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DEPARTEMENT DE GENIE CIVIL
GROUPE DE RECHERCHE SUR L'EAU EN MILIEU URBAIN

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G.R.E.M.U. WATER QUALITY INDICES

par

Patrick Béron, Luc Valiquette et Gilles Patry

EP82-R-18
GREMU 82/01
March 1982

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DEPARTEMENT DE GENIE CIVIL

GROUPE DE RECHERCHE SUR L'EAU EN MILIEU URBAIN
(URBAN WATER RESEARCH GROUP)

don

G.R.E.M.U.

WATER QUALITY

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FOREWORD

This report is a condensed version of the following report (in French):

"INDICES DE QUALITE DES EAUX DU G.R.E.M.U."
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by Patrick Béron, Luc Valiquette and Gilles Patry
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ABSTRACT

The surface water quality index presented herein is specific to seven water uses. This simple mathematical tool can be used for planning and/or control purposes, such as determining potential water uses or controlling and monitoring the quality of a water body.

In developing the index, the most important water quality parameters related to each water use were taken into consideration. For each water use, water quality parameters are divided into two groups, the most significant parameters being assigned to the first group. A primary numerical index is first calculated, along with a measure of reliability for the two classes of parameters. The final index is then determined by transforming these three numerical values into three letter grades that can be more easily interpreted.

RESUME

L'indice de qualité des eaux de surface présenté dans ce rapport est spécifique de sept usages de l'eau. C'est un outil mathématique simple pouvant être utilisé entre autres afin d'évaluer la qualité d'un cours d'eau ou ses potentiels d'utilisation.

Les paramètres de qualité considérés sont les plus représentatifs pour un usage donné et sont répartis en deux classes suivant leur importance. Un indice primaire numérique est d'abord calculé, ainsi que le pourcentage de paramètres mesurés pour les deux classes. L'indice final apparaît sous la forme de trois lettres, plus faciles à interpréter que des chiffres.

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1. INTRODUCTION

Because of the ever increasing water pollution problems associated with industrialization and demographic growth, more and more water quality data are continuously being collected all over the world. The costs involved are, to say the least, quite important! Many water quality parameters need to be investigated and often, it is not necessary to measure all parameters: rather it is necessary to take into account the importance of each parameter for the various water uses. Furthermore it is often very difficult, given a set of results, to interpret these data, i.e. to assess the suitability of the water to a specific water use.

2. PURPOSE

The purpose of the water quality index described in this report is to provide a simple but yet reliable tool designed to aggregate analytical results of all the important parameters for a particular water use, into a readily interpretable expression.

3. CHARACTERISTICS OF THE INDEX DESIRED

The index is a compact expression of a complex combination of several factors. To be useful, it must be reliable and supply as much information as possible.

It is expected that the index assesses the water quality for several water uses; thus, for one sample, it will be necessary to compute an index for each use associated with the water body.

The index must be simple, and easily computed, either by hand or with the aid of a calculator. It is essential that the selected parameters be significant to the water use considered, however redundant parameters must be avoided. The number of parameters must lie within a reasonable range: if this number is too high, the index risks of suffering of a lack of sensitivity and to lose a part of its interest (increased complexity and costs); if the number is to small, the index is likely to be too sensitive and important aspects can be eclipsed.

4. PREVIOUS INDICES

4.1 Introduction

The first who thought of aggregating water quality results seems to be Hutchinson (1957), who proposed trophic state indices, related to limnological parameters. Later, Horton (1965) proposed an index-number system for rating quality and since these pioneers, over one hundred water quality indices have been proposed and two references provide information on them (Ott, 1978, Rosen et al., 1978). It would be a serious error to think that all these indices are equivalent, although the basic concept is the same, i.e. to replace a set of data (either analytical, economical or geographical, etc...) by a figure, generally dimensionless, more easily interpreted and handled.

Some of these indices have been designed to assess the overall general quality of a water sample (Brown et al., 1974, Greeley et al., 1972, Landwehr et al., 1974 Truett et al., 1975, Harkins, 1974, Pratri et al., 1971, McDuffie and Haney, 1973), while others take into account specific water uses (Lamontagne and Provencher, 1978, Walski and Parker 1974, Stoner, 1975). Some authors (Yu and Fogel, 1978) include in their index cost and benefit functions associated with treatment of wastewater in order to determine the optimal concentration of a pollutant. Recently, Dunette (1979) proposed a geographically variable index based on the average quality of streams in a watershed. Inhaber (1974a; 1974b) combined receiving water quality together with annual waste loads to assess the environmental quality of a watershed. Finally, a different class of indices need to be mentioned, diversity or biotic indices, the most popular being the indices by Chutter (1972), Heister (1972), Cairns et al. (1968, 1971), Stoneburger et al. (1976), Patten (1962) and Verneaux and Tuffery (1970).

4.2 Indices by Brown and Landwehr

Two indices were developped by Brown et al. (1970 and 1973); the first is an additive one, the second being multiplicative:

$$WQIA = \sum_{i=1}^{9} w_i \; q_i \tag{4.1}$$

$$WQIM = \prod_{i=1}^{9} q_i^{w_i} \tag{4.2}$$

where w_i = relative weight of the i^{th} parameter,

with:

$$\sum_{i=1}^{9} w_i = 1.0 \tag{4.3}$$

q_i = sub-score of the i^{th} parameter, ranging from 0 to 100.

These two indices offer an estimation of the general water quality using nine parameters, namely dissolved oxygen, fecal coliform bacteria, pH, five day biochemical oxygen demand (BOD_5), nitrates, phosphates, deviation from equilibrium temperature, turbidity and total solids.

The effect of weighing factors was studied by Landwehr (1976) and conducted to two unweighted indices:

$$WQIAU = \frac{1}{9} \sum_{i=1}^{9} q_i \tag{4.4}$$

$$WQIMU = \left(\prod_{i=1}^{9} q_i \right)^{1/9} \tag{4.5}$$

These four indices are presently commonly used in the United States and can be useful to identify areas where pollution problems are serious. They can also be used to assess time variations of water quality and effectiveness of pollution abatement programs. However, good management of water quality must take into account beneficial water uses and quality criteria associated with the uses. Thus, it seems preferable to give more significance to an index specific to these water uses.

4.3 Index by Walski and Parker

In 1974, Walski and Parker proposed an index based on criteria related to recreational uses, since after Smith (1973), public is mainly concerned with these uses. This multiplicative index was defined as follows:

$$WQI = \left[\prod_{i=1}^{n} f_i^{a_i} (P_i) \right]^{\frac{1}{\sum_{i=1}^{n} a_i}} \qquad (4.6)$$

Where: P_i : value of the i^{th} parameter

f_i : transformation fonction associated with the i^{th} parameter

a_i : weight of the i^{th} parameter

n : number of parameters

Sub-scores, which can be exponential, parabolic or logarithmic functions, range from 0 (very bad) to 1.0 (very good). This index is more of a "canvas" from which others can build their own index. While the following parameters were considered: temperature (or departure from equilibrium temperature), nutrients (or nitrates and phosphates), suspended solids, turbidity, coliform bacteria, dissolved oxygen, color, pH, oil and grease (or thickness of film), odor and water transparency, every user can choose his own set of parameters (depending of local conditions), his own transformation functions and his own weights. This can be interesting but eliminates the possibility of comparing results obtained by different users.

4.4 Indices by Lamontagne and Provencher

Lamontagne and Provencher (1978) have developped a set of indices, each specific to a different water use, for a total of seventeen different indices. Most of the water uses are industrial while socio-ecological water uses have been somewhat neglected.

Basically, their indices are multiplicative weighted indices, with the exception that the socio-ecological indices are unweighted. Subscores vary from 0 through 100, with a cut at 60; below this value, a treatment is necessary, sophistication increasing with a decreasing value in subscore. These treatments are compatible with an industrial use but not with a socio-ecological one.

Nevertheless, proper credit has to be given to the authors for an important observation: they recommended that at least 75% of the parameters be measured to obtain a significant value of the index. Moreover, for socio-ecological uses the index takes into account some toxics when their concentrations are above a certain pre-established limit.

4.5 Harkins' index

The index developped by Harkins (1974) was designed to avoid the sub; ectivity involved in the construction of the transformation curves. The index can be classified as a statistical index, taking into account deviations from a standard. All the antecedent observations are considered and ranked and a statistical study of the series is achieved. This index can be useful for some specific cases but its weakness lies in the large data base needed. Moreover, when a new observation is available, all previous indices have to be recomputed, because of the ranking method used and of the estimation of the variance of the ranks of each parameter.

5. GREMU INDEX

5.1 Selection of water uses and parameters

At first, twelve water uses were considered: domestic water supply, protection of aquatic life-tolerant species, protection of aquatic life-sensitive species, fishing, recreational activities (swimming), recreational activities (boating), stock and wildlife watering, irrigation (cooked and uncooked vegetables), commercial navigation, hydroelectric power production and self-purification of water courses. Because of similarities in quality criteria for some uses, only seven water uses were finally selected"

- domestic water supply,
- protection of aquatic life (sensitive species),
- protection of aquatic life (tolerant species),
- recreational activities such as bathing or swimming,
- recreational activities such as boating or aesthetic enjoyment,
- stock and wildlife watering,
- irrigation.

For each water use, three lists of parameters were established, according to their importance for the water use considered. The main parameters are refered to as *primary* parameters: they are considered *fundamental* for the use considered and are associated with a transformation curve and a weight. Aggregation of subscores derived via transformation curves supplies a numerical value, ranging from -50 through 100, and is called the *primary index*. The second group of parameters are the *complementary* parameters.

They are generally as fundamental as the primary parameters but can not be associated with transformation curves and rather act as "flags". These two subsets of parameters constitute the *basic* parameters set.

The third subset is made up of *supplementary* parameters, mainly toxics, which are to be considered only when their concentrations are above a given level.

The basic parameters for each use, along with lower and upper limits and weights (for primary) are given in Tables 5.1 through 5.7, while limits associated with supplementary parameters for each water use are given in Tables 5.8 through 5.14.

5.2 Selection of parameters

Several guidelines have been considered in the selection of parameters:

domestic water supply:

- public health protection
- protection of domestic water supply networks (scaling and corrosion)
- Treatment (efficiency)
- Treatment cost
- Aesthetics.

protection of aquatic life:

- ecological considerations
- direct or induced toxicity

recreational activities:

- public health
- aesthetics
- safety

stock and wildlife watering:

- health of animals
- health of man

TABLE 5.1 - Basic parameters
(Domestic water supply)

PARAMETER	UNITS	WEIGHT	LOWER LIMIT	UPPER LIMIT
PRIMARY				
Orthophosphates	µg/l $P\text{-}PO_4$	0.0620	0.	900.
Turbidity	JTU	0.1241	0.	30.
Fecal coliform bacteria	count/100ml	0.1241	0.	2000.
Nitrates	mg/l $N\text{-}NO_3$	0.0991	0.	14.
Carbon chloroform and alcoolic extracts	mg/l	0.1057	0.	0.5
pH	pH units	0.0750	3.	10.
Ammonia nitrogen	µg/l $N\text{-}NH_4$	0.0750	0.	700.
Surfactants	mg/l NaLS	0.0750	0.	0.65
Hardness	mg/l $CaCO_3$	0.0620	0.	625.
Total dissolved solids	mg/l	0.0500	0.	2000.
Iron	mg/l	0.0370	0.	0.5
Copper	mg/l	0.0370	0.	2.
Phenols	mg/l C_6H_5OH	0.0370	0.	3.5
True color	Pt-Co units	0.0370	0.	75.
COMPLEMENTARY				
Alkalinity	mg/l $CaCO_3$	-	30.	500.
Sulfates	mg/l	-	0.	500.
Chlorides	mg/l	-	0.	250.
Total coliform bacteria	count/100ml	-	0.	5000.
Fluorides	mg/l	-	0.	2.
Total radioactivity	pBq/l	-	0.	10.
Salmonellae bacteria	count/100ml	0	0.	0.

TOTAL NUMBER: 21

TABLE 5.2 - Basic parameters
(protection of aquatic life - sensitive species)

PARAMETER	UNITS	WEIGHT	LOWER LIMIT	UPPER LIMIT
PRIMARY				
Orthophosphates	µg/l $P\text{-}PO_4$	0.0810	0.	145.
Dissolved oxygen	% saturation	0.1610	55.	115.
pH	pH units	0.1290	5.5	9.
Nitrates	mg/l $N\text{-}NO_3$	0.0650	0.	3.2
Nitrites	mg/l $N\text{-}NO_2$	0.0480	0.	0.2
Suspended solids	mg/l	0.1290	0.	200.
Ammonia nitrogen	mg/l $N\text{-}NH_4$	0.1130	0.	75.
Total residual chlorine	mg/l	0.0970	0.	3.
Alkalinity	mg/l $CaCO_3$	0.0810	10.	275.
Phenols	mg/l C_6H_5OH	0.0480	0.	30.
Surfactants	mg/l NaLS	0.0480	0.	0.80
COMPLEMENTARY				
Temperature	°C	-	0.	15.
Oil and grease	visible film	-	0.	0.
Total radioactivity	pBq/l	-	0.	10.

TOTAL NUMBER: 14

TABLE 5.3 - Basic parameters
(protection of aquatic life - tolerant species)

PARAMETER	UNITS	WEIGHT	LOWER LIMIT	UPPER LIMIT
PRIMARY				
Orthophosphates	µg/l $P\text{-}PO_4$	0.0810	0.	145.
Dissolved oxygen	% saturation	0.1610	35.	115.
pH	pH units	0.1290	5.5	9.
Nitrates	mg/l $N\text{-}NO_3$	0.0650	0.	6.
Nitrites	mg/l $N\text{-}NO_2$	0.0480	0.	0.60
Suspended solids	mg/l	0.1290	0.	200.
Ammonia nitrogen	µg/l $N\text{-}NH_4$	0.1130	0.	170.
Total residual chlorine	mg/l	0.0970	0.	15.
Alkalinity	mg/l $CaCO_3$	0.0810	10.	275.
Phenols	mg/l C_6H_5OH	0.0480	0.	30.
Surfactants	mg/l NaLS	0.0480	0.	0.
COMPLEMENTARY				
Temperature	°C	-	0.	25.
Oil and grease	visible film	-	0.	0.
Total radioactivity	pBq/l	-	0.	10.

TOTAL NUMBER: 14

TABLE 5.4 - Basic parameters
(recreational activities - swimming and bathing)

PARAMETER	UNITS	WEIGHT	LOWER LIMIT	UPPER LIMIT
PRIMARY				
Orthophosphates	µg/l $P\text{-}PO_4$	0.0640	0.	110.
Dissolved oxygen	% saturation	0.0970	40.	115.
Fecal coliform bacteria	count/100ml	0.2900	0.	2000.
pH	pH units	0.2260	5.	9.2
Temperature	°C	0.1940	15.	34.
Transparency	Secchi meters	0.1290	0.4	200.
COMPLEMENTARY				
Floating materials	Presence	-	0.	0.
Undesirable color	Presence	-	0.	0.
Oil and grease	Visible film	-	0.	0.
Undesirable odor	Presence	-	0.	0.
Total radioactivity	pBq/l	-	0.	10.
Salmonellae bacteria	count/100ml	-	0.	0.

TOTAL NUMBER: 12

TABLE 5.5 - Basic parameters
(Recreational activities - boating and aesthetics enjoyment)

PARAMETER	UNITS	WEIGHT	LOWER LIMIT	UPPER LIMIT
PRIMARY				
Orthophosphates	µg/1 $P\text{-}PO_4$	0.2500	0.	110.
Dissolved oxygen	% saturation	0.2500	25.	140.
pH	pH units	0.2500	4.75	9.5
Transparency	Secchi meters	0.2500	0.40	200.
COMPLEMENTARY				
Floating materials	Presence	-	0.	0.
Undesirable color	Presence	-	0.	0.
Oil and grease	Visible film	-	0.	0.
Undesirable odor	Presence	-	0.	0.

TOTAL NUMBER: 8

TABLE 5.6 - Basic parameters
(Stock and wildlife watering)

PARAMETERS	UNITS	WEIGHT	LOWER LIMIT	UPPER LIMIT
PRIMARY				
Total dissolved solids	mg/l	0.3000	0.	3250.
Fluorides	mg/l	0.2000	0.	3.
Fecal coliform bacteria	count/100ml	0.2000	0.	1000.
Nitrates	mg/l $N\text{-}NO_3$	0.1500	0.	150.
Nitrites	mg/l $N\text{-}NO_2$	0.1500	0.	15.
COMPLEMENTARY				
pH	pH units	-	4.	9.5
Salmonellae bacteria	count/100ml	-	0.	0.
Total radioactivity	pBq/l	-	0.	10.

TOTAL NUMBER: 8

TABLE 5.7 - Basic parameters
(Irrigation)

PARAMETERS	UNITS	WEIGHT	LOWER LIMIT	UPPER LIMIT
PRIMARY				
Total dissolved solids	mg/l	0.2000	0.	3000.
SAR	$[meq/l]^{V2}$	0.2500	See below	
Fecal coliform bacteria	count/100-1	0.2000	0.	1500.
pH	pH units	0.1500	4.	9.20
Boron	mg/l	0.1000	0.	0.95
Iron	mg/l	0.1000	0.	25.00
COMPLEMENTARY				
Alkalinity	mg/l $CaCO_3$	-	30.	600.
Total radioactivity	pBq/l	-	0.	10.

TOTAL NUMBER: 8

LIMITS FOR SAR

Conductivity (µS/cm)		
⩽ 250	0.	22.
⩽ 750	0.	18.
⩽ 2250	0.	14.

TABLE 5.8 - Supplementary parameters
(Domestic water supply)

PARAMETER	UNITS	LIMITS
Silver	UG/L	75.0000
Arsenic	UG/L	100.0000
Baryum	UG/L	1500.0000
Cadmium	UG/L	10.0000
Hexavalent chromium	UG/L	50.0000
Cobalt	UG/L	200.0000
Free Cyanides	UG/L	75.0000
Manganese	UG/L	5.0000
Mercury	UG/L	50.0000
Nickel	UG/L	100.0000
Lead	UG/L	10.0000
Selenium	UG/L	100.0000
Organo-phosphorus	UG/L	17.0000
Aldrin	UG/L	3.0000
Chlordan	UG/L	100.0000
2,4-D	UG/L	6.0000
DDD	UG/L	2.0000
DDT	UG/L	17.0000
Dieldrin	UG/L	1.0000
Endrin	UG/L	18.0000
Heptachlor	UG/L	4.0000
Lindan	UG/L	100.0000
Methoxychlor	UG/L	2.0000
2,4,5-T	UG/L	10.0000
2,4,5-TP (Silvex)	UG/L	5.0000

TABLE 5.9 - Supplementary parameters
(Protection of aquatic life - sensitive species)

PARAMETER	UNITS	LIMITS
Silver	UG/L	2.2500
Arsenic	UG/L	50.0000
Baryum	UG/L	50000.0000
P.C.B.	UG/L	1.5000
Cadmium	UG/L	3.0000
Hexavalent chromium	UG/L	150.0000
Free cyanides	UG/L	7.5000
Iron	MG/L	1.0000
Mercury	UG/L	0.0500
Nickel	UG/L	25.0000
Lead	UG/L	30.0000
Selenium	UG/L	2.0000
Aldrin	UG/L	0.0030
Chlordan	UG/L	0.0100
2,4-D	UG/L	100.0000
DDT	UG/L	0.0010
Demeton	UG/L	0.1000
Dieldrin	UG/L	0.0030
Endrin	UG/L	0.0040
Guthion	UG/L	0.0100
Heptachlor	UG/L	0.0010
Lindan	UG/L	0.0100
Malathion	UG/L	0.1000
Methoxychlor	UG/L	0.0300
Mirex	UG/L	0.0010
Parathion	UG/L	0.0400
Toxaphen	UG/L	0.0050
2,4,5-T	UG/L	2.0000
2,4,5-TP (Silvex)	UG/L	1.0000
Thiodan	UG/L	0.0030

TABLE 5.10 - Supplementary parameters
(Protection of aquatic life - tolerant species)

PARAMETER	UNITS	LIMITS
Silver	UG/L	2.2500
Arsenic	UG/L	50.0000
Baryum	UG/L	50000.0000
P.C.B.	UG/L	1.5000
Cadmium	UG/L	6.5000
Hexavalent chromium	UG/L	150.0000
Free cyanides	UG/L	7.5000
Iron	MG/L	1.0000
Mercury	UG/L	0.0500
Nickel	UG/L	25.0000
Lead	UG/L	30.0000
Selenium	UG/L	2.0000
Aldrin	UG/L	0.0030
Chlordan	UG/L	0.0100
2,4-D	UG/L	100.0000
DDT	UG/L	0.0010
Demeton	UG/L	0.1000
Dieldrin	UG/L	0.0030
Endrin	UG/L	0.0040
Guthion	UG/L	0.0100
Heptachlor	UG/L	0.0010
Lindan	UG/L	0.0100
Malathion	UG/L	0.1000
Methoxychlor	UG/L	0.0300
Mirex	UG/L	0.0100
Parathion	UG/L	0.0400
Toxaphen	UG/L	0.0050
2,4,5-T	UG/L	2.0000
2,4,5-TP (Silvex)	UG/L	1.0000
Thiodan	UG/L	0.0030

TABLE 5.11 - Supplementary parameters
(Recreational activities - bathing and swimming)

PARAMETER	UNITS	LIMITS
Total coliform bacteria	count/100ml	10000.0000
Phenols	mg/l C_6H_5OH	50.0000

TABLE 5.12 - Supplementary parameters
(Recreational activities - boating and aesthetics enjoyment)

PARAMETER	UNITS	LIMITS
Total radioactivity	pBq/l	10.

TABLE 5.13 - Supplementary parameters
(Stock and wildlife watering)

PARAMETER	UNITS	LIMITS
Arsenic	UG/L	500.0000
Cadmium	UG/L	10.0000
Hexavalent chromium	UG/L	1000.0000
Cobalt	UG/L	1000.0000
Free cyanides	UG/L	200.0000
Mercury	UG/L	5.0000
Lead	UG/L	100.0000
Selenium	UG/L	10.0000
Organo-phosphorus	UG/L	100.0000
Aldrin	UG/L	17.0000
Chlordan	UG/L	3.0000
DDT	UG/L	42.0000
Dieldrin	UG/L	17.0000
Endrin	UG/L	1.0000
Heptachlor	UG/L	18.0000
Lindan	UG/L	56.0000
Methoxychlor	UG/L	35.0000
Toxaphen	UG/L	5.0000

TABLE 5.14 - Supplementary parameters
(Irrigation)

PARAMETER	UNITS	LIMITS
Arsenic	UG/L	100.0000
Cadmium	UG/L	50.0000
Hexavalent chromium	UG/L	500.0000
Cobalt	UG/L	5000.0000
Free cyanides	UG/L	200.0000
Fluorides	MG/L	15.0000
Manganese	UG/L	500.0000
Mercury	UG/L	1.0000
Nickel	UG/L	100.0000
Lead	UG/L	1800.0000
Selenium	UG/L	50.0000

Irrigation:

- phytotoxicity
- public health
- improvement of plant growth.

5.3 Transformation curves

A transformation curve is associated with each primary parameter. The purpose of these transformation curves is to transform an analytical value, which can have any dimension, into a dimensionless number, referred to as the subscore, which allows comparison of parameters. These subscores range from -50 (very poor quality) through +100 (excellent quality), except for domestic water supply, for which the lower limit is -100, which allows to take into account possible treatment.

These transformation curves, presented in Appendix A, were built from criteria, guidelines, standards and other recommendations found in literature. The bibliography appearing at the end of the report lists the papers that have been consulted.

5.4 Weighing of parameters

For a specific water use, parameters do not all have the same importance; consequently, it was decided to consider the relative importance of the different parameters through the use of a weighing factor. These weights are based on weights found in other indices along with the judgement of the authors and those of water quality experts, including biologists and engineers. The information gathered was then transformed in order to standardize the weights, i.e. to express them as relative fractions, the sum of all the weights for a water use being equal to one.

5.5 Index structure and calculation

A primary index is first computed, according to equation 5.1:

$$I_{P_j} = \sum_{i=1}^{n_j} w_{i,j} \; q_{i,j} \qquad (5.1)$$

where I_P = primary index

w = weight

q = subscore

n = number of parameters

j = subscript for the water use

i = subscript for the primary parameter

This numerical value is then transformed into a letter grade ranging from A through E, according to Table 5.15. This table shows subscores limits for several quality levels and corresponding interpretation for primary index. The lag between quality levels associated with subscores and primary index provides a safety factor to take into account synergism between quality parameters. Furthermore, the limit of 0 for the primary index, below which the use is impaired, simplifies the interpretation of the index: any negative value means that the water quality is not suitable for the intended use.

Then, two measures of reliability are calculated, one for basic parameters and one for supplementary parameters. Both measures of reliability are calculated as follows:

$$R_j = \frac{N_j}{N_{T_j}} * 100 \qquad (5.2)$$

where R = reliability in percent

N = number of parameters actually measured

N_T = total number of parameters included in the index

j = subscript for the water use

As for the primary index, these two measures of reliability are transformed into a letter grade, according to Tables 5.16 and 5.17 respectively.

Finally, the index appears as:

$$I = X\ Y\ Z \qquad (5.3)$$

X, Y, Z standing for previously determined letter grades, in the order of definition.

Particular situations may occur where:

- at least one primary parameter has a subscore of -50
- at least one complementary parameter is out of permissible range
- at least one supplementary parameter is above permissible concentration.

TABLE 5.15 - Quality levels

SUBSCORES	QUALITY LEVEL OF A PARAMETER	PRIMARY INDEX	QUALITY LEVEL OF THE PRIMARY INDEX	LETTER GRADE
100	Excellent	100	Excellent	
	Very good	75	Very good	A
70			Good	B
	Good	50		
40			Long-term acceptable	C
	Long-term acceptable	25		
			Short-term acceptable	D
0		0		
	Short-term acceptable		Not acceptable	E
-50	Critical	-50		

TABLE 5.16 - Letter grades for basic reliability

COMPUTED RELIABILITY	LETTER GRADE	OBSERVATION
$\geqslant 90$	A	Excellent
$\geqslant 85$	B	Very good
$\geqslant 80$	C	Good
$\geqslant 70$	D	Acceptable
< 70	E	Too much poor

TABLE 5.17 - Letter grades for supplementary reliability

COMPUTED RELIABILITY	LETTER GRADE	OBSERVATION
$\geqslant 85$	A	Excellent
$\geqslant 70$	B	Very good
$\geqslant 50$	C	Good
$\geqslant 30$	D	Acceptable
< 30	E	Too much poor

Such a situation is flagged in the final index by writing a minus sign before the first letter. This flag indicates that at least one parameter impairs the water use.

Another situation is often encountered and is of great importance: the case where some values are missing. If such a situation occurs, the subscore of the missing parameter can not be determined and is assumed to be equal to -1., i.e. the parameter is considered to be short-term acceptable. In the extreme case where no parameter is measured, the primary index will therefore be equal to -1., which means: "not acceptable".

6. USE OF THE INDEX

These indices can be used for two main purposes: assessment of potential water uses and control of water quality for specific uses.

Typical computations of the index are given in Appendix B along with their interpretation in order to familiarize the reader with this simple tool.

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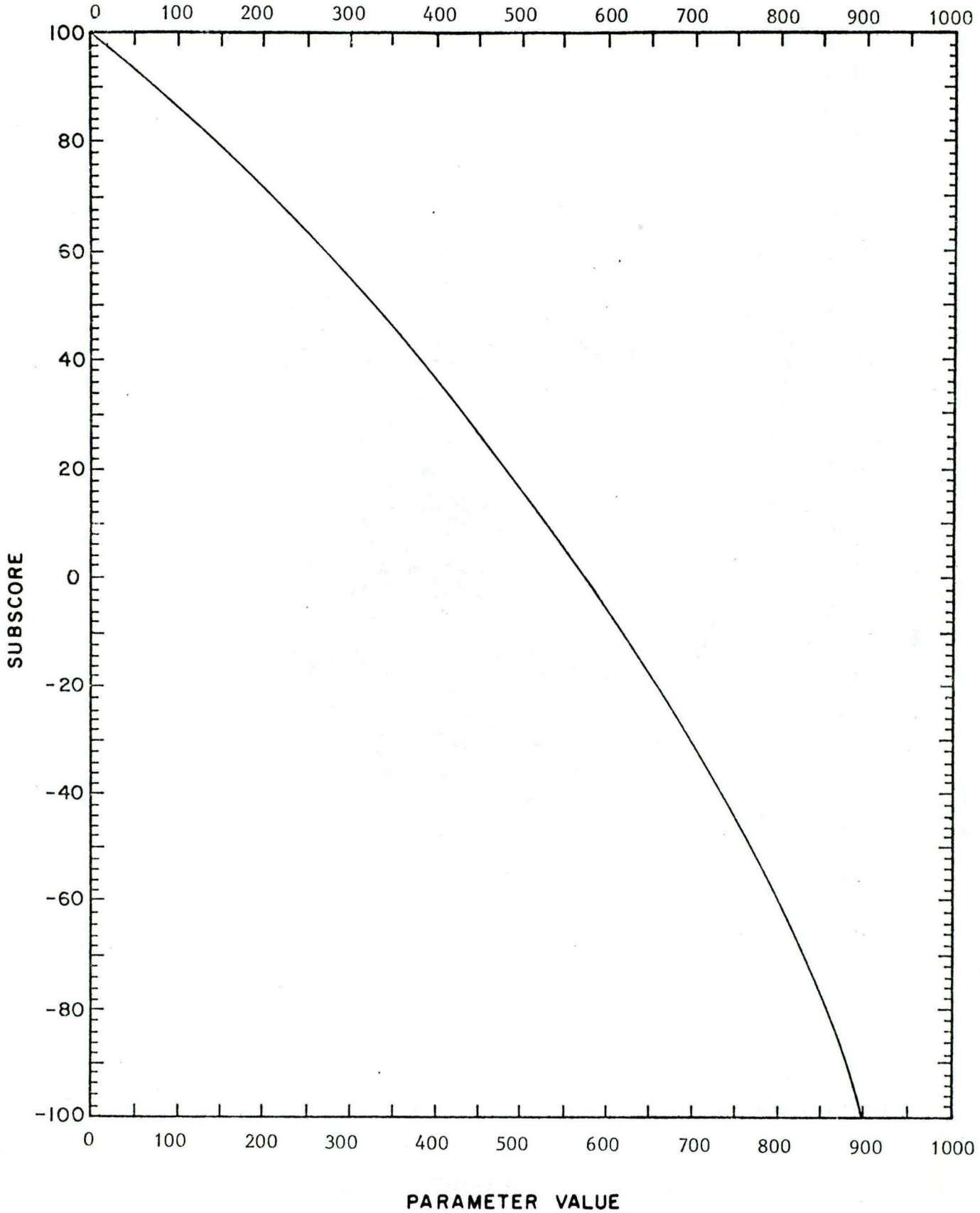
APPENDIX A

