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NEMATODES AS INDICATORS OF RIVER POLLUTION

by

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The extent of pollution of a river is often ascertained by examining the bottom meso- and macro-fauna, and standardized testing schedules have been proposed to express the « health condition » of the water in comparative quantitive terms (Woodiwiss, 1964; Tuffery and Verneaux, 1968; Sladecek, 1973). However, the molluscs, annelids and insect larvae which are the animal group used, are not always sufficiently abundant to allow statistical analysis, and insect populations fluctuate with seasonal conditions so that a satisfactory appraisal can therefore be established only by taking many samples and at several times during the year. Moreover, these animal groups, with the exception of oligochaetes (Brinkhurst, 1962), are virtually absent at high levels of pollution.

The present paper proposes the use of nematodes as indicators of river pollution. They are universally present in the river bed, regardless of whether it is stony, muddy or sandy; populations are not subject to seasonal fluctuations to any extent; and some groups are present even under the most extreme conditions of pollution.

Localities and methods

The investigation was carried out in the Seveso river, one of the most polluted in Italy (Fig. 1). Its source is at San Fermo della

Battaglia at 425 m high, among woody hills of sandstone and eocenic-miocenic marl sandy clays. After 3 to 4 km the slope of the land lessens and the river flows through the morenic for about 15 km, cutting through the near diluvium until it reaches Milano (Villa, 1965). Details about the physical, chemical and biological characteristics of the Seveso river are given by Marchetti (1968). Nematode sampling was undertaken at each of the following five stations:

1. San Fermo della Battaglia, 1-2 km from the source; water clean and without pollution.
2. San Fermo della Battaglia, about 3 km from the source; relatively unpolluted water although a short distance upstream the San Fermo sewer discharges into the river; watershed area of 3,000 inhabitants with textile and ironware factories.
3. Fino Mornasco, 11 km from the source; water of deep brown colour, heavily polluted; an area of 25,000 inhabitants with textile, ironware and chemical industries.
   Ephemeroptera, Trichoptera, Diptera, Crustacea, Gastropoda and Hirudinea no more present and Oligochaeta almost so.
4. Varedo, 32 km from the source; water very polluted with deep grey sediments; 180,000 inhabitants with textile, furniture, ironware and chemical industries.
5. Niguarda (Milano), 41 km from the source; water very polluted, deep grey colour, and malodorous; 400,000 inhabitants in the upstream watered area with a wide range of industries.

At each station five to 10 samples of sediment were taken a few metres apart from each other. The samples from each station were bulked and the nematodes extracted in a fluidising column (Trudgill *et al.*, 1973). Samples were taken at monthly intervals from August 1974 to May 1975 at Station 1 and from March 1974 to March 1975 at the other stations, with the exception of February 1975 when sampling was not undertaken at any of the stations. There was little month to month variation in the numbers or species of nematodes and the data are therefore presented as mean annual values.

Results and discussion

The results of chemical and other analyses are given in Table I. Organic pollution was estimated by O_2 and COD analyses, inorganic

