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The silicon cycle in the southern Bight of the North Sea

Several investigators took part in a chemical oceanographic program, carried out during ten cruises in 1967, 1968 and 1969 by the Neth. Inst. for Sea Research. TIJSSEN (1) already reported results for S $^{o}/oo$, T, O_2, PO_4-P, NO_2-N, NO_3-N and Secchi disc visibility. DE KROON measured potential primary productivity during part of the cruises; results are presented by DE KROON and GIESKES to this ICES assembly (2). Determinations of reactive silicate (further called Si; all values in μgat/L) and phytoplankton counts with special attention to diatoms were made by this author.

The general hydrography of the eastern part of the southern Bight discernes two water types, English Channel Water (E.C.W.) and river water, for about 80% consisting of Rhine water, the other 20% originating from the Meuse and the Scheldt. Tidal currents and a northeast flowing residual current mix these two watertypes into a watermass, Dutch Coastal Water (D.C.W.), for which a pattern of isosalines parallel to the Dutch coast is characteristic.

Results of Si-determinations will be published in the near future. Only some general statements can be given here. Contour lines of Si (see fig. 1A and 1B) agree well with those found by JOHNSTON and JONES (3), except in august.

In the central southern Bight distribution of Si and of diatoms is patchy all the year round. In february diatom patches (Chaetoceras, Rhizoselenia species) coincide with Si minima and pot. prim. prod. maxima. Sometimes Si and

NO_3 are depleted simultaneously, sometimes Si reaches values of 0.1, while NO_3 is still about 2 and PO_4 about 0.25.
In may all Si values are smaller than 1.
In august a tongue of water with relatively high Si, high salinity and very small amounts of phytoplankton was repeatedly found as indicated in fig. 1A. This feature could be traced only due to the dense station grid we used; it is not shown in the atlas of the marine environment (loc. cit.). This water is assumed to be E.C.W. In november a longish patch of low Si (1-2) is present at near maximum salinities and not coinciding with appreciable amounts of diatoms.
In <u>Dutch coastal water</u> Si is a conservative factor in february and november, not in may and august, when Si is smaller than 1 at salinities ranging from about 30 to 34 $^{o}/oo$.
Then, more Si is only found very near to river mouths.
Many diatoms are present in may (Rhizoselenia, Eucampia species) and in august (Thallassiosira, Chaetoceras species).
Potential primary production was high in spring and especially in summer, when it gradually increased towards the coast. This heavy summer population of diatoms is clearly caused by intrusion of polluted river water.

Some rough calculations were made on the nutrient budget in the august 1968 situation for the area indicated in fig. 1A. In this area the water has a residence time of the order of one month. Two groups of stations, lying in D.C.W. were averaged, A with S $^{o}/oo$ about 32 and B around 29.5 S $^{o}/oo$, meaning 7 and 15% of river water respectively. PO_4, NO_3 and S $^{o}/oo$ were taken from TIJSSEN (loc. cit.) and for river (Rhine) water from the reports of the International Rhine Commission (4).
Calculations were made in the manner indicated in fig. 3, figures in parenthesis give the contribution of river water, taken as Rhine water, to the calculated amount of nutrients. NO_3 removal values are minimum amounts; the

60 μgat/L present in the Rhine as NH_3-N could not be taken into account, as this compound was not measured in D.C.W.

	S $^o/oo$	PO_4-P	H_4SiO_4-Si	NO_3-N
E.C.W.	34.55	0.12	3	0.2
RHINE	0.5	4.5	50	160
A calculated		0.43 (0.32)	6.5 (3.5)	11 (11)
found	32.1	0.10	0.5	0.6
removed		0.33	6	10.4
B calculated		0.78 (0.68)	10 (7.5)	24
found	29.5	0.5	2	9
removed		0.28	8	15

Consumption of P, Si and N, presumably by phytoplankton is thus found to occur in the ratio of 1 : 18 : 31 for A and 1 : 29 : 54 for B. The Si/N ratio compares favourable to results of SCHOTT and EHRHARDT (5) who found in september 1968 P, Si and N in a ratio of 1 : 6 : 12 below the thermocline in the northern North Sea.
Clearly the amount of P removed is too low, however, extra sources of P are known to exist. A big amount of domestic waste is discharged in the coastal area and VEGTER (6) found an extra input of P in the transition zone between river and D.C.W., probably caused by accumulation and subsequent mineralisation of organic matter in this transition zone.