TRANSFORMATION CURVES

WATER USE : DOMESTIC WATER SUPPLY

PARAMETER : ORTHOPHOSPHATES

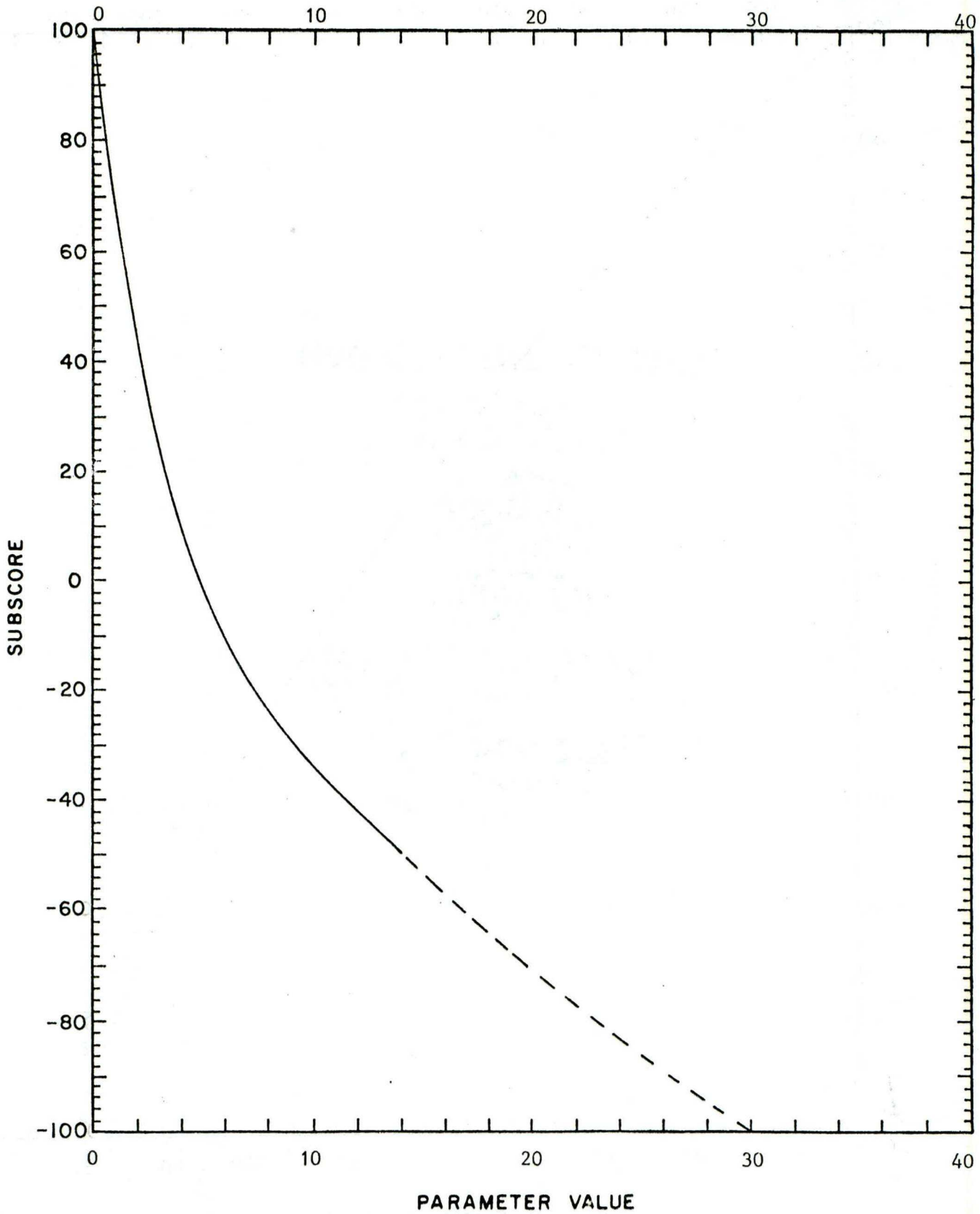
UNIT : µG/L $P-PO_4$



WATER USE : DOMESTIC WATER SUPPLY

PARAMETER : TURBIDITY

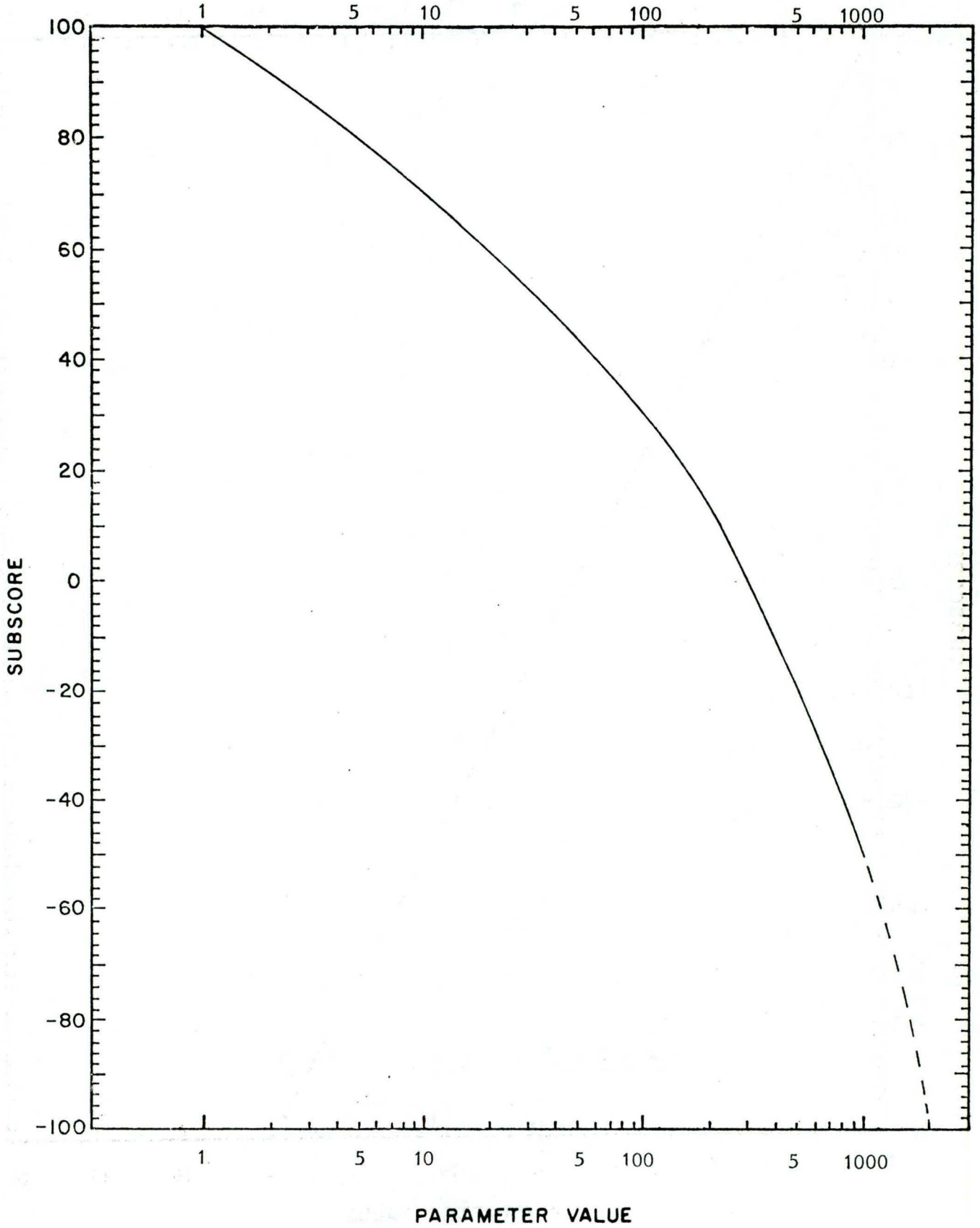
UNIT : JACKSON TURBIDITY UNIT (JTU)



