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Comparison of two biological index-systems for water quality assessment in Belgium

by G. VANHOOREN

Summary

Two biological water quality monitoring methods : the Biotic Index (NBN-T92-402,1984) and the General Biological Index (NF-T90-350,1985), have been tested on their usefulness in the Belgian rivers. These tests have been carried out on 203 sampling sites belonging to very different kinds of watertypes.
Both methods are complementary to each other. The Biotic Index gives a better classification for the highly polluted waters, whereas the the General Biological Index furnishes a higher number of quality-scores for the cleaner waters. The application of both methods gives us the possibility to register and to judge, at a more precise level, the disturbances and effects on the macro-fauna, taking into account the maximal attainable quality of the concerned rivers.
Key-words : Macro-invertebrates, biotic index, water quality monitoring.

Samenvatting

Twee biologische waterbeoordelingsmethoden : de Biotische Index (NBN-T92-402,1984) en de Globale Biologische Index (NF-T90-350,1985) werden getoetst naar hun bruikbaarheid voor de Belgische rivieren. Dit gebeurde aan de hand van 203 stalen afkomstig van zeer diverse watertypen in België. Beide methoden zijn verschillend doch vullen elkaar aan. De Biotische Index geeft een betere klasse-indeling weer voor de zwaar vervuilde wateren, terwijl de Globale Biologische Index een groter aantal kwaliteitscores oplevert voor de minder vervuilde wateren. De toepassing van beide methoden biedt ons de mogelijkheid om op een fijnere manier de storingen en effecten op de macro-fauna te registreren en te beoordelen, rekening houdend met de maximaal haalbare kwaliteit van de betreffende waterlopen.
Trefwoorden : Macro-invertebraten, biotische index, waterkwaliteit.

1.Introduction

Since the edition of the maps of the biological quality of the watercourses in Belgium (1979, 1986) studies on macro-invertebrates have increased. Also, in relation to the water policy decisions concerning surface water management, the biological assessment is taken as an argument. Based on several studies performed in the previous years (De Pauw, Vanhooren, 1983, De Pauw, 1988) and relying on the experience shared in many EEC seminars (Tittizer, 1976, Woodiwiss, 1978, Ghetti, 1980) it has been proved that macro-invertebrates are the most valuable group for biological surveillance of water quality and that the most suitable reference methods would be based on a biotic index or score system, because, compared to other class-systems, these are both more sensitive and objective (Woodiwiss, 1980).
The biotic-index methods are developed in running waters (with rocky and sediment bottoms) and are related to the aeration rate and the organic load in the water. The fauna-components used in the system cover a wide range of organisms present in different food-chains and in different habitats in rivers from the spring to the mouth. An increase in pollution, whether of a chemical or physical nature, generally results in a reduction in macro-invertebrate taxa. These effects of elimination may affect particular taxonomic groups called bioindicators sensitive to different and specific degrees of pollution.
The Belgian method combines the adventages of the River Trent (Woodiwiss, 1964) and the Tuffery-Verneaux (1968) biotic-index systems in a practical, intelligible and surveyable standard method (NBN-T92-402, 1984).
Meanwhile the Belgian standard Biotic-Index method is applied in a high number of private, university and scientific laboratories and is taught at universities, high-schools and also at secundary and primary education schools.
In other countries also new methods have been developed for routine purposes : the Biological Monitoring Working Party score (B.M.W.P.) and the Average Score Per Taxon (A.S.P.T.) in England (Armitage et al., 1983), the General Biological Index (G.B.I.) in France (Verneaux, 1982, NF-T90-350, 1985), the Quality Index (K.1.3.5.) in the Netherlands (Gardeniers and Tolkamp, 1976) and the Saprobity-Index and the extension of the saprobity-fauna lists in Germany (Landesambt für Wasser und Abfall, Düsseldorf, 1982).
These methods cited above can mostly be used without problems in any other country for water quality assessment (De Pauw, 1988, ISO-draft 147/SC 5, 1984, Helawell, 1986). But each method has its own specificity in relation to pollution characteristics. Several methods are typical of organic pollution (Saprobity). Others are valuable only for one type of water : e.g. K-index for lowland rivers (Moller-Pillot, 1971).