Conclusions on the macronutrients budget, as influenced by the Rhine are different for N, P and Si.
All nitrogen is supplied by river water.
Most of the phosphorus is also supplied by land drainage, either directly by river water and sewage outfalls or indirectly in a mineralisation zone in the estuary. River contribution of silicon is relatively lower than for N and P, it increases towards the coast. Everywhere in D.C.W.

Si concentrations are lower than those of N and P, hence Si seems to be the limiting factor in maintaining the diatom population.
In other river plumes, nitrogen is often found to be the limiting macronutrient. The unusual situation in Dutch Coastal Water may be caused by the quite low quantity of Si in the Rhine (50; world river average 215), enhanced by the marked seasonal periodicity as shown in fig. 2.
This seasonal periodicity of Si is also found in the Meuse (180 in winter; 25 in summer) in the Ems (220 and 8), but not in the Scheldt (220)

Literature cited:

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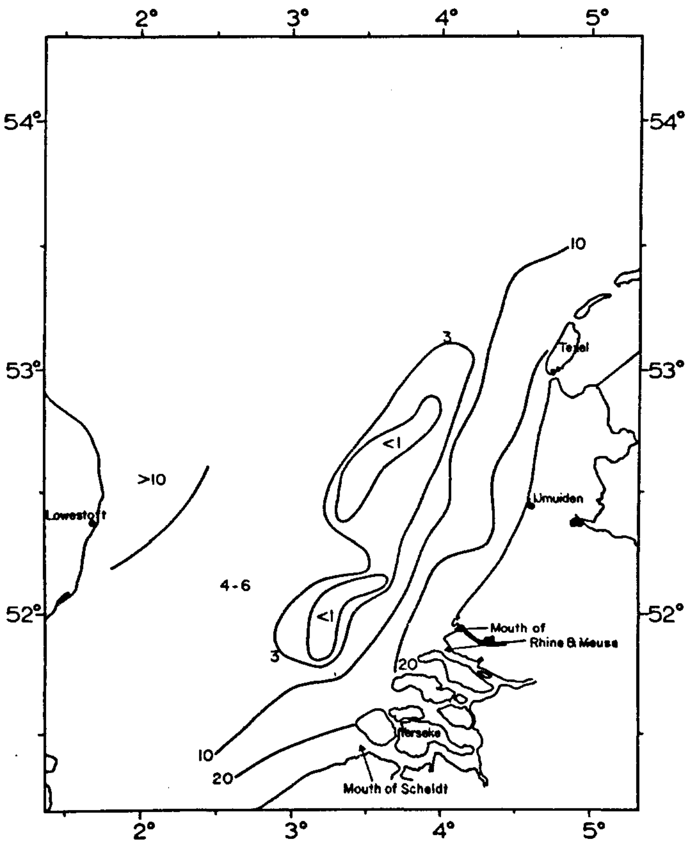