WATER USE : DOMESTIC WATER SUPPLY

PARAMETER : FECAL COLIFORM BACTERIA

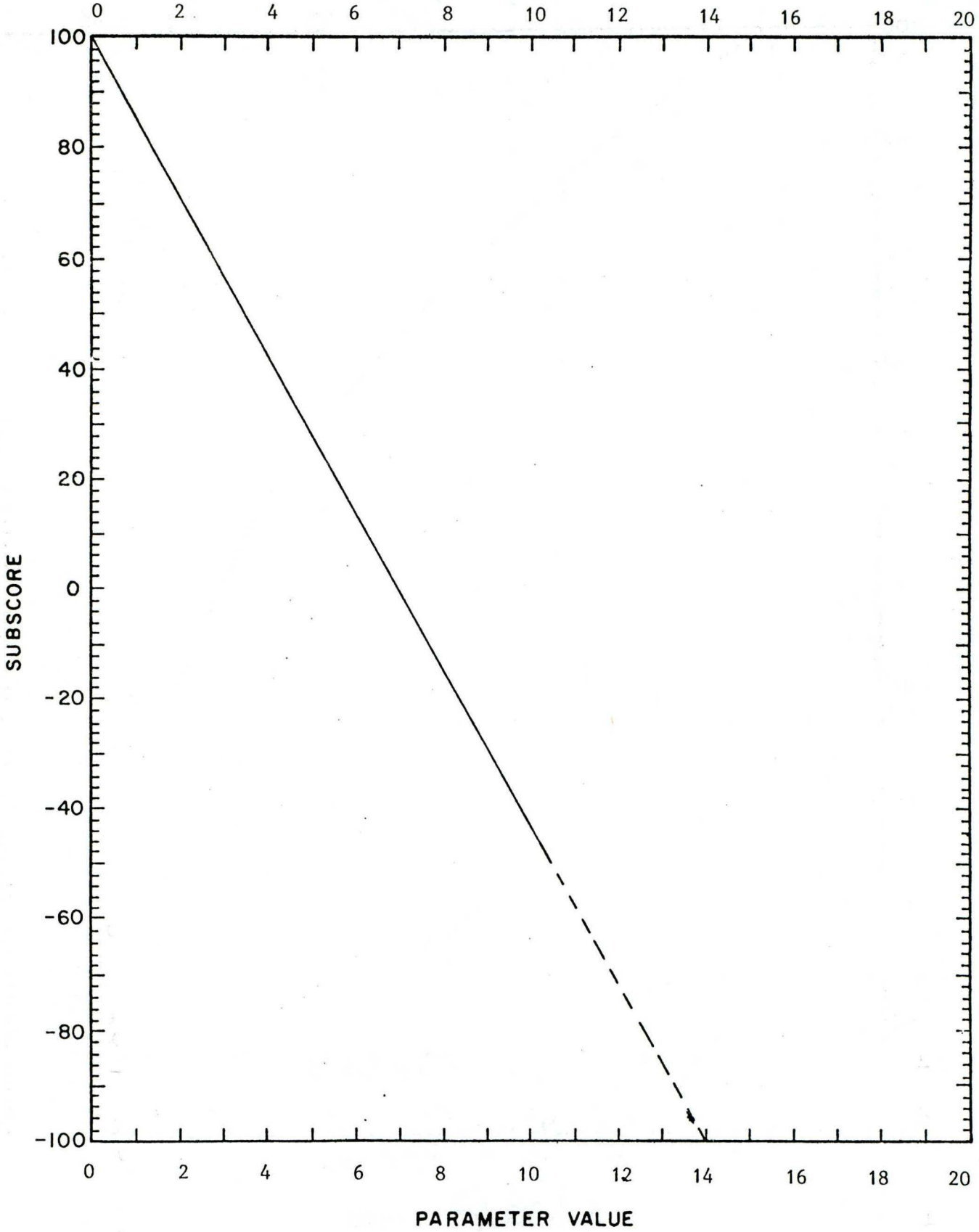
UNIT : COUNT PER 100 ML



WATER USE : DOMESTIC WATER SUPPLY

PARAMETER : NITRATES

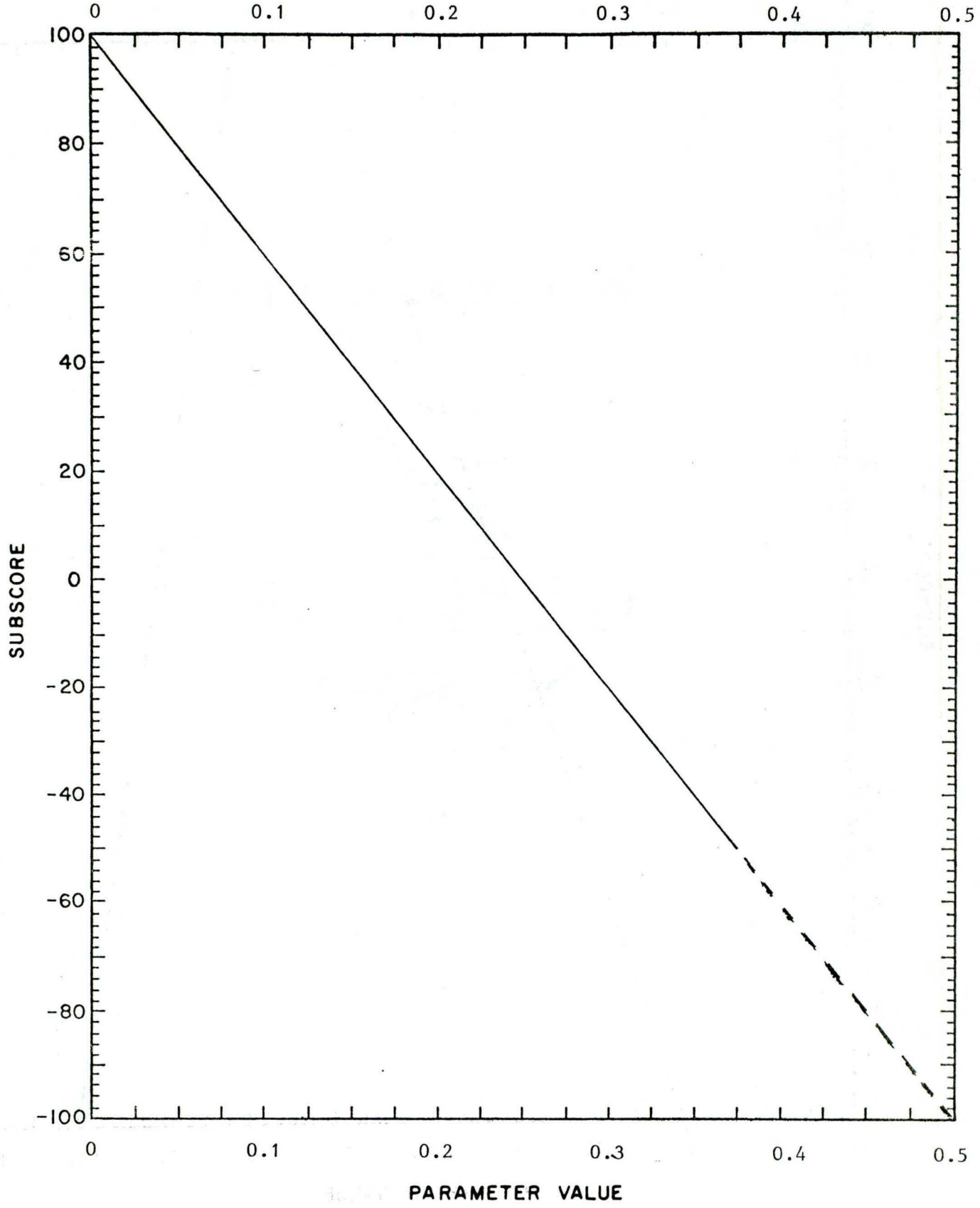
UNIT : MG/L $N\text{-}NO_3$



WATER USE : DOMESTIC WATER SUPPLY

PARAMETER : CCE + CAE

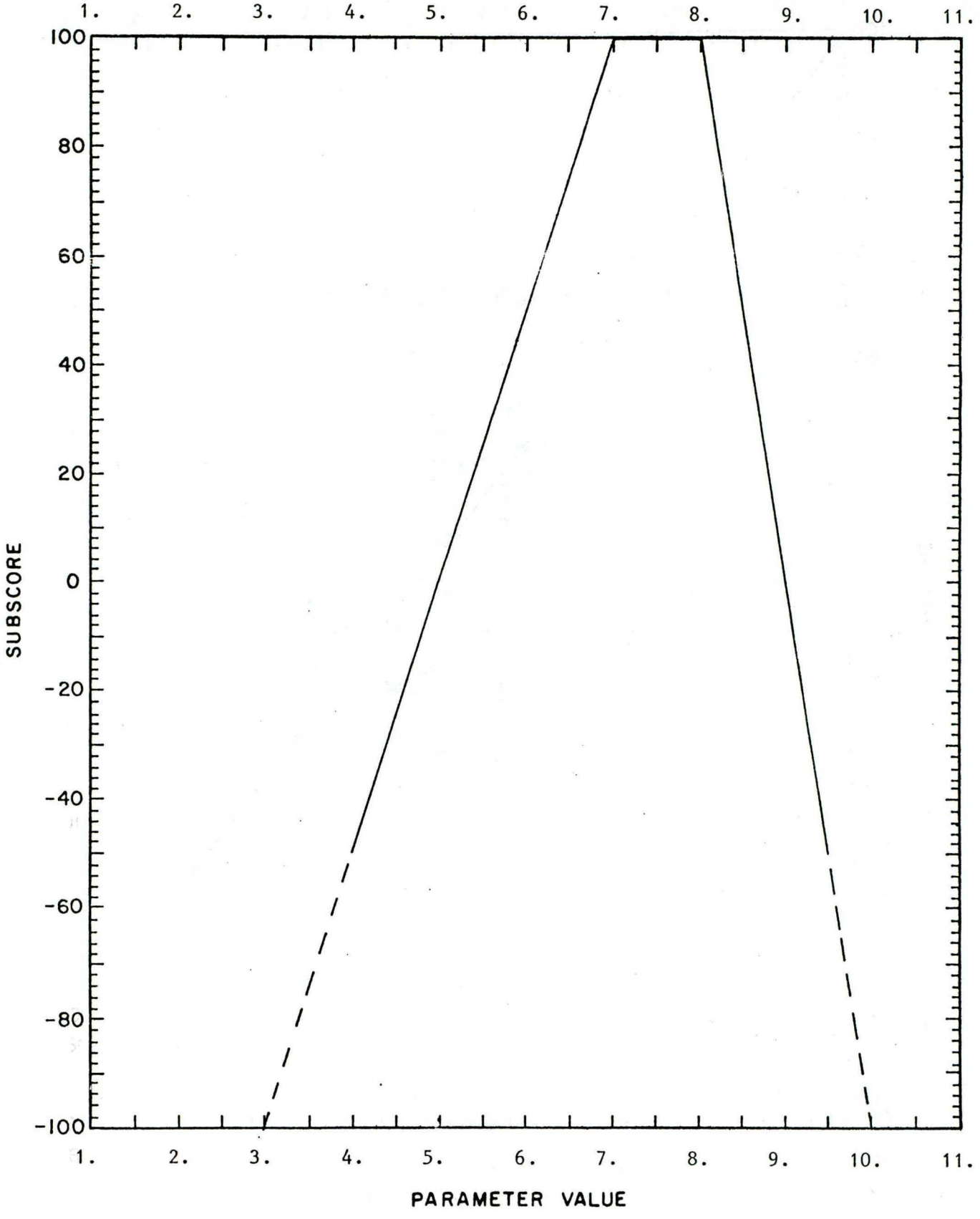
UNIT : MG/L



WATER USE : DOMESTIC WATER SUPPLY

PARAMETER : PH

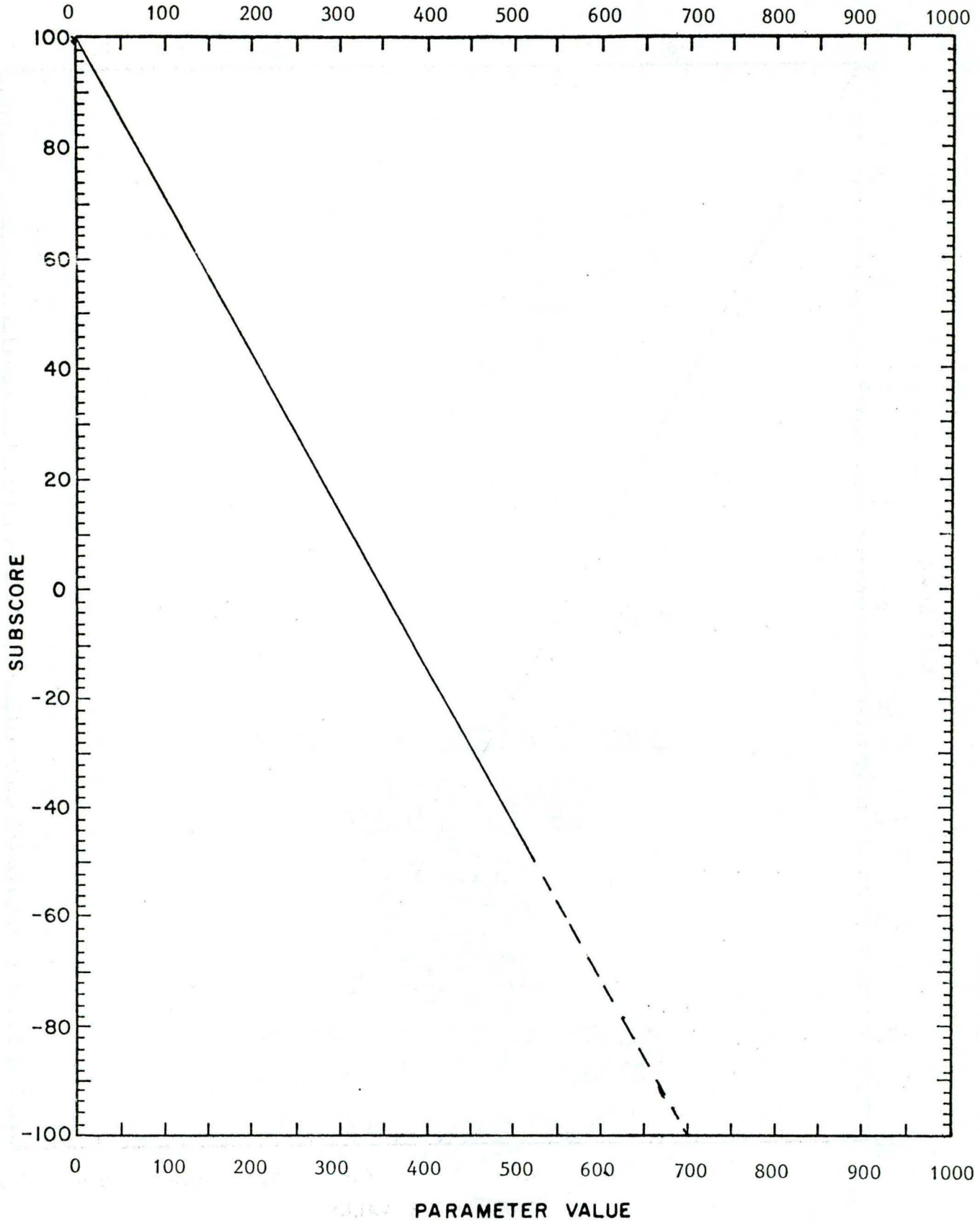
UNIT : PH UNITS



WATER USE : DOMESTIC WATER SUPPLY

PARAMETER : AMMONIA NITROGEN

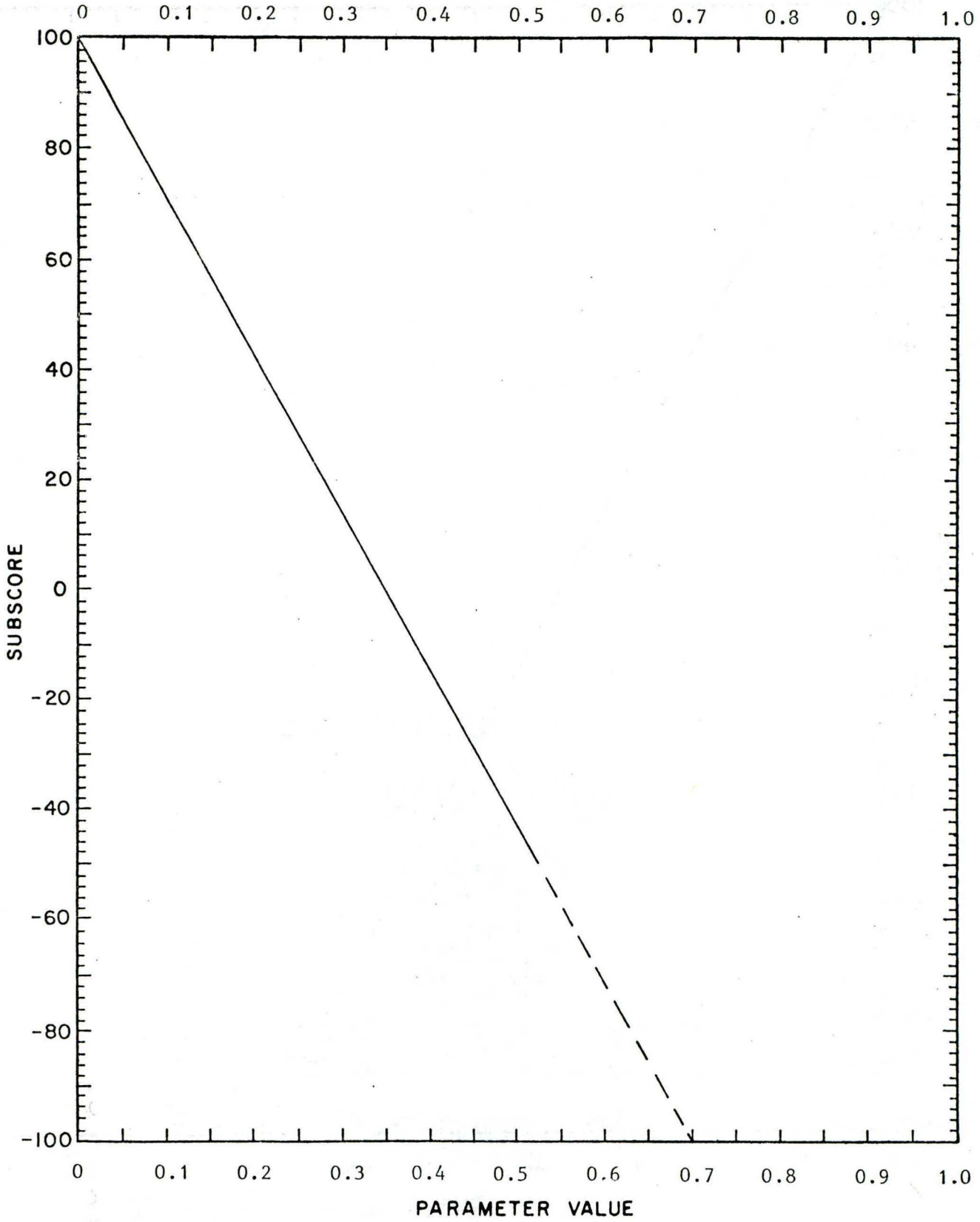
UNIT : µG/L $N\text{-}NH_3$



WATER USE : DOMESTIC WATER SUPPLY

PARAMETER : SURFACTANTS

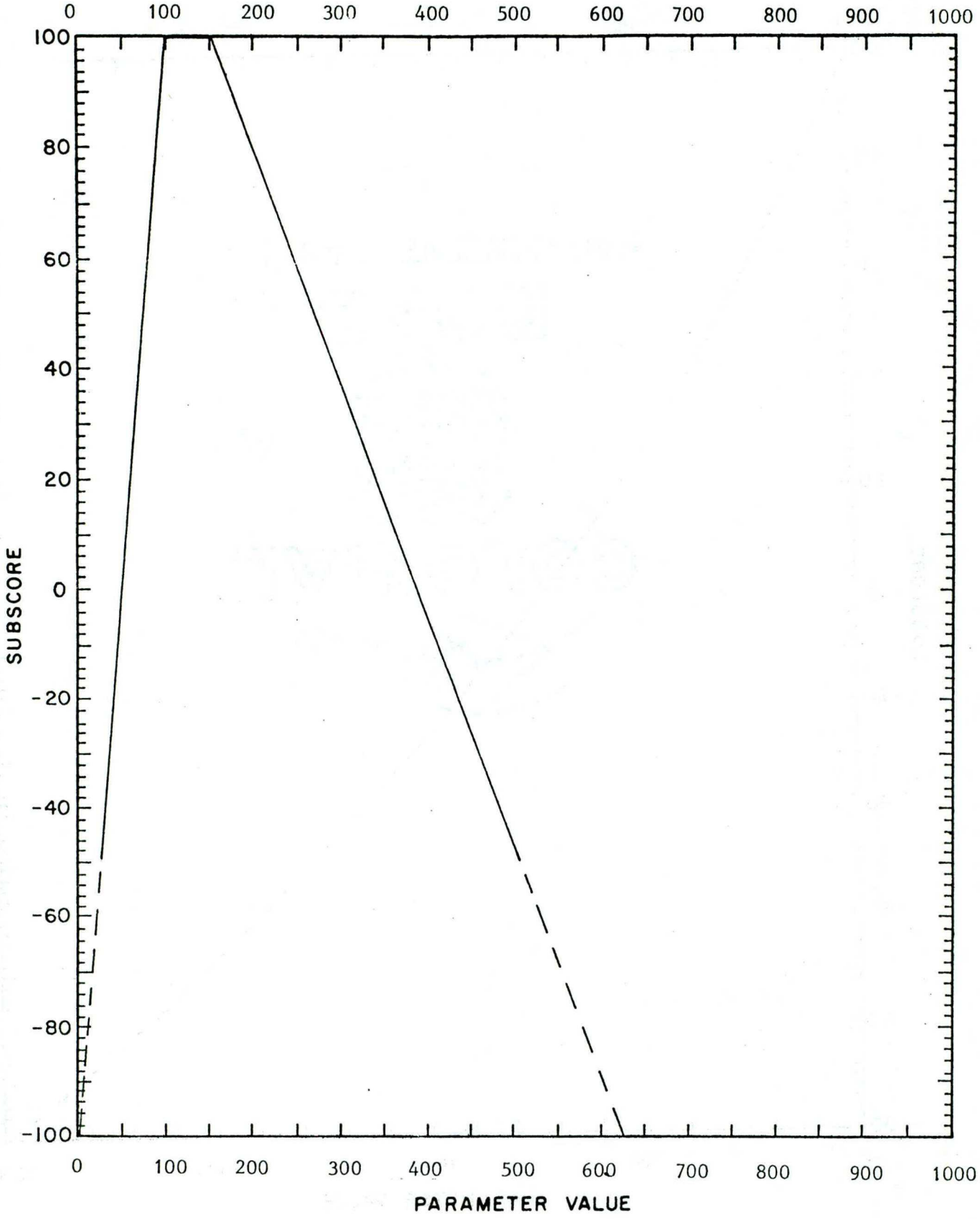
UNIT : MG/L NALS



WATER USE : DOMESTIC WATER SUPPLY

PARAMETER : HARDNESS

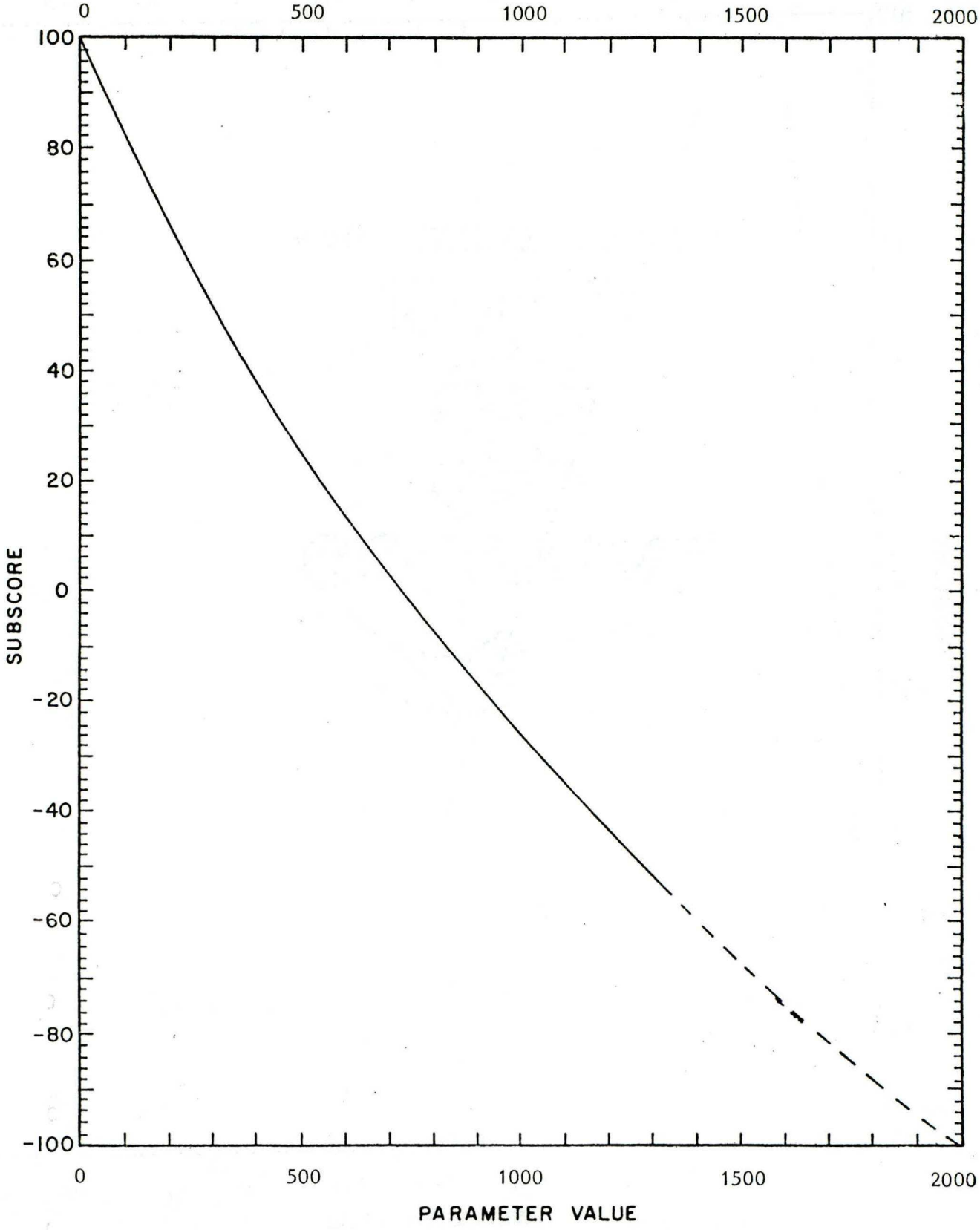
UNIT : MG/L $CaCO_3$



WATER USE : DOMESTIC WATER SUPPLY

PARAMETER : TOTAL DISSOLVED SOLIDS

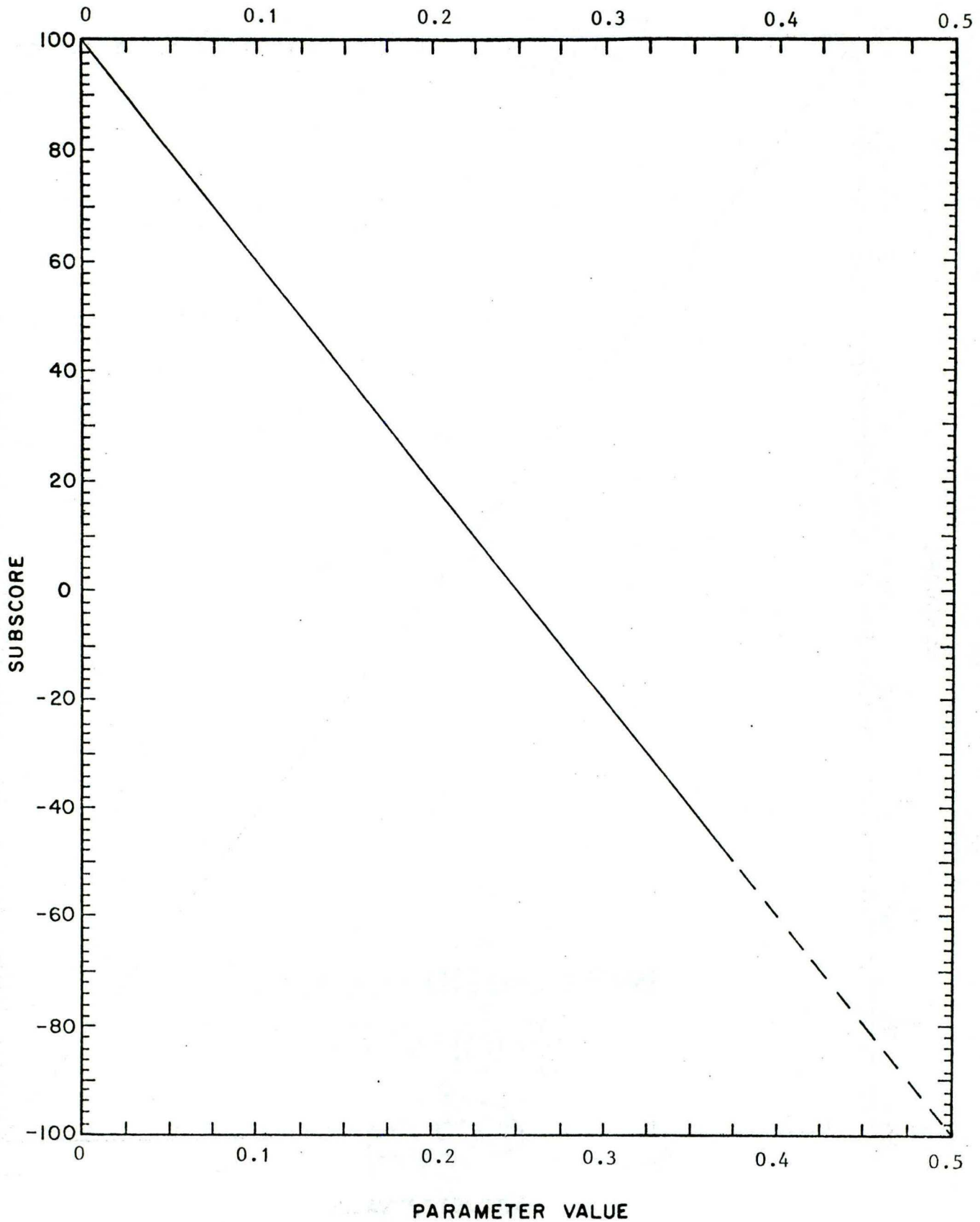
UNIT : MG/L



WATER USE : DOMESTIC WATER SUPPLY

PARAMETER : IRON

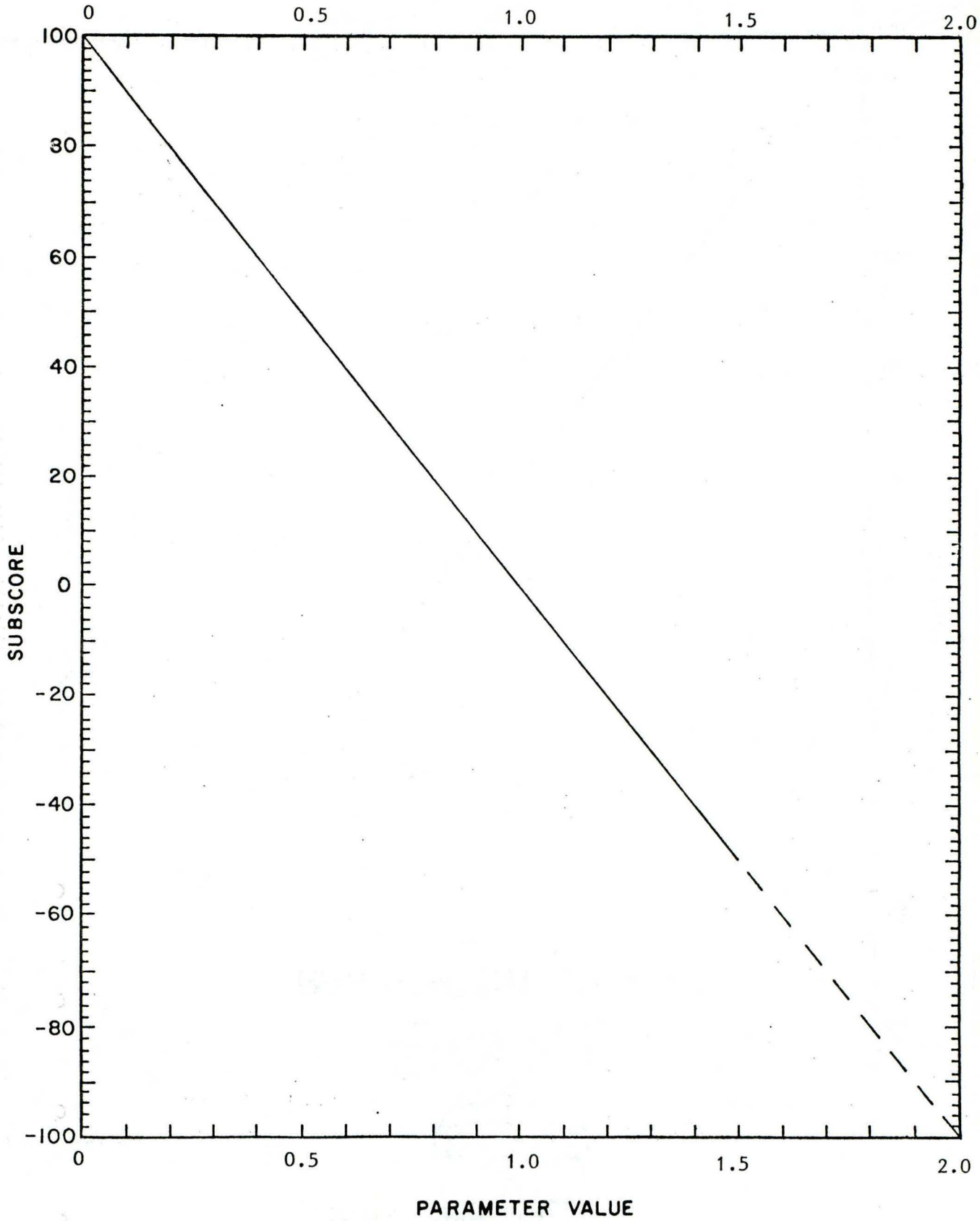
UNIT : MG/L



WATER USE : DOMESTIC WATER SUPPLY

PARAMETER : COPPER

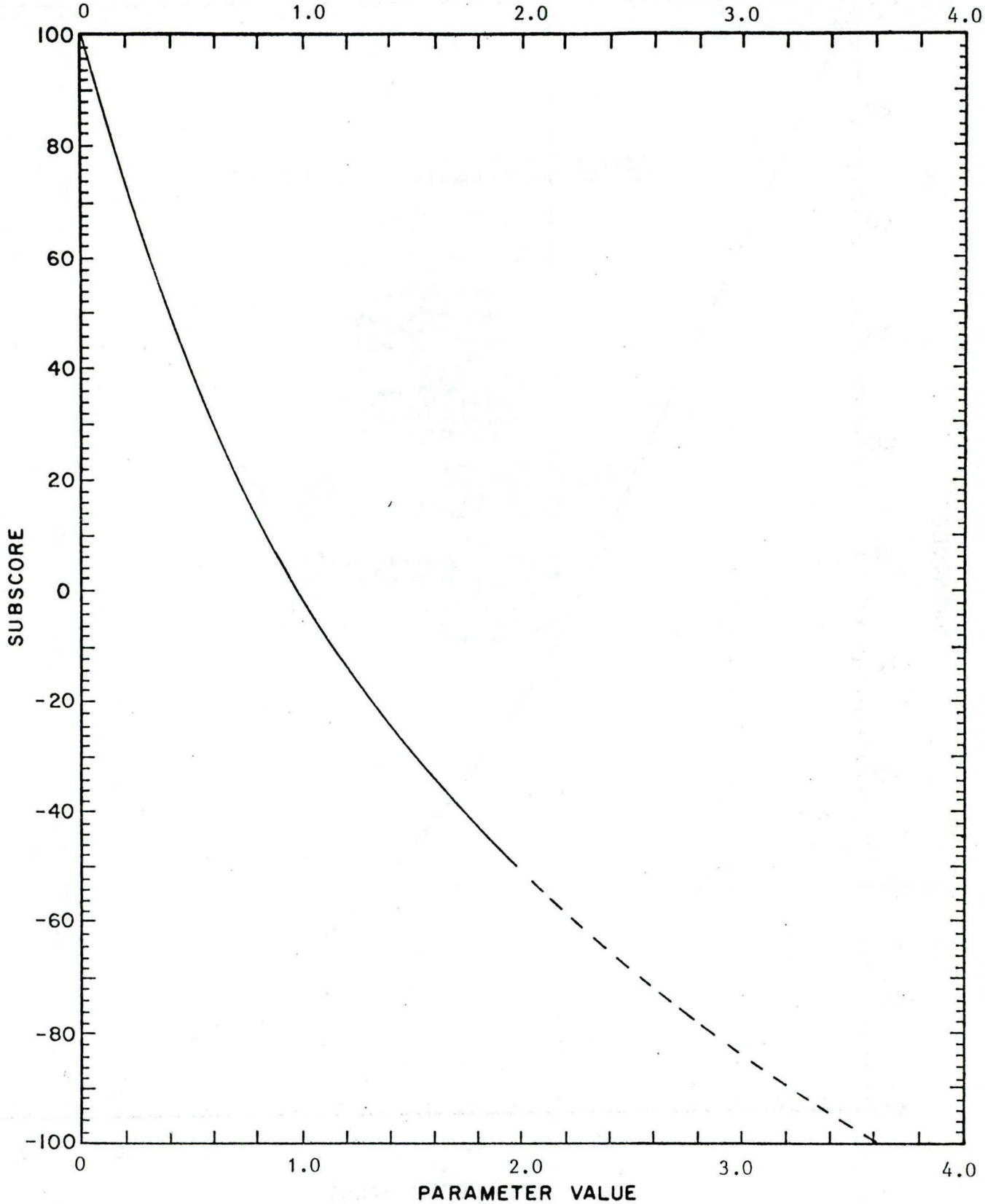
UNIT : MG/L



WATER USE : DOMESTIC WATER SUPPLY

PARAMETER : PHENOLS

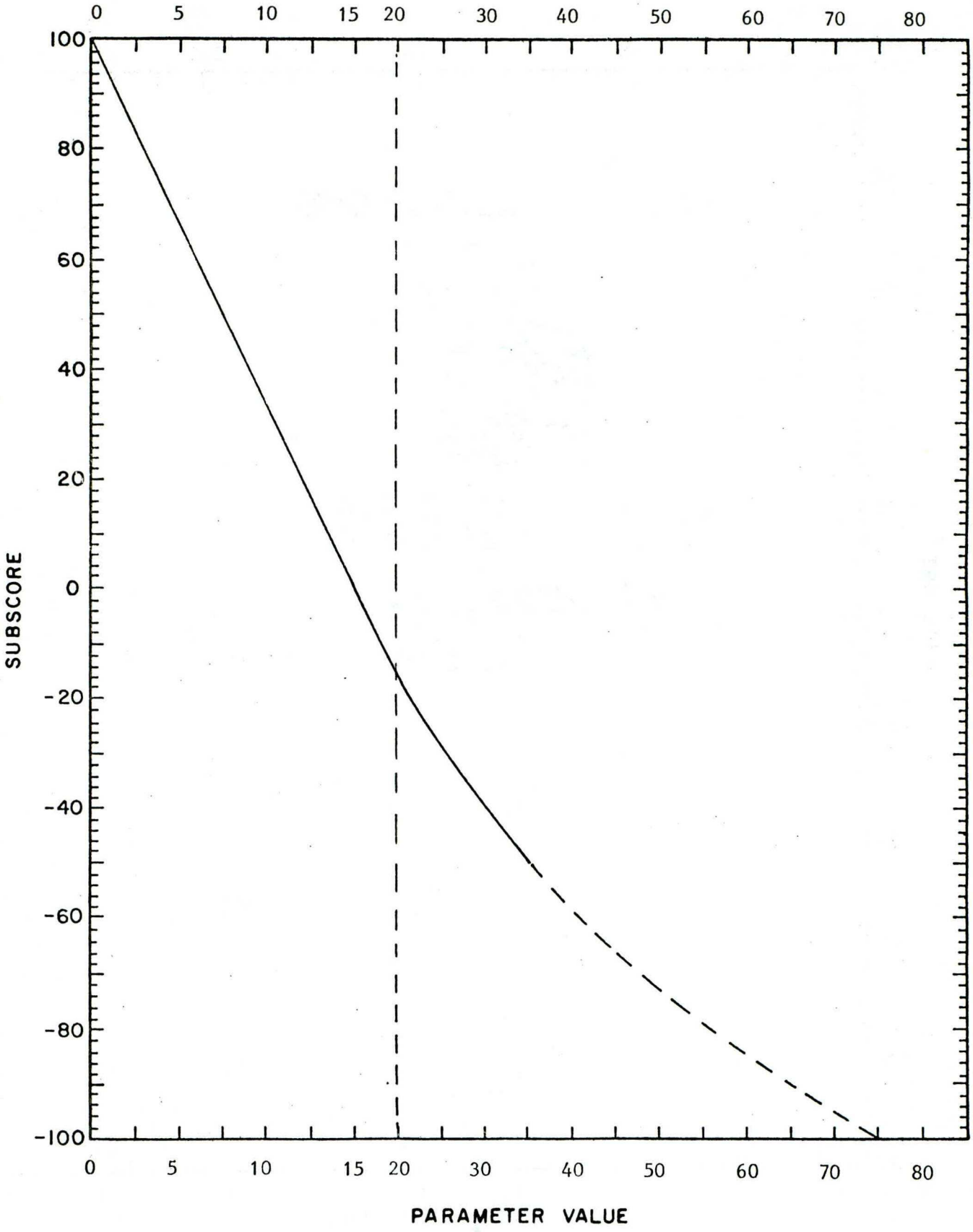
UNIT : MG/L C_6H_5OH



WATER USE : DOMESTIC WATER SUPPLY

PARAMETER : TRUE COLOR

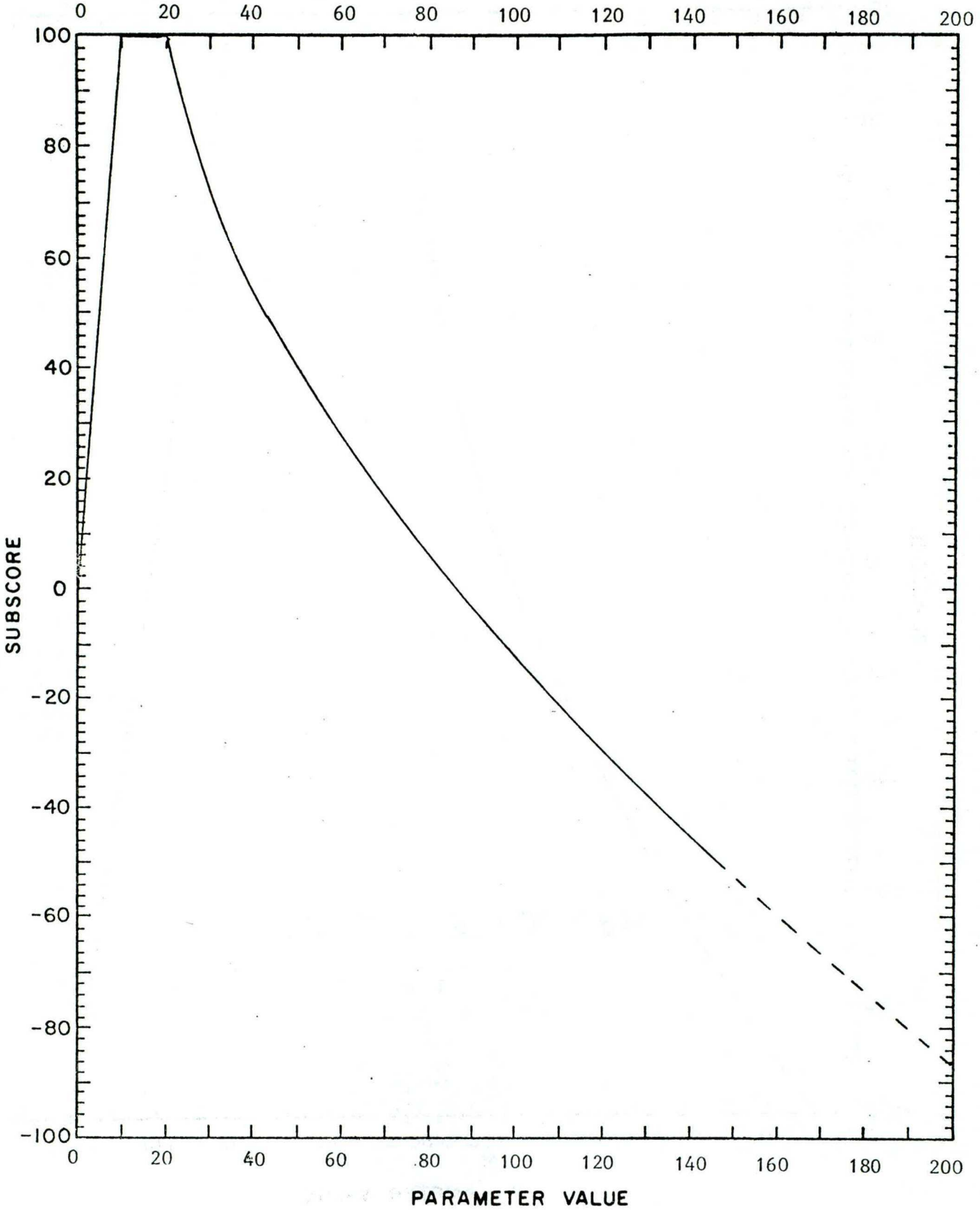
UNIT : PT-CO UNITS



WATER USE : PROTECTION OF AQUATIC LIFE (SENSITIVE SPECIES)

PARAMETER : ORTHOPHOSPHATES

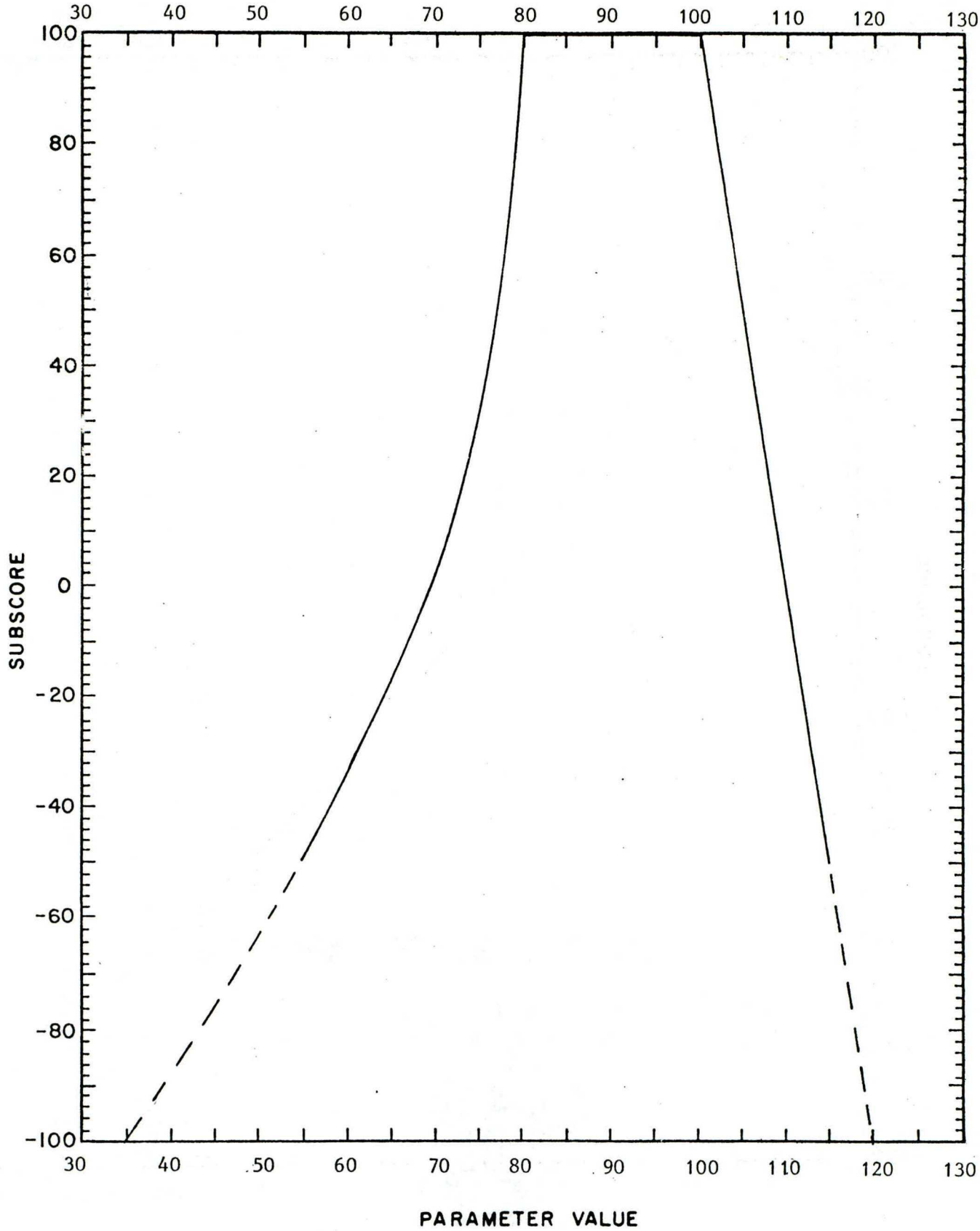
UNIT : µG/L $P-PO_4$



WATER USE : PROTECTION OF AQUATIC LIFE (SENSITIVE SPECIES)

PARAMETER : DISSOLVED OXYGEN

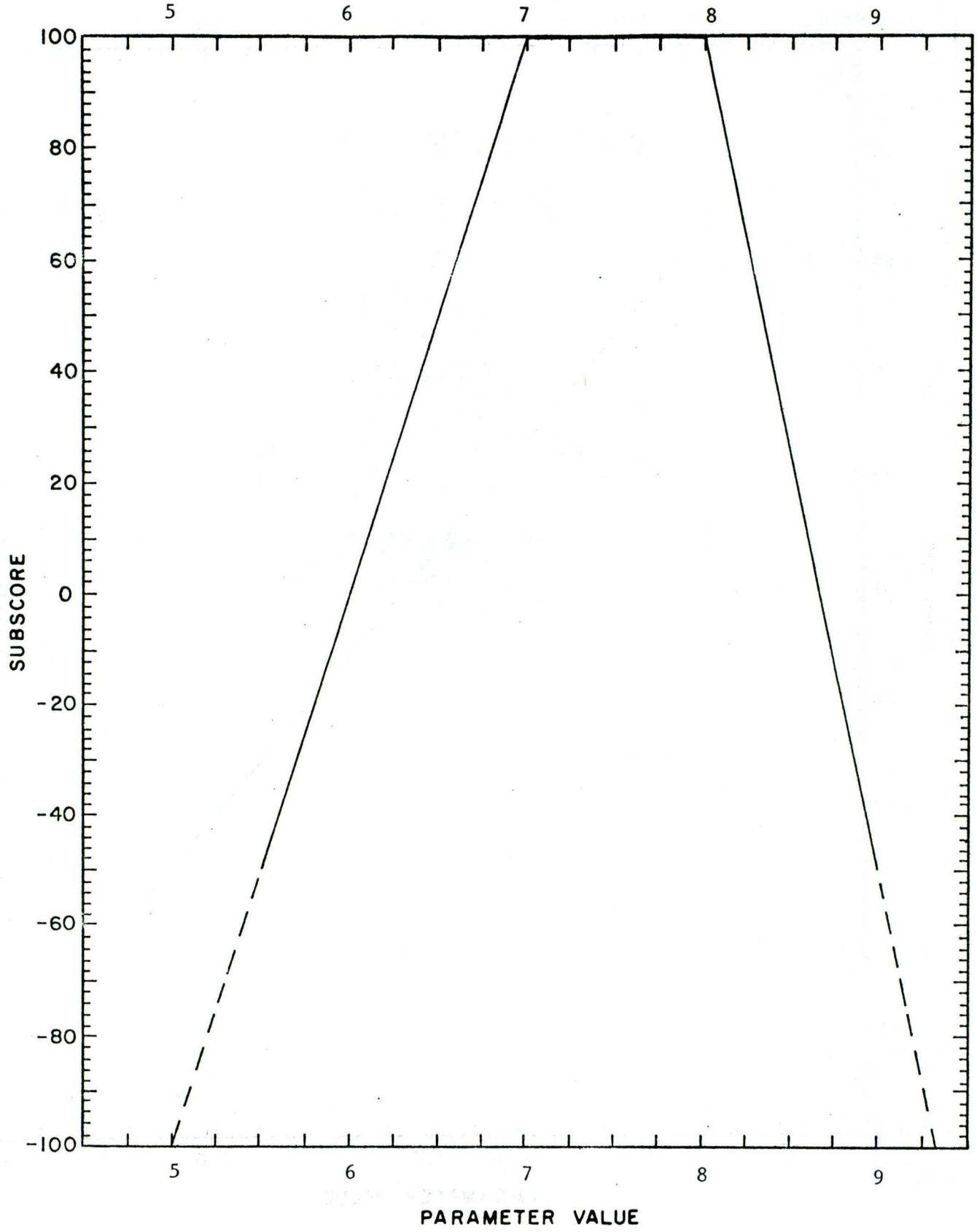
UNIT : PERCENT OF SATURATION



WATER USE : PROTECTION OF AQUATIC LIFE (SENSITIVE SPECIES)

PARAMETER : PH

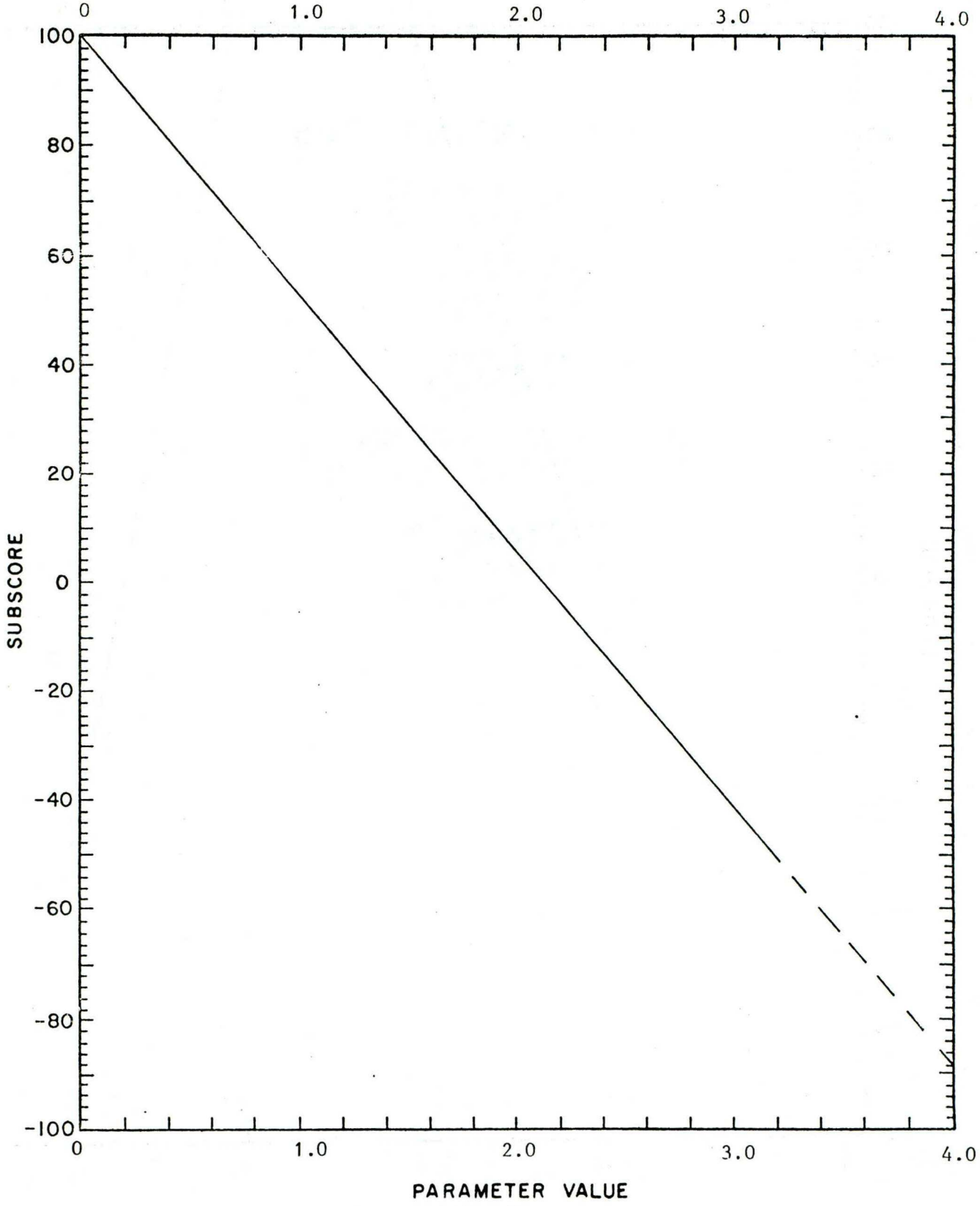
UNIT : PH UNITS



WATER USE : PROTECTION OF AQUATIC LIFE (SENSITIVE SPECIES)

PARAMETER : NITRATES

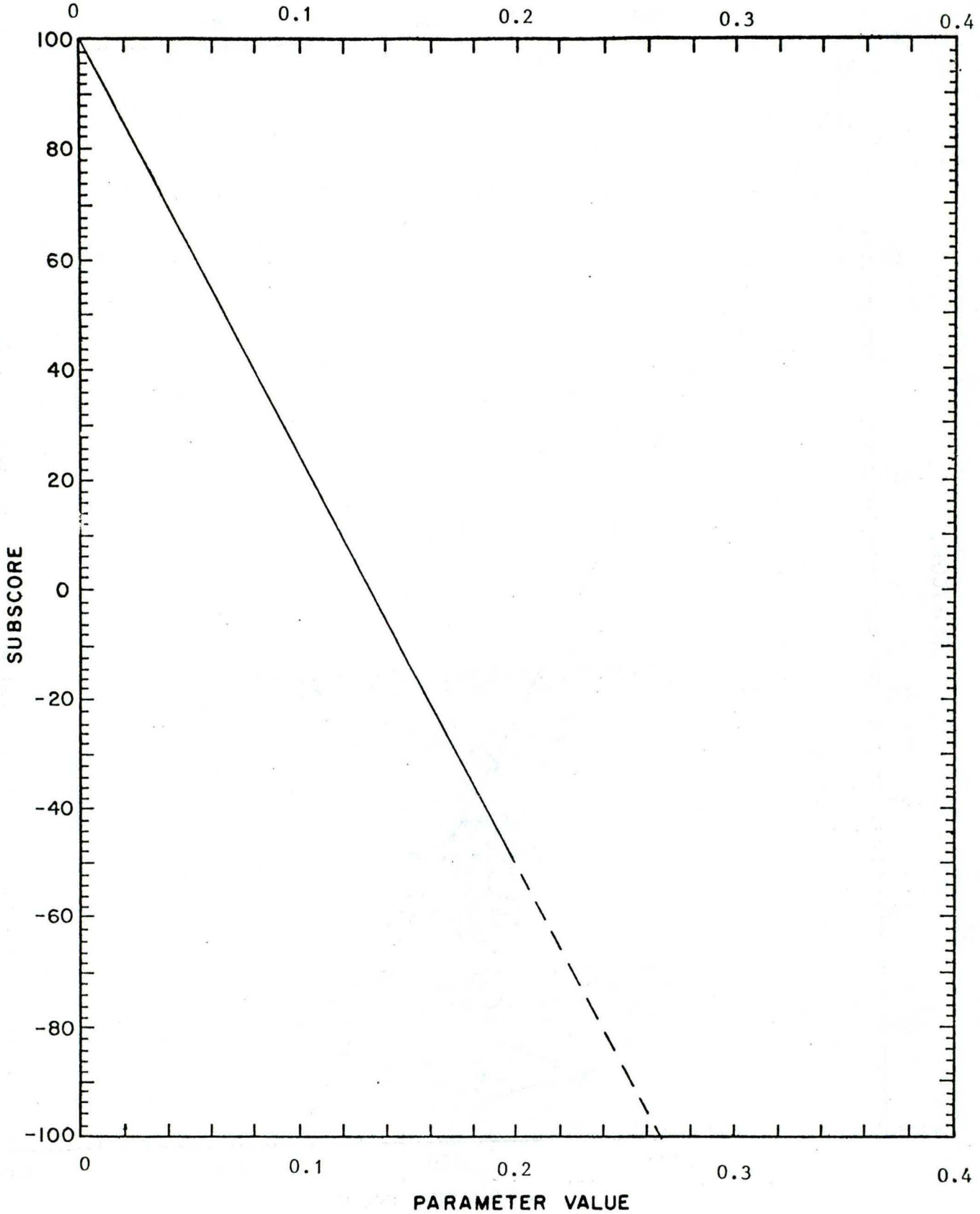
UNIT : MG/L $N\text{-}NO_3$



WATER USE : PROTECTION OF AQUATIC LIFE (SENSITIVE SPECIES)

PARAMETER : NITRITES

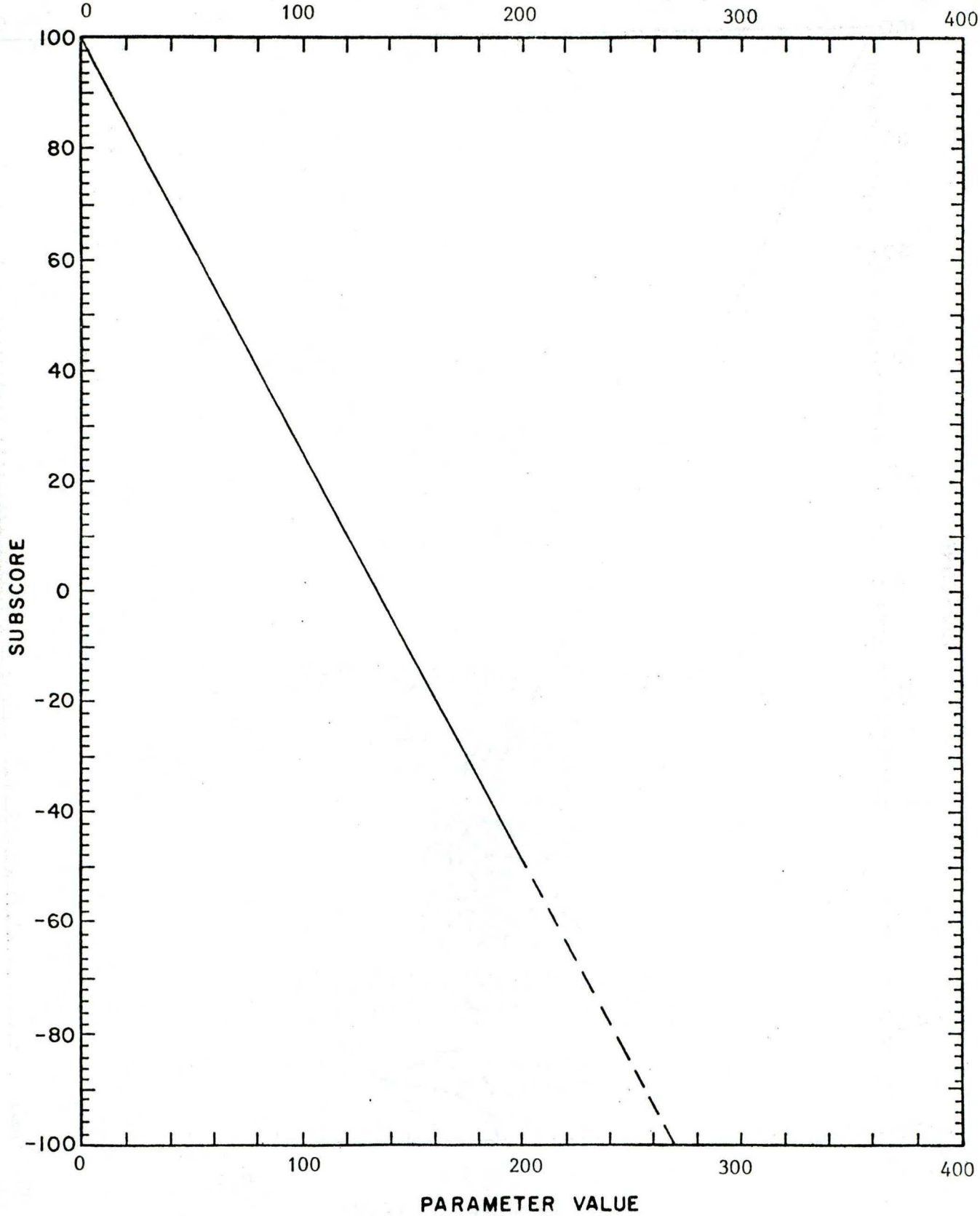
UNIT : MG/L $N\text{-}NO_2$



WATER USE : PROTECTION OF AQUATIC LIFE (SENSITIVE SPECIES)

