, Littoral Waters Quality Regulations (Decree 14/1996), and Andalusian Littoral Waters

Classification (Order 02-14-1997). In the latter, two annexes are included. Annex I classifies waters into four categories or zones: special waters, limited waters, normal waters and less-limited waters. Annex II defines quality objectives for littoral waters in each category. Thus, this is the first Spanish legislation that contemplates quality objectives regarding hydrology and environmental conditions.

In 1995, in order to develop these annexes, the Andalusian Environmental Agency (known by its Spanish initials, AMA) signed an agreement with the University of Cadiz for the elaboration of the document *An Approach to Andalusian Littoral Waters Quality Objectives* (López-Aguayo and Sales-Márquez, 1996). In this document, various sections are included: (1) environmental quality guidelines; (2) an analysis of the indicative parameters of quality; and (3) quality objectives in seawater.

MATERIALS AND METHODS

The main difficulty in the elaboration and management of quality criteria is the lack of standard methodologies for designing legal criteria on the part of international organisations and government agencies. Thus, a review of the most relevant of these shows that some methodologies and criteria are too simple or too complex, too strict or too lax, and too detailed or too ambiguous (Laws, 1993).

We reviewed two of the world's most important examples of seawater quality criteria legislation those of the European Union and the United States and used them as point of reference for determining guidelines in order to design our own quality objectives (legal quality criteria) for the Andalusian Territorial Sea.

Legislation in the European Community

In the European Union, environmental protection can be achieved in different ways. Firstly, the different environmental categories (air, soil, and water) should have a minimum quality to serve their various functions. Thus, quality objectives can be set to protect designated use, e.g. for bathing or fishing (Clark, 1996). Secondly, the sources of pollution have to be kept under control by regulating chemicals. Finally, accidental spills have to be pre-

vented and waste disposal has to be controlled by appropriate regulations (Rand, 1995).

The Commission of the European Community proposes laws and controls, which are to be adopted by the Council of Ministers. Although, the Commission may adapt environmental laws to scientific or technical findings, set out in annexes to the legislation, in most cases this process is too slow. These annexes contain descriptions of methods, list of chemicals, and several types of limiting values, critical quantities, etc., but do not include the legal and standard methodology for designing the criteria.

The Council adopts directives to be implemented by national laws of the member states. A directive is binding as to the result to be achieved, but leaves to the member states the choice of form and methods. A directive is the main tool for environmental policy. It empowers the Council to define objectives, standards, and procedures that allow the member states some flexibility in implementation, so they can use their usual national regulative processes.

In the EU, the quality objectives are expressed in terms of two values: guide values the adequate concentration to safeguard the ecological quality of the waters, or the quality for designated use and imperative values the maximum allowable concentration of a toxic substance or maximum value of a variable in water (Anon., 1992b; Rand, 1995).

Environmental protection by Seawater Quality Objectives

Tables I, II and III summarise the EU directives and the Spanish laws regarding seawater quality. These tables contain a short description of their main objectives and characteristics (Vilacoba, 1991; Anon., 1992b; Rand, 1995; Enquix *et al.*, 1996; Garrido, 1997).

Legislation in the United States: The Clean Water Act

In the United States, the document that provides suitable protection for all surface waters (freshwater and seawater) is the Clean Water Act (CWA). Its principal objective is to restore and maintain the chemical, physical and biological integrity of waters

Table I. A chronological summary of the regulation of water quality criteria in the European Union