Fig. 1a 1968, aug. 26 - sept. 6

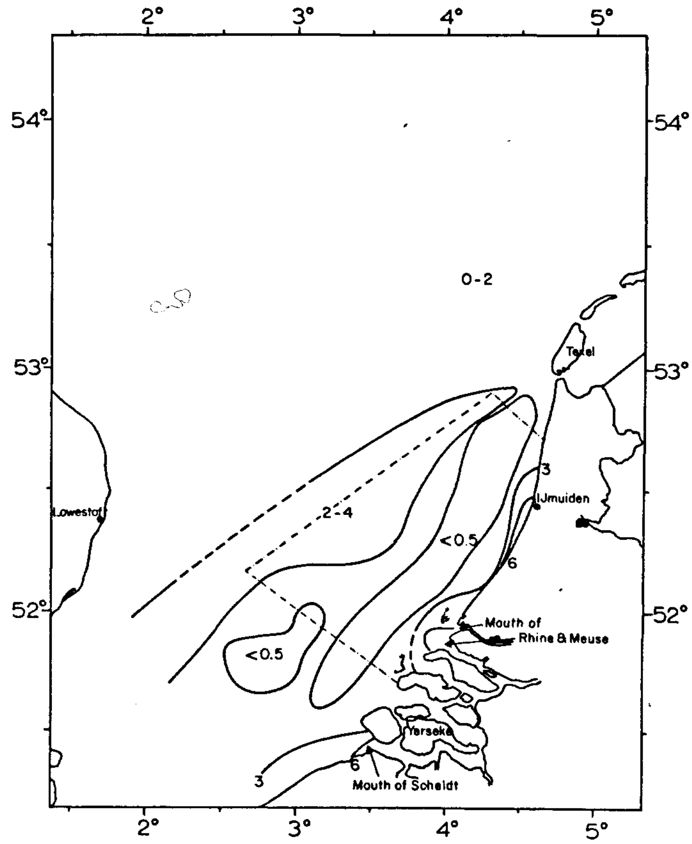

Fig. 1b 1969, feb. 7 - 18

Reactive Silicate in the southern North Sea
Figures in μ gat/L

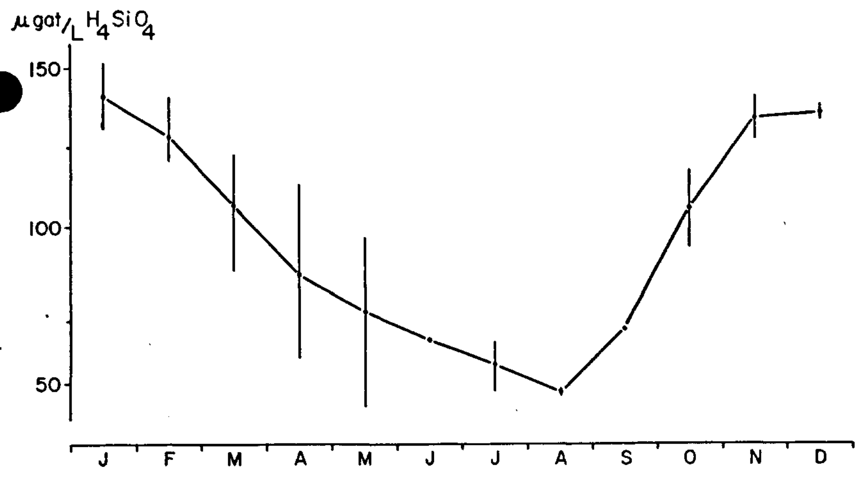

Fig. 2 Monthly averages and ranges of reactive silicate in the river Rhine, irregularly sampled 1967 - 1971

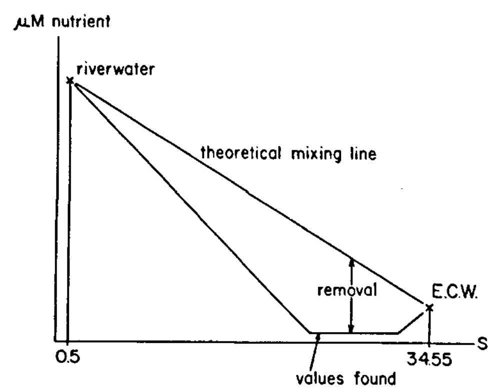

Fig. 3 Procedure for calculations of nutrient removal.