Copyright ©

Kieler Meeresforsch., Sonderh. 5, 304 – 310. Kiel 1981

DOC-turnover and microbial biomass production*

M. Bölter
Sonderforschungsbereich 95 an der Universität Kiel
Kiel, Germany

Abstract

Uptake data of seven sugars (mono- and disaccharides) were used to calculate DOC-turnover and microbial biomass production. The sugars investigated in this study represent 1–2 % of the DOC and up to 30 % of the free dissolved carbohydrates. The uptake measurements were not based on a kinetic approach. Uniformly labelled ^{14}C-carbohydrates were added to the samples, the concentrations reaching maximally 10 % of the corresponding natural substrate concentration. Taking the natural substrate concentration into account, it is possible to calculate the actual uptake rates, turnover times and microbial C-production. An investigation in the Kiel Fjord during 1978/79 shows turnover times for glucose between 1.7 and 600 hours. The microbial biomass production varies between 0.01 and 10 $\mu g\ C\ l^{-1}\ h^{-1}$, i.e. 0.2 – 83 % of the primary production. The ratio between incorporation and gross uptake is between 0.62 and 0.95, which supports the assumption that free dissolved carbohydrates are biochemically wellutilized substrates. The relation to exudates is discussed.

Introduction

Dissolved organic carbon (DOC) is an important energy source for bacteria and other heterotrophs in the sea. Measurements on the standing stock of the DOC result in 0.5 – 5 mg l^{-1}, depending on the trophic level of the ecosystem (PARSONS and STRICKLAND 1962, BANOUB and WILLIAMS 1973, SHARP 1973, HOOD 1970). However, a detailed view of this group of substances shows that only about 30 % of this pool is analysable (DUURSMA 1961, DEGENS 1970, WILLIAMS 1975). The residual is sometimes summarized as the pool of humics or 'Gelbstoff' which may be regarded as not involved in the fast cycling of the food chain. Free dissolved amino acids and sugars may represent only 1 – 2 % of the DOC-pool (MOPPER et al. 1980, LIEBEZEIT, pers. comm.).

Many investigations into this pool of free dissolved organic substances show that they are involved in a very fast-moving cycle and are attacked immediately by microorganisms.

Material and methods

The sampling station was located in the inner Kiel Fjord. The water sample was taken with a sterile sampler and processed in the laboratory at *in situ* temperature. Uptake studies were carried out by the tracer technique using U-^{14}C-carbohydrates with high specific activity. The glucose used in this study had a specific activity of 313 mCi $mmol^{-1}$, the added amount per 10 ml water sample was 0.025 μCi, i.e. 0.0145

* Publication No. 280 of the Joint Research Program at Kiel University (Sonderforschungsbereich 95 der Deutschen Forschungsgemeinschaft).

μg. Duplicate samples and a blank (fixed with 50 μl of formalin) were run for different incubation times, 15', 30', 60', 90', 120' (180'). Duplicate sets were used to measure incorporation (filtration through 0.2 μm membrane filters) and respiration (acidification with 0.2 ml. 5 N H_2SO_4 and trapping the $^{14}CO_2$ by 0.15 ml ethanolamin). Radioactivity was determined in a liquid scintillation counter using a dioxane-naphthaline medium containing 120 g naphthaline per liter dioxane and 5.5 g Permablend III (Packard). The uptake rates were calculated (non-kinetic approach) from the slope of the uptake curves by linear regression. Actual uptake rates result from multiplying gross uptake (incorporated plus respired ^{14}C-glucose) with the quotient of the total amount of glucose present in the sample and the amount of labelled solute added. The determinations of glucose were carried out by LIEBEZEIT according to the method described by LIEBEZEIT et al. (1980), the measurements on primary prodcution and exudates were carried out by WOLTER (1980).

Results and discussion

The seasonal cycle shows marked variations in the parameters measured. Figure 1 shows the fluctuations in the glucose concentrations, the actual uptake rates and the turnover times of glucose during the investigation period. The mean value of the glucose concentration is 32 μg l^{-1}, i.e. 0.4 % of the DOC. The actual uptake rate varies from 0.03 to 38 μg $l^{-1}h^{-1}$, corresponding to a variation of the turnover time from 188 to 1.8 h.

In comparison to other monosaccharides (fructose, galactose, mannose, ribose, and xylose) which were also analysed in this study, glucose exhibits the highest uptake rates and seems to dominate the system.