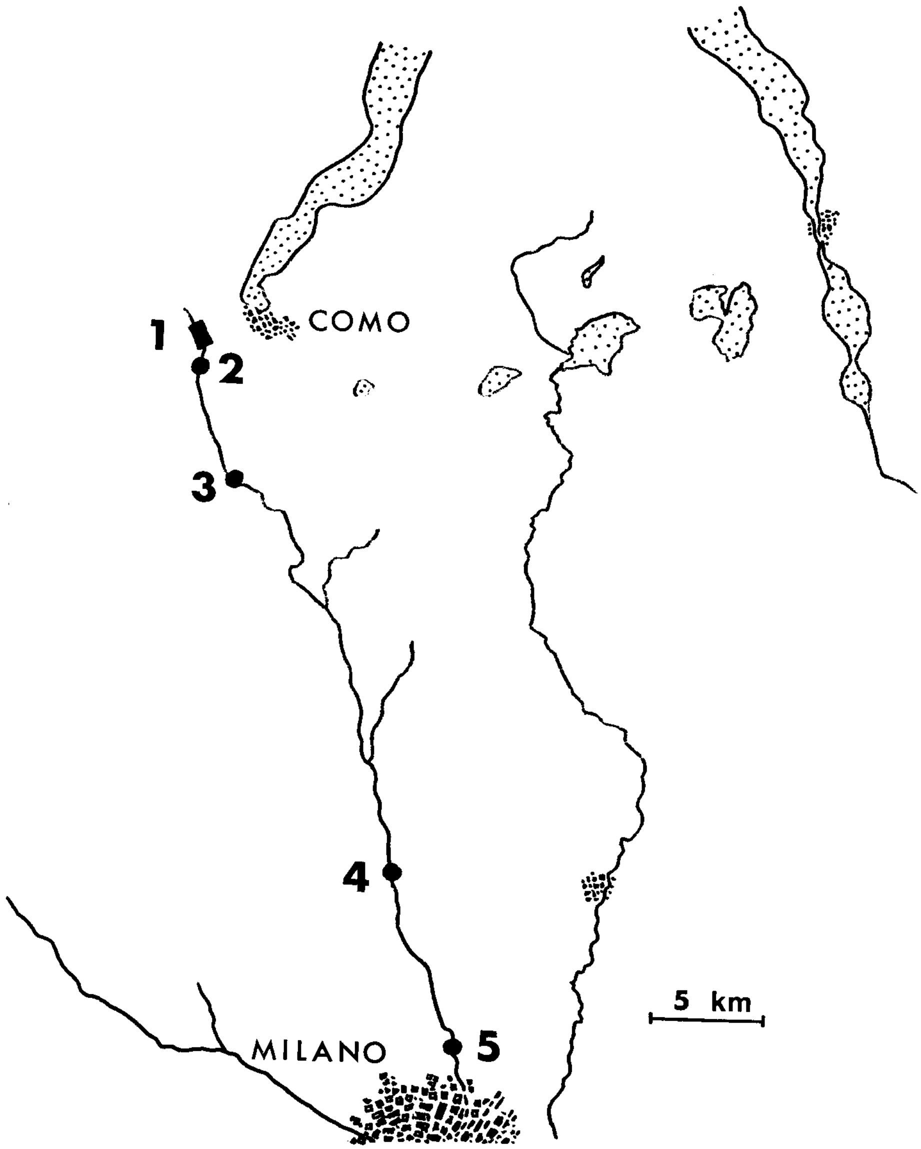

Fig. 1 - Course of the torrent Seveso with sampling stations. Towards Milano flow also the river Olona, on the west, and the river Lambro, on the east, both famous for their polluted waters.

salts pollution by conductivity measurements, and a general estimate of water toxicity by a fish survival test undertaken with trout (*Salmo gairdneri* Rich.). Sedimentary material was measured by Imhoff cones after 2 hours sedimentation. Fig. 2 shows the marked deterioration in the river environment with increasing distance from the source.

Table I - *Physical and chemical parameters of Seveso waters. Annual means and standard error.*

	Stat 1	Stat 2	Stat 3	Stat 4	Stat 5
Temp. (°C)	4.5-16.2	4.5-19.3	6.7-20.0	6.7-24.0	12.7-22.8
pH	8.2 ± 0.3	8.0 ± 0.1	8.1 ± 0.2	8.1 ± 0.2	7.6 ± 0.2
μS	255 ± 43	307 ± 21	505 ± 58	637 ± 95	881 ± 74
% O_2	96 ± 5	83 ± 5	60 ± 8	60 ± 9	35 ± 10
COD	12 ± 5	21 ± 5	133 ± 28	131 ± 31	235 ± 46
Imhoff cones	0	0	0.4 ± 0.2	1.3 ± 0.3	2.4 ± 0.3
Fish test	0	0.3	0.7	1.3	1.7

A total of 5,008 nematodes were collected in which 70 species were identified (Table II). Nematodes were abundant in the sediment at all stations but Rhabditinae and Diplogasteridae, and generally all Secernentea, were abundant at the downstream polluted stations, see also Hirschmann, 1952, whereas Adenophorea were more abundant in cleaner waters upstream (Table II, Fig. 3). The percentage occurrence of Secernentea [*Koerneria fictor* (Bastian, 1865) is not considered here since considering the shape of its stoma it is not a bacteriophagus. In fact, this species has been found in cleaner water of station 1] parallels the COD curve and is reciprocal to the curve for dissolved oxygen from which it can be concluded that they are indicators of organic pollution. The Diplogasteroidea were most numerous in conditions of medium to high pollution, while Rhabditoidea were more numerous with very high pollution such as in the vicinities of sewers or factory discharge outlets.

