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Practical Application of French Biological Diatom Index (Indice Biologique Diatomées) in Water Quality Assessment

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Since, in 1970, diatoms and diatom indices was first used in measuring quality of streams and rivers at the Seine Water Agency in France, five other water agencies began to show interests since 1990. In 1994, associated with CEMAGREF (Centre National du Machinisme Agricole du Génie Rural et des Eaux et des Forêts : environmental science and expertise for the sustainable management of land and water), the six French Water Agencies (Seine, Rhone-Mediterranee-Corse, Artois-Picardie, Loire-Bretagne, Rhin-Meuse and Adour-Garonne) developed a practical diatom index, which is liable to be used routinely in the territorial streams and rivers of whole France, and which is liable to promote and facilitate its use in monitoring water networks. In 1995, the first version of a biological diatom index (IBD) was generated by them. Since then, the software update for IBD calculation and the user's network have led to numerous practical applications in France. Furthermore, the Water Agencies have run applicable programs on the National Basin Network from 1996, and the initial data set of IBD was completed. Re-examination of the complete data set was done at the end of 1998, and the tests on different calculation options of the IBD led to a third version of this index in June, 2000 (AFNOR NF T 90-354).

Key words : French IBD (Indice Biologique Diatomées)

INTRODUCTION

Since the early 1970s, there have been scientific attempts to use the diatom in order to standardize the biological index based on these properties to assess the water quality, especially in the streams and rivers in Europe including France. Due to its structural advantages caused by its unique evolution process, the diatom has become a major vegetal group in waters and in sediments (Lewis *et al*., 1999; Chung and Le Cohu, 2001; Hamm *et al*., 2003). Not only scientific interests and trials but also legal efforts to establish an adequate diatom index over the French territory were joined in France (Prygiel and Coste, 2000). To apply the 'Polluter-Pay-Principle' in order to reduce the oxygen-demand related pollution at a local site scale, 'Water Catchment Authorities' (Agences Financières de Bassin) was created in 1964 by the first French 'Water Law (Loi sur l'Eau)' as the first step, and later Water Catchment Authorities became Water Agencies (Agences de l'Eau) was established (see Tassin *et al*., 2003). The French standard 'biological diatom index' (Indice Biologique Diatomées, hereafter IBD) was drew attentions in 2000 (Prygiel and Coste, 2000), and the diatom index is now routinely applied and used to assess a general water quality at the level of national scale in France. Thus, the author would like to describe a kind of short history focused on the IBD just by 2000, when this index became a French standard. This short note covers three parts: (1) an overview, mainly direct cita-

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tion from the works by other authors (Prygiel and Coste) without precision, except for some cases; (2) brief reasons for this success story; (3) several figures and tables after IBD methodology guide.

OVERVIEW

The use of diatoms and diatom indices in the networks for measurement of the quality of French streams and rivers was initiated at the Seine Water Agency in 1974. Applications in four water agencies (the Rhone-Mediteranee-Corse, the Artois-Picardie, the Rhin-Meuse and the Adour-Garonne basins) reflected a renewed interest. According to the authors (Prygiel and Coste, 2000), the thought of a practical biological index based on diatoms, at the beginning, was very simple in order "to resolve the sampling problems encountered with the group of macro-invertebrates in canalized environment". Thereafter, to obtain a reliable methodology and applied routinely to all types of French streams and rivers with exception of natural salted areas, especially estuaries, the first agreement was made between Water Agencies and CEMAGREF in 1994. The efforts led to publish a software (OMNIDIA) in 1992, and also led to publish the first IBD version in 1995. The regular update of IBD calculation software and the users' network have led to numerous practical applications. Moreover, the Agences de l'Eau have run application programs since 1996 in the National Basin Network (NBN) and completed the initial IBD data set. The complete set of data was re-examined at the end of 1998 and different calculation options of the IBD were tested, which led to a third version of the index, the standard in June 2000 (Prygiel and Coste, 2000).