Based on the incorporation of the substrate, it is possible to calculate the biomass production. Figure 2 shows the bacterial biomass production which is based on the glucose incorporation in relation to the primary production. The bacterial production varies between 0.07 and 61 μg C l^{-1} 6 h^{-1}, the primary production shows fluctuations between 1 and 500 μg C l^{-1} 6 h^{-1}.

The comparison between the mean values of the bacterial biomass production based on the different hexoses shows that the values due to glucose are fairly similar to those based on the exudates (c.f. WOLTER 1980). Both estimations on (biomass) production result in approximately 8 μg C l^{-1} 6 h^{-1}. The production based on fructose, galactose and ribose averages altogether only 45 % of that of glucose. This close relation between glucose and exudates, where the latter may be regarded as a natural primary substrate for the bacterial population, may also be documented by their combined relation to the primary production for most seasons of the year.

Figure 3 gives an impression of the bacterial production based on glucose and exudates in relation to the primary production which was set to 100 per cent. It is of interest that the exudates are sometimes "unused", i.e. they show very long turnover times (e.g. March and October 1978). This further indicates the differences in the availability of these substrates. In winter, when the primary production drops to 1 μg C l^{-1} 6 h^{-1} (cf. fig 2) the bacterial biomass production based on glucose seems to govern the system; nevertheless, its production is low.

Taking into account the standing stock of the bacterial biomass, it is possible to calculate the corresponding turnover times. Figure 4 shows these different patterns in microbial biomass production, i.e. microbial activity based on these substrates. During

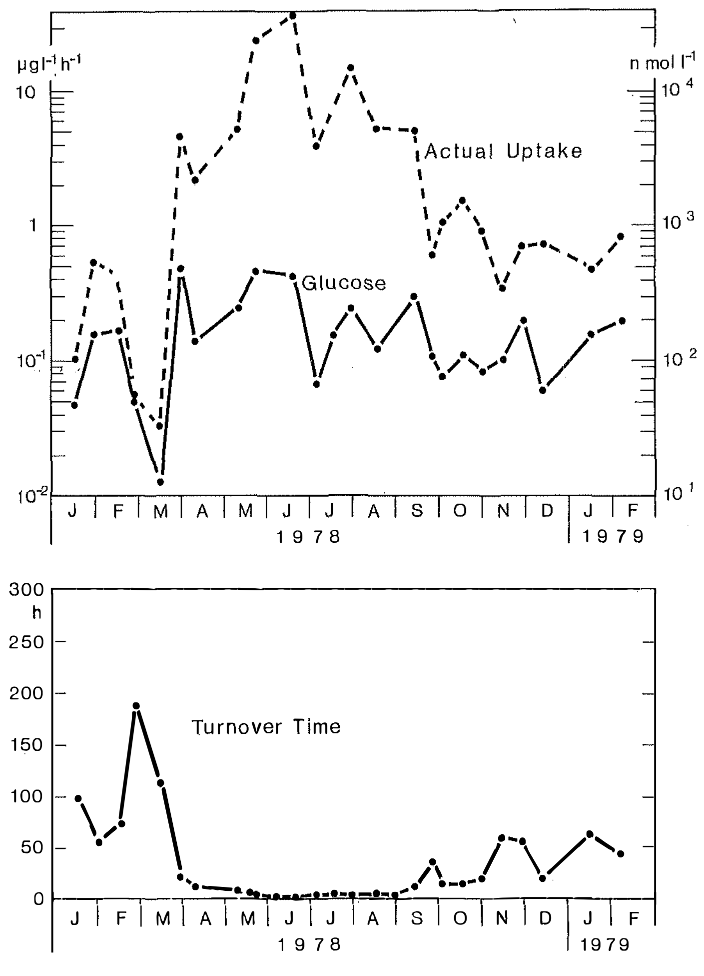

Figure 1

Annual cycle of the glucose concentration and the actual uptake of glucose (upper diagram) and the turnover time of glucose

April to October only small variations in the turnover of these compounds are visible. The data in early spring 1978 and October/November 1978, however, show drastic changes in the use of the substrates: glucose and espescially the exudates do not correspond to well-usable substrates. However, the high turnover times for glucose in January and March 1978 may also be strongly effected by the low temperatures near 0°C.

