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ECOLOGICALLY BASED STANDARDS FOR NUTRIENTS IN STREAMS AND DITCHES IN THE NETHERLANDS

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ABSTRACT

General and specific water quality standards were formulated on a national scale in The Netherlands in the eighties of this century. A general environmental quality was defined as the minimum acceptable water quality level for all inland waters. For this quality level, standards for total phosphorus and total nitrogen were derived from measurements in shallow lakes sensitive to eutrophication for this quality level. No standards were developed for specific environmental quality.

In this study we tested whether single nutrient standards are sufficient to guarantee the minimum quality level in streams and ditches. We also investigated whether specific environmental quality requires specific standards. We, therefore, analyzed data collected by regional waterboards in The Netherlands.

The results show that nutrient standards for the general quality are not sufficient to guarantee the minimum quality for all water types. They do not provide appropriate protection for aquatic life. More specific standards should be set to protect and preserve the full biodiversity of ditches and streams.

Setting a single standard for general environmental quality and one for specific environmental quality for all types of water is not defendable. Different types of water have different aquatic communities and different nutrient levels. It is therefore recommended that water type dependent standards should be developed. In this study, standards for both general and specific environmental quality in respect to nutrients are proposed for six stream types and for six ditch types. © 1998 IAWQ. Published by Elsevier Science Ltd

KEYWORDS

Assessment; ditches; ecological; eutrophication; standards; streams; typology; water quality.

INTRODUCTION

Environmental standards play an important role in the protection of the quality of air, soil and water. They can be considered as the interface between the social value system from which the management objectives and policies are derived (Lijklema, 1995). One of the central objectives of Dutch governmental policy on water quality is 'to protect and develop healthy water systems that guarantee a sustainable use' (Anonymous, 1985). To that end two ecological objectives were formulated in the eighties of this century (Anonymous, 1989).

The first objective aimed at a so-called 'general environmental quality', being a minimum acceptable water quality level for all inland waters. This basic quality level had to be reached within a limited period of time (5 years). Standards for the minimum water quality were set by a list of physical and chemical values and by a verbal description of the biotic community that had to be present.

The second objective aimed at a specific (and higher) quality level referring to natural conditions with minimized human influence. The natural conditions might differ according to the type of water (Anonymous, 1988). No standards for this second objective were set.

With respect to nutrients, standards for general environmental quality were set at 0.15 mg/l for total phosphorus and 2.2 mg/l for total nitrogen which concerns the summer-average value for shallow waters sensitive to eutrophication (Anonymous, 1994a). The standard for phosphorus concerns an annual-average value for all other inland waters.

In recent years additional standards, mainly based on the biotic components of the aquatic ecosystem, have been developed. Starting from the legal verbal description (Anonymous, 1988) for each of 25 water types, we set an ecological standard for general environmental. Also ecological standards for higher quality levels were proposed for each type of water. We developed ecological assessment systems to monitor water quality and to test these new standards in the five main inland water types in The Netherlands. These systems are extensively described in 5 reports of the Dutch Association for Applied Water Research (Anonymous, 1992, 1993a, 1993b, 1994b, 1994c; Klapwijk *et al.*, 1995).

In this study, we investigated whether the existing single nutrient standards are sufficient to guarantee the minimum quality level in stream and ditches. We also analyzed whether specific environmental quality requires specific standards. Data collected by regional waterboards in streams and ditches in The Netherlands were analyzed in respect to the new ecological standards, specified as quality classes of the ecological assessment systems. The results were used to propose new standards for nutrient concentrations for minimum (general) and higher (specific) quality levels in streams and ditches.

METHODS

In this study, two of the previously mentioned assessment systems (for streams and for ditches) were used. The main principles of both systems follow below.

The assessment system for running waters (Anonymous, 1992; Peeters *et al.*, 1994) uses the abundance of indicative macroinvertebrates to describe the ecological quality range with respect to the main environmental factors (current, substratum, saprobity, eutrophication) and to the functional organization (percentage shredders, collectors, grazers). Six types of running waters are distinguished: upper, middle and lower reach of hill streams and upper, middle and lower reach of lowland streams.

The assessment system for ditches (Anonymous, 1993a) uses the abundance of indicative macrophytes, macro-invertebrates, epiphytic diatoms and some environmental variables to describe the ecological quality range with respect to the main environmental factors (eutrophication, saprobity, salinity, acidity and management). Six types of ditches are distinguished: sand, clay, peat, acid, brackish and slightly brackish ditches.