Overlap between the methods is quite important. For these reasons, some researchers recommend to use more than one method according to the purpose and watertypes (H. Tolkamp, 1985).
Concerning the Biotic Index method, Verneaux (1982), De Piereux (1983) and Leclerq (1988), have found that the biotic index scores 9-10 don't reflect very well pollution stress in the cleaner waters, and underestimate the pollution in these ecosystems.
Therefore Verneaux has developed the G.B.I. method (1982, 1985) to reach a more precise estimation of the pollution stress on the fauna, by using the total family-richness of macro-invertebrates in cleaner waters and related to the different watertypes, lowland-, hill- and mountainrivers. This corroborates the conclusions of De Piereux (1983) that different zones of rivers (BI = 9-10) are represented by different communities and diversities of macro-invertebrates .

2.Methods

2.1.Sampling sites

203 stations from the physico-chemical waterways network of the Institute of Hygiene and Epidemiology were sampled for biological examination in 1986 and 1987. These stations belong to different hydrographical basins and regions. The tributaries were normally sampled at their confluence. For each station, physico-chemical results from the same years are available.

2.2.Invertebrate sampling

Invertebrates were collected by means of a handnet with a mesh size of 500 μm. To obtain comparable samples, the sampling time was set at three minutes for rivers less than two meters wide and five minutes for larger rivers; a river stretch of ten to twenty meters was explored for macro-invertebrates. The complete description of the sampling procedure is given in NBN-T92-405 (1984).
The collected sample was fixed in situ with a 4 % solution of formaldehyde and transferred to the laboratory. At the laboratory the organisms were sorted out and preserved in 70° alcohol.

2.3. Identification

After separation, macro-invertebrates are identified under a stereoscopic dissection microscope (magnification 10 to 50). When possible lists at species level are established. In the other cases the proposed levels of identification according to the B.B.I.-method (genus, family-level) were used. The most consulted identification handbooks are these of the Freshwater Biological Association and of Tachet, Bournaud and Richaux (1984).

2.4.The biological index-systems

In this study two index-systems are compared : the Belgian Biotic Index system (B.B.I.-T92-402, 1984) and the General Biological Index method, modified by the French Institute of Normalisation (NF-T90-350,1985). The method for the establishment of the General Biological Index differs from the Biotic Index system by :
1) differences in sampling. According to the NF-method the sample is defined by the sampling area. This consists of eight sample units taken at eight different habitats (coupled substrate-current differences) if present, by means of a Surber-sampler delimiting an area of about 0,05 m^2. The sample may also consists of eight sample units taken at a homogeneous site from the dominant substrate at different currents.
In deeper waters a handnet is used, collecting organisms from four substrates covering each an area of 0,1 m2. A river stretch with a length of ten time its width is explored.
We didn't apply this sampling procedure but used the handnet-technic described in 2.2.
Based on our experience by counting organisms collected with the handnet-technic and according to the surbersampler-procedure (VANHOOREN, DEHAVAY, 1978, LAFONTAINE et AL 1979), we can conclude that the sampling-results are comparable, when only a qualitative examination of the fauna is needed, although the number of individuals in the samples may vary widely. In this way the presence of one, two or three individuals in the sample has an influence on the final scores. Therefore the abundances were estimated and up to three individuals counted per species.
2) differences to determine the systematic units. Each family is considered as a systematic unit, even if they are represented by only a single individual, except the Oligochaeta, Nemathelminthes, Hydracarina, Hydrozoa, Porifera, Bryozoa and Nemertini, which are taken as a group.
3)the standard tables used to calculate the indexes are different : several families of the orders Plecoptera, Ephemeroptera and Trichoptera are ranked separately according to their sensitivity to pollution. In order to be of any significance, the most sensitive indicator-family has to be represented by at least 3 individuals in the sample.