PARAMETER : SUSPENDED SOLIDS

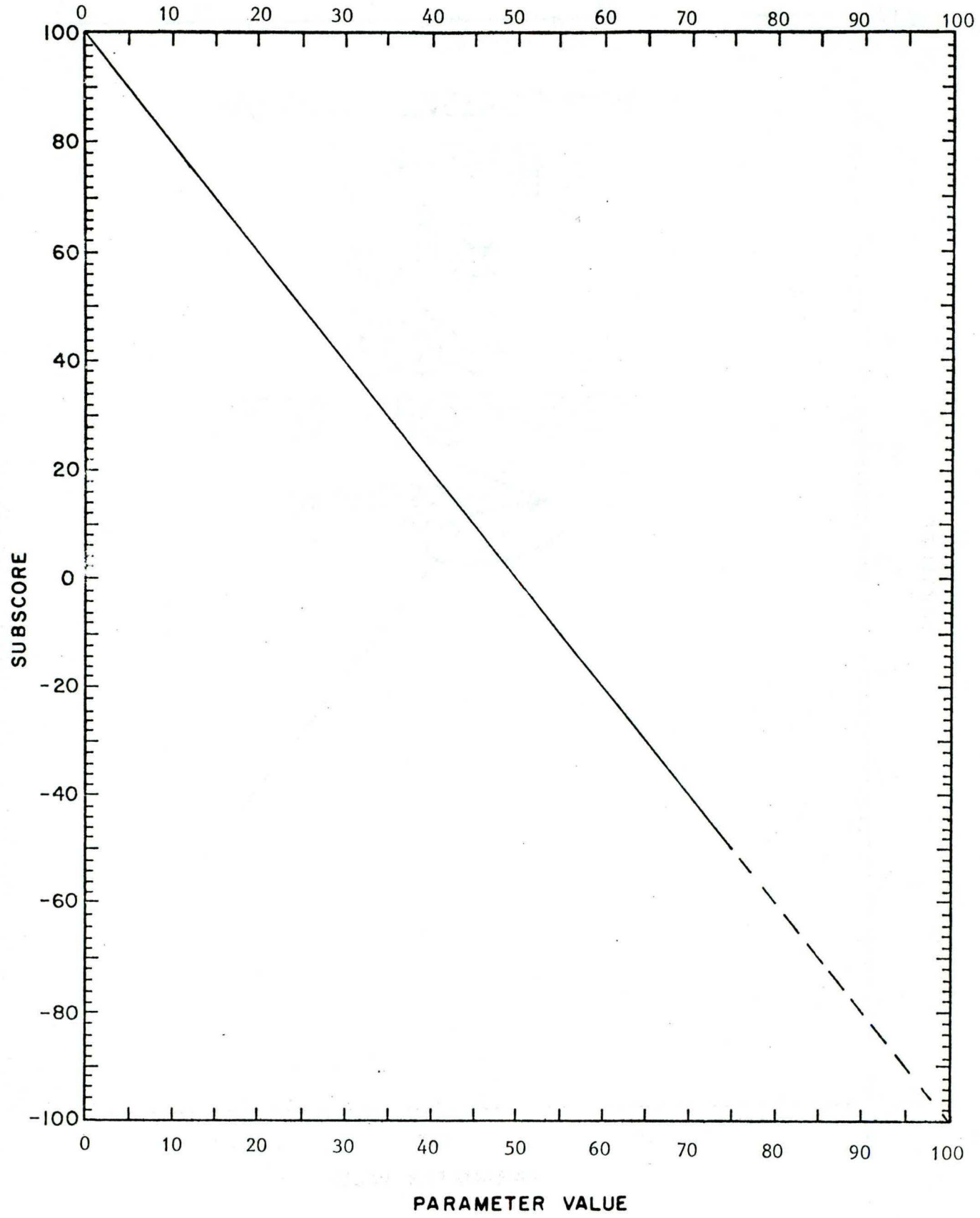
UNIT : MG/L



WATER USE : PROTECTION OF AQUATIC LIFE (SENSITIVE SPECIES)

PARAMETER : AMMONIA NITROGEN

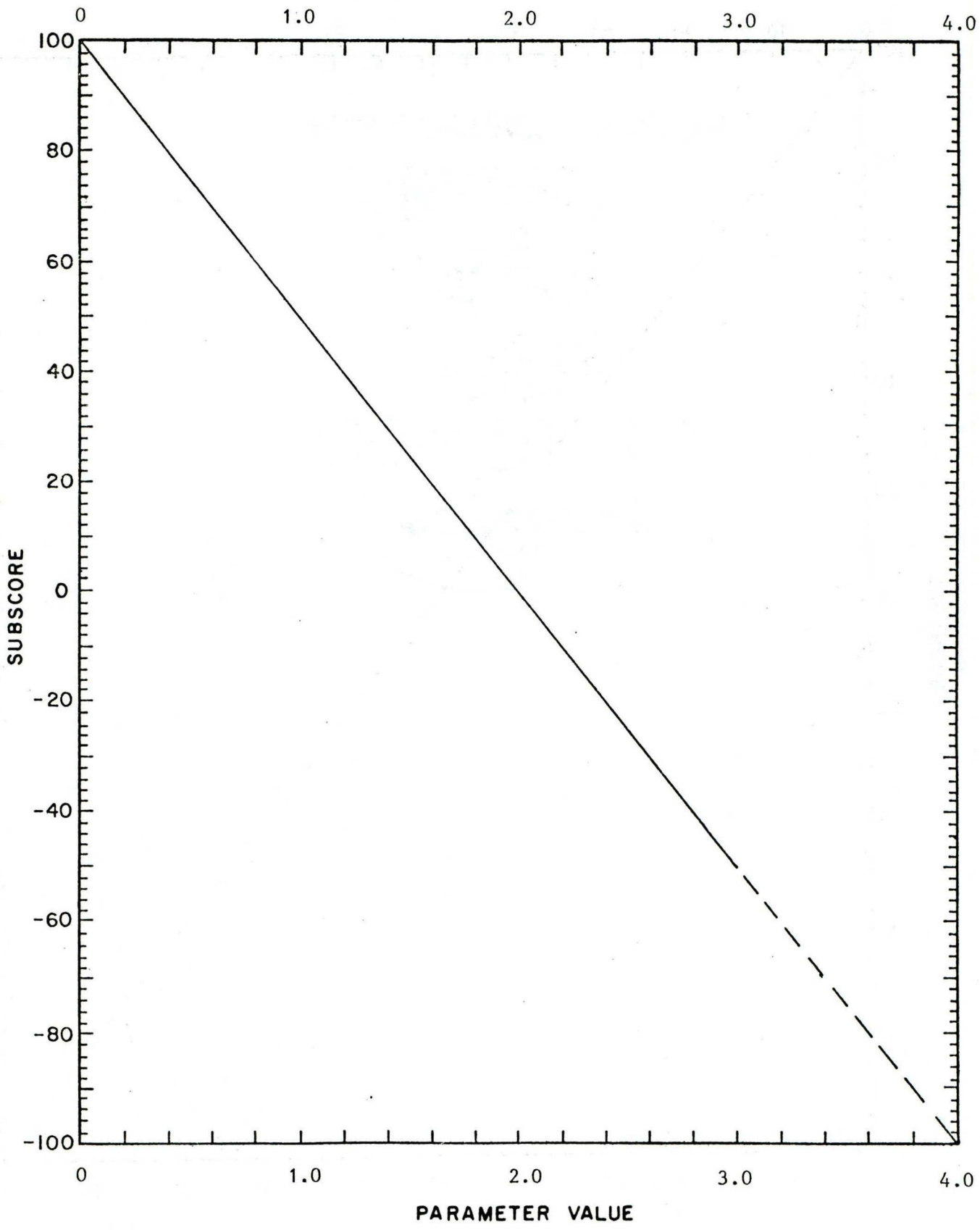
UNIT : µG/L N-NH_3



WATER USE : PROTECTION OF AQUATIC LIFE (SENSITIVE SPECIES)

PARAMETER : TOTAL RESIDUAL CHLORINE

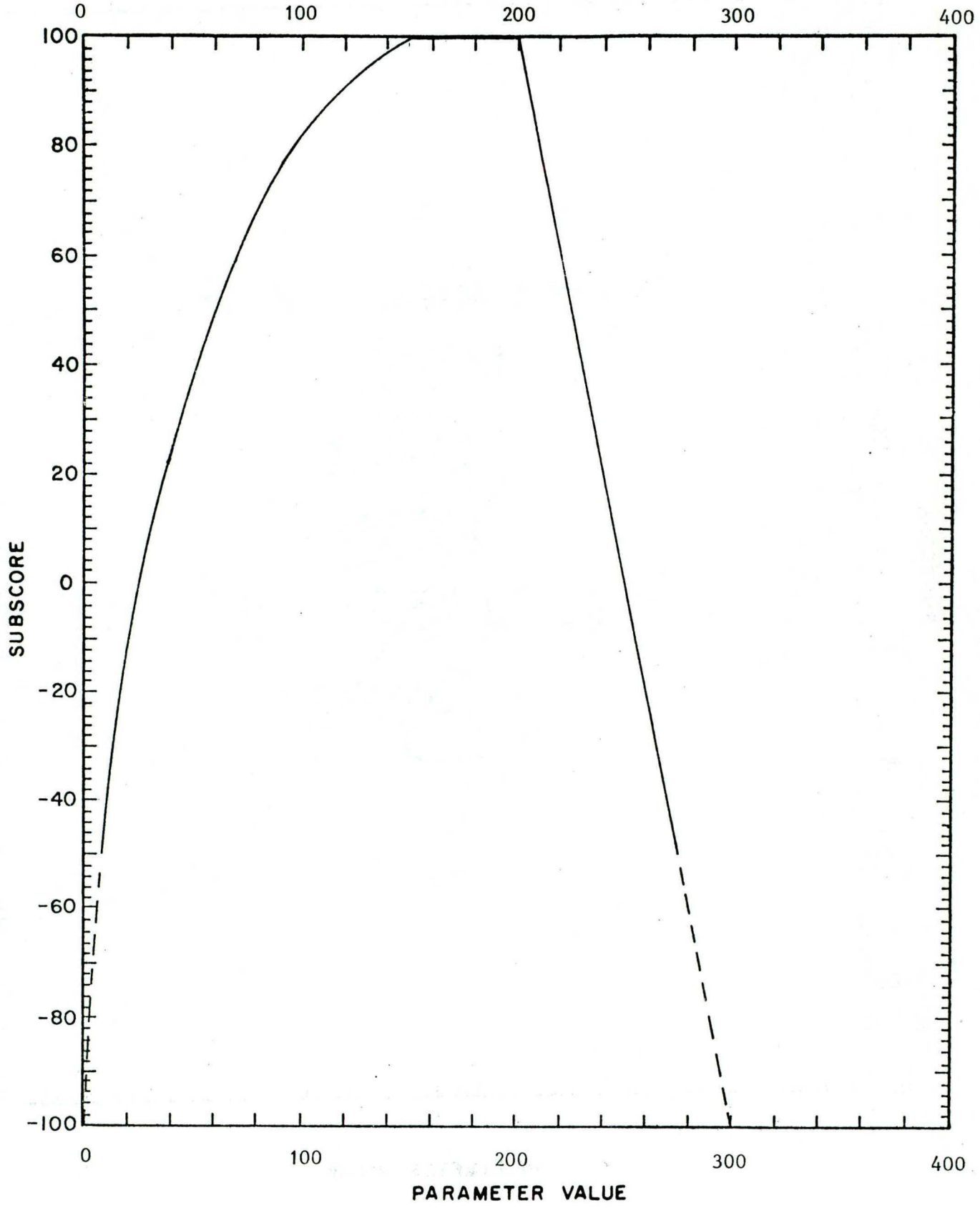
UNIT : MG/L



WATER USE : PROTECTION OF AQUATIC LIFE (SENSITIVE SPECIES)

PARAMETER : ALKALINITY

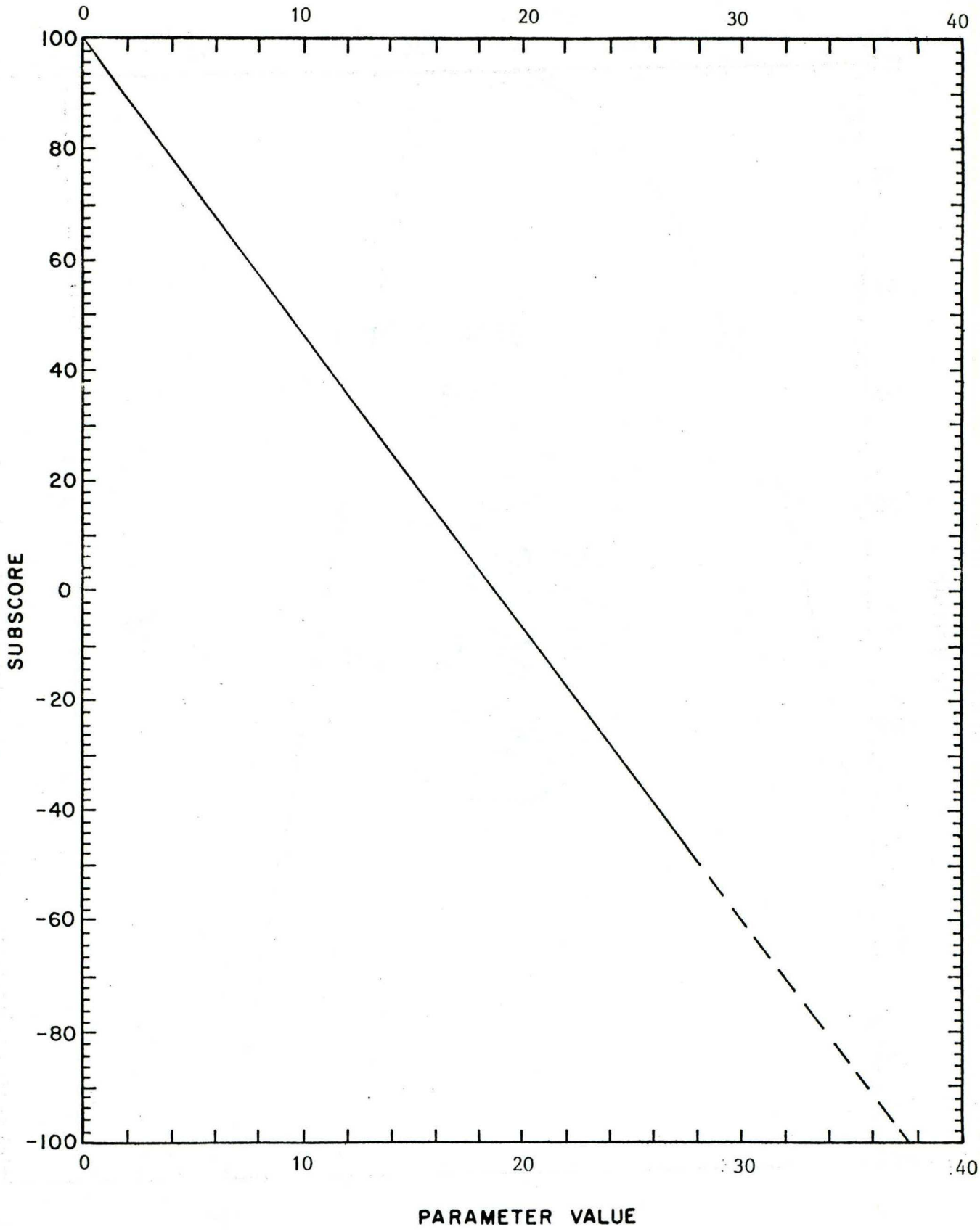
UNIT : MG/L $CaCO_3$



WATER USE : PROTECTION OF AQUATIC LIFE (SENSITIVE SPECIES)

PARAMETER : PHENOLS

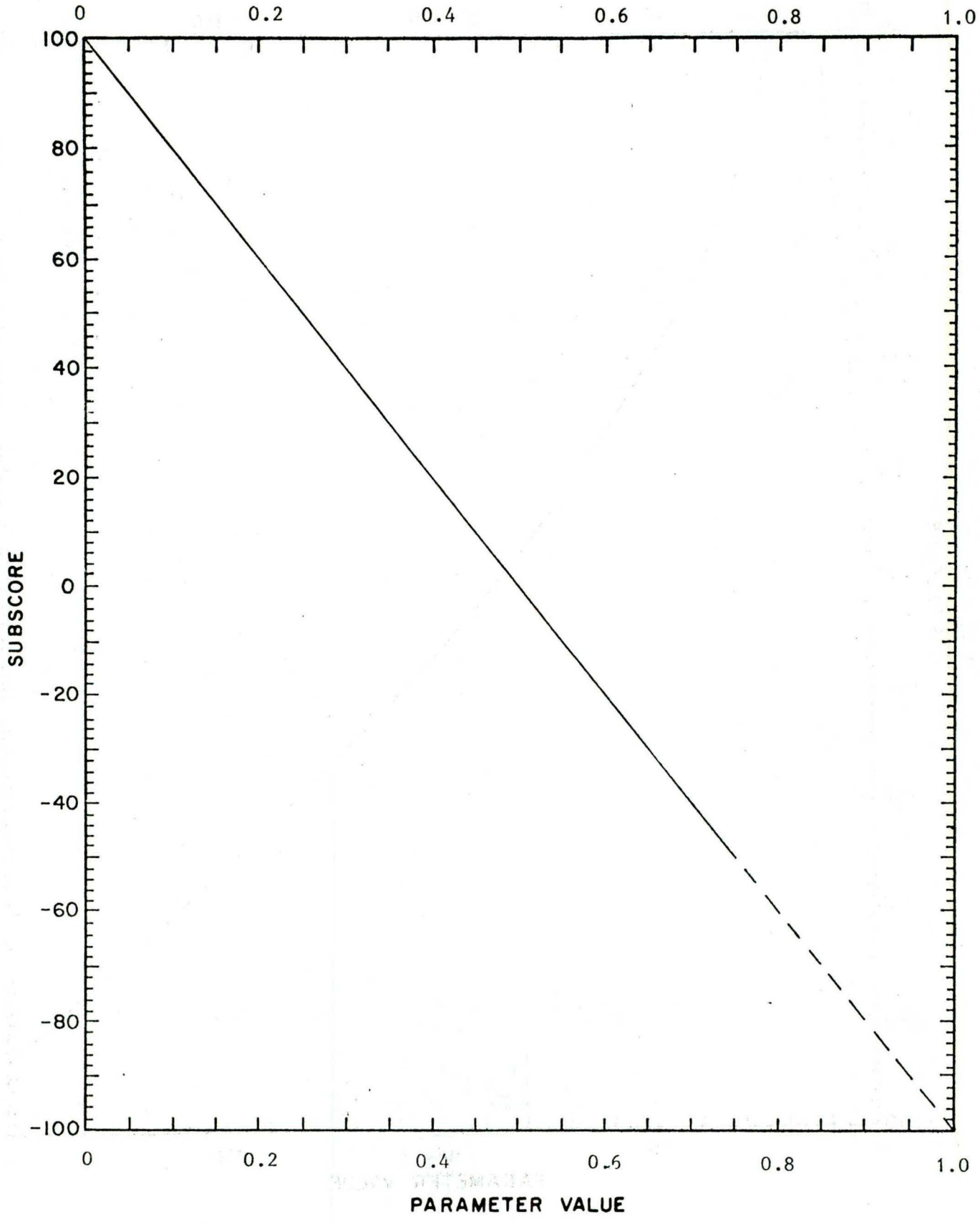
UNIT : MG/L C_6H_5OH



WATER USE : PROTECTION OF AQUATIC LIFE (SENSITIVE SPECIES)

PARAMETER : SURFACTANTS

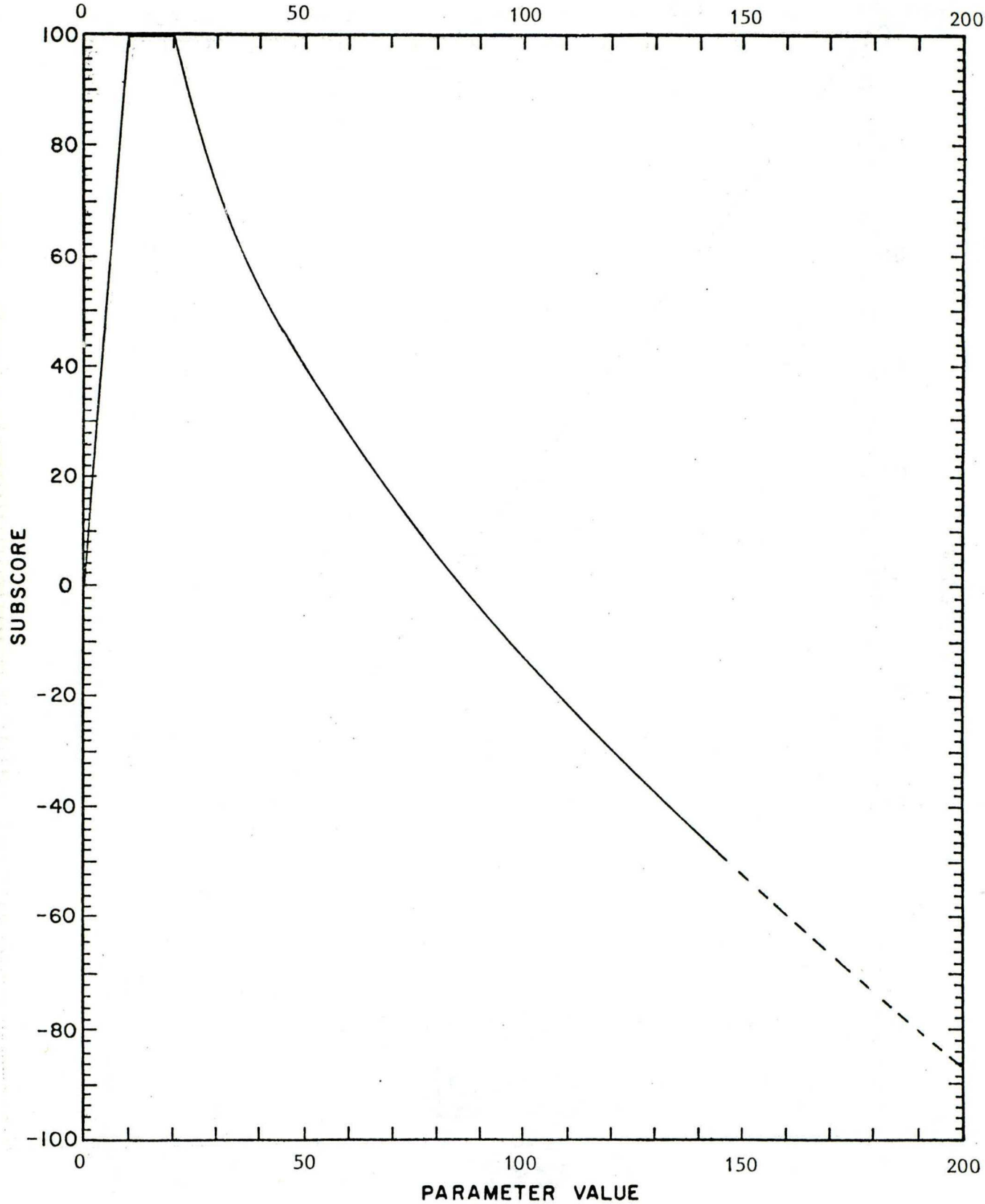
UNIT : MG/L NALS



WATER USE : PROTECTION OF AQUATIC LIFE (TOLERANT SPECIES)

PARAMETER : ORTHOPHOSPHATES

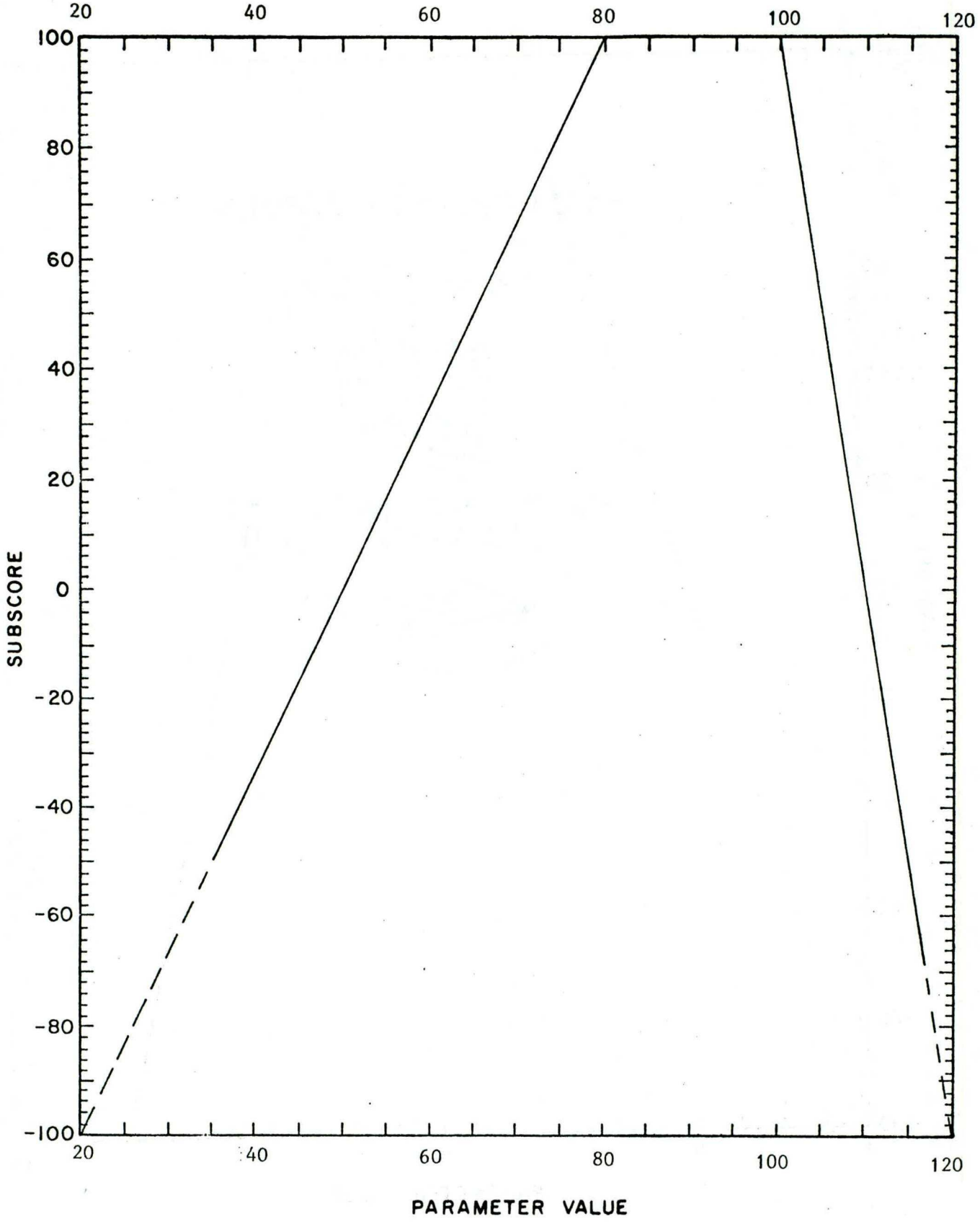
UNIT : µG/L $P\text{-}PO_4$



WATER USE : PROTECTION OF AQUATIC LIFE (TOLERANT SPECIES)

PARAMETER : DISSOLVED OXYGEN

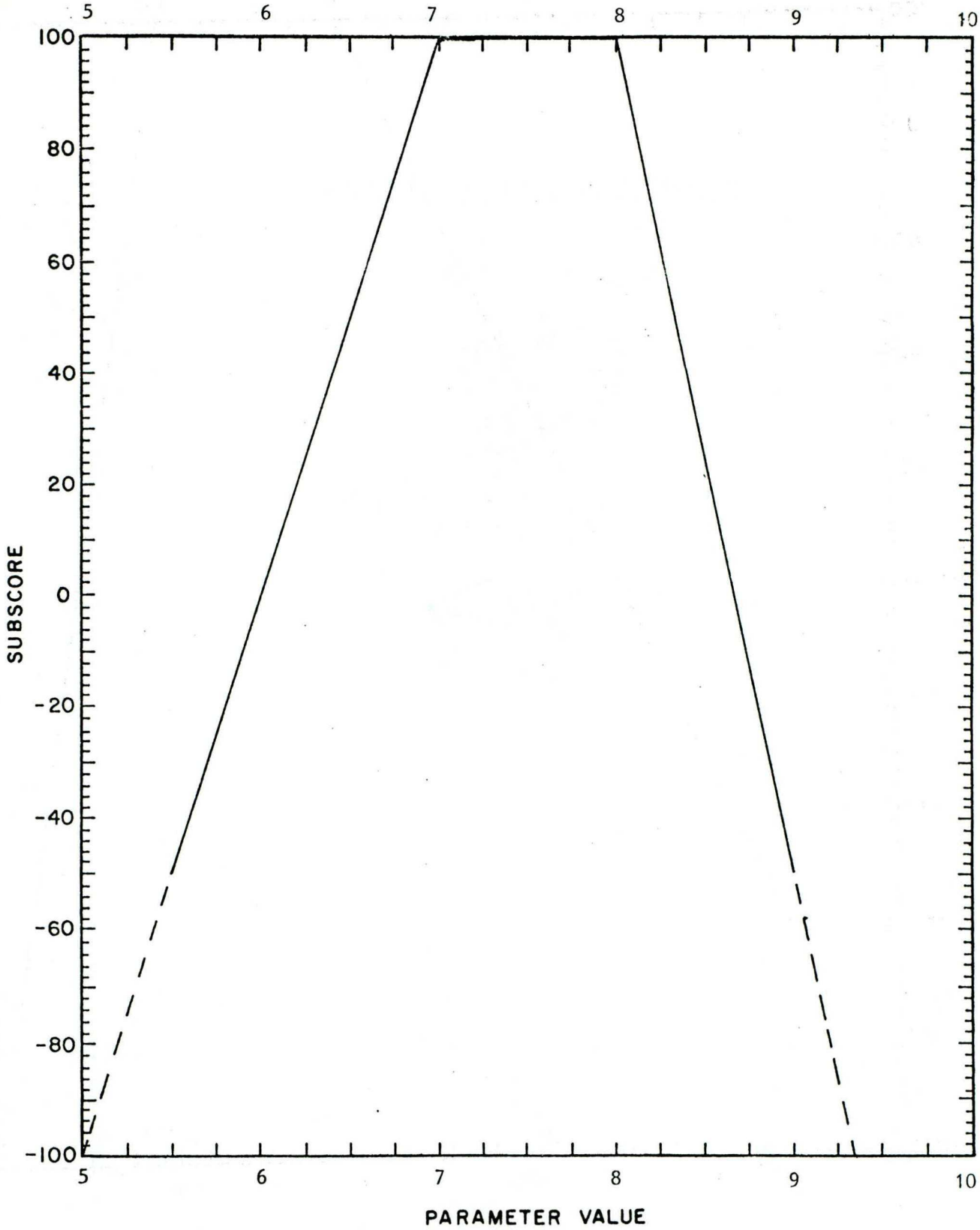
UNIT : PERCENT OF SATURATION



WATER USE : PROTECTION OF AQUATIC LIFE (TOLERANT SPECIES)