Until a historical June 2000, various steps were taken by the Agences de l'Eau, CEMAGREF and other partners so that the IBD could be implemented rapidly for the surveillance networks. These include production of the determination key and specific IBD index calculation tools, training programs and several projects related to long-term storage of information, such as the creation of a collection of samples and slides and a national database for the inventories. Thus, a series of tests carried out in the six major hydrographical basins show that this index is operational in many countries. Several steps were taken to make the index for water quality manager-friendly to apply, such as computer tools for calculating the index and to aid identification of diatoms, technical assistance to the users and standardization of the index. In order to consolidate the IBD, programs to acquire new data were launched taking into account the division of France into eco-regions (ecologically homogeneous regions), something which was hardly, if at all, taken into account at the beginning. New developments are also under study with a view to integrate the IBD into the Quality Assessment System (SEQ, Système d'Evaluation de la Qualité : Quality Assessment System) for the French streams and rivers introduced by Water Agencies in 1999. As this system takes into account water quality, the quality of the physical environment and biological quality, comparisons are foreseen between information gained from the IBD index with other biological variables such as macrophytes and phytoplankton composition, as well as chemical and physical variables. These activities re-supervised by a Group of Scientific Interest of Diatoms of Continental Waters, which has, since its creation, managed an IBD inter-comparison exercise with the Association des Diatomistes de Langue

Fig. 1. The distribution of inventory databases among the six Water Agencies (Administrative basins) in France.

Française (ADLaF). These initiatives have led to the introduction of the IBD in the Hydrobiology Accreditation Programme of the Comite Francais d'Accrediation (COFRAC).

This IBD index relies on diatomic inventories acquired on the whole French surveillance networks of water quality. The water chemistry of 1,332 inventories has been associated with 14 parameters (see in details Figures and Tables). Moreover, mathematical analysis of these data has permitted the definition of 7 chemical classes of water quality and the distinction of 209 taxa. A probability of presence has been calculated within each class of water quality. Seventy eight other taxa have been paired (to 57 among the 209) on the basis of their close morphology. Furthermore, an indicative value has been given to each of the 209 taxa, the value of which intervenes in the calculation of the IBD (Prygiel and Coste, 2000).

This success using diatoms has led to recommendations concerning sampling and subsequent processing of the material with a view towards eventual normalization throughout Europe. This is an essential stage on the way towards complete acceptance of diatoms as indicators of water quality throughout the continent (Prygiel *et al*., 2000).

Table 1. The numbers and sampling dates of inventory databases from the six Water Agencies (Administrative basins) in France.

Basin	Number of records	Sampling dates
Adour–Garonne	165	1979 to 1994
Artois–Picardie	271	1990
Loire–Bretagne	41	1979 to 1980
Rhin–Meuse	740	1992
Rhone–Mediterranee–Corse	66	1977 to 1988
Seine–Normandie	49	1979 to 1994
France	1332	1979 to 1994

A SUCCESS STORY AND WHY?

Why a general water quality index based on diatoms was successful, especially in France? There should be two reasons. Firstly, France possesses not only a long regulatory history on water quality management (Tassin *et al*., 2003) but also a long experience of bio–indication by the diatom (Prygiel and Coste, 2000). In most cases, the very dense monitoring program is quite related to scientific works in limnology (Tassin *et al*., 2003). Concerning French streams and rivers, due to historical reasons (the first French water law "loi sur l'eau" in 1964 seven years before the creation of the Ministry of the Environment), their monitoring was launched at the end of the 1960s in a national scale, and now many local authorities have developed their own monitoring networks. Rivers and streams are now monitored by several systems from the national scale to a very local one, ensuring a fairly good knowledge of their physical, chemical, biological and ecological status (Tassin *et al*., 2003). Secondly, there is a fantastic teamwork between diatom biologists (e.g. M. Coste–

Table 2. Averages and standard deviations of physico–chemical variables for the 7 classes of water quality defined by the initial dataset.