3. The results

The following parameters have been studied : the Biotic Index (B.I.), the General Biotic Index (G.B.I.) and the systematic units (S.U.) These indices are also compared with the Chemical water quality Index (C.I.) obtained at the same stations for the same years. This Chemical Index consists in assigning a rating between 3 and 15

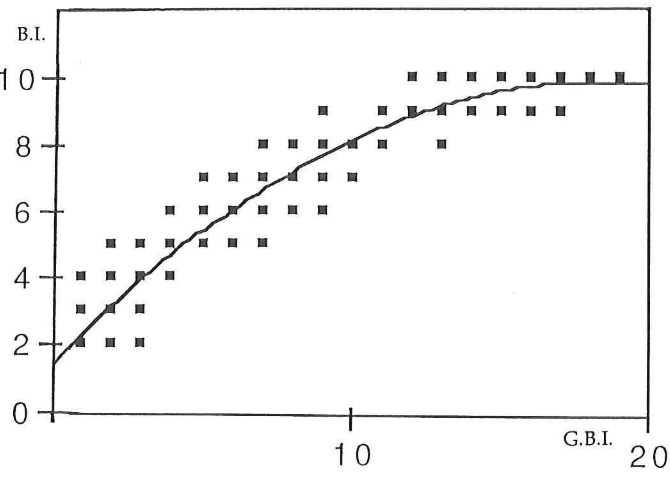

Fig. 1. Polynomial regression curve B.I. - G.B.I.

points obtained by the addition of the ratings for three parameters : % saturation of oxygen, biochemical oxygen demand and ammonium content (Ministerie van Verkeer en Waterstaat, 's Gravenhage, 1975, and Lafontaine, De Brabander, Herman, 1985). In contrast with the Biotic Indexes, high scores of the C.I. mean gross pollution.

4. Relationship between the indices

4.1.Correlation-test

The relationship between the B.I., G.B.I., C.I. and S.U. obtained by Spearman-rank correlation tests are very high. This can be explained by the fact that the index-calculations are based on the same fauna-data.
The Spearman-rank correlations between the biological indices and the chemical indices are lower :
between B.I. and G.B.I. : R = 0,97 for 203 observations
between B.I. and S.U. : R = 0,94 for 203 observations
between G.B.I. and S.U. : R = 0,96 for 203 observations
between C.I. and B.I. : R = 0,70 for 154 observations
between C.I. and G.B.I. : R = 0,73 for 154 observations
between C.I. and S.U. : R = 0,67 for 154 observations
The best regression curve fit between the B.I. and G.B.I. is given in the figure 1.

4.2.Division into quality classes

Table 1 shows for each Biotic Index-score : the corresponding mean values of the G.B.I., and the standard deviations. A scale division(1) is performed based on these mean values(1) and on a series of scale intervals(2) given by the regression curve (fig. 1).
The phase B.I. 0-6 is equivalent to the phase 0-7 of the G.B.I., but the value B.I. 5 corresponds more with the G.B.I. 4 and B.I. 3-4 with the G.B.I. 3 , the values B.I. 7-10 are separated along a non-linear scale of the G.B.I. 7-20.

In order to synthetisize the results, the 10 Biotic Index scores are ranked in 5 quality classes. The 20 General Biological Index scores are divided into 7 classes and the Chemical Index scores into 5 classes. These classes may be visualised by different colors (table 2). The value 0 indicating a complete absence of macroinvertebrates is in black.