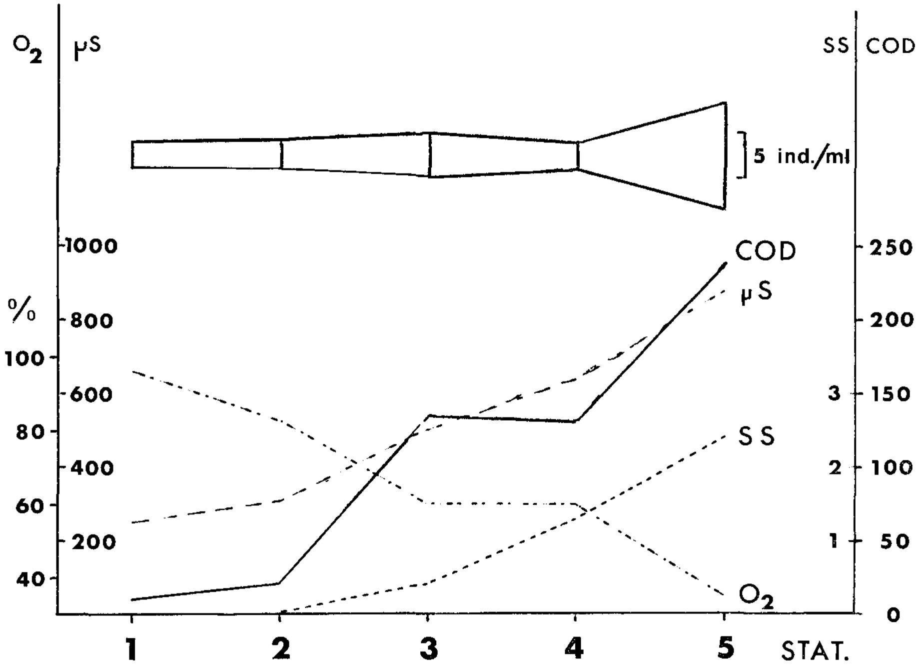

Fig. 2 - Average values of COD, of oxygen saturation, of conductivity (µS), and of suspended solids (SS in ml/l sedimented in 2 hours) of the waters in the 5 stations studied on Seveso river. Density of nematodes in the sediment is also represented.

The relative occurrence of the more commonly occurring species is shown in Fig. 4. *Tobrilus* most frequently occurred in unpolluted waters (station 2), but peak numbers of *Paroigolaimella bernensis* (Steiner, 1914) occurred in moderately polluted waters (station 3), *Acrostichus nudicapitatus* (Steiner, 1914) in the more polluted station 4 and *Rhabditis oxycerca* (De Man, 1895) in the extreme pollution of station 5. Thus the nematodes species composition of the river sediment relates to the degree of water pollution, particularly with organic pollution and nematode analysis can be linked with chemical analysis to provide a more complete picture of the extent of pollution.