PARAMETER : PH

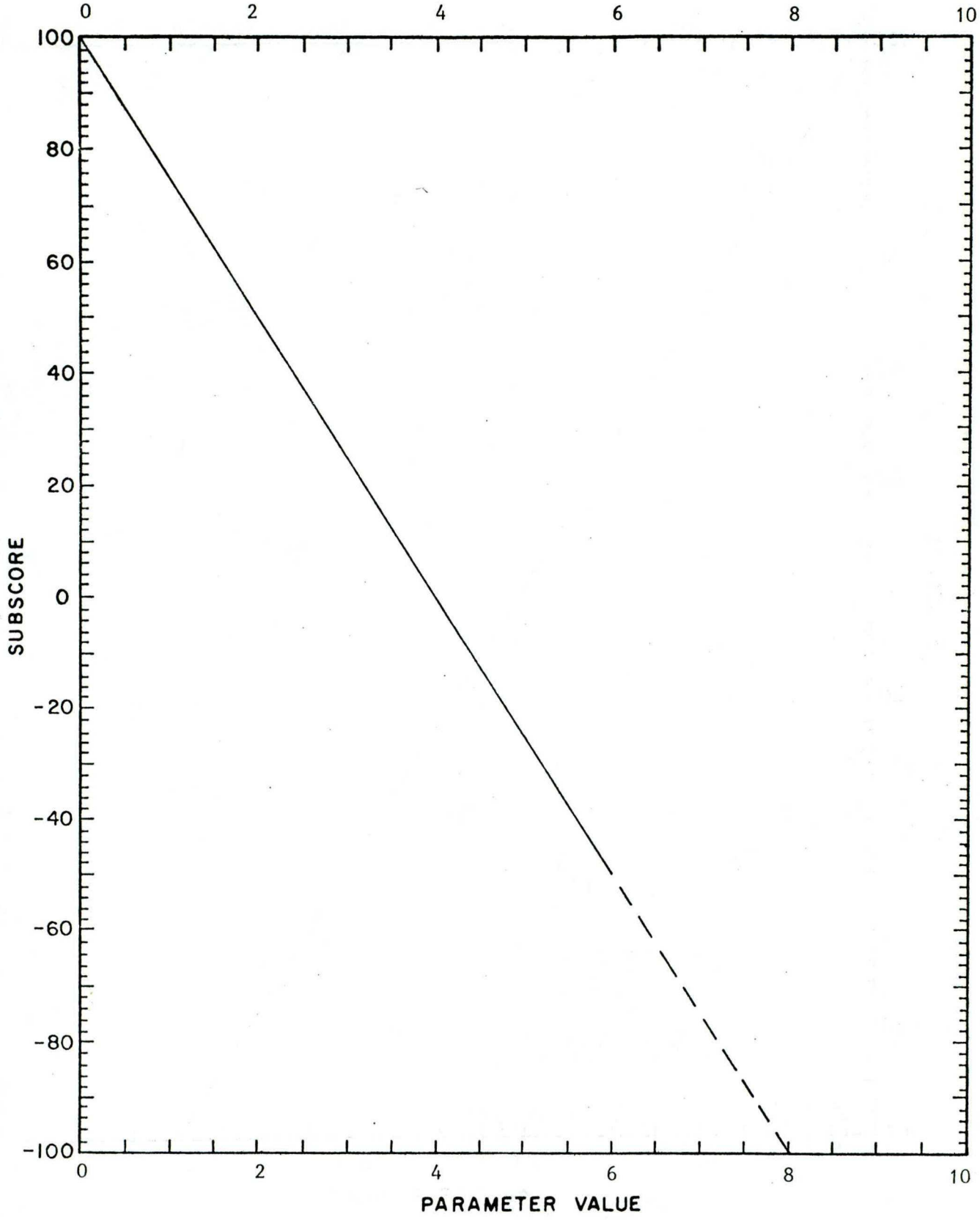
UNIT : PH UNITS



WATER USE : PROTECTION OF AQUATIC LIFE (TOLERANT SPECIES)

PARAMETER : NITRATES

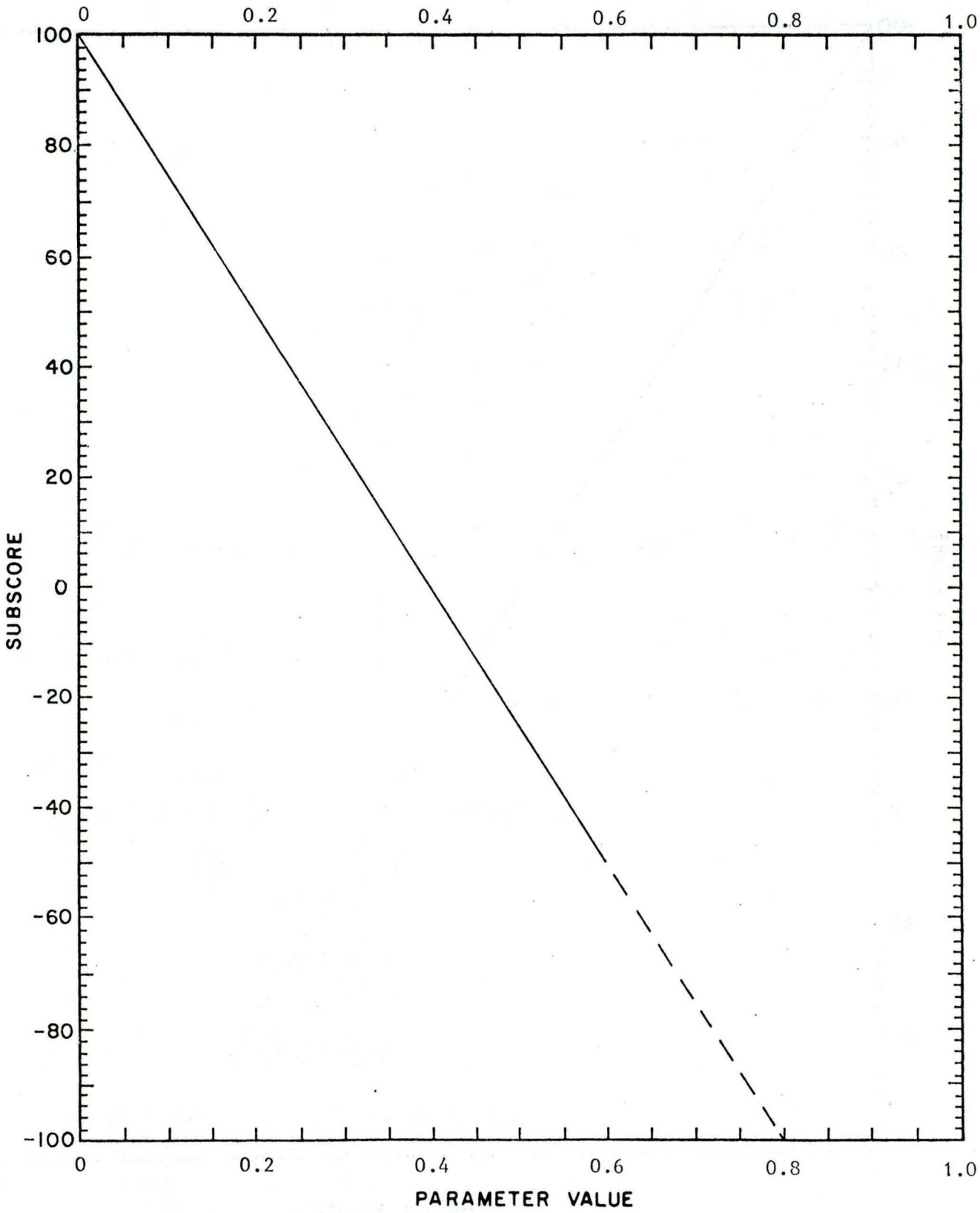
UNIT : MG/L $N\text{-}NO_3$



WATER USE : PROTECTION OF AQUATIC LIFE (TOLERANT SPECIES)

PARAMETER : NITRITES

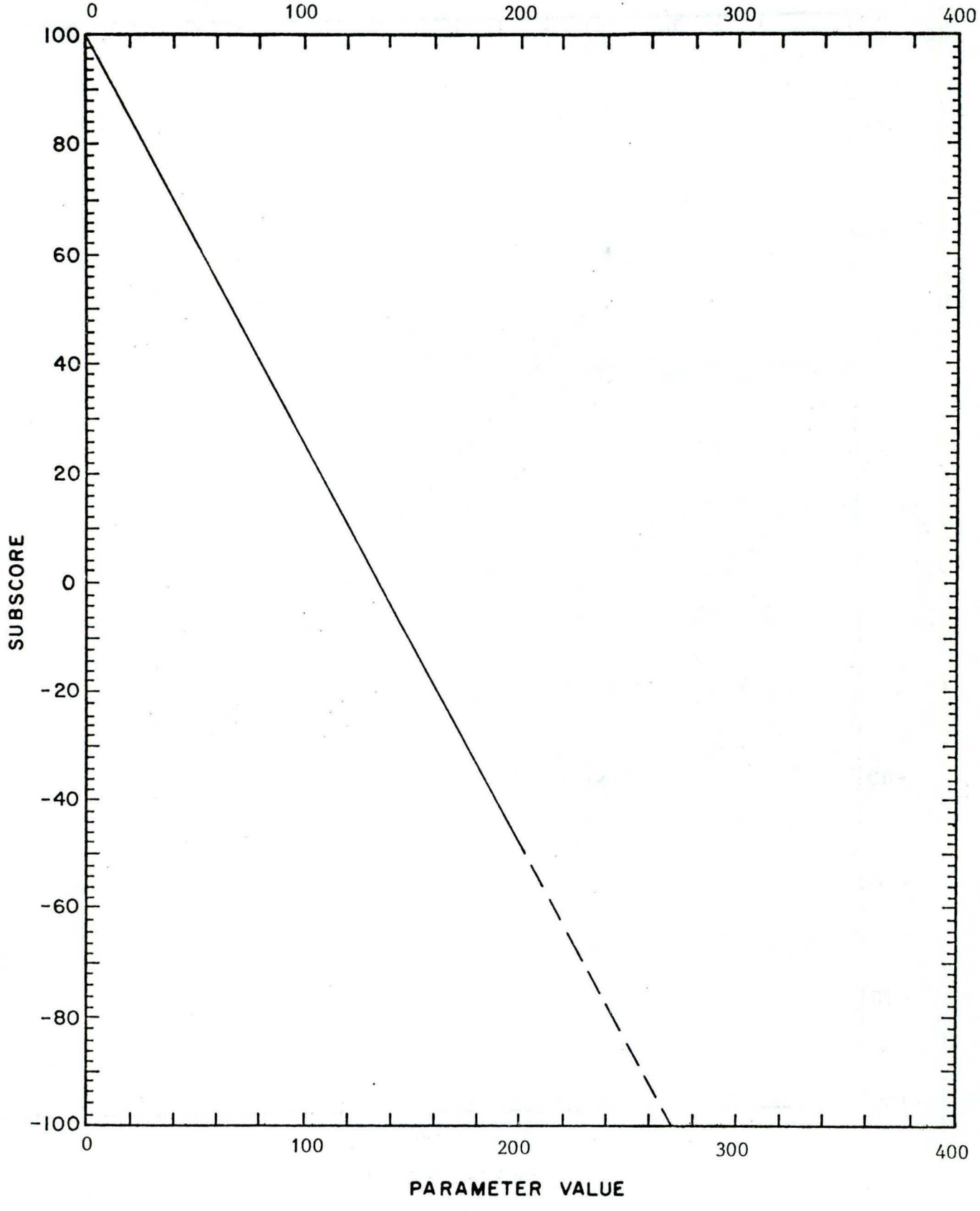
UNIT : MG/L $N\text{-}NO_2$



WATER USE : PROTECTION OF AQUATIC LIFE (TOLERANT SPECIES)

PARAMETER : SUSPENDED SOLIDS

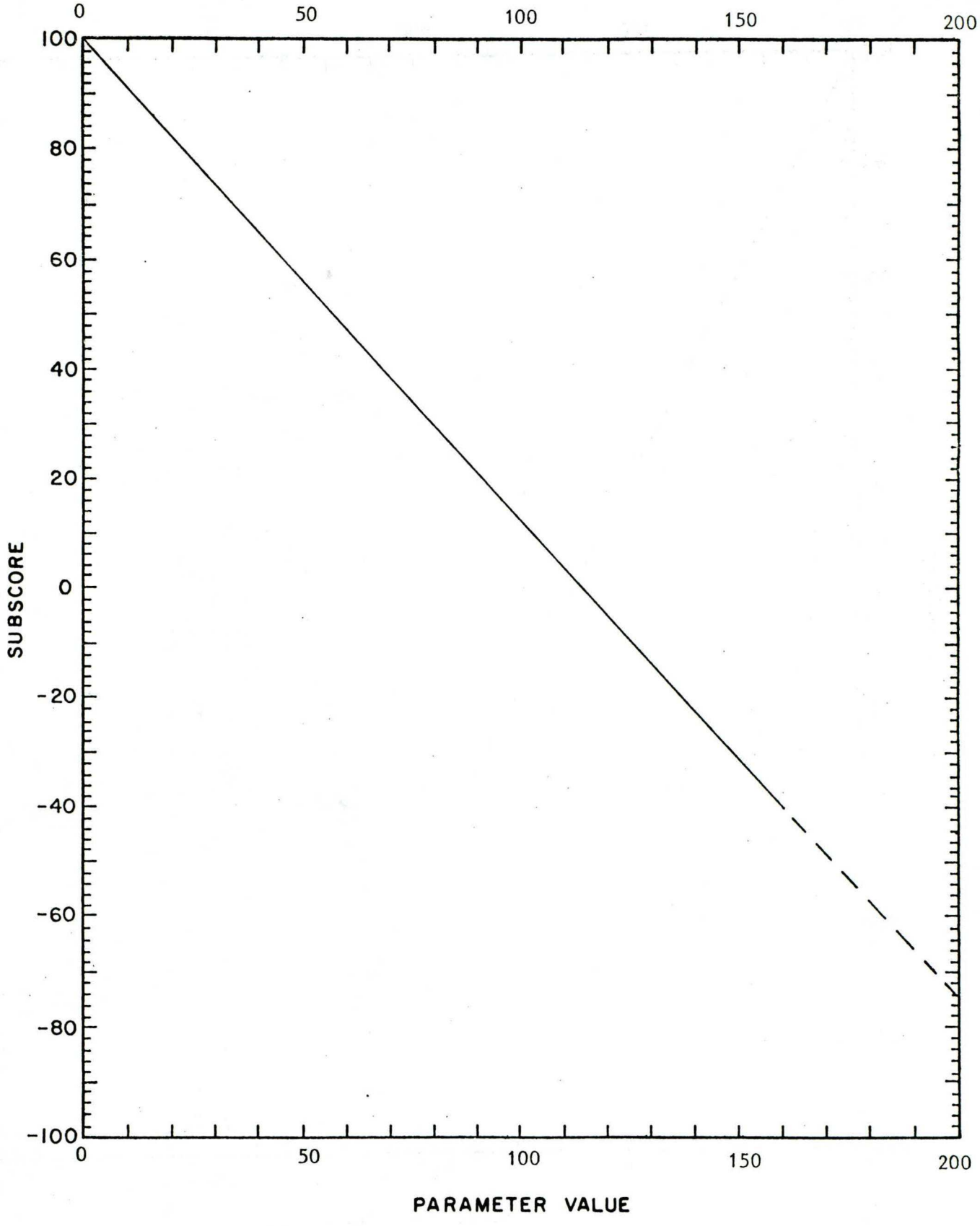
UNIT : MG/L



WATER USE : PROTECTION OF AQUATIC LIFE (TOLERANT SPECIES)

PARAMETER : AMMONIA NITROGEN

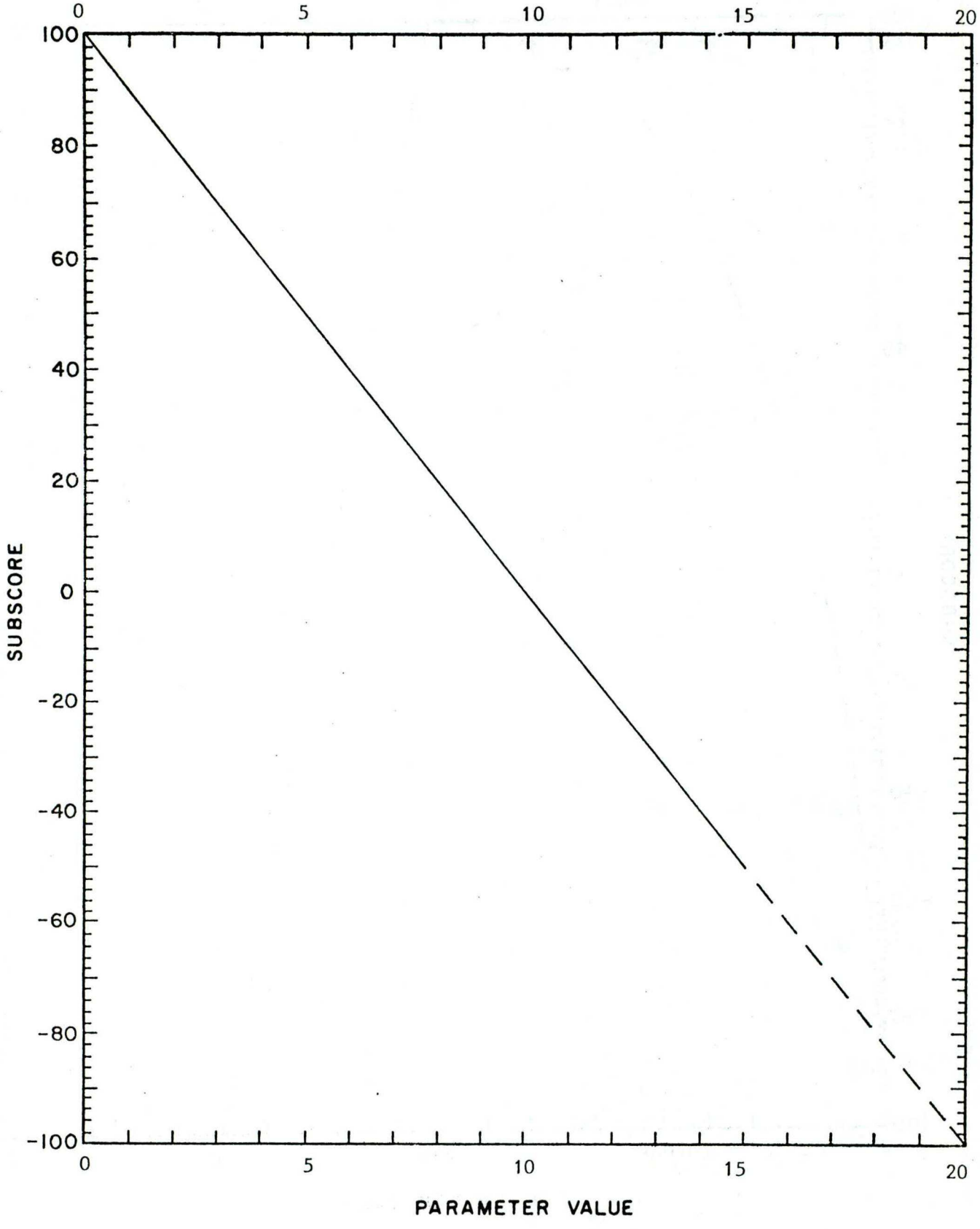
UNIT : µG/L $N\text{-}NH_3$



WATER USE : PROTECTION OF AQUATIC LIFE (TOLERANT SPECIES)

PARAMETER : TOTAL RESIDUAL CHLORINE

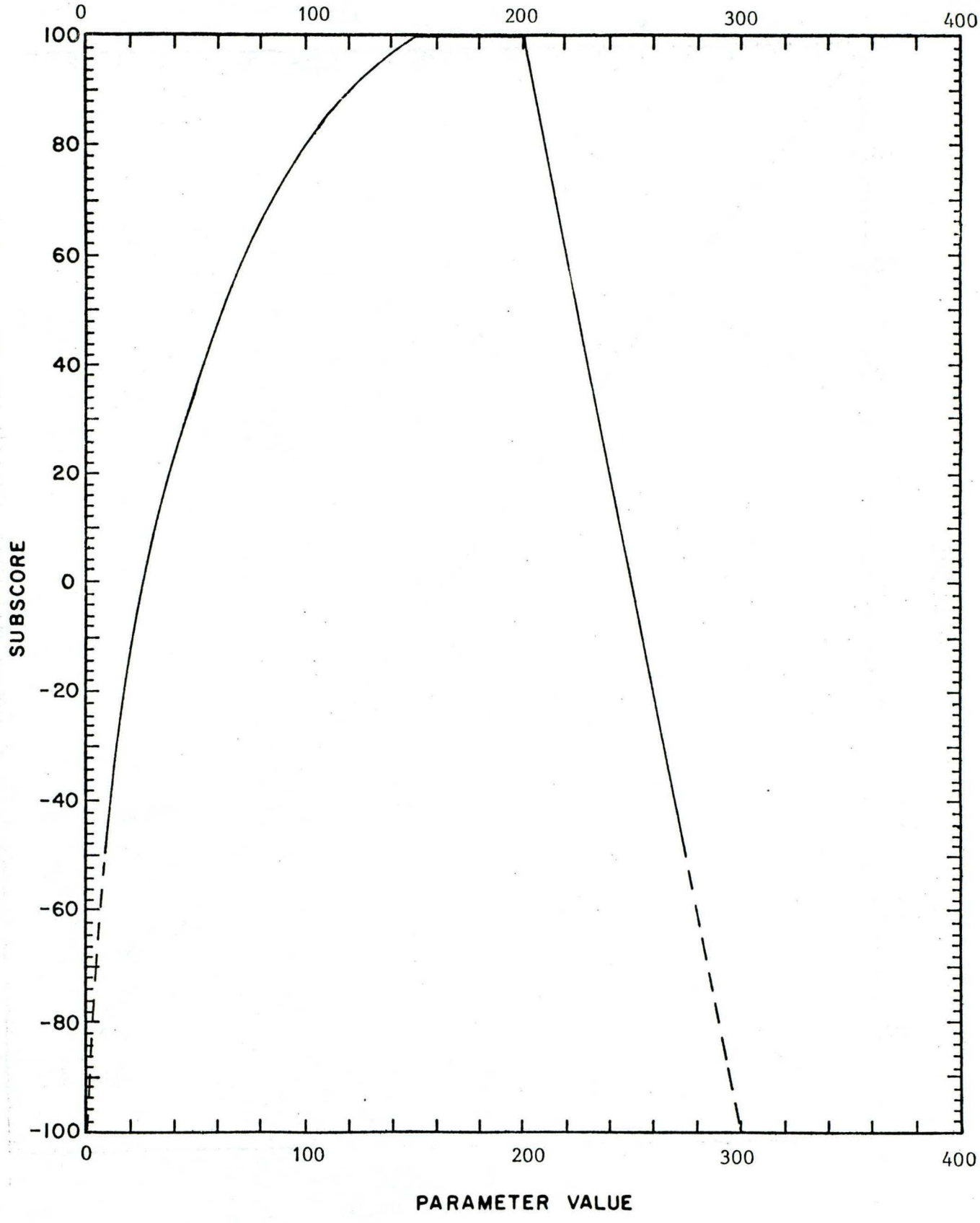
UNIT : MG/L



WATER USE : PROTECTION OF AQUATIC LIFE (TOLERANT SPECIES)

PARAMETER : ALKALINITY

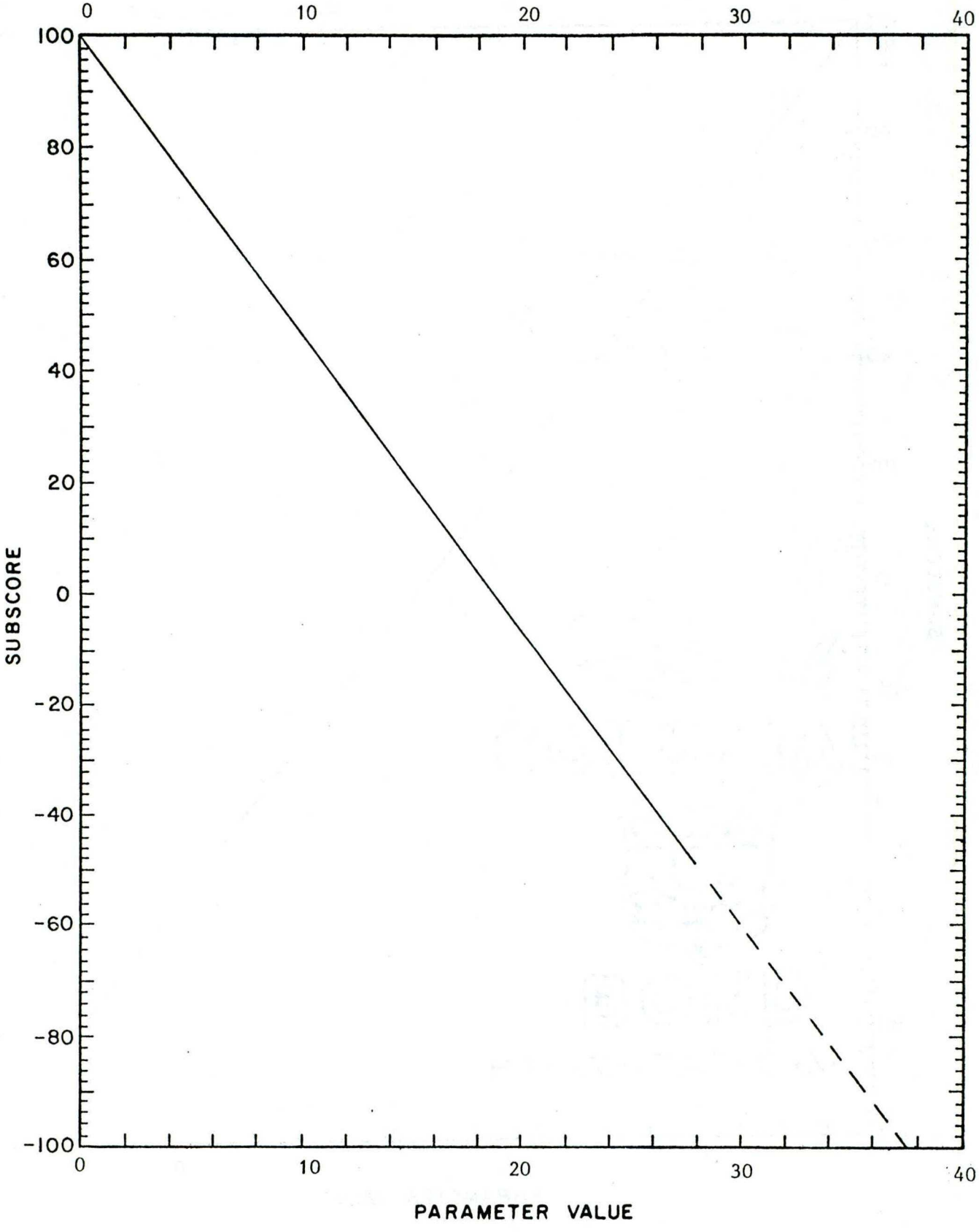
UNIT : MG/L $CaCO_3$



WATER USE : PROTECTION OF AQUATIC LIFE (TOLERANT SPECIES)

PARAMETER : PHENOLS

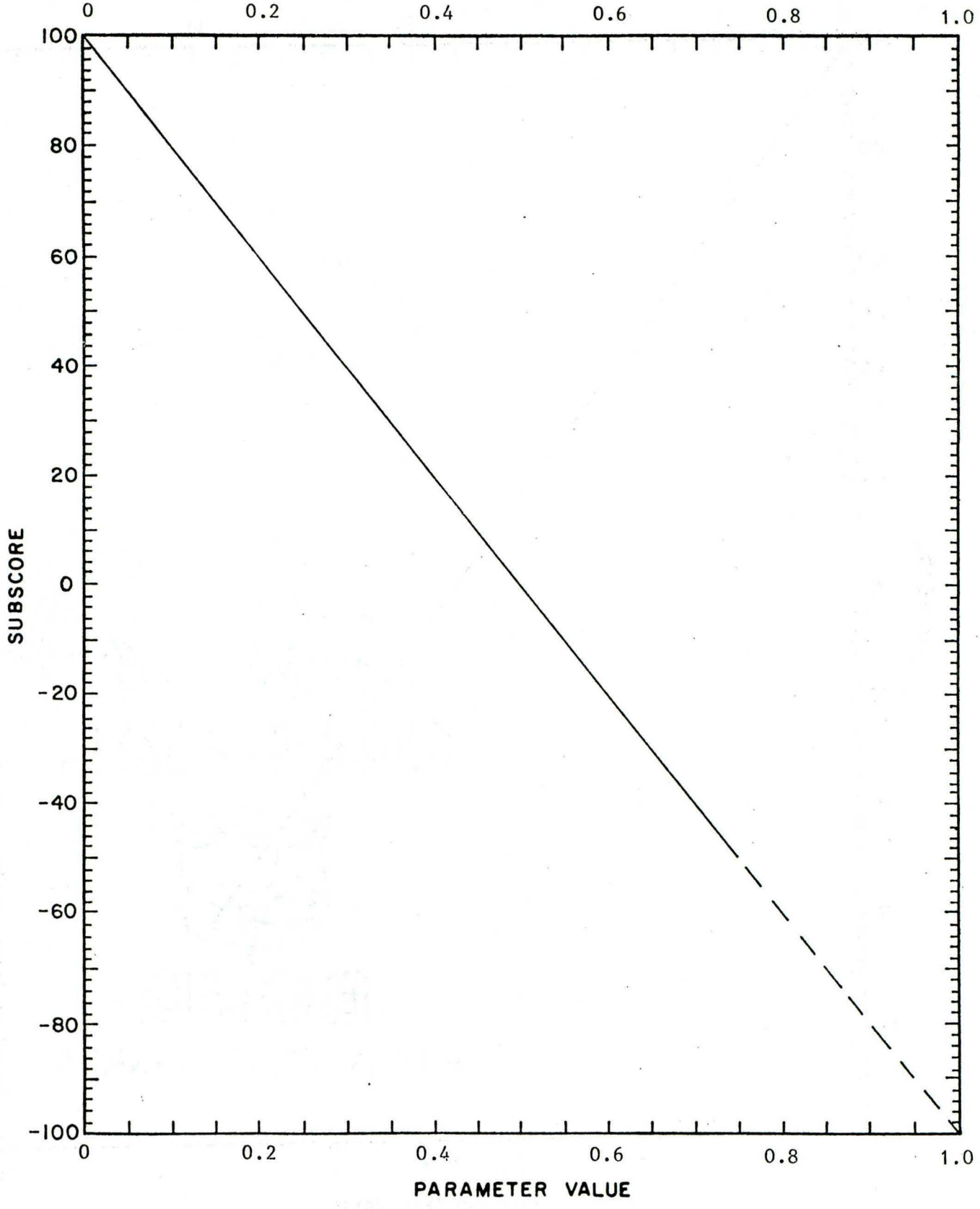
UNIT : MG/L C_6H_5OH



WATER USE : PROTECTION OF AQUATIC LIFE (TOLERANT SPECIES)

PARAMETER : SURFACTANTS

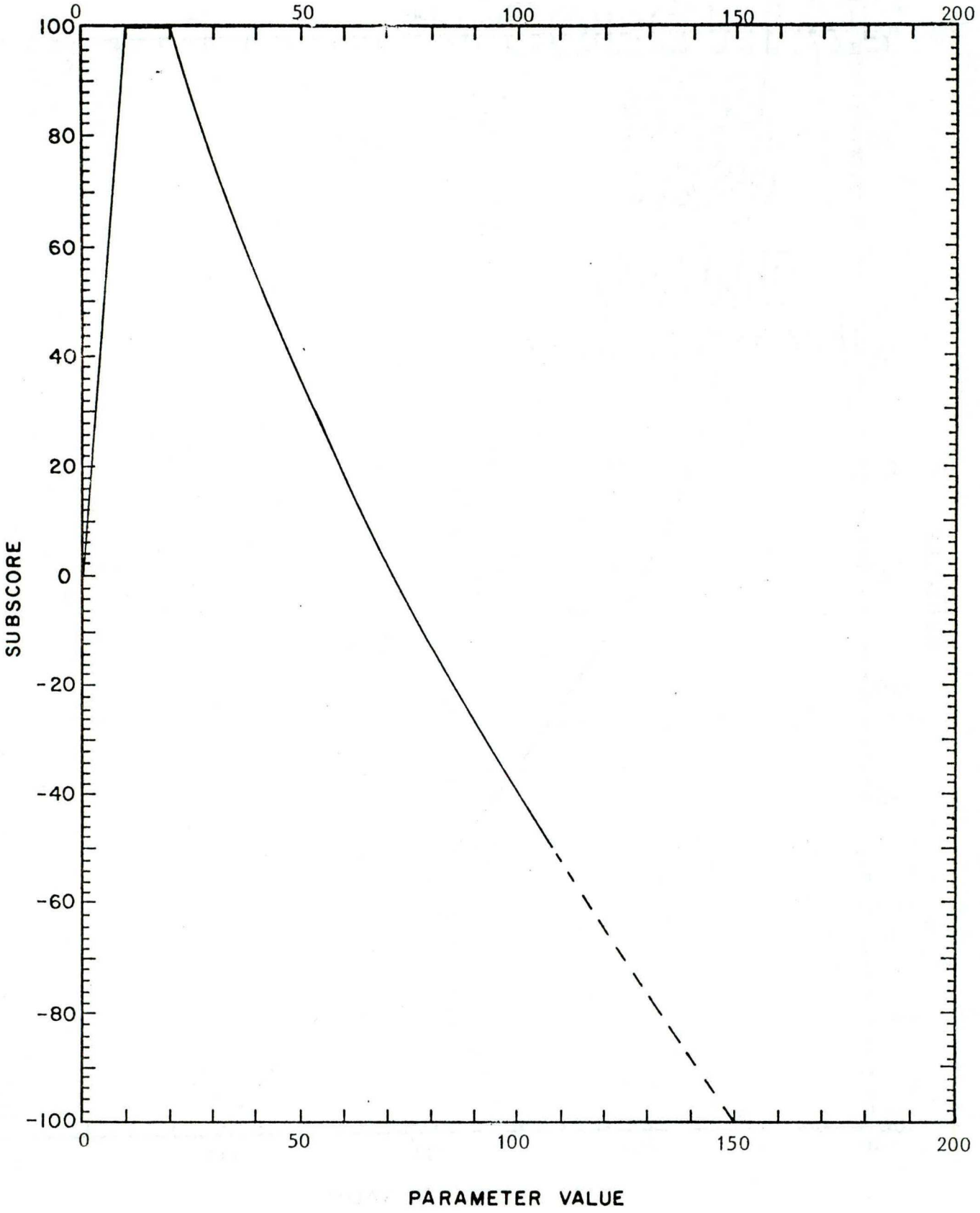
UNIT : MG/L NALS



WATER USE : RECREATIONAL ACTIVITIES (SWIMMING AND BATHING)

PARAMETER : ORTHOPHOSPHATES (RIVER)