5. Discussion

The results of the B.I. and G.B.I. are represented by different symbols on maps. (fig. 2,3). The waters characterised by BI ⩽6, or surface waters with visible and heavy pollution, are now more indicated and classified by the G.B.I. as polluted surface waters. The G.B.I. scores are usually lower than the B.I. scores at the same site.
The waters with B.I. ⩾6 are divided by the G.B.I. into 4 quality classes giving a series of gradients-against 2 by the B.I.- by means of which it is possible to detect some disturbances on the fauna (loss of a great number of families).
The Biotic Index scores 9-10 considered as the quality class for clean waters, are divided by the G.B.I. over a large range of index scores 13-20, or 2 quality classes.
Furthermore, attention is to be paid to understand the values of the index scores and to determine the maximal attainable quality of the rivers.
According to Verneaux (1982), the G.B.I. resumes better the whole information of the biogenic qualities of the site belonging to either natural, artificial or degraded waterecosystems than the B.I. reflects.
Fast running waters, belonging to the fish region of the salmon zone (salmonids) and the middle-zone of carp (cyprinids) have a G.B.I. ⩾18 when non polluted. Lowlandrivers and large streams have often a G.B.I. ⩾15. Only real springs, fen-regions or moorland rivers and some oligotrofic waters and canals give lower maximal values of the G.B.I.
Belgium is dealing with quite different watertypes such as canals, lowlandrivers, streams, hill- and mountainrivers. Fast running waters have in most cases a high fauna-diversity, with many families of Plecoptera, Trichoptera and Ephemeroptera. The fauna components of low running or stagnant watercourses and canals are characterised by other families like Nemouridae, Limnophilidae, Baetidae and bottom dwelling organisms.
A good correlation between the biotic indices and the chemical water quality indices has been proved earlier by De Brabander & De Schepper (1981). The same can be concluded for the C.I. and de G.B.I., but the chemical indices, based on only 3 parameters, are of limited value. Biological assessments using macroinvertebrates and translated into a biotic index, accurately reflects the general ecological degradation occuring in cases of organic as well as toxic pollution. A good