	European Union Legislation	Objectives/Observations
1976	Directive 76/160 Quality of bathing water	Its objective is to safeguard the health of bathers and maintain the quality of bathing waters. The most important of the standards are the coliform counts, which should be met in waters where bathing is explicitly authorised or traditionally practised and not prohibited.
1976	Directive 76/464 Dangerous substances	Its objective is to control the pollution of surface water with dangerous substances. This directive provides a framework for the elimination or reduction of water pollution by particularly dangerous substances. Member states are to take appropriate steps to eliminate pollution by substances of list I and to reduce pollution by substances of list II. List I contains organohalogen and organophosphorus compounds, organotin compounds, carcinogenic substances, mercury, and cadmium compounds. List II includes biocides not included in list I; metalloids/metals and their compounds; toxic or organic compounds of silicon; inorganic compounds of phosphorous, ammonia, and nitrites; cyanides and fluorides; and nonpersistent mineral oils and hydrocarbons of petroleum origin. Several 'daughter' directives concern discharges of dangerous substances. According to these directives, member states must prepare limit values or quality objectives.
1979	Directive 79/923 Shellfish waters	Its objective is to protect coastal and brackish waters in order to support shellfish populations and to prevent contamination of the harvested product.
1982	Directive 82/176 Mercury discharged from the chloralkali industry	A 'daughter' directive of Council Directive 76/464. Limits values in effluents and defines quality objectives in territorial seas.
1983	Directive 83/513 Discharges of cadmium	A 'daughter' directive of Council Directive 76/464. Limits values in effluents and defines quality objectives in territorial seas.
1984	Directive 84/156 Mercury discharged from other industrial processes	A 'daughter' directive of Council Directive 76/464. Limits values in effluents and defines quality objectives in territorial seas.
1986	Directive 86/280 Discharges of other dangerous substances	Another 'daughter' directive, intended to accelerate implementation of Directive 76/464. It requires that a comparative assessment of the implementation be reported by the Commission and submitted to the Council every 5 years. Limits values in effluents and defines quality objectives in territorial seas. The substances are: carbon tetrachloride, DDT and pentachlorophenol.
1988	Directive 88/347 Discharges of other dangerous substances	Modifies Annex II of Directive 86/280. Limits values in effluents and defines quality objectives in territorial seas. The substances are: chloroform, aldrin, dieldrin, endrin, isodrin, hexachlorobenzene and hexachlorobutadiene.
1990	Directive 90/415 Discharges of other dangerous substances	Modifies Annex II of Directive 86/280. Limits values in effluents and defines quality objectives in territorial seas. The substances are: 1,2-dichloroethane (EDC), trichloroethylene (TRI), perchloroethylene (PER) y trichlorobenzene.
1991	Directive 91/271 Urban Waste Water Treatment	Its objective is to reduce the pollution of surface waters with nutrients (particularly nitrates and phosphates) from urban waste water, one of the major sources of nutrient pollution and, hence, of eutrophication. One important aspect of this directive is the classification of the receiving water in sensitive waters and less-sensitive waters based on their hydrology and ecology.
1991	Directive 91/676 Nitrates from agricultural sources	Its objective is to complement the Urban Waste Water Treatment Directive by dealing with nitrate pollution from agricultural sources, another major source of nitrates pollution.
1993	Proposed Directive Ecological Quality of Water	Its objective is to maintain and improve the habitat potential of surface waters and, by doing so, to improve the quality of such waters generally and increase their potential value as sources of waters for drinking and other purposes and to increase their amenity value. The proposed directive would require member states to monitor the ecological status of their surface waters, identify sources of pollution or adverse anthropogenic influence, establish 'operational targets' for the achievement of 'good ecological quality' and implement 'integrated programmes' in order to reach those targets.
1994	Proposed Directive Quality of Bathing Waters	This proposal is a revision of the former Directive.