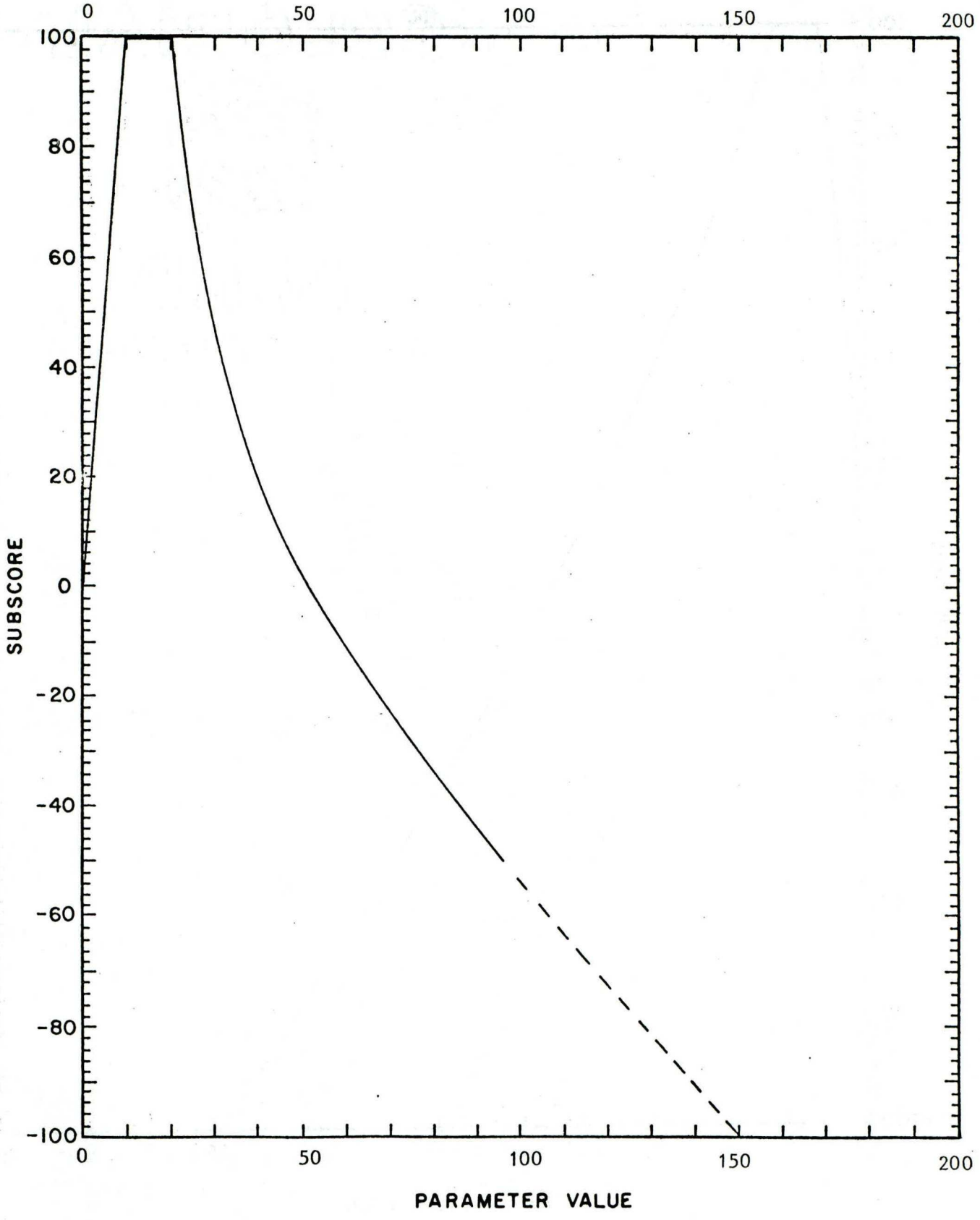
UNIT : µG/L $P-PO_4$



WATER USE : RECREATIONAL ACTIVITIES (SWIMMING AND BATHING)

PARAMETER : ORTHOPHOSPHATES (LAKE)

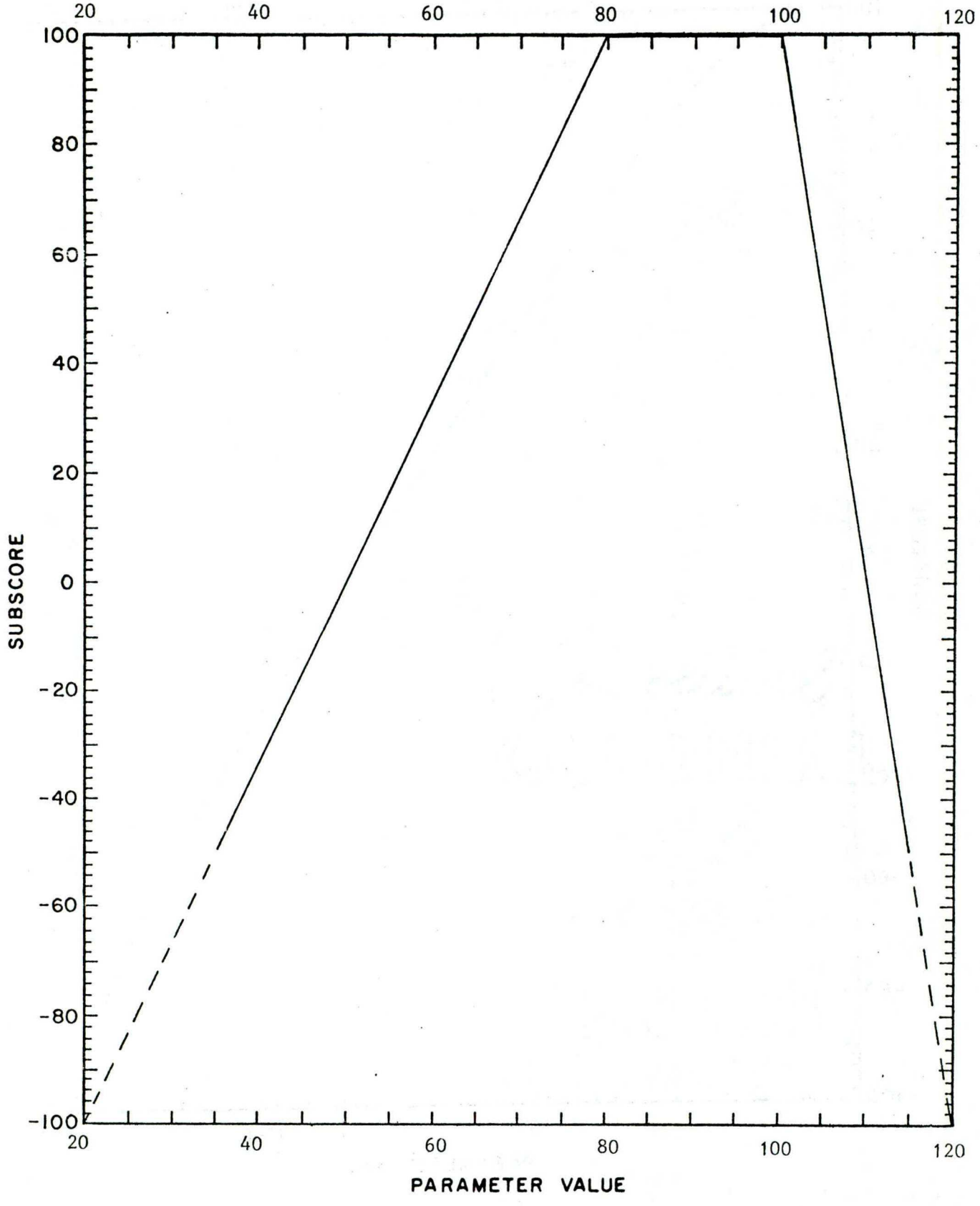
UNIT : µG/L $P-PO_4$



WATER USE : RECREATIONAL ACTIVITIES (SWIMMING AND BATHING)

PARAMETER : DISSOLVED OXYGEN

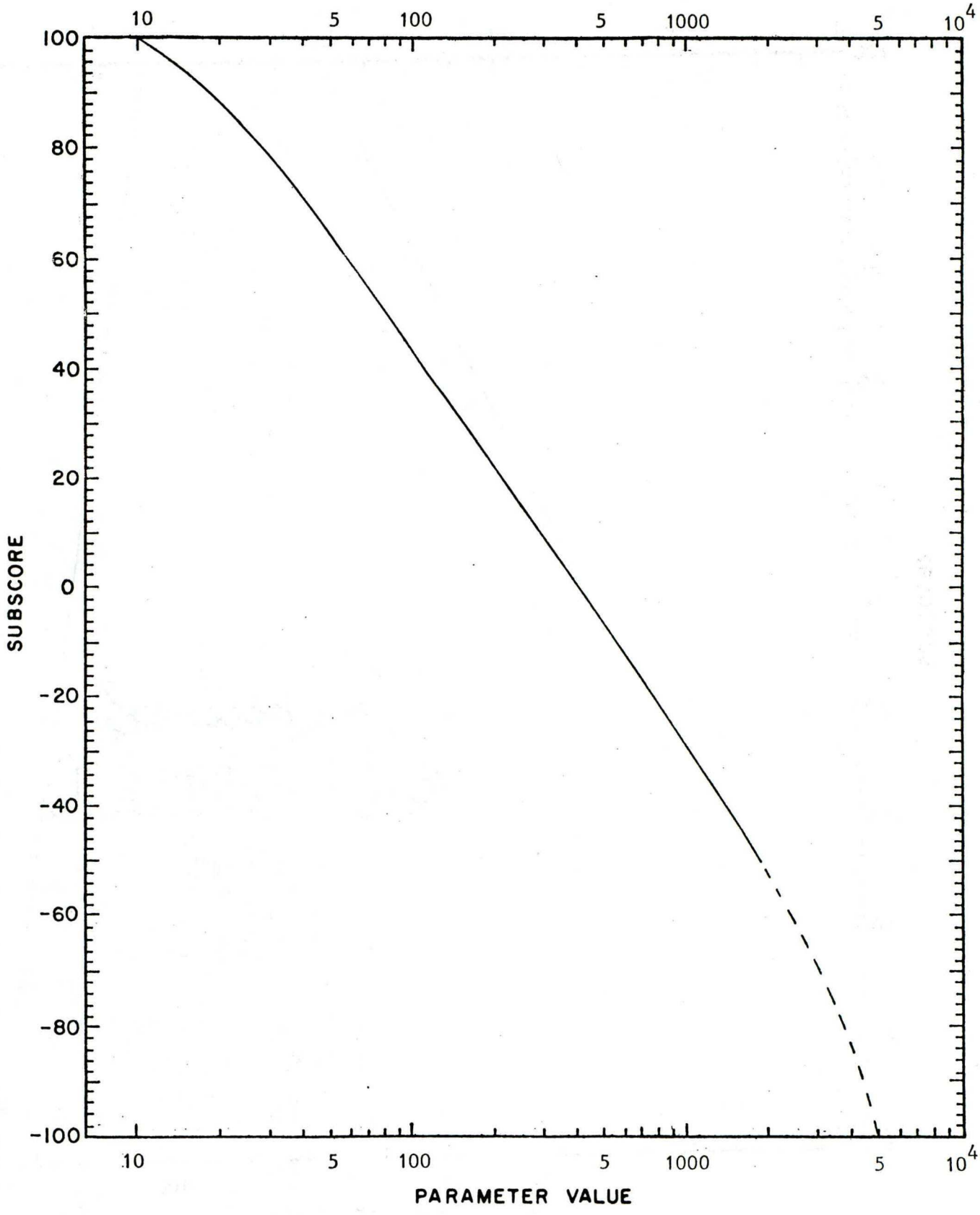
UNIT : PERCENT OF SATURATION



WATER USE : RECREATIONAL ACTIVITIES (SWIMMING AND BATHING)

PARAMETER : FECAL COLIFORM BACTERIA

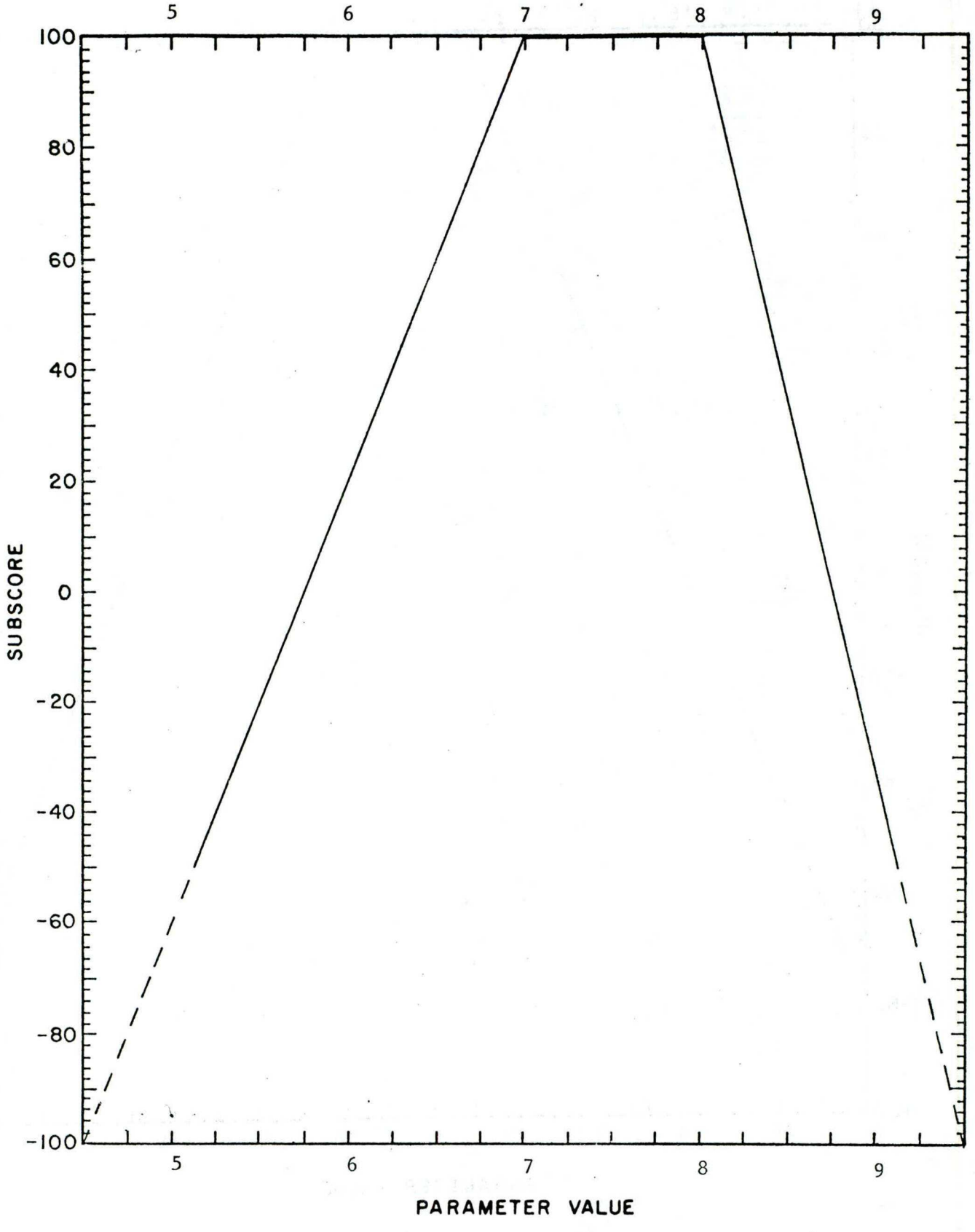
UNIT : COUNT PER 100 ML



WATER USE : RECREATIONAL ACTIVITIES (SWIMMING AND BATHING)

PARAMETER : PH

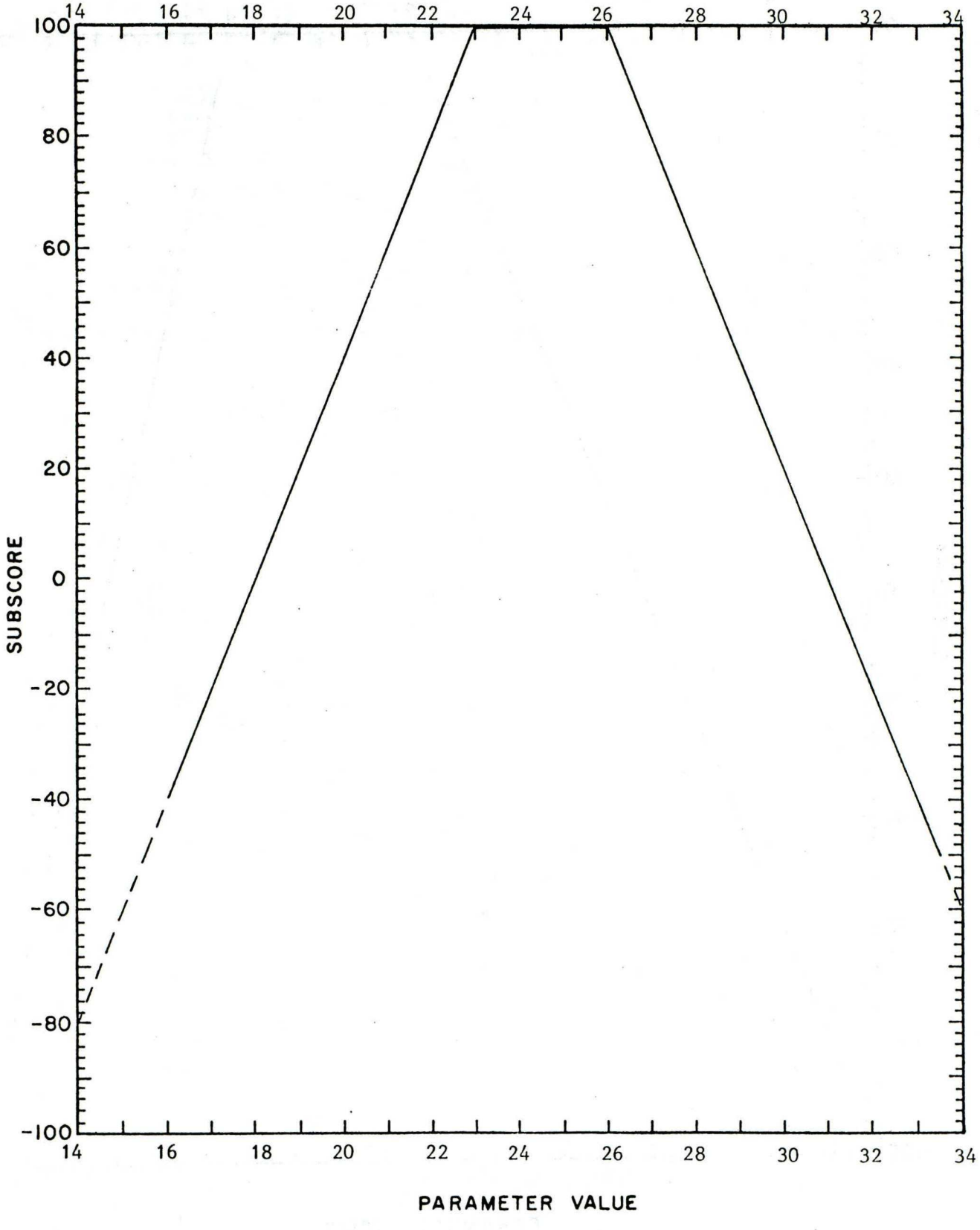
UNIT : PH UNITS



WATER USE : RECREATIONAL ACTIVITIES (SWIMMING AND BATHING)

PARAMETER : TEMPERATURE

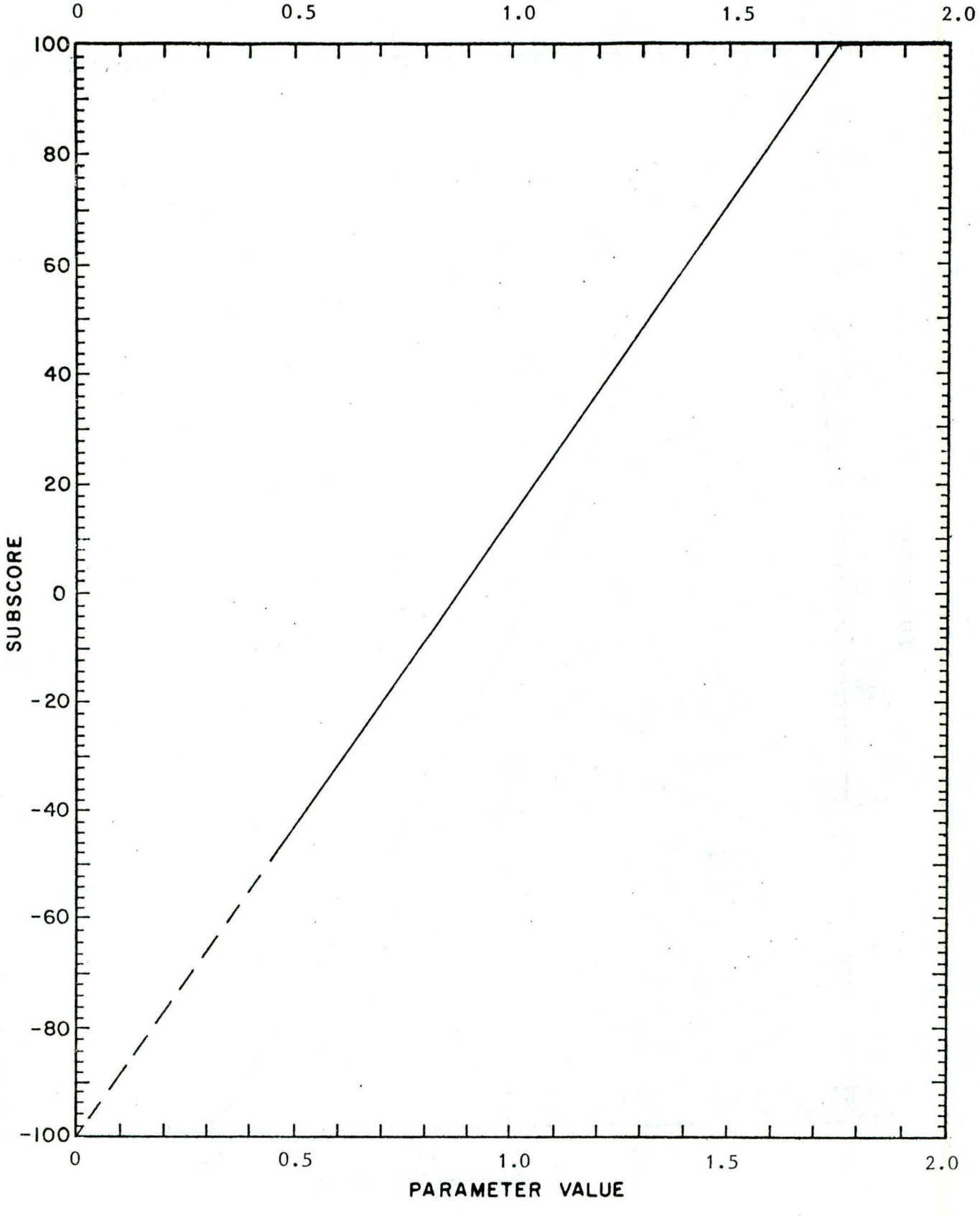
UNIT : DEGREES CELSIUS



WATER USE : RECREATIONAL ACTIVITIES (SWIMMING AND BATHING)

PARAMETER : TRANSPARENCY

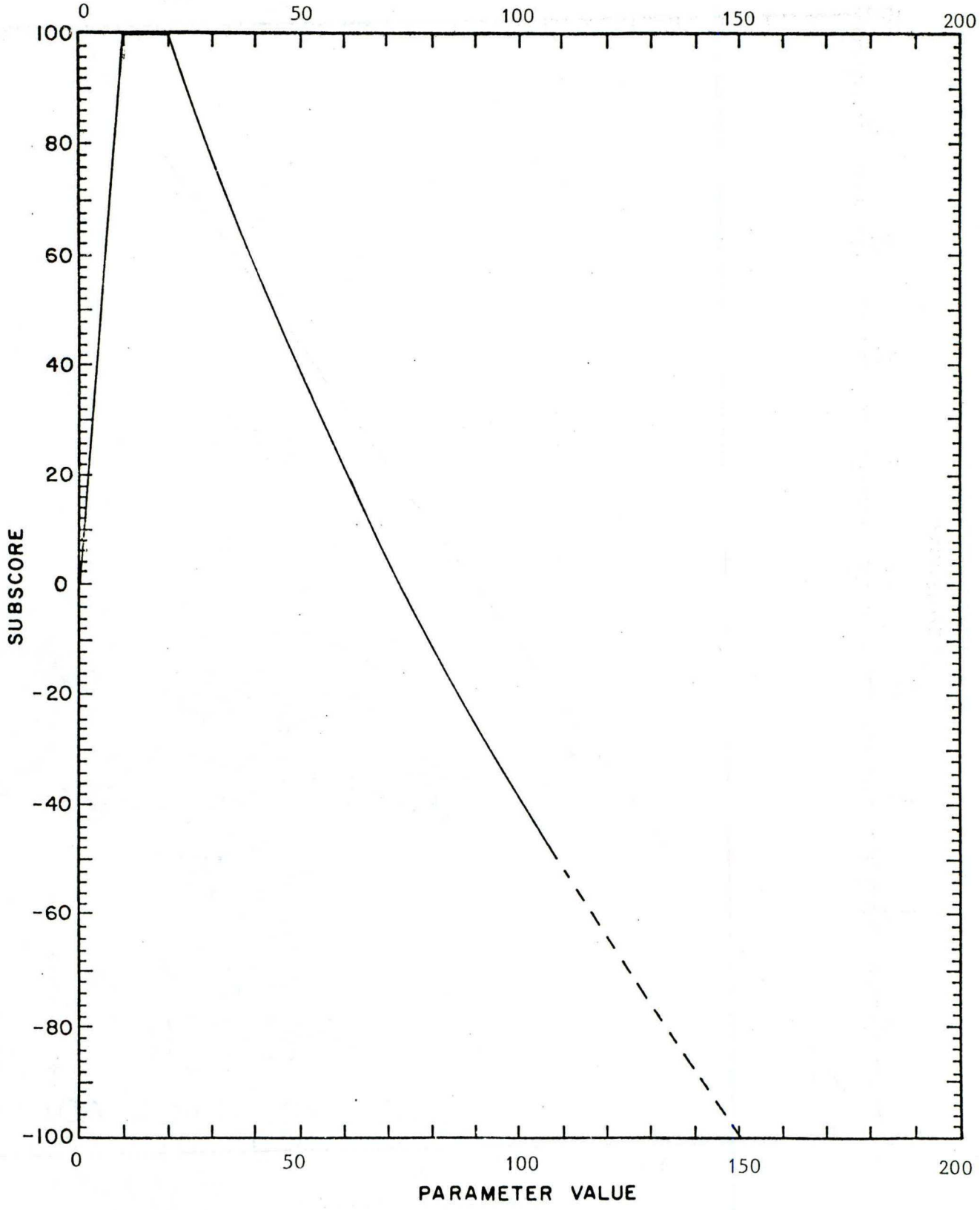
UNIT : SECCHI METERS



WATER USE : RECREATIONAL ACTIVITIES (BOATING AND AESTHETICS ENJOYMENT)

PARAMETER : ORTHOPHOSPHATES (RIVER)

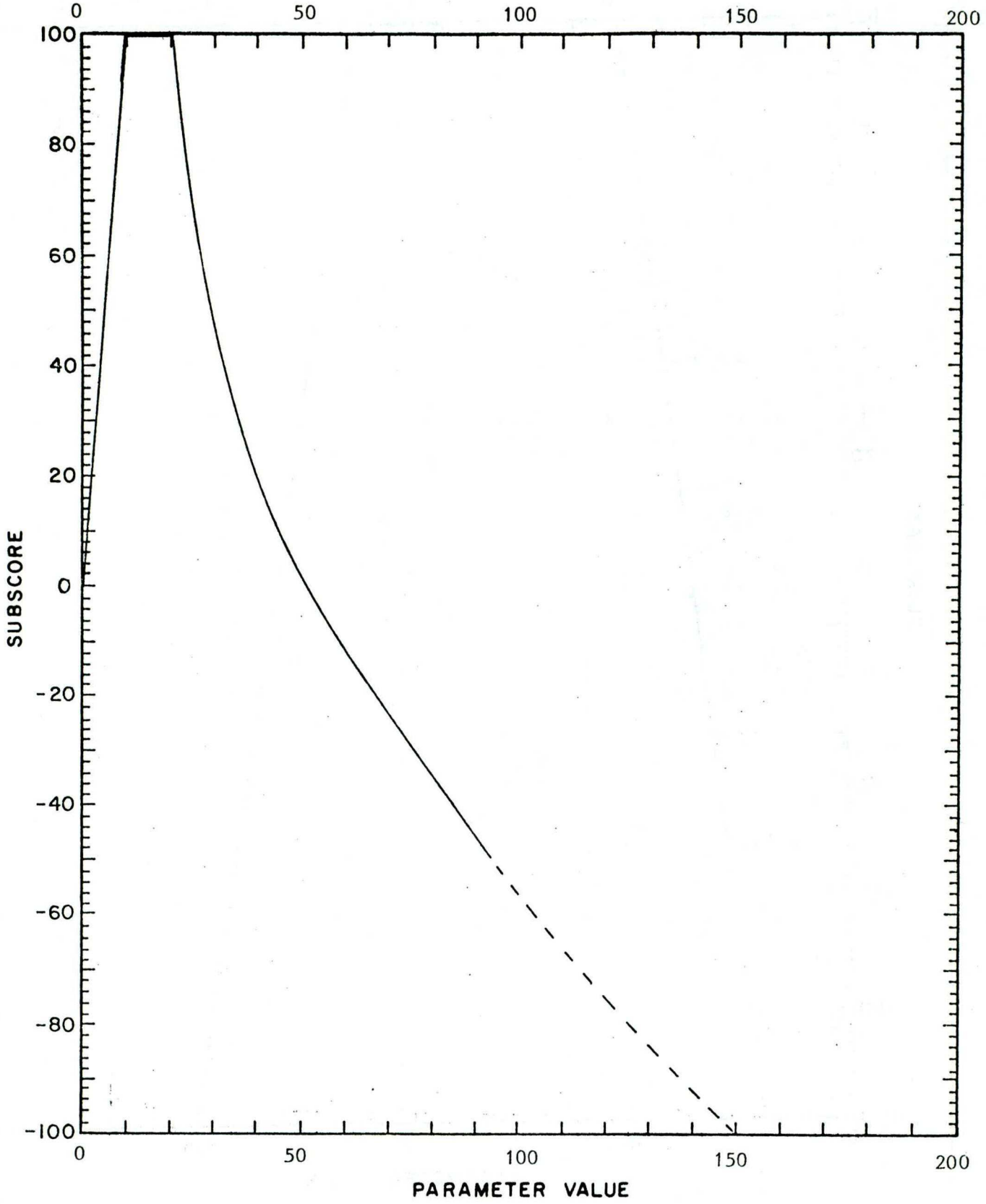
UNIT : µG/L $P-PO_4$



WATER USE : RECREATIONAL ACTIVITIES (BOATING AND AESTHETICS ENJOYMENT)

PARAMETER : ORTHOPHOSPHATES (LAKE)

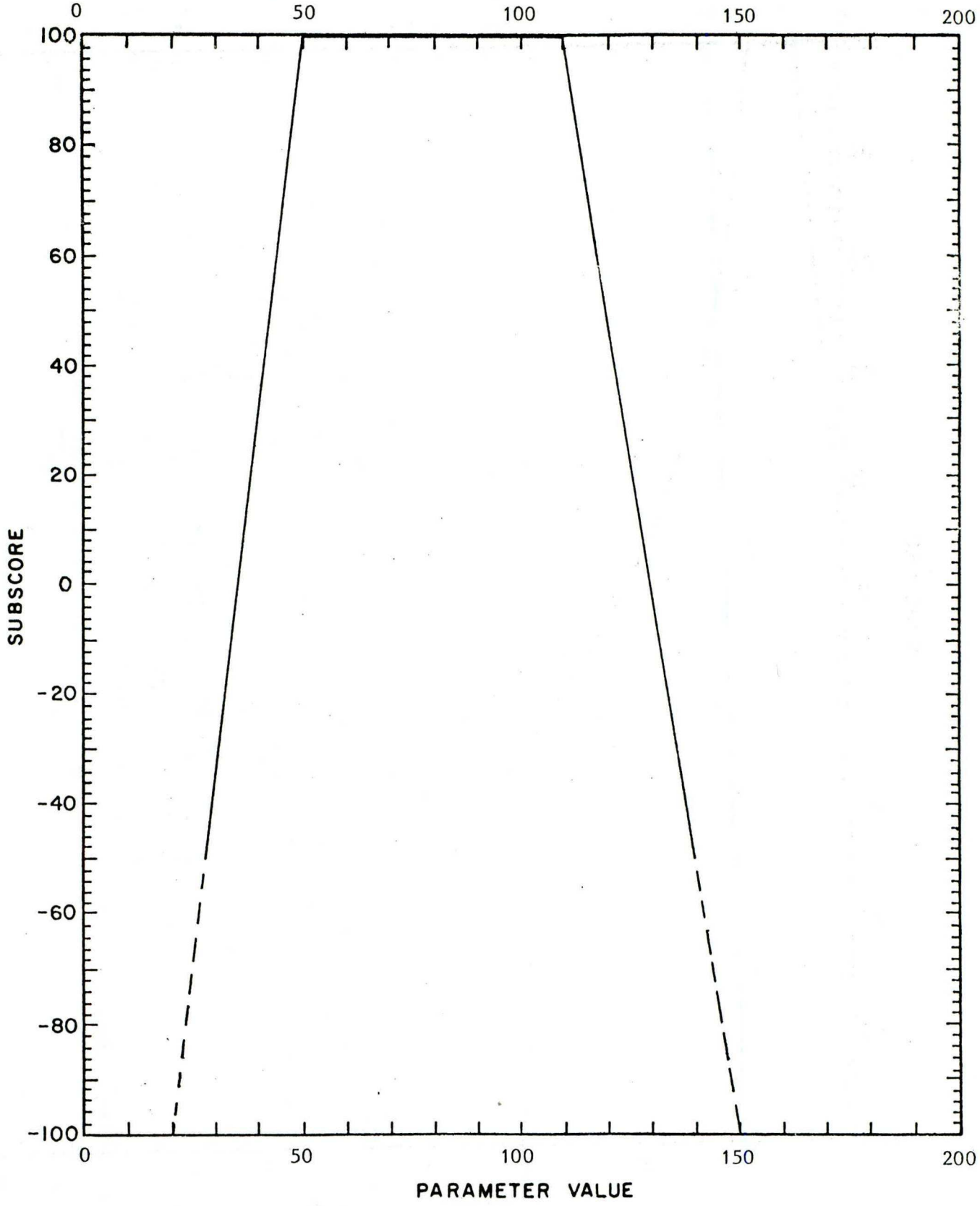
UNIT : µG/L $P\text{-}PO_4$



WATER USE : RECREATIONAL ACTIVITIES (BOATING AND AESTHETICS ENJOYMENT)