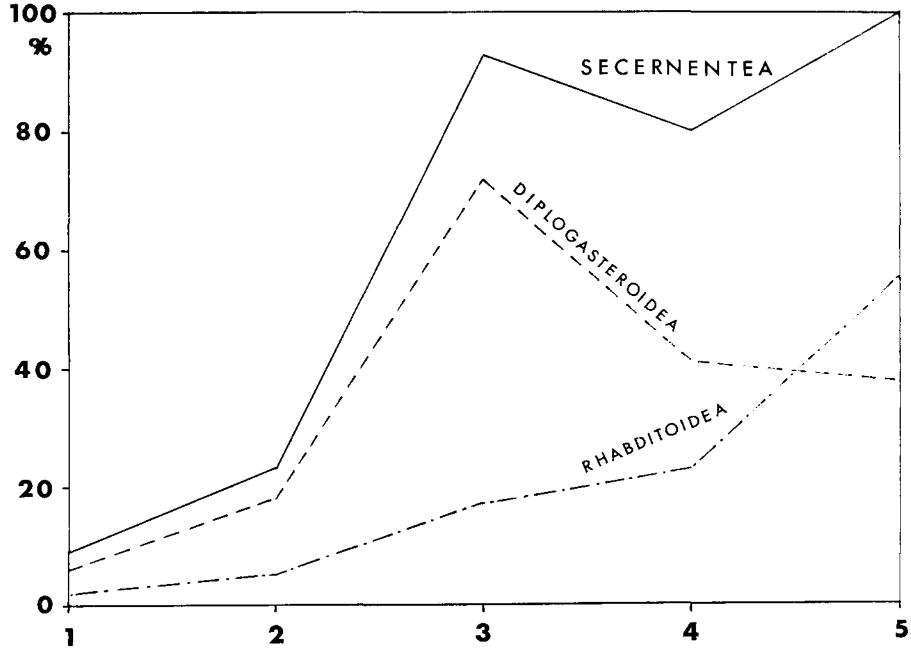

Fig. 3 - Percentages of presence of nematodes belonging to the subclass Secernentea in respect to the total presence of nematodes in each station. Diplogasteroidea and Rhabditoidea are Secernentea with a different grade of saprophily.

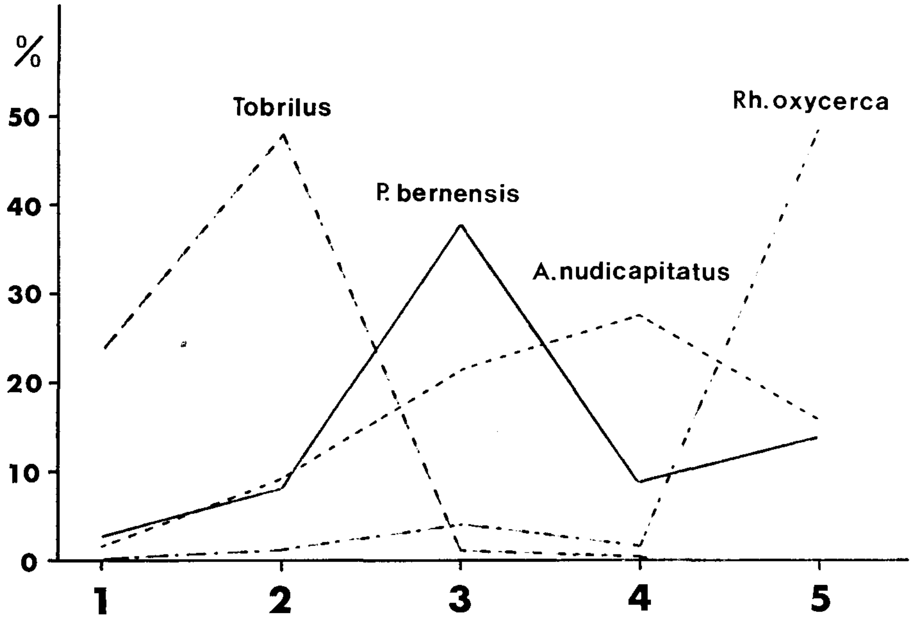

Fig. 4 - The species of genus *Tobrilus*, *Paroigolaimella bernensis*, *Acrostichus nudicapitatus* and *Rhabditis oxycerca* are the four most common forms of nematodes found in Seveso; each one becomes dominant at definite pollution levels.

Table II - *Nematodes, subdivided in Secernentea and Adenophorea, collected in the 5 stations. Values expressed in percentages.*