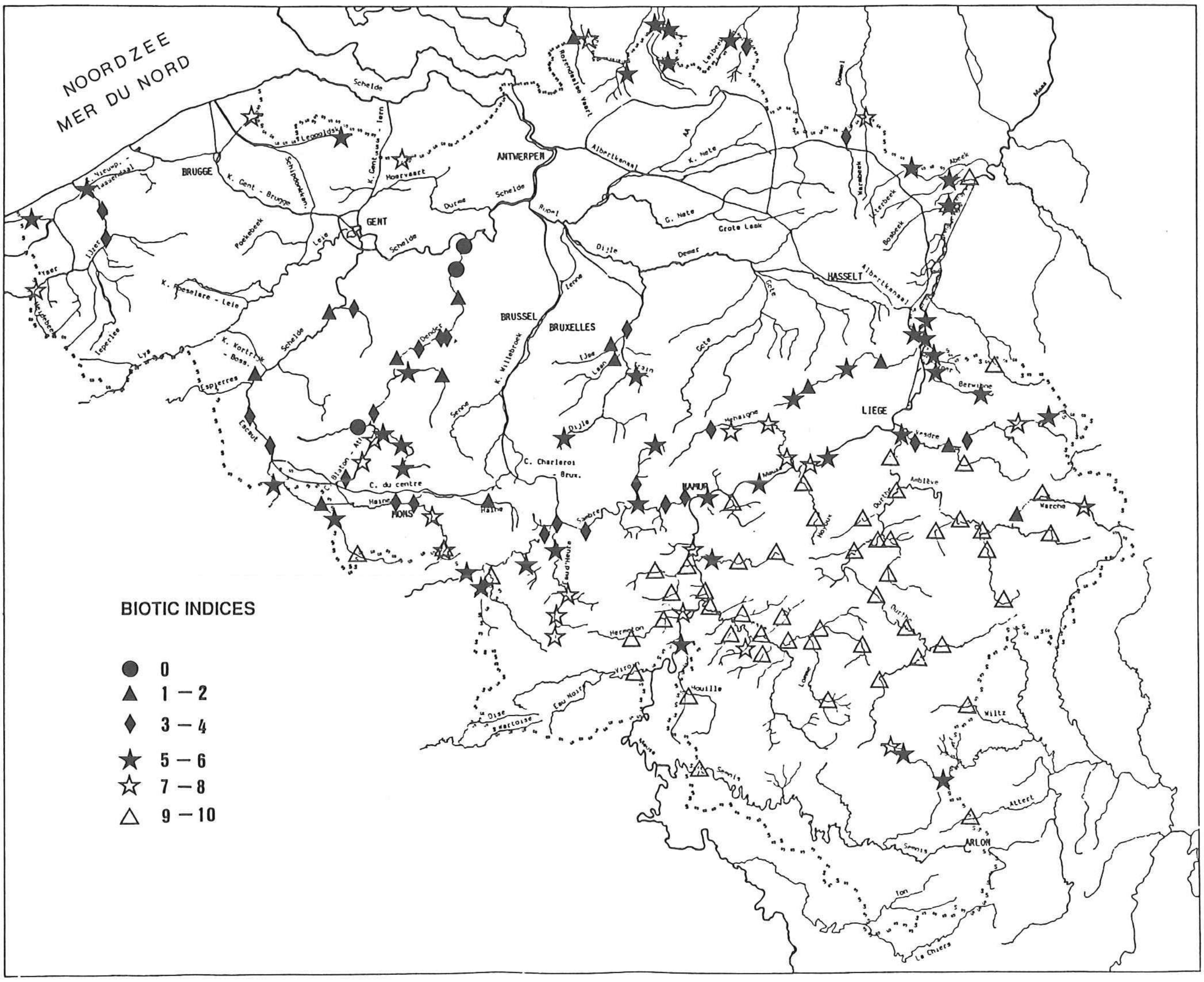

Fig. 2. Biotic indices.

correlation with the G.B.I. is also found with the work of Dehavay (1987) concerning the potential ichtyology of hydrographical basins in Belgium.

6. Conclusions

The General Biological Index reflects the fauna composition, the habitat characteristics and the water quality. Each result of the G.B.I. at a site may be compared with the maximal attainable G.B.I. of the site in non polluted conditions. Each decrease of the G.B.I. may be considered as a significant disturbance or effect on the fauna. In most cases these effects are related to pollution influences or stress.

The biotic-index gives a better description of the organic polluted waters than de G.B.I. because of the overlapping of some G.B.I. scores (3-4). On the other hand the G.B.I. gives the possibility to evaluate the maximal biological quality of the site by the extension of the highest scores.

Both methods the B.I. and the G.B.I. are complementary to each other. They can be used with the same fauna-data.

Degradations such as mechanical pollution, dredging, canalisation, modification of the river regime may influence the fauna composition and the biological quality. The biological assessments should be considered as early warning signals.

With both biological index-methods an instrument is given to the water authorities to define the water quality at a more accurate level and to tighten up the waterquality objectives in function of the optimal attainable quality of the concerned rivers.