Average	T°C	pH	Cond	SS	O_2	%Sat	BOD_5	COD	TKN	NH_4–N	NO_2–N	NO_3–N	PO_4–P	Cl
1	19.5	7.6	1260	19	1.6	18	65	15	18.8	16.8	2.1	10	8.05	143
2	18.6	7.6	955	16	3.3	36	40	16	9.6	8.3	1.7	10.9	5.57	88
3	18.6	7.8	1044	14	6.1	65	19	19	4	2.8	0.8	12	2.29	154
4	18	7.9	822	19	8.5	90	9	16	2	0.6	0.4	11.1	0.67	74
5	16.8	7.8	447	14	9.3	95	4	13	1.3	0.2	0.2	10.3	0.28	21
6	15.3	7.4	162	7	10.1	100	2	12	1	0.2	0.1	5.6	0.13	10
7	12.8	6.9	75	4	11.7	111	1	9	0.7	0.1	0	4.5	0.08	7
Sta.dev.	T°C	pH	Cond	SS	O_2	%Sat	BOD_5	COD	TKN	NH_4–N	NO_2–N	NO_3–N	PO_4–P	Cl
1	1.6	0.2	263	8	1.9	22	27	7	7.5	6.6	2.3	11.6	4.05	59
2	2.5	0.2	212	11	2.7	29	19	18	4.4	4.9	1.5	9.4	3.5	65
3	2.9	0.3	479	10	2.1	24	17	13	3.9	3.4	0.6	8.3	2.06	165
4	2.6	0.3	534	26	1.9	21	10	11	4.5	1	0.9	6.1	0.68	99
5	2.7	0.3	212	19	1.4	15	4	8	1	0.3	0.2	6.3	0.25	14
6	3	0.5	110	5	1.6	17	2	7	0.8	0.2	0.1	9.2	0.13	7
7	2.4	0.3	17	5	1.1	9	1	6	0.4	0.1	0.1	1.5	0.09	1

CEMAGREF) and representatives from Water Agencies (e.g. J. Prygiel-the Artois-Picardie). In my opinion, the last point is decisively crucial to concretize an adequate index based on diatoms for each country as well as to apply routinely on a national scale.

PERSPECTIVES

Both in Japan and in Korea, there have been some attempts in establishing an accurate diatom index to assess a general water quality, either scientific attempts in Japan or administrative attempts in Korea. Though DAIpo (diatom assemblage index to organic water pollution) was first established by Watanabe in 1988 (cited from Lee 2001) to assess an organic water pollution in Japan, the attempts have been very limited in Korea. The author believes that, in Korea, the French approach might be useful in reaching the goal in order not only to establish a robust and scientific index based on diatoms but also to apply routinely at the level of nation basin scale. To achieve this goal, long term collaboration between diatom biologists and administrative workers with patience and passion would be crucial in Korea.

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＜**국문적요**＞

France 하천 수질 평가법으로 이용하는 규조류 지수에 관한 소개

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France에서는 국가적 차원에서 지난 1994년부터 수역관리청(French Water Agencies : Seine, Rhône-Méditerranée-Corse, Artois-Picardie, Rhin-Meuse and Adour-Garonne)과 연합한 농공환경연구소(CEMAGREF)의 주도로 France 영토(France본토 및 부속 도서에 해외 영토가 지구상에 걸쳐 존재함) 내에서 신뢰도를 가지고 간단히 이용할 수 있는 수질감시망 방법론으로 실용적인 규조류 지수(Indice Biologique Diatomées)를 만들기로 하였다. 물론 이전인 1970년대부터 Seine 강 수역관리청에서 규조류 지수를 이용하기 시작하였고, 1990년대부터 다른 5개 수역관리청에서도 도입한 바가 있다. 이 후 1995년에 최초의 지수를 공표하였고, 지속적이고 정기적인 자료원의 최신화와 보강을 거듭하여 1996년에 최초로 6대 수역관리청에서 적용하였으며 1998년에는 미비한 자료를 완결시키고 기존의 프로그램을 재검토하여 2000년 6월에 표준화된 3번째 판인 IBD가 만들어졌다. 이 방법론은 France의 표준화법인 AFNOR에 NF T 90-354로 출간되어 범용화단계를 시작하였다.