PARAMETER : DISSOLVED OXYGEN

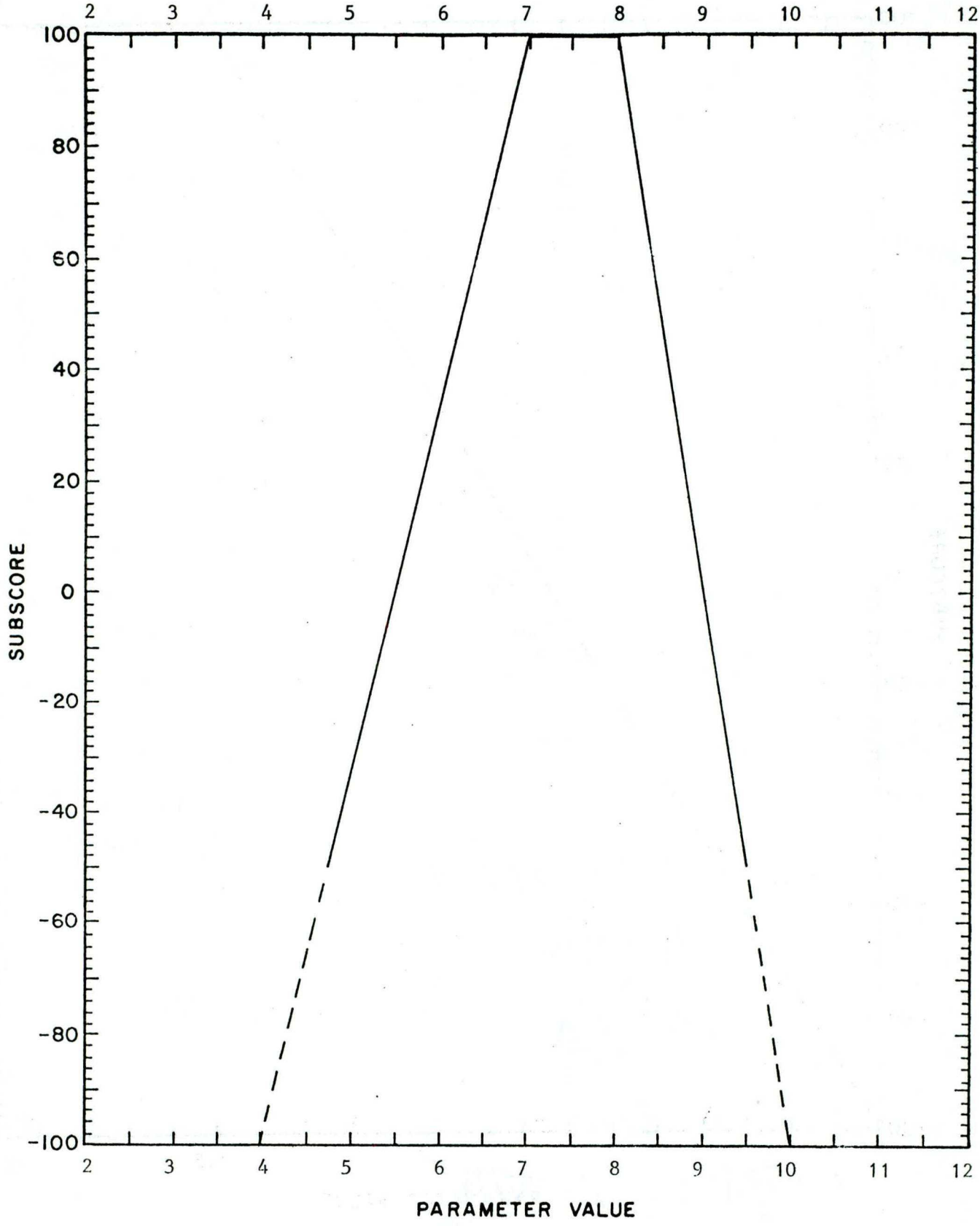
UNIT : PERCENT OF SATURATION



WATER USE : RECREATIONAL ACTIVITIES (BOATING AND AESTHETICS ENJOYMENT)

PARAMETER : PH

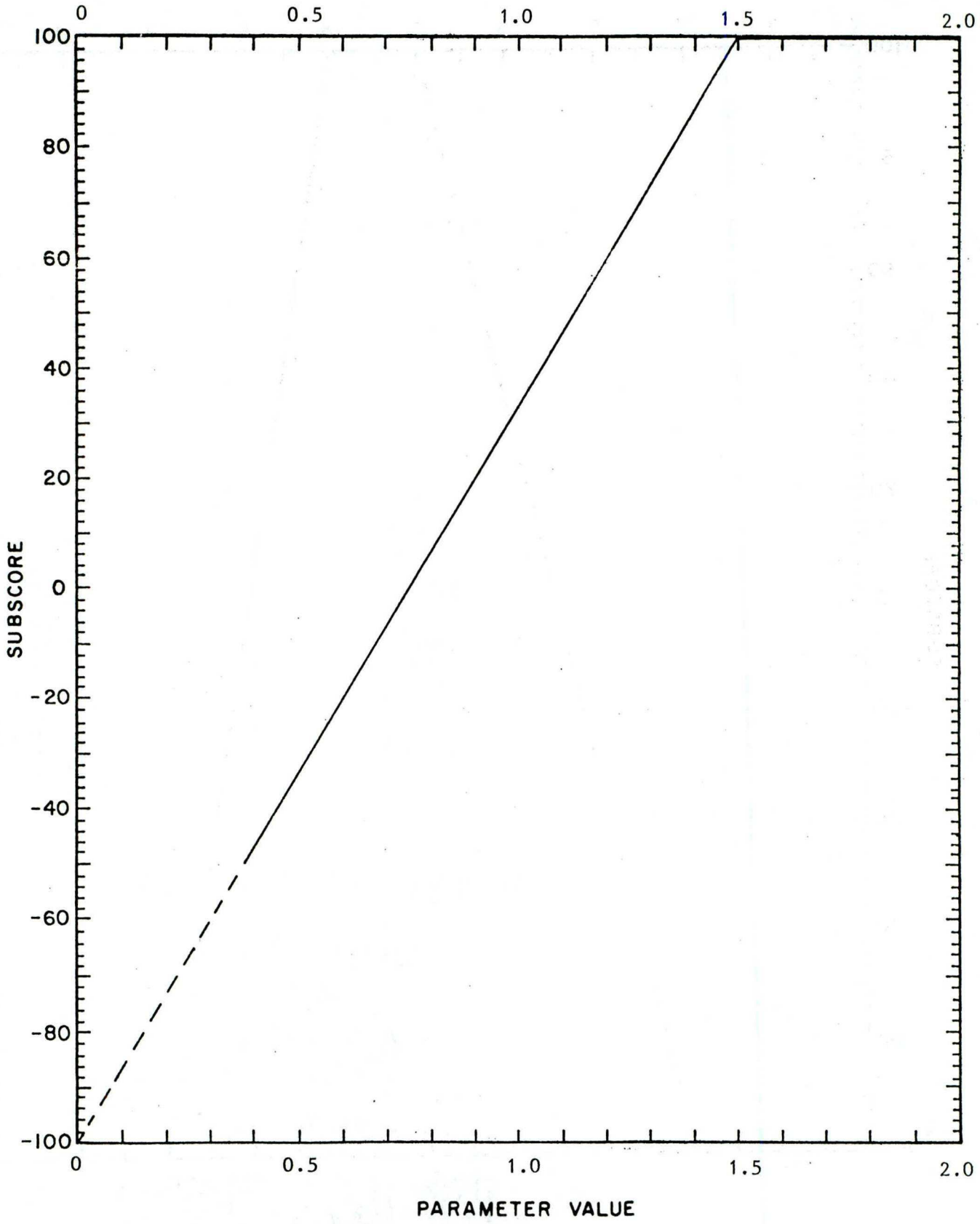
UNIT : PH UNITS



WATER USE : RECREATIONAL ACTIVITIES (BOATING AND AESTHETICS ENJOYMENT)

PARAMETER : TRANSPARENCY

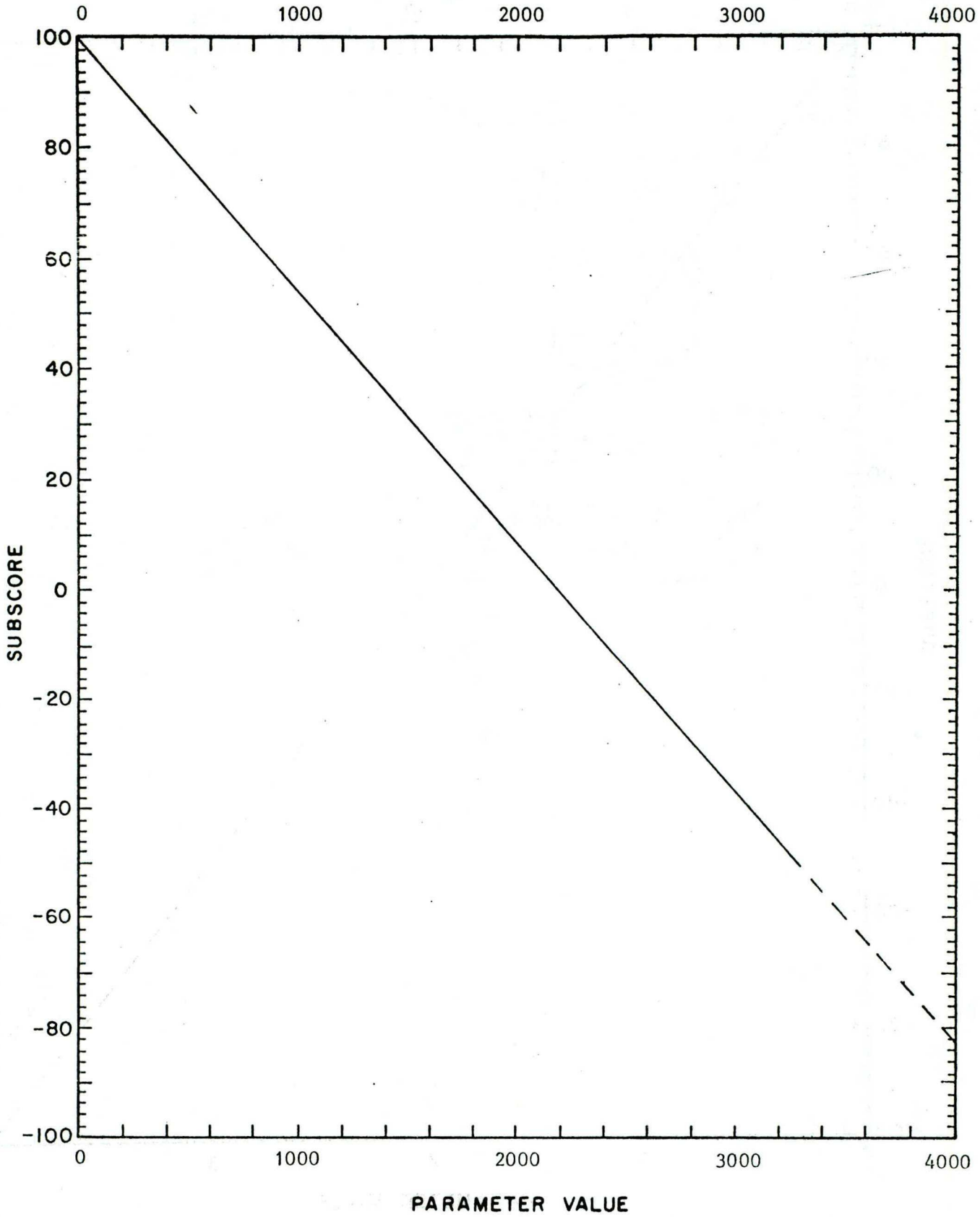
UNIT : SECCHI METERS



WATER USE : STOCK AND WILDLIFE WATERING

PARAMETER : TOTAL DISSOLVED SOLIDS

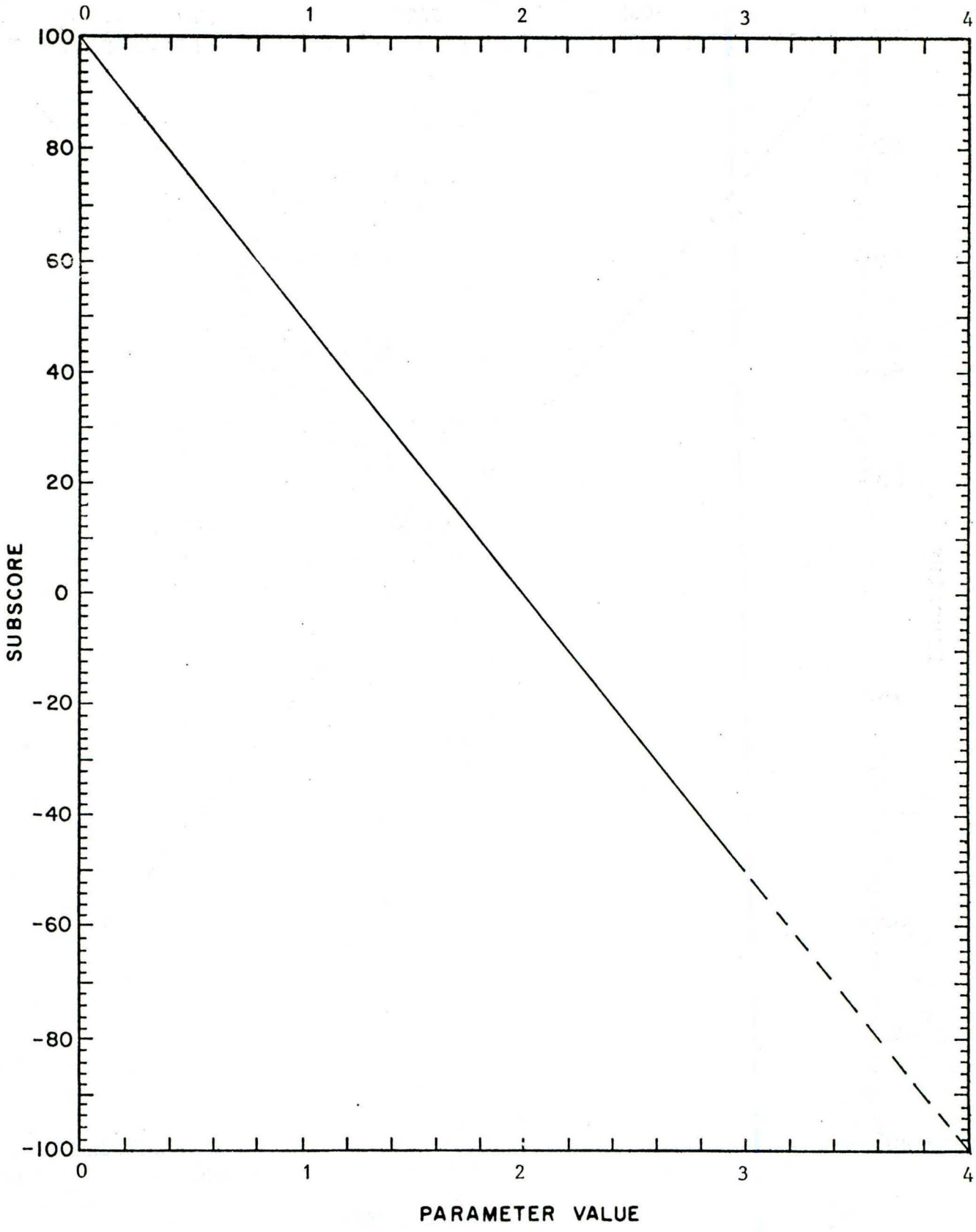
UNIT : MG/L



WATER USE : STOCK AND WILDLIFE WATERING

PARAMETER : FLUORIDES

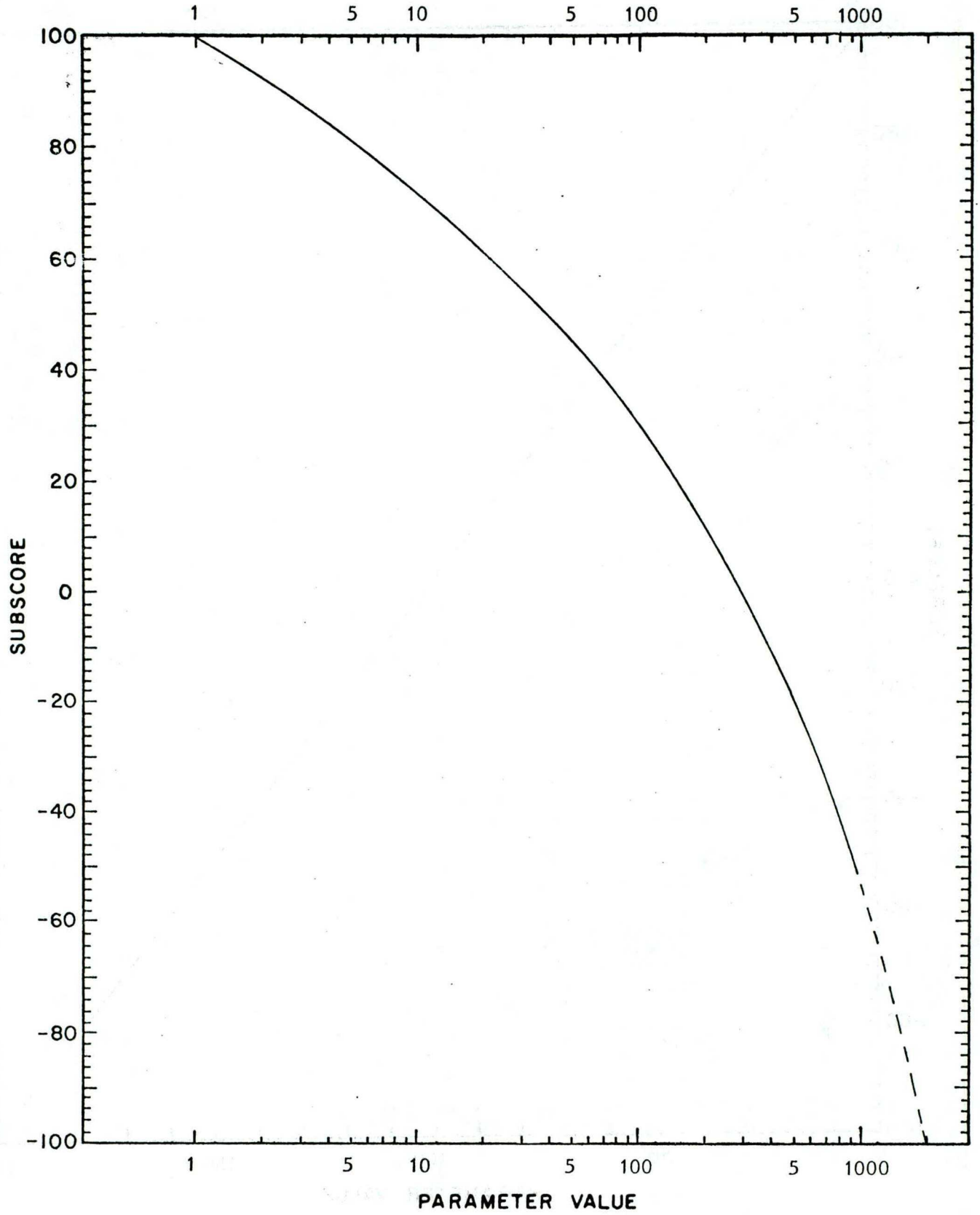
UNIT : MG/L



WATER USE : STOCK AND WILDLIFE WATERING

PARAMETER : FECAL COLIFORM BACTERIA

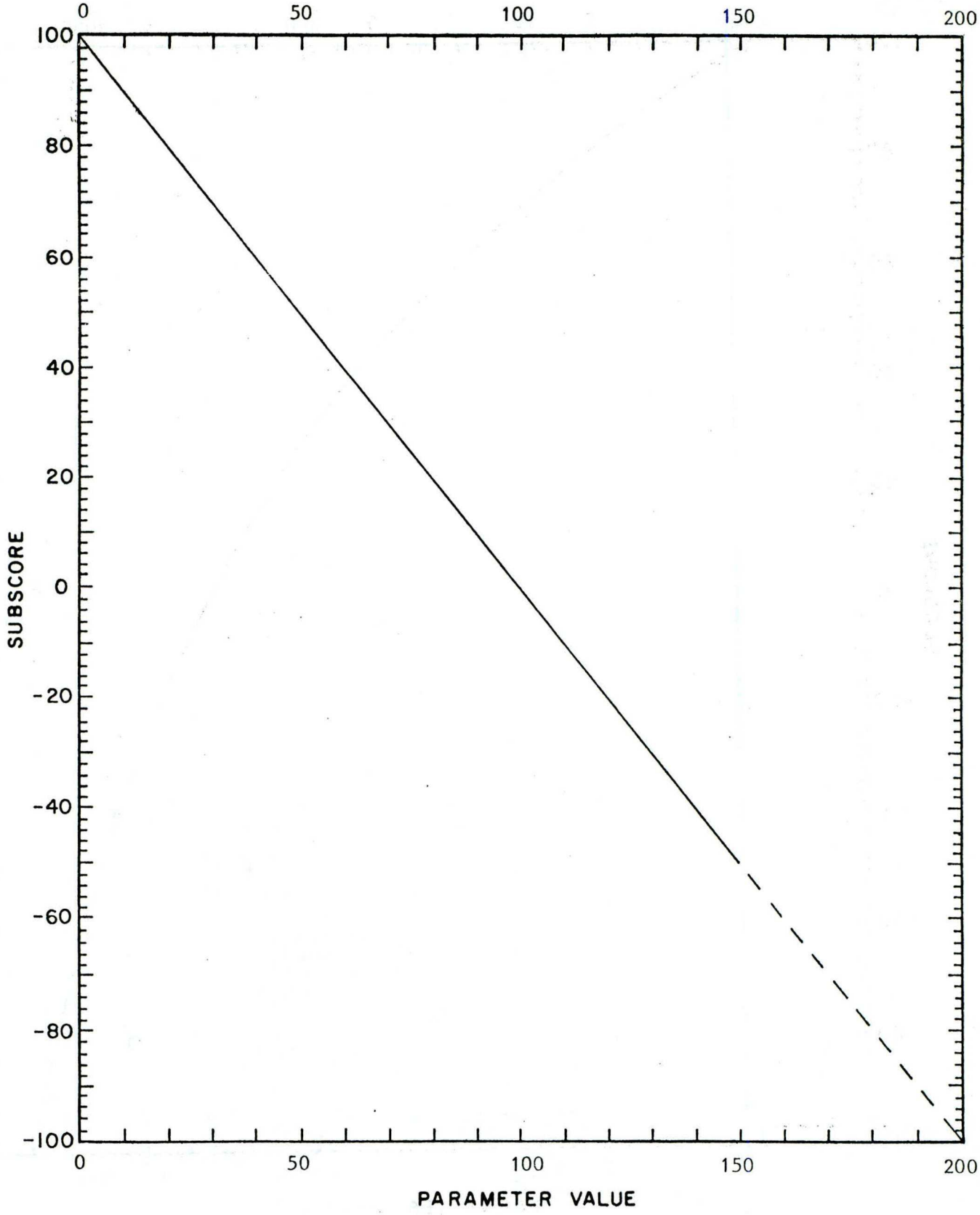
UNIT : COUNT PER 100 ML



WATER USE : STOCK AND WILDLIFE WATERING

PARAMETER : NITRATES

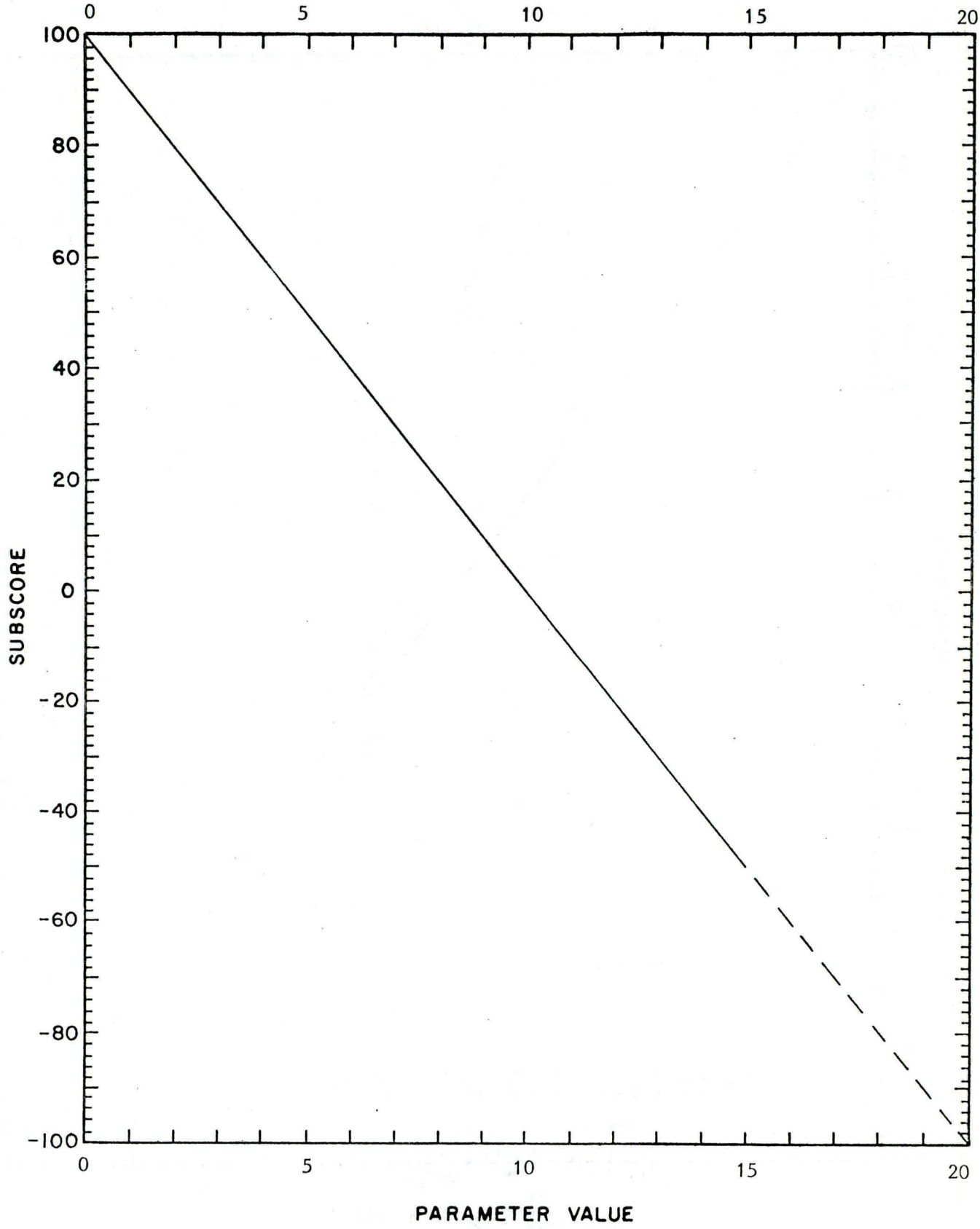
UNIT : MG/L $N\text{-}NO_3$



WATER USE : STOCK AND WILDLIFE WATERING

PARAMETER : NITRITES

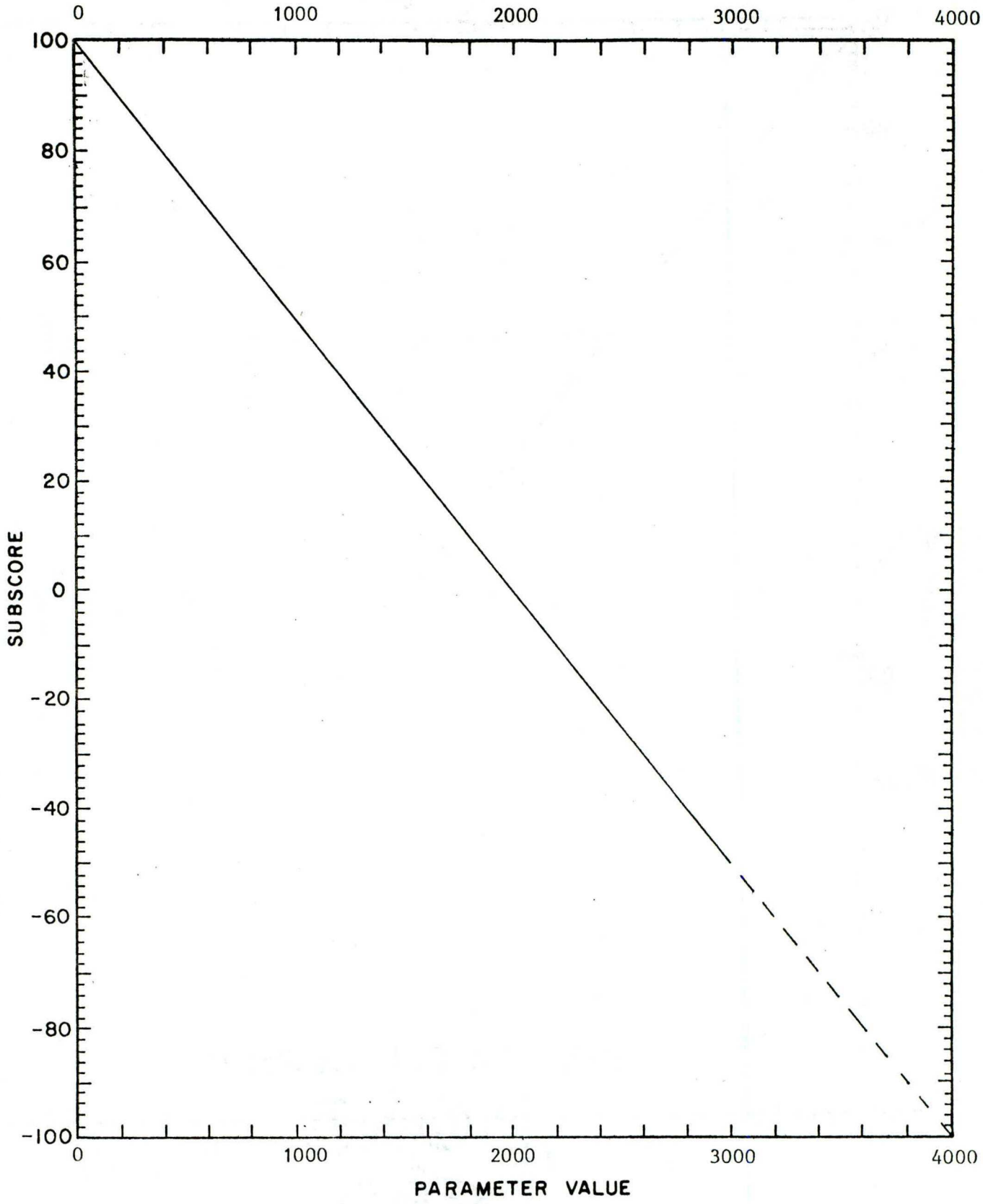
UNIT : MG/L $N\text{-}NO_2$



WATER USE : IRRIGATION

PARAMETER : TOTAL DISSOLVED SOLIDS

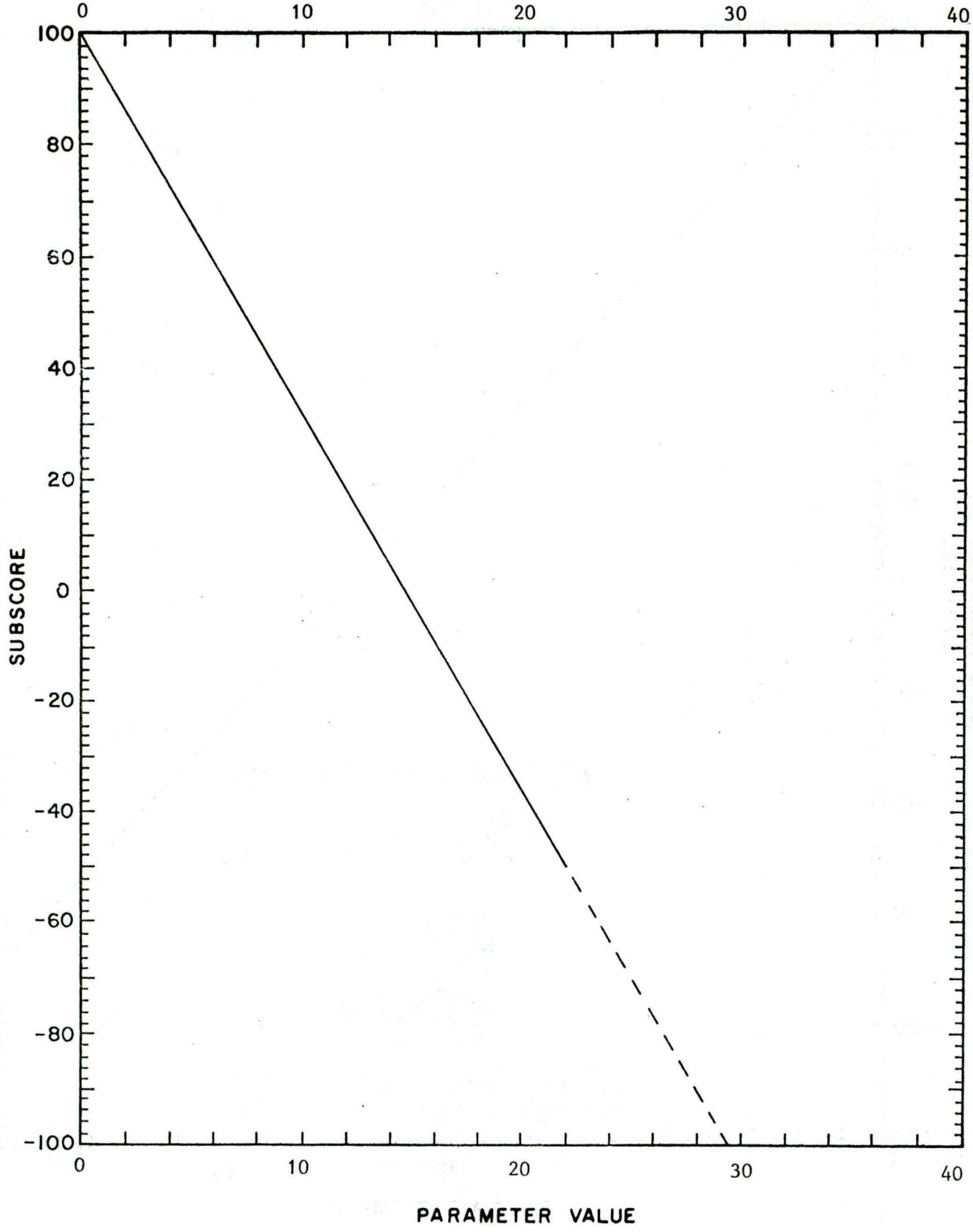
UNIT : MG/L



WATER USE : IRRIGATION

PARAMETER : SODIUM ADSORPTION RATIO ($\chi \leq 250$ µS/CM)