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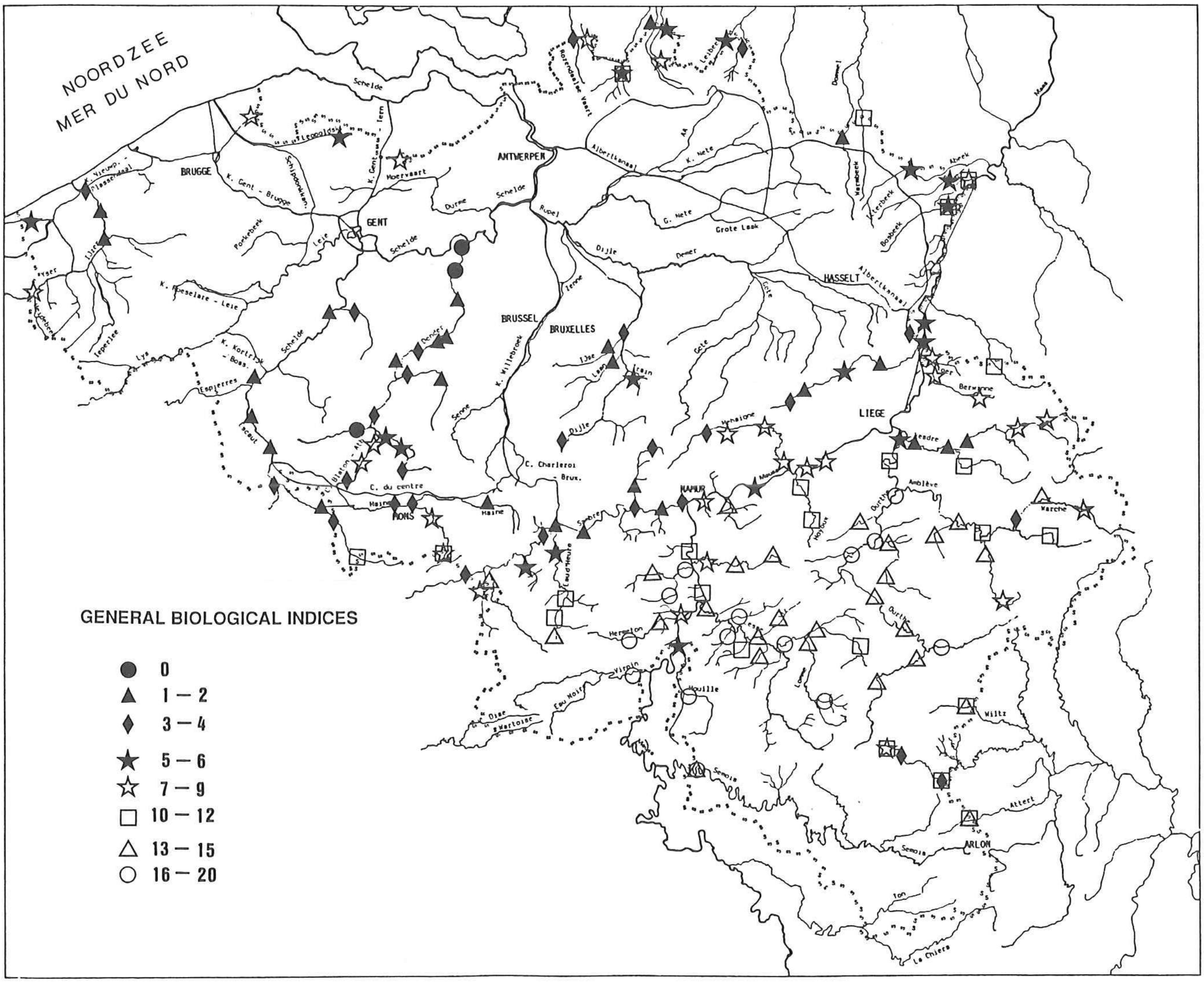

Fig. 3. General biological indices

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Table 1. Division of the General Biological Index (G.B.I.) into quality classes. B.I. : Biotic Index, n : number samples, (1) based on mean values and standard deviations. (2) based on the regression curve. S.U. : systematic units.

B.I.	n	G.B.I.	Scale-intervals (1)	Scale-intervals (2) given by the regression curve	S.U.
2 red	17	1,5 ± 0,6	≤ 2	≤2	4 ± 1
3 orange	10	2,3 ± 0,6	2 - 3	3	6 ± 2
4	18	2,5 ± 0,7	2 - 3	4	8 ± 3
5 yellow	29	4,5 ± 1,1	4 - 5	5	10 ± 1
6	31	6,1 ± 1,0	5 - 7	6	13 ± 2
7 green	22	7,6 ± 1,1	6 - 9	7-9	16 ± 3
8	13	10,0 ± 1,5	9 -12	10-12	22 ± 2
9 blue	37	13 ± 1,7	11-15	13-15	26 ± 3
10	23	15,6 ± 1,8	13-18	16-20	34 ± 4

Table 2. Comparison of quality classes. B.I. Biotic Index, G.B.I. : General Biological Index, classes of G.B.I. according to VERNEAUX (N.F.), C.I. : chemical index.

	red	orange	yellow	green		blue	
				dark	light	dark	light
B.I.	0-2	3-4	5-6	7-8		9-10	
G.B.I. VANHOOREN	≤2	3-4	5-6	7-9	10-12	13-15	16-20
G.B.I. Verneaux (NF)	≤4	5-8	9-12	13-16		≥17	
C.I.	15-13,6	13,5-10,6	10,5- 7,6	7,5 - 4,6		4,5 - 3	

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