Table II. A chronological summary of water quality criteria regulations in Spain

	Spain legislation	Objectives/Observations
1988	Decree 734/1988 Quality of Bathing Waters	Regulation of bathing waters in Spain.
1988	Law 22/1988 Coast Law	Its principal objective is to protect the littoral and the water quality of the territorial seas and estuaries, and to regulate the discharges of dangerous substances and grant jurisdiction to regional government over their coastal waters.
1989	Decree 258/1989 Discharges of dangerous substances	This regulation adopts Council Directive 76/464, so its objective is to control the pollution of surface water with dangerous substances.
1989	Order 10-31-1989 Discharges of dangerous substances	Adopts a number of EU directives regarding dangerous substances in the same text. It establishes limit values for effluents, quality objectives in territorial seas, and methods of analysis and monitoring of the substances in Spain.
1989	Decree 1471/1989 Coast Law General Regulations	Establishes the conditions for permits and control of discharges into the sea.
1991	Order 05-09-1991 Discharges of dangerous substances	Adopts the EU directive regarding hexachlorobenzene. Establish limit values for effluents, quality objectives in territorial seas, and methods of analysis and monitoring.
1992	Order 10-28-1992 Discharges of dangerous substances	Adopts the remaining EU directives. Establishes limit values for effluents, quality objectives in territorial seas, and methods of analysis and monitoring of the substances.
1993	Decree 345/1993 Shellfish Waters	Regulation of shellfish waters in Spain.
1994	Law 7/1994 Environmental Protection	Andalusia's environmental protection regulations. Its objectives are distributed into four Titles: General Dispositions, Environmental Prevention, Environmental Quality, and Environmental Discipline. The objective of Chapter III of Title III, Water Quality, is to safeguard and maintain the health of Andalusian littoral waters.
1996	Decree 261/1996 Nitrates from agricultural sources	Adopts the Directive 91/676
1996	Decree 14/1996 Quality of Littoral Waters Reglament	Andalusian regulations to establish limit values for effluents and methods of analysis and control of emissions of a number of substances discharged by industrial installations into the sea.
1997	Order 02-14-1997 Andalusian Littoral Waters Classification	Andalusian regulations with two main objectives: (1) classification of Andalusian seawaters into four zones—special waters, normal waters, limited waters and less-limited waters—based on their hydrology and ecological resources; (2) seawater quality objectives for each zone.

in the United States, and it provides statutory authority for the Environmental Protection Agency (EPA) to establish standard methodologies to design numerical criteria in water based on aquatic toxicity, and water quality management plans (Anon., 1992a).

One of the most important aspects of the CWA is found in Title III. It contains several sections specifically related to the issue of aquatic toxicity. Section 304 of the CWA contains the statutory authority for the EPA to, among other requirements, development methodologies and test procedures for analysis of pollutants, and periodically update environ-

mental quality criteria to protect aquatic life and human health (Anon. 1992a).

For our objectives, an important aspect of the EPA's methodology is the development of protocols and criteria for more precisely addressing site-specific conditions for an individual body of water (Abel, 1991; Anon., 1992; Laws, 1993). If we assume that this methodology is valid, we can apply these protocols to Andalusian littoral waters.

The water quality standards are expressed in two forms: criteria to protect aquatic life and criteria to protect human health.

An aquatic life criterion derived from the EPA's section 304(a) CWA method is an estimate of the

Table III. Seawater quality objectives legislation. (S): throughout Spain; (A): only in Andalusian Autonomous Community

European Union	Spain
Discharges of Dangerous Substances into the Sea	
Directive 76/464. Dangerous substances	Decree 258/1989. Dangerous substances (S)
Directive 82/176. Mercury discharged from the chloralkali industry	Order 10-31-1989. Discharges of Dangerous Substances (S)
Directive 83/513. Discharges of cadmium	Order 10-31-1989. Discharges of Dangerous Substances (S)
Directive 84/156. Mercury discharged from other industrial processes	Order 10-31-1989. Discharges of Dangerous Substances (S)
Directive 84/491. Discharges of hexachlorocyclohexane	Order 10-31-1989. Discharges of Dangerous Substances (S)
Directive 86/280. Discharges of other dangerous substances	Order 10-31-1989. Discharges of Dangerous Substances (S)
Directive 88/347. Discharges of other dangerous substances	Order 10-31-1989. Discharges of Dangerous Substances (S)
Directive 90/415. Discharges of other dangerous substances	Order 10-28-1992. Discharges of Dangerous Substances (S) Decree 14/1996. Quality of Littoral Waters Regulations (A)
Water Quality—Uses	
Directive 76/160. Quality of bathing water	Decree 734/1988. Quality of Bathing Waters (S)
Directive 79/923. Shellfish waters	Decree 345/1993. Shellfish Waters (S)
Water Quality—Zones	
	Order 02-14-1997. Andalusian Littoral Waters Classification (A)