Species (Secernentea) Stations	1	2	3	4	5
Tylenchus filiformis (Bütschli 1873)	0 2	—	1.7	4.9	0.7
Tylenchorhynchus sp.	0.1	—	—	—	—
Ditylenchus sp.	0 2	—	0.5	0.5	3.3
Helicotylenchus erythrinae (Zimmermann 1904)	0.5	0.4	—	—	—
Criconema sp.	—	0.1	—	—	—
Criconemoides sp.	—	0.4	—	0.1	—
Hemicycliophora sp.	—	—	0.2	—	0.8
Aphelenchus avenae Bastian 1865	—	0.1	—	—	—
Aphelenchoides cfr. *parientinus* (Bastian 1865)	—	—	—	0.2	0.5
Rhabdontolaimus sp.	—	—	0.7	0.5	2.6
Rhabdontolaimus stigmatus (Steiner 1930)	0.6	0.3	10.0	1.9	1.6
Paroigolaimella bernensis (Steiner 1914)	2 9	8.1	37.8	8.7	13.8
Acrostichus nudicapitatus (Steiner 1914)	1.7	9.0	21.5	27.6	16.0
Mononchoides sp.	0.5	0.3	0.9	0.1	0.3
Koerneria fictor (Bastian 1865)	27.2	—	—	—	—
Koerneria sp.	—	—	1.2	1.6	2.4
Hemidiplogaster agilis (Skwarra 1921)	—	—	—	1.0	1.6
Rhabditis filiformis Bütschli 1873	0.2	0.1	0.2	0.2	0.2
Rhabditis oxycerca de Man 1895	0,5	1.1	8.0	2.8	48.3
Rhabditis curvicaudata (Schneider 1866)	0.7	0.6	0.5	0.1	0.2
Pelodera chitwoodi (Bassen 1940)	0.5	0.5	7.9	4.9	6.0
Caenorhabditis dolichura (Schneider 1866)	0.2	1.9	—	15.0	0.1
Mesorhabditis sp	0.1	0.4	—	0.2	0.2
Diploscapter coronata (Cobb 1893)	—	0.1	—	0.1	0.1
Panagrolaimus sp.	0.1	—	0.3	0.1	1.0
Eucephalobus striatus (Bastian 1865)	—	0.1	1.9	9.1	—
Euteratocephalus palustris (de Man 1880)	—	—	0.2	—	—

Species (Adenophorea) Stations	1	2	3	4	5
Plectus parietinus Bastian 1865	9.2	1.1	0.3	0.1	0.1
Plectus cirratus Bastian 1865	1.0	3.4	0.9	0.1	0.1
Plectus rhizophilus de Man 1880	—	0.1	—	0.2	—
Plectus parvus Bastian 1865	0.2	0.5	0.5	0.1	0.1
Anaplectus cfr. *granulosus* Bastian 1865	0.1	—	—	0.2	—
Bastiania gracilis de Man 1876	0 1	—	—	—	—
Cylindrolaimus bambus Andrassy 1968	0.2	—	—	—	—
Monhystera paludicola de Man 1881	2.2	3.6	—	—	—
Monhystera filiformis Bastian 1865	1.2	12.4	0.5	0.3	—
Monhystera dispar Bastian 1865	1.5	1.6	0.2	—	—

(Table II - continued)

Species (Adenophorea) Stations	1	2	3	4	5
Prismatolaimus intermedius (Bütschli 1873)	0.5	0.1	0.2	2.0	—
Prismatolaimus dolichurus (de Man 1880)	0.4	—	—	—	—
Achromadora ruricola (de Man 1880)	0.7	—	0.2	—	—
Achromadora terricola (de Man 1880)	4.7	0.1	—	—	—
Ethmolaimus pratensis (de Man 1880)	0.7	—	—	—	—
Alaimus primitivus de Man, 1880	0.2	—	—	—	—
Amphidelus sp.	—	0.1	—	—	—
Tripyla sp.	1.1	0.9	—	0.1	-
Tobrilus gracilis (Bastian 1865)	17.7	46.3	1.2	—	—
Tobrilus helveticus (Hofmänner 1914)	5.3	—	—	—	—
Tobrilus longus (Leidy 1852)	0.2	0.9	—	0.1	—
Tobrilus pellucidus (Bastian 1865)	0.8	0.6	—	—	—
Ironus tenuicaudatus de Man, 1876	0.6	—	—	—	—
Ironus longicaudatus de Man 1884		0.1	—	—	—
Mononchus truncatus Bastian 1865	0.4	1.3	1.7	0.4	0.1
Mononchus longicaudatus Cobb 1893	2.6	—	—	—	—
Clarkus papillatus (Bastian 1865)	0.4	—	—	—	—
Mylonchulus brachyuris (Bütschli 1873)	0.1	—	—	1.3	—
Mylonchulus sigmaturus (Cobb 1917)	0.2	0.1	—	0.8	0.1
Iotonchus sp.	0.1	—	—	0.1	—
Dorylaimus stagnalis Dujardin 1845	3.4	2.6	0.3	0.8	—
Mesodorylaimus centrocercus (de Man 1880)	0.5	—	—	—	—
Mesodorylaimus sp.	0.2	0.4	0.3	9.6	—
Eudorylaimus cfr. *carteri* (Bastian 1865)	1.0	—	—	—	—
Eudorylaimus sp.	0.2	0.1	—	—	—
Aporcelaimellus cfr. *obtusicaudatus* (Bastian 1865)	4.2	—	—	4.0	—
Paractinolaimus macrolaimus (de Man 1884)	0.1	—	—	—	—
Paravulvus hartingii (de Man 1880)	0.4	0.1	—	—	—
Tylencholaimus mirabilis (Bütschli 1873)	0.1	—	—	—	—
Tylencholaimus stecki (Steiner 1914)	0.6	—	—	—	-
Dorylaimellus sp.	—	—	0.1	—	—
Trichodorus sp.	0.4	—		—	—
Mermithidae gen. sp.	0.2	—	—	—	—
Number of specimens	854	798	572	1651	1133
Number of species	55	57	28	37	24
Diversity index	3.97	2.99	2.92	3.53	2.52
Evenness	0.53	0.58	0.62	0.68	0.55