The presence and abundance of critical, common and tolerant indicator species was used to divide the quality range of each environmental factor in five quality classes, from lowest (1) to highest quality level (5) (Table 1). Critical species only occur in (nearly) undisturbed pristine conditions. Common species occur over a wide range of water types with some degree of disturbance. Tolerant species are found in (heavily) impacted waterbodies.

The Dutch ministry of Transport and Water Management decided that the middle ecological quality level of the assessment systems (class 3) conforms to the general environmental quality (Anonymous, 1996), whereas the highest levels (class 4 and 5) conform to the specific environmental quality.

Table 1. Demarcation of quality classes by indicator species

indicator species	quality level highest (5)	nearly highest (4)	middle (3)	lowest (2)	beneath lowest (1)
critical	XX*	X			
common		X	XX	X	
tolerant				X	XX

* XX: present in high numbers (abundant)
X: present in low numbers

For this study, data were used that were collected by several waterboards from 1980 to 1990 in streams (> 4000 samples) and ditches (>1000 samples) representing the full range of quality classes. Data on macroinvertebrates were collected in both streams and ditches, whereas data on macrophytes and epiphytic diatoms were only collected in ditches.

In both streams and ditches, data on 60 environmental variables were collected (e.g. temperature, current, pH, phosphorus, nitrogen, conductivity, soiltype, land-use, morphology) and on 7 management variables (e.g. function/use, maintenance measures) (Roos *et al.*, 1991). All data were stored in a relational database.

Data on orthophosphate, total phosphate, nitrite+nitrate-nitrogen, ammonium, and chlorophyll-a, being primary measures of eutrophication, are used to set standards for nutrients. Data on chlorophyll-a were available from ditches only. Additionally data on conductivity, chloride and potassium are used as a check to the primary criteria: conductivity as a measure for the total ion content, chloride as a conservative tracer of the origin of water and potassium as related to agriculture. .

Software packages were developed by us in addition to the assessment systems. These software packages, EBEOSWA (Anonymous, 1993c) and EBEOSLO (Anonymous, 1994d), were used to calculate the ecological quality of the streams and ditches, respectively.

Data were available from undisturbed pristine sites to strongly impacted sites and all stages in between. The data were analyzed stepwise in order to get an impression of the changing values of environmental variables over this gradient. Criteria for this stepwise analysis were taken from the quality levels of the assessment systems. Several selections were made (Table 2). In Selection I, all available data from the whole range of quality classes were used. Selections II, III, and IV have been made according to the ecological standards for the general and specific environmental quality.

Frequency analyses were carried out per eutrophication measure for each of the 12 types of streams and ditches using 5, 10, 25, 50, 75, 90, and 95 percentiles and mean, minimum and maximum values together with number of observations.

Selecting sites with only middle quality level for saprobic and trophic degree for ditches and for streams also middle quality level for current resulted in too few observations. Selection II, with at least middle quality level (Table 2), gave a larger number of observations. The general environmental quality will, therefore, be based on this Selection. However, in that case the majority of sites has to meet the value derived and therefore the 75 percentile was chosen for the proposed standard. The median values from the frequency analyses of Selection IV (Table 2) were used to derive the standards for the specific environmental quality. When Selection IV resulted in less than 25 observations the median from Selection III was used.

Table 2. Criteria used for making Selections

Selection	criteria	
I		all available data
II	current[1] saprobic degree trophic degree	at least middle level
III	current saprobic degree trophic degree	at least nearly highest level
IV	current saprobic degree trophic degree	highest level

[1]: criterion only applied to streams

RESULTS AND DISCUSSION

The results of the frequency analyses are given in detail for one water type, lowland streams upper reaches (Table 3). The overall pattern for the other 11 types of water was similar. Table 3 shows that the concentrations become lower with decreasing numbers of influenced sites (Selection I to IV), *e.g.* 50 percentile for ammonium decreased from 0.40 through 0.28 and 0.14 to 0.10 mg/l. In general, all percentiles and minimum, maximum and average values decreased with increasing constraint on quality.

From the table it is also clear that for Selections IV and III in some cases only a few observations were left, *e.g.* for potassium. Especially for three types of ditches (acid, slightly brackish and brackish), Selections III and IV had too few observations. Therefore, standards for the specific environmental quality can not be derived for these types.