highest concentration of a substance in water which does not present a significant risk to the aquatic organisms in the water and their uses. The term 'their uses' refers to consumption by humans and wildlife. Numerical aquatic criteria are expressed as short-term and long-term numbers, rather than a single number, so that the criteria more accurately reflect toxicological and practical realities. The combination of a criteria of maximum concentration (CMC) (a 1-hour average acute limit), and criteria of continuous concentration (CCC) (a 4-day average concentration chronic limit) provides protection for aquatic life and its uses, from acute and chronic toxicity to animals and plants, and bioconcentration in aquatic organisms. The two-number criteria are intended to identify average pollutant concentrations which will produce water quality generally suited to maintenance of aquatic life and its uses, while restricting the duration of excursions over the average so that total exposures will not cause unacceptable adverse effects (Anon., 1992a; Laws, 1993).

Criteria to protect human health attempt to minimise or specify the potential risk of adverse human effects due to substances in ambient water. The EPA has established two procedures for calculating the criteria: one for carcinogens and one for non-carcinogens. The criteria are designed based on various parameters: RfD or Reference Dose, ADI or

Acceptable Daily Intake, BCF or Bioconcentration Factor, and Cancer Risk Level. The standard criteria for toxic substances are based on carcinogenicity on a 106 risk level. Therefore, the EPA has proposed two criteria: Human Health Criteria for consumption of water and organisms and Human Health Criteria for consumption of organisms only (Anon., 1992a; Laws, 1993).

DISCUSSION

Considerations for designing water quality objectives in Andalusian littoral waters

Two of the most important sets of environmental legislation in the world have been reviewed: EU legislation and the EPA's quality criteria. To establish quality objectives for the Andalusian Territorial Sea, these considerations were taken into account:

- Compliance with the quality objectives legislated in the European Union.
- EPA protocols to protect aquatic life and human health are scientifically valid to protect other bodies of water if their specific conditions (e.g. hydrology, ecology, industrialisation and pollution) are considered. The EPA's general quality criteria (which protect all waterbodies) are also valid as an initial approach to

the numerical criteria for parameters for a specific body of water.

- So, a set of quality criteria are defined. The criteria proposed will be in this set.
- Quality objectives should be designed for each zone (special, normal, limited and less-limited waters).
- Quality objectives should be expressed as imperatives values. In less-limited waters, these should be expressed as guide values, since they

have to be the body of water's normal concentration.

Seawater quality objectives in Andalusian littoral waters

Table IV shows the proposed quality objectives of the University of Cadiz. It contains 62 variables (microbiological, physical and chemical parameters)

Table IV. Quality objectives of Andalusian littoral waters. (SW): special waters; (LW): limited waters; (NW): normal waters; (LLW): less-limited waters; (MN): normal concentration in seawater not affected by discharges

Parameter	EW	LW	NW	LLW	Parameter	EW	LW	NW	LLW		
Microbiological Parameters					32	Cobalt µg/L	< 2	10	< 5	20	
1	Faecal coliforms /100 ml	< 2,000	< 2,000	< 2,000	Absence	33	Copper µg/l	< 30	45	< 40	50
2	Total coliforms /100 ml	< 10,000	< 10,000	< 10,000	Absence	34	Total Chromium µg/l	< 50	100	< 75	100
3	Faecal streptococci /100 ml	< 1,000	< 1,000	< 1,000	Absence	35	Tin µg/l	< 5	10	< 5	10
4	Salmonella /l	Absence				36	Manganese µg/l	< 30	50	< 40	50
5	Enterovirus /l	Absence				37	Total Mercury µg/l	< 0.1	0.3	< 0.2	0.3
Physical Parameters					38	Molybdenum µg/l	< 10	20	< 10	30	
6	Temperature °C	MN+2	MN+3	MN+2	MN+3	39	Nickel µg/l	< 50	100	< 75	100
7	Colour mg Pt/l, Pt-Co scale	MN+10	No abnormal change			40	Silver µg/l	< 0.50	1.00	< 0.75	1.00
8	Transparency m, Secchi's disc	2	1	1	2	41	Lead µg/l	< 25	50	< 25	50
Chemical Parameters					42	Selenium µg/l	< 5	10	< 5	20	
9	pH	7-9	6-9	6-9	6-9	43	Thallium µg/l	< 0.1	0.1	< 0.1	0.1
10	Solid suspended mg/l	MN + 0.07MN	MN + 0.15MN	MN + 0.15MN	MN + 0.15MN	44	Titanium µg/l	< 2	10	< 5	10
11	Salinity	25-38	12-38	25-38	25-38	45	Uranium µg/l	< 2	10	< 5	10
12	Dissolved oxygen % Saturation O ₂	> 80	> 60	> 70	> 60	46	Vanadium µg/l	< 2	10	< 5	10
13	Cyanides µg/l	< 5	5	< 5	5	47	Zinc µg/l	< 25	50	< 25	50
14	Fluoride mg/l	< 1.7	1.7	< 1.7	1.7	Dangerous Substances					
15	Ammonia µg/l	< 200	1,000	< 500	1,000	48	Hexachlorocyclohexane ng/l	< 20	20	< 20	40
16	Nitrates µg/l	< 500	1,000	< 500	1,000	49	Carbon tetrachloride µg/l	< 12	12	< 12	12
17	Nitrites µg/l	< 100	200	< 100	200	50	DDTs µg/l	< 10 p-p-DDT < 25 DDT tot.			
18	Phosphates µg/l	< 200	700	< 200	1,000	51	Pentachlorophenol µg/l	< 2	2	< 2	2