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SUMMARY

The analysis of nematodes of freshwater sediments is proposed as a biological pollution parameter. The percentage of nematodes belonging to the subclass Secernentea appeared to be proportional to the COD value of water and inversely proportional to the quantity of dissolved oxygen. Within Secernentea, Diplogasteroidea are more numerous in waters with medium and high pollution, while in extremely polluted waters Rhabditoidea are dominant.

RIASSUNTO

Nematodi come indicatori del grado di inquinamento dei fiumi.

L'analisi dei nematodi dei sedimenti dei corsi d'acqua viene proposta quale parametro biologico d'inquinamento. La percentuale dei nematodi appartenenti alla sottoclasse Secernentea si è dimostrata essere proporzionale al valore di COD dell'acqua e inversamente proporzionale alla quantità di ossigeno disciolto. Nell'ambito dei Secernentea, i Diplogasteroidea sono più numerosi nelle acque a medio e forte inquinamento, mentre in quelle estremamente pollute prevalgono i Rhabditoidea.

RÉSUMÉ

Nématodes comme indicateurs de pollution des rivières.

L'analyse des nématodes dans les sédiments d'une rivière vient d'être proposée comme index biologique de pollution. Le pourcentage des nématodes appartenant à la sous-classe des Secernentea s'est montré proportionnel à la valeur de COD de l'eau et inversement proportionnel à la quantité d'oxygène dissous. Parmi les Secernentea, les Diplogasteroidea sont plus nombreux dans les eaux à moyenne et forte pollution, tandis que dans les eaux extrêmement polluées les Rhabditoidea prévalent.

LITERATURE CITED

BRINKHURST R. O., 1962 - The biology of Tubificidae with special reference to pollution. *Biol. Probl. Water Poll. III Sem.*, 57-66.

HIRSCHMANN H., 1952 - Die Nematoden der Wassergrenze mittelfränkischer Gewässer. *Zool. Jb. (Syst.)*, *81*: 313-436.

MARCHETTI R., 1968 - Indagine sul torrente Seveso. Pub. Etas-Kompass, Milano, 233 pp.

SLADECEK V., 1973 - System of water quality from the biological point of view. *Arch. Hydrobiol., Ergebn. Limnol.*, 7: 1-218.

TRUDGILL D. L., EVANS K. and FAULKNER G., 1972 - A fluidising column for extracting nematodes from soil. *Nematologica, 18*: 469-475.

TUFFERY G. and VERNEAUX J., 1968 - Methode de determination de la qualité biologique des eaux courantes. *C.E.R.A.F.E.R. Sect. Pêche et Pisciculture*, 1-21.

VILLA F., 1965 - Aspetti morfologici, geologici e idrogeologici del corso del torrente. In: R. Marchetti (1968) « Indagine sul torrente Seveso ». Pub. Etas-Kompass, Milano, 14-17.

WOODIWSS F. S., 1964 - The biological system of stream classification used by the Trent river board. *Chem. and Industry, 14*: 443-447.

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