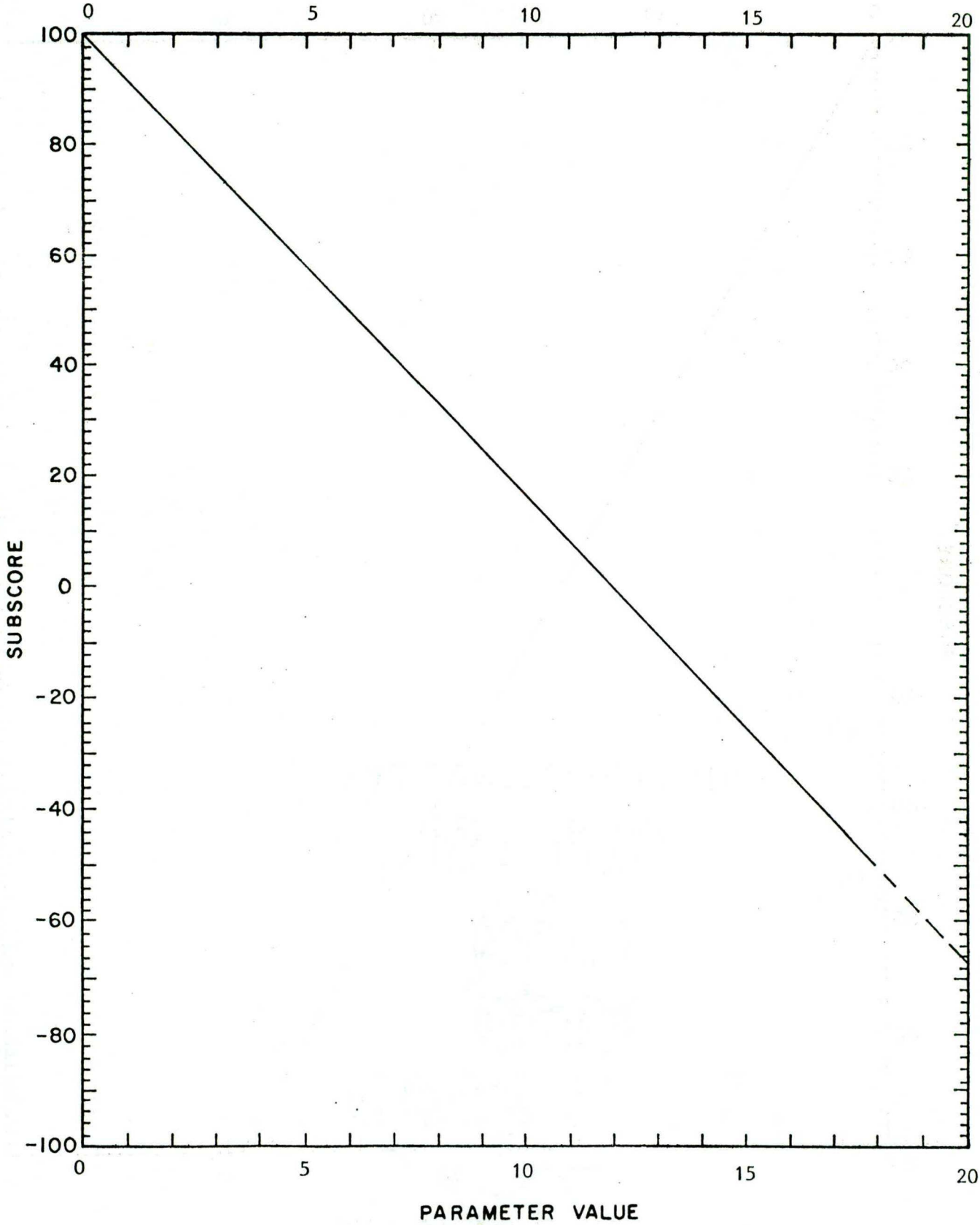
UNIT : $[MEQ/L]^{1/2}$



WATER USE : IRRIGATION

PARAMETER : SODIUM ADSORPTION RATIO ($\chi \leq 750$ µS/CM)

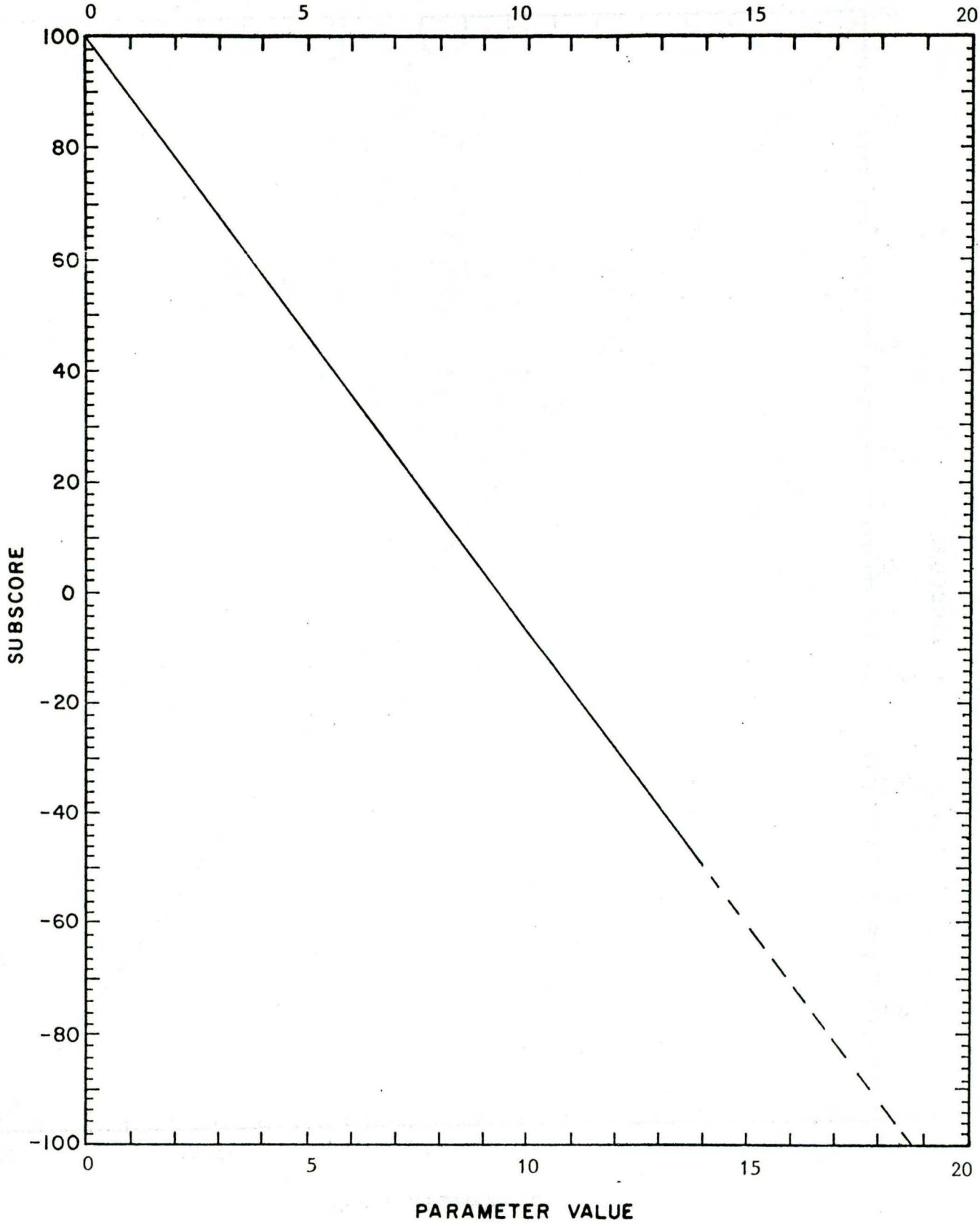
UNIT : $[MEQ/L]^{1/2}$



WATER USE : IRRIGATION

PARAMETER : SODIUM ADSORPTION RATIO ($\chi \leq 2250$ µS/CM)

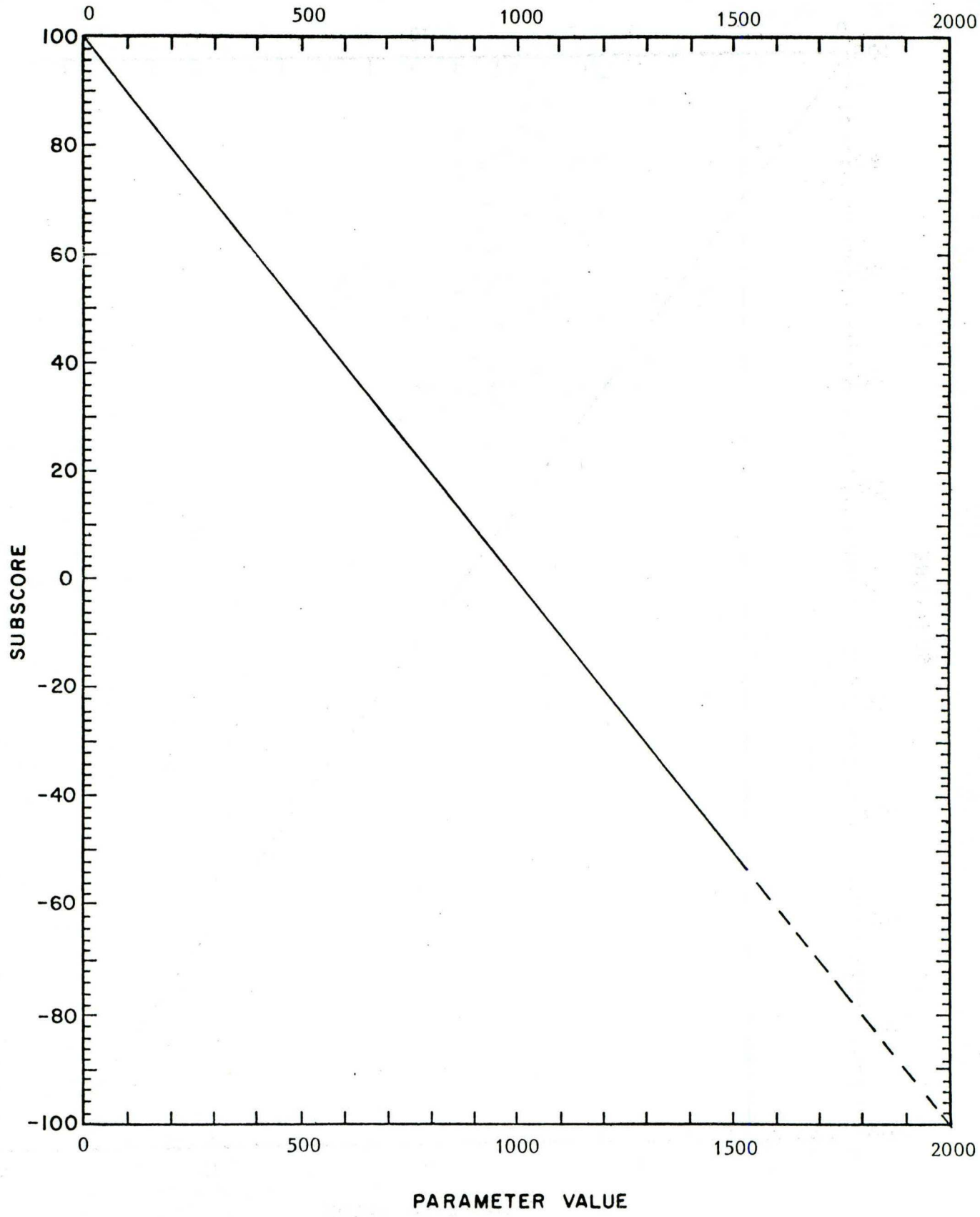
UNIT : $[MEQ/L]^{1/2}$



WATER USE : IRRIGATION

PARAMETER : FECAL COLIFORM BACTERIA

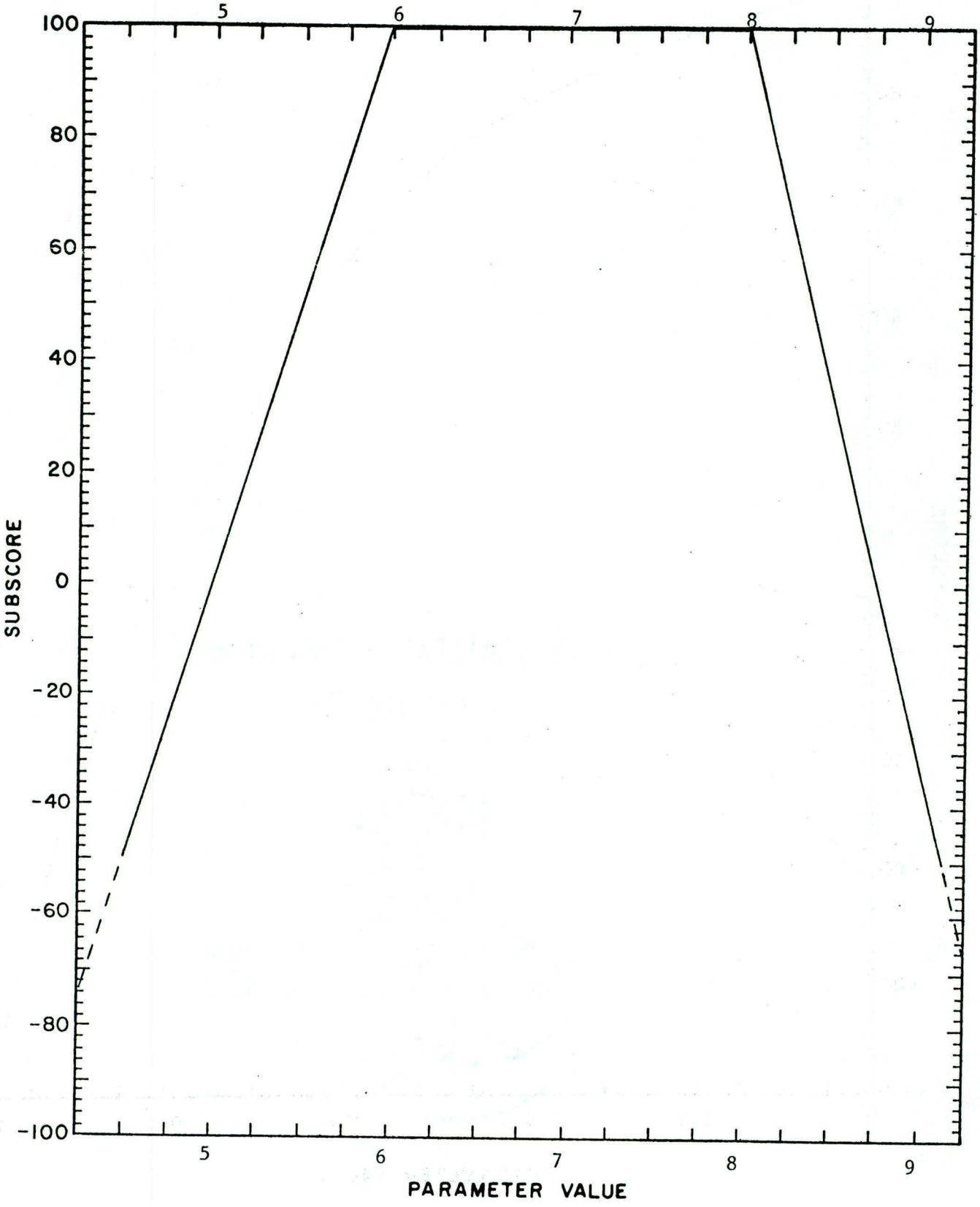
UNIT : COUNT PER 100 ML



WATER USE : IRRIGATION

PARAMETER : PH

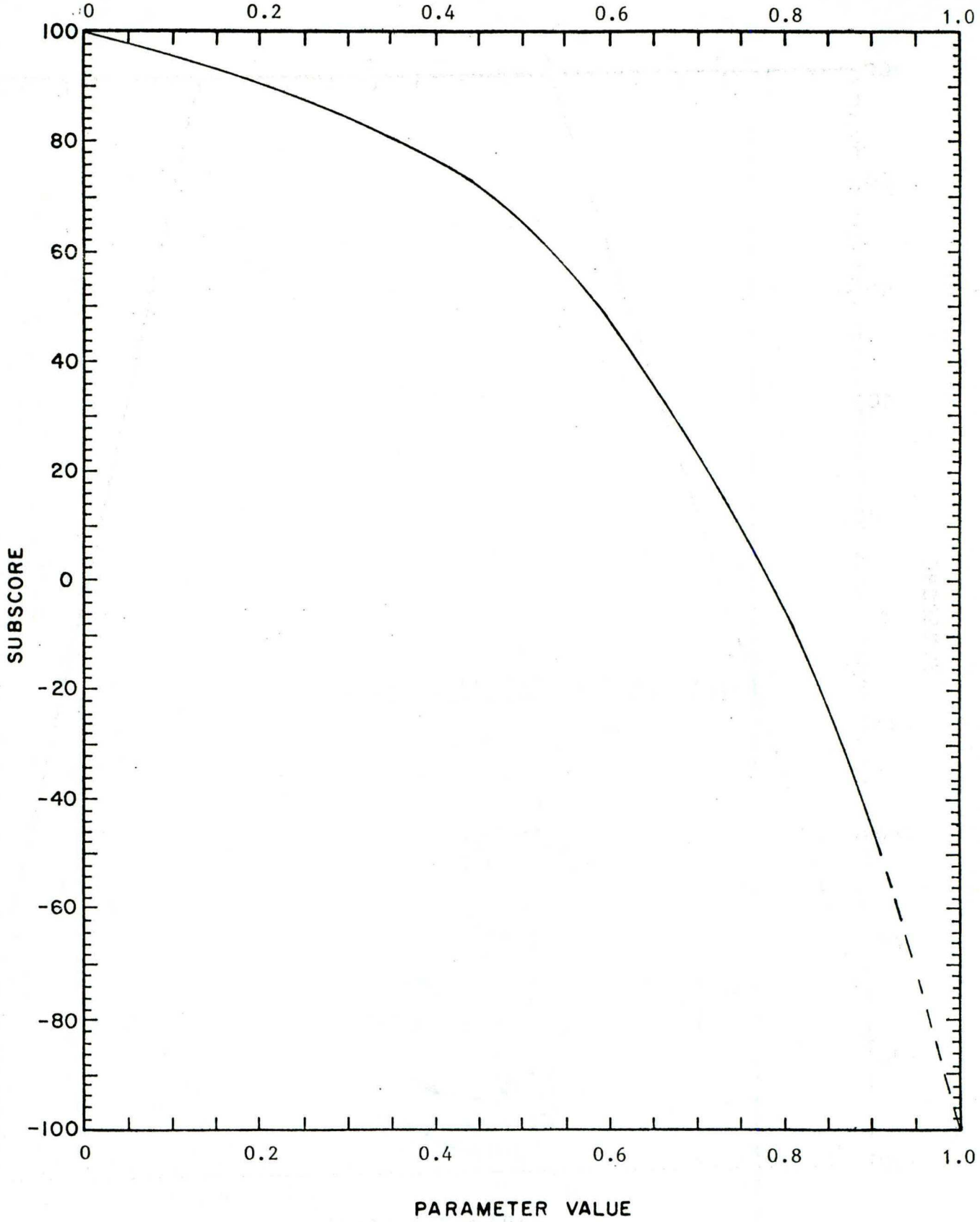
UNIT : PH UNITS



WATER USE : IRRIGATION

PARAMETER : BORON

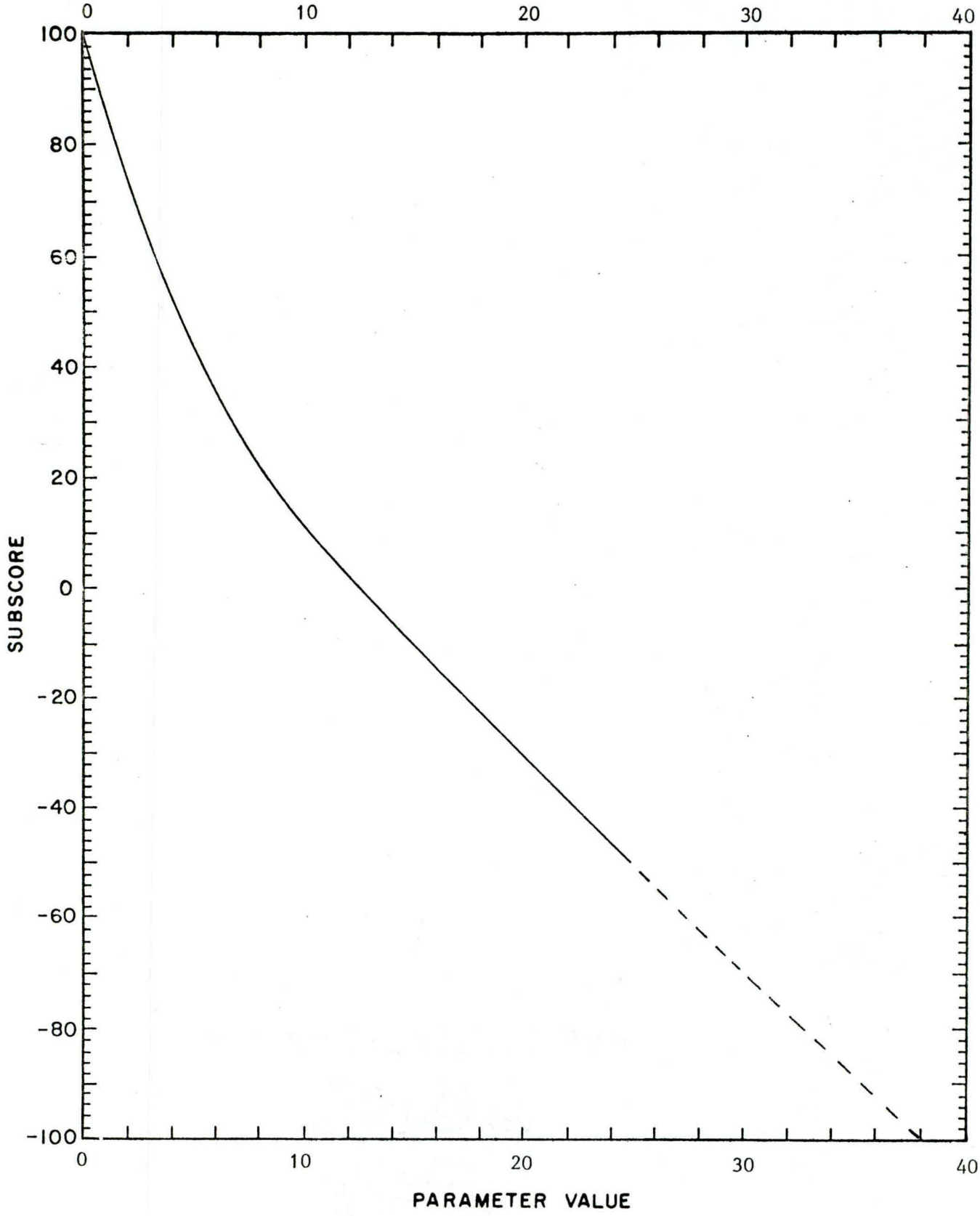
UNIT : MG/L



WATER USE : IRRIGATION

PARAMETER : IRON

UNIT : MG/L



APPENDIX B

EXAMPLES

EXAMPLE #1

WATER USE: Recreational activities (swimming and bathing)

PRIMARY PARAMETERS

PARAMETERS	UNITS	WEIGHTS	VALUES	SUBSCORES
Orthophosphates	µg/l $P\text{-}PO_4$	0.064	-	- 1.0
Dissolved Oxygen	% saturation	0.097	-	- 1.0
Fecal coliforms	count/100ml	0.290	500	- 6.6
pH	pH units	0.220	6	20.0
Temperature	°C	0.194	23	100.0
Transparency	Secchi meters	0.129	-	-

COMPLEMENTARY PARAMETERS

PARAMETERS	UNITS	LOWER LIMITS	VALUES	UPPER LIMITS
Floating materials	Presence	0	-	0
Undesirable color	Presence	0	0	0
Oil and grease	Visible film	0	0	0
Undesirable odor	Presence	0	-	0
Total radioactivity	pBq/l	0	8	10
Salmonellae	count/100ml	0	0	0

SUPPLEMENTARY PARAMETERS

PARAMETERS	UNITS	VALUES	UPPER LIMITS
Total coliforms	count/100ml	-	10000
Phenols	mg/l C_6H_5OH	20	50

SUMMARY

Number of primary parameters measured : 3 out of 6
Number of complementary parameters measured: 4 out of 6
Number of basic parameters measured : 7 out of 12
Number of supplementary parameters measured: 1 out of 2

Primary index : 22
Basic reliability : 58
Supplementary reliability: 50

Final index : DEC

INTERPRETATION

The first letter grade is D, thus indicating a short term acceptable quality. Nevertheless, basic reliability is too low to give a valid interpretation.

CONCLUSION

More basic parameters should be measured. Doubtful quality.

EXAMPLE # 2

WATER USE: Stock and wildlife watering

PRIMARY PARAMETERS

PARAMETERS	UNITS	WEIGHTS	VALUES	SUBSCORES
Dissolved solids	mg/l	0.3	2000	6
Fluorides	mg/l	0.2	2	0
Fecal coliforms	count/100ml	0.2	500	-18.5
Nitrates	mg/l $N\text{-}NO_3$	0.15	50	50
Nitrites	mg/l $N\text{-}NO_2$	0.15	1	90

COMPLEMENTARY PARAMETERS

PARAMETERS	UNITS	LOWER LIMITS	VALUES	UPPER LIMITS
pH	pH units	4	6	9.5
Salmonellae	count/100ml	0	0	0
Total raidoactivity	pBq/l	0	8	10

SUPPLEMENTARY PARAMETERS

PARAMETERS	UNITS	VALUES	UPPER LIMITS
Arsenic	µg/1	10.0	500
Cadmium	µg/1	5.0	10
Hexavalent chromium	µg/1	200.0	1000
Cobalt	µg/1	200.0	1000
Free cyanides	µg/1	100.0	200
Mercury	µg/1	0.1	5
Lead	µg/1	20.0	100
Selenium	µg/1	2.0	10
Organo-phosphorus	µg/1	80.0	100
Aldrin	µg/1	0.1	17
Chlordan	µg/1	0.1	3
DDT	µg/1	1.0	42
Dieldrin	µg/1	5.0	17
Endrin	µg/1	0.01	1
Heptachlor	µg/1	1.0	18
Lindan	µg/1	-	56
Methoxychlor	µg/1	-	35
Toxaphen	µg/1	-	5

SUMMARY

Number of primary parameters measured : 5 out of 5
Number of complementary parameters measured: 3 out of 3
Number of basic parameters measured : 8 out of 8
Number of supplementary parameters measured: 15 out of 18

Primary index : 19
Basic reliability : 100
Supplementary reliability: 83

Final index : DAB

INTERPRETATION

The first letter grade, D, indicates a short term acceptable quality. An attempt to reduce coliforms would improve this quality.

CONCLUSION

Poor quality. Water to be used only for a short period. Reduce coliforms if possible.

E X A M P L E # 3

WATER USE: Domestic water supply

PRIMARY PARAMETERS

PARAMETERS	UNITS	WEIGHTS	VALUES	SUBSCORES
Orthophosphates	µg/l $P\text{-}PO_4$	0.0620	50.0	93.1
Turbidity	JTU	0.1241	0.5	83.7
Fecal coliforms	count/100ml	0.1241	10.0	69.9
Nitrates	mg/l $N\text{-}NO_3$	0.0991	0.1	98.6
CAE + CCE	mg/l	0.1057	0.02	92.0
pH	pH units	0.0750	7.5	100.0
Ammonia nitrogen	mg/l $N\text{-}NH_3$	0.0750	0.05	100.0
Surfactants	mg/l NaLS	0.0750	0.1	69.2
Hardness	mg/l $CaCO_3$	0.0620	120.0	100.0
Dissolved solids	mg/l	0.0500	200.0	67.0
Iron	mg/l	0.0370	0.1	60.0
Copper	mg/l	0.0370	0.1	90.0
Phenols	mg/l C_6H_5OH	0.0370	0.2	73.3
True color	Pt-Co units	0.0370	5.0	66.7

COMPLEMENTARY PARAMETERS

PARAMETERS	UNITS	LOWER LIMITS	VALUES	UPPER LIMITS
Alkalinity	mg/l $CaCO_3$	30	92.0	500
Sulfates	mg/l	0	50.0	500
Chlorides	mg/l	0	10.0	250
Total coliforms	count/100ml	0	200.0	5000
Fluorides	mg/l	0	1.2	2
Total radioactivity	pBq/l	0	3.0	10
Salmonellae	count/100ml	0	0	0

SUPPLEMENTARY PARAMETERS

PARAMETERS	UNITS	VALUES	UPPER LIMITS	
Silver	µg/1	1.0	75	
Arsenic	µg/1	10.0	100	
Baryum	µg/1	150.0	1500	
Cadmium	µg/1	2.0	10	
Hexavalent chromium	µg/1	5.0	50	
Cobalt	µg/1	15.0	200	
Free cyanides	µg/1	7.0	75	
Manganese	µg/1	2.0	5	
Mercury	µg/1	0.02	50	
Nickel	µg/1	20.0	100	
Lead	µg/1	2.0	10	
Selenium	µg/1	1.5	100	
Organo-phosphorus	µg/1	3.0	17	
Aldrin	µg/1	0.001	3	
Chlordan	µg/1	0.005	100	
2,4-D	µg/1	2.0	6	
DDD	µg/1	1.5	2	
DDT	µg/1	0.005	17	
Dieldrin	µg/1	2.0	1	Out of range
Endrin	µg/1	0.003	18	
Heptachlor	µg/1	0.0005	4	
Lindan	µg/1	0.005	100	
Methoxychlor	µg/1	0.007	2	
2,4,5-T	µg/1	1.0	10	
2,4,5-TP	µg/1	0.5	5	

SUMMARY

Number of primary parameters measured : 14 out of 14
Number of complementary parameters measured: 7 out of 7
Number of basic parameters measured : 21 out of 21
Number of supplementary parameters measured: 25 out of 25

Primary index : 85
Basic reliability : 100
Supplementary reliability: 100

Final index : -AAA

INTERPRETATION

All parameters were measured. One supplementary parameter (Dieldrin) is above maximum level.

CONCLUSION

Excellent quality. Dieldrin ought to be checked.

E X A M P L E # 4

WATER USE: Domestic water supply

PRIMARY PARAMETERS

PARAMETERS	UNITS	WEIGHTS	VALUES	SUBSCORES
Orthophosphates	µg/l $P\text{-}PO_4$	0.0620	50.0	93.1
Turbidity	JTU	0.1241	0.5	83.7
Fecal coliforms	count/100ml	0.1241	10.0	69.9
Nitrates	mg/l $N\text{-}NO_3$	0.0991	0.1	98.6
CAE + CCE	mg/l	0.1057	0.02	92.0
pH	pH units	0.0750	7.5	100.0
Ammonia nitrogen	mg/l $N\text{-}NH_3$	0.0750	0.05	100.0
Surfactants	mg/l NaLS	0.0750	0.1	69.2
Hardness	mg/l $CaCO_3$	0.0620	120.0	100.0
Dissolved solids	mg/l	0.0500	200.0	67.0
Iron	mg/l	0.0370	0.1	60.0
Copper	mg/l	0.0370	0.1	90.0
Phenols	mg/l C_6H_5OH	0.0370	0.2	73.3
True color	Pt-Co units	0.0370	5.0	66.7

COMPLEMENTARY PARAMETERS

PARAMETERS	UNITS	LOWER LIMITS	VALUES	UPPER LIMITS
Alkalinity	mg/l $CaCO_3$	30	92	500
Sulfates	mg/l	0	50	500
Chlorides	mg/l	0	10	250
Total coliforms	count/100ml	0	200	5000
Fluorides	mg/l	0	1.2	2
Total radioactivity	pBq/l	0	3	10
Salmonellae	count/100ml	0	0	0

SUPPLEMENTARY PARAMETERS

PARAMETERS	UNITS	VALUES	UPPER LIMITS
Silver	µg/l	1.0	75
Arsenic	µg/l	10.0	100
Baryum	µg/l	150.0	1500
Cadmium	µg/l	2.0	10
Hexavalent chromium	µg/l	5.0	50
Cobalt	µg/l	15.0	200
Free cyanides	µg/l	7.0	75
Manganese	µg/l	2.0	5
Mercury	µg/l	0.02	50
Nickel	µg/l	20.0	100
Lead	µg/l	2.0	10
Selenium	µg/l	1.5	100
Organo-phosphorus	µg/l	-	17
Aldrin	µg/l	0.001	3
Chlordan	µg/l	0.005	100
2,4-D	µg/l	2.0	6
DDD	µg/l	1.5	2
DDT	µg/l	-	17
Dieldrin	µg/l	-	1
Endrin	µg/l	-	18
Heptachlor	µg/l	-	4
Lindan	µg/l	-	100
Methoxychlor	µg/l	-	2
2,4,5-T	µg/l	-	10
2,4,5-TP	µg/l	-	5

SUMMARY

Number of primary parameters measured	:	14 out of 14
Number of complementary parameters measured	:	7 out of 7
Number of basic parameters measured	:	21 out of 21
Number of supplementary parameters measured	:	16 out of 25

Primary index	:	85
Basic reliability	:	100
Supplementary reliability	:	64
Final index	:	AAC

INTERPRETATION

Excellent quality. Some problems could arise due to unmeasured supplementary parameters (see example 3).

CONCLUSION

Excellent quality. Unmeasured supplementary parameters ought to be verified.