Table IV (continued)

Parameter	EW	LW	NW	LLW	Parameter	EW	LW	NW	LLW
19 Chlorophyll- <i>a</i> µg/l	15	25	15	25	52 Chloroform µg/l	< 12	12	< 12	24
20 Mineral oils	No film visible on the surface of the water and no odor				53 Aldrin and products ng/l	10 Aldrin, Dieldrin and/or Chlordane 5 Endrin and/or Isodrin			
21 Oil origin hydrocarbons mg/l	15	15	15	15	54 Hexachlorobenzene ng/l	< 30	30	< 30	30
22 Anionic surfactants µg/l, LAS	< 30	50	< 30	50	55 Hexachlorobutadiene ng/l	< 100	100	< 100	100
23 Phenols µg/l, C ₆ H ₅ OH	< 10	50	< 20	50	56 1,2-dichloroethane µg/l	< 10	10	< 10	20
24 Tarry residues and floating materials µg/l	Absence				57 Trichloroethylene	< 10	10	< 10	20
Heavy Metals					58 Perchloroethylene µg/l	< 10	10	< 10	20
25 Metal Index µg/l	13	25	16	26	59 Trichlorobenzene µg/l	< 0.4	0.4	< 0.4	0.4
26 Antimony µg/l	< 5	10	< 7	30	60 Other Pesticides ng/l	< 100 individual substances < 500 total			
27 Arsenic µg/l	< 25	50	< 25	50	61 TBT ng/l	< 20	20	< 20	50
28 Barium µg/l	< 100	1,000	< 200	1,000	62 PAH ng/l	< 200	200	< 200	400
29 Beryllium ng/l	< 1	3	< 2	3					
30 Boron mg/l	6	6	6	6					
31 Cadmium µg/l	< 2.5	5	< 2.5	5					

selected from EU directives and Spanish legislation. In most cases, it is the first time that a numerical criterion has been defined in Spain.

CONCLUSIONS

Considerations concerning the methodologies

International organisations are making a major effort to establish seawater quality objectives. In the EU and Spain, some aspects of this methodology need to be revised, i.e. a standard methodology to design legal quality objectives. In order to establish a standard methodology, the EPA provides a scientific and reproducible method that is valid for specific bodies of water and although most aspects are currently under discussion by the scientific community in the United States, this is a first approach to the most adequate standard methodology for quality criteria in water.

The EU directives regulate a number of dangerous substances, but there are others whose control

is also necessary. The adoption of standard protocols will make it possible to control them better in the near future than at present.

Considerations regarding Andalusian legislation and quality objectives in seawater

The Andalusian region is Spain's pioneer in designing legal quality objectives in seawater including such aspects as hydrology and ecological values of littoral waters and coastal ecosystems.

Having achieved this, scientific and technical progress must be focused on improving the methodologies and adapting the numerical criteria to new natural conditions.

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