Table 3 shows that, in general, the mean was higher than the median, for example, nitrite+nitrate-N in Selection II gave a mean of 5.87 mg/l and a median of 3.45 mg/l. The differences between mean and median value indicate that some extreme (high) values were present. The differences between the mean and the median become smaller from Selection I to Selection IV. For example, the difference between mean and median for total phosphorus was 0.72 mg/l in Selection I and 0.11 mg/l in Selection III.

The values for conductivity, chloride, and potassium show became lower with increasing constraint on quality. This confirms the removal of influenced sites by selecting higher quality levels.

The proposed standards for the general and specific environmental quality are given in Table 4. This table shows considerable differences between the standards for the 12 types of water. *E.g.* nitrite+nitrate-N concentrations for the specific environmental quality ranged from 2.40 to 5.00 mg/l for streams and from 0.11 to 0.89 mg/l for ditches. Differences were found for both the general environmental quality and the specific environmental quality. In his cenotype approach, Verdonschot (1990) also pointed at differences that exist between aquatic communities and environmental variables in different types of waterbodies. Therefore, it can be concluded that different standards for different water types are needed.

Table 3. Results of the frequency analyses for lowland streams upper reaches

variable / Selection[1]	mean	min	max	percentile 5	10	25	50	75	90	95	n[2]
orthophosphate (mg/l)											
I	0.72	0.01	17.16	0.03	0.03	0.06	0.10	0.25	0.91	3.53	329
II	0.25	0.01	7.80	0.03	0.03	0.05	0.09	0.15	0.43	0.70	160
III	0.09	0.01	0.55	0.02	0.03	0.03	0.06	0.09	0.23	0.42	33
IV	0.11	0.01	0.37	-[3]	-	0.03	0.06	0.17	-	-	9
totalphosphate (mg/l)											
I	0.99	0.02	18.00	0.05	0.07	0.13	0.25	0.66	2.08	3.96	353
II	0.41	0.02	8.50	0.04	0.06	0.10	0.18	0.40	0.77	1.33	155
III	0.20	0.02	0.77	0.03	0.06	0.09	0.15	0.22	0.52	0.75	40
IV	0.23	0.05	0.77	-	0.05	0.09	0.17	0.27	0.74	-	10
nitrite+nitrate (mg/l)											
I	4.88	0.01	31.18	0.12	0.31	0.89	2.55	7.27	13.10	17.00	396
II	5.87	0.06	31.08	0.15	0.38	1.00	3.45	9.54	15.11	18.35	176
III	4.80	0.06	31.08	0.11	0.12	0.70	2.40	7.71	13.09	20.12	39
IV	5.30	0.41	31.08	-	0.47	0.74	1.73	7.72	26.44	-	11
ammonium (mg/l)											
I	1.26	0.01	57.00	0.02	0.08	0.14	0.40	1.00	2.31	4.91	377
II	0.53	0.01	4.90	0.01	0.03	0.10	0.28	0.70	1.50	2.10	183
III	0.24	0.01	1.10	0.01	0.02	0.10	0.14	0.26	0.78	1.00	40
IV	0.18	0.01	0.87	-	0.1	0.06	0.10	0.15	0.75	-	11
conductivity (µS/cm)											
I	472	88	1287	158	193	310	473	615	737	861	329
II	432	88	1117	143	160	254	432	578	715	795	164
III	405	94	1117	95	109	175	319	616	835	954	35
IV	478	154	1117	-	-	177	325	843	-	-	9
chloride (mg/l)											
I	44	8	251	14	17	24	38	51	77	99	377
II	39	8	251	10	15	21	35	46	71	90	183
III	39	8	251	9	10	16	33	47	72	86	40
IV	59	12	251	-	12	18	31	78	218	-	11
potassium (mg/l)											
I	7.8	0.2	39.1	0.9	1.1	2.0	4.8	9.2	22.1	25.1	98
II	8.9	0.2	39.1	0.8	1.0	2.0	5.1	16.5	23.0	26.7	57
III	9.1	0.2	26	-	0.8	1.0	3.9	18.5	23.3	-	18
IV	8.0	1.1	20.0	-	-	1.1	3.0	-	-	-	3

[1]: see table 2 for selection criteria
[2]: number of observations
[3]: too few observations

The standard for total phosphorus (0.15 mg/l) in the Netherlands for the general environmental quality is based on summer average values of monthly samples from shallow stagnant waters sensitive to eutrophication (Anonymous, 1994a). This standard is used as an annual-average of monthly samples for all other inland waters. The proposed standards for the general environmental quality as given in Table 4 differ from this standard. The value for acid ditches is lower than the standard, whereas for all other water types the value is (much) higher. According to this study the extrapolation of the standard from shallow stagnant waters to other types of water is not defendable.

Table 4.Proposed standards for nutrients for the general (GEQ) and specific environmental quality (SEQ). GEQ derived from 75 percentile from Selection II. SEQ derived from 50 percentile from Selection IV or Selection III

	orthophosphate (mg P/l)		totalphosphate (mg P/l)		nitrite-nitrate (mg N/l)		ammonium (mg N/l)		chlorophyll-a (mg/l)	
	GEQ[1]	SEQ[2]	GEQ	SEQ	GEQ	SEQ	GEQ	SEQ	GEQ	SEQ
hill stream upper reach	0.14	0.08	0.38	0.24	11.00	4.95	0.30	0.20	x[3]	x
hill stream middle reach	0.94	0.54	1.03	0.72	8.10	4.24	1.05	0.30	x	x
hill stream lower reach	1.00	0.80	1.35	1.00	5.00	4.65	1.59	1.30	x	x
lowland stream upper reach	0.15	0.06	0.40	0.15	9.54	2.40	0.70	0.14	x	x
lowland stream middle reach	0.36	0.14	0.76	0.18	6.51	5.64	1.20	0.37	x	x
lowland stream lower reach	0.43	0.19	0.76	0.36	6.10	5.00	2.30	0.70	x	x
sandy bottom ditch	0.06	0.05	0.32	0.08	2.12	0.34	0.65	0.27	41.0	6.5
clayish bottom ditch	0.38	0.08	0.66	0.17	2.20	0.89	0.37	0.16	39.0	10.0
peaty bottom ditch	0.07	0.05	0.28	0.14	0.34	0.11	0.40	0.20	52.0	10.0
acid ditch	0.05	-[4]	0.05	-	0.14	-	0.05	-	-	-
brackish ditch	0.20	-	0.42	-	2.30	-	1.80	-	-	-
slightly brackish ditch	0.82	-	1.90	-	1.28	-	3.40	-	104	-

[1]: general environmental quality
[2]: specific environmental quality
[3]: no data available
[4]: too few observations

Natural background concentrations of phosphorus have been studied earlier in the Netherlands (Anonymous, 1988). As an upper limit for orthophosphate, the value of 0.10 mg P/l is mentioned for streams and fresh water ditches and 0.20 mg P/l for brackish ditches. The values from this study for the specific environmental quality are lower for all ditch types and for upper reaches of both lowland and hill streams and higher for the middle and lower stream reaches. Therefore, it can be concluded that the specific environmental quality requires more specific water type dependent standards for phosphate.

The standard for nitrogen concerns an annual-average of monthly samples from total nitrogen (Kjeldahl- N and nitrite-nitrate-N). The values for nitrite-nitrate-nitrogen found in this study are higher than the standard for total nitrogen. The proposed standards for nitrite-nitrate-nitrogen are a factor 2 to 5 higher than the standard for total nitrogen. According to this study the existing standard for nitrogen (2.2 mg N/l) is not defendable for streams and ditches.

Natural background concentrations for nitrate have been mentioned as being between 0 and 1 mg/l for both streams and ditches (Anonymous, 1988). The proposed standards for all types of streams are much higher. The standard for the general environmental quality for chlorophyll-a is 100 mg/l (Anonymous, 1994a). The proposed standards for ditches from this study are much lower.

CONCLUSIONS

Setting a single standard for general environmental quality and one for specific environmental quality for all types of water is not defendable according to the results of the ecological approach conducted in this study. Water types differ in aquatic communities and nutrient levels. It is therefore recommended to develop standards that are water type dependent.

The existing standards for the general environmental quality for nutrients (0.15 mg P/l and 2.2 mg N/l) are not appropriate for water types other than shallow lakes. These standards do not guarantee the minimum quality level in stream and ditches and do not protect the relevant aquatic communities.

To preserve and protect the full biodiversity in ditches and streams more specific standards should be set. In this study, standards based on an ecological approach are proposed.

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