Since glucose represents 60 ± 20 % of the free dissolved monosaccharides at nearly all times of the year and the residual is mainly represented by fructose (LIEBEZEIT 1980), this sugar may be regarded as a functional constituent of the free dissolved carbohydrates available for bacteria. Thus, glucose may be considered a central module in the DOC turnover.

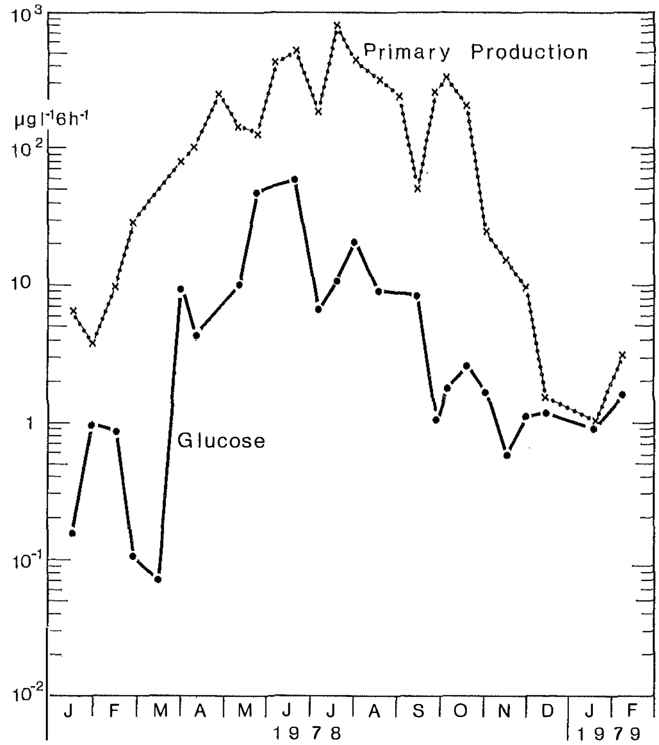

Figure 2

Seasonal cycle of primary production (dashed line) and bacterial biomass production based on glucose (solid line)

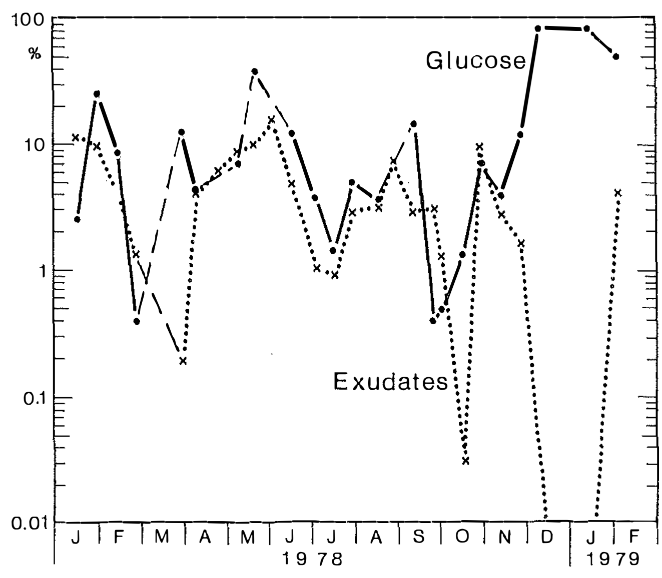

Figure 3

Microbial biomass production based on exudates and on glucose in relation to primary production (Prim. Prod. = 100 %)

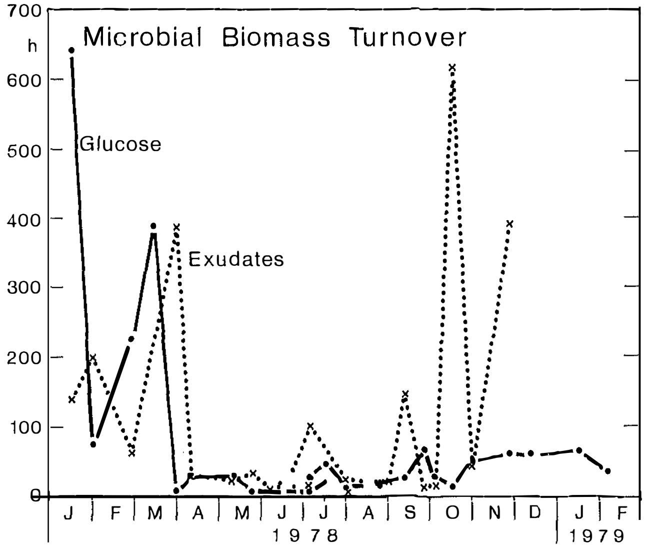

Figure 4

Microbial biomass turnover based on the biomass production according to the incorporation of exudates and glucose

The similar fluctuations of the uptake of glucose and the uptake of exudates show their equivalent availability and use by microorganisms. Further, this leads to the assumptions that both exudates and monosaccharides are in the same range of molecular weight and molecular structure.

However, the variations of microbial biomass production based on the different sugars and exudates show that there are distinguishable differences in these substrates and/or changes in the bacterial population which prefer the one or other source of energy. The general utilization of glucose for microbial biomass production is furhter evident by the ratio of incorporated versus respired material which was found to be between 0.62 and 0.95 in the annual cycle, the mean value being 0.76. This supports the assumption that glucose is really used for biomass production. The respiration on exudates was in the range of 18 to 62 % (WOLTER 1980).

Based on the amount of glucose respired, it is possible to calculate the remineralization rate. Figure 5 shows the annual cycle of this parameter which was found to be between 1.7 and 12.9 x 10^{-3} μg glucose l^{-1} h^{-1}. Compared with the corresponding oxygen consumption, this rate is on average 1.6 μg 0_2 l^{-1} h^{-1}.

Under the assumption that all free monosaccharides and similar substrates are broken down in a similar way and that glucose represents 10 – 50 % of these substances, one can calculate a biological oxygen demand (BOD) of 0.07 – 0.4 mg l^{-1} d^{-1}. This value is approximately within the range of BOD-measurements from the Kiel Fjord, done in the same investigation period by SALTZMANN (1980). Other calculations (SADJADI 1980) from the water column in July in Kiel Bight result in an oxygen consumption of 0.2 mg 0_2 l^{-1} d^{-1}.

These conformities show that glucose may be accepted as a model for the free available substances which are used as main energy sources by microbial populations and their biomass production. Thus free dissolved carbohydrates and

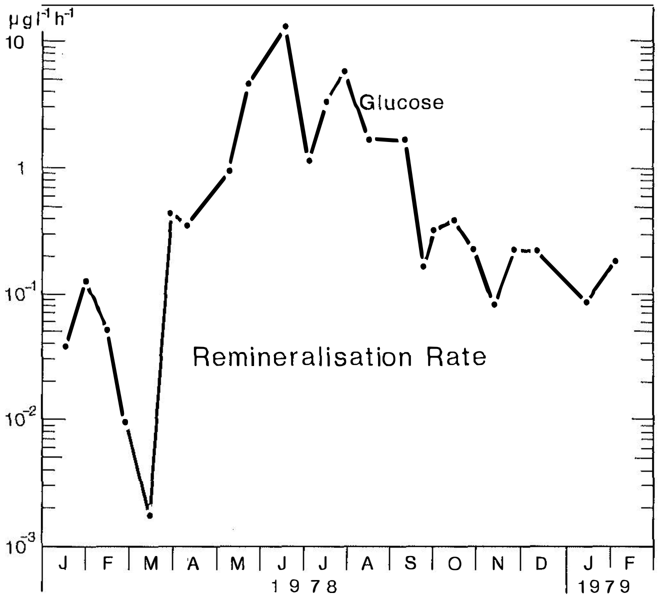

Figure 5
Remineralisation rate of glucose during the annual cycle

their turnover may be compared to exudates and other "natural", i.e. functional, substances. They are valuable links between dissolved and particulate matter, as represented also by bacteria, which are then available to other members of the food chain.

References

BANOUB, M. W. and P.J. LeB. WILLIAMS, 1973. Organic material in the sea. J. Mar. Biol. Ass. U.K. **53**, 695–704.

DEGENS, E. T., 1970. Molecular nature of nitrogenous compounds in sea water and recent marine sediments. In: D.W. Hood, (ed.): Organic matter in natural waters. Inst. Mar. Sci. Occ. Publ. **1**, 77–106.

DUURSMA, E. D., 1961. Dissolved organic carbon, nitrogen and phosphorous in the sea. Neth. J. Sea Res. **1**, 1–148.

HOOD, D. W. (ed.), 1970. Organic matter in natural waters. Inst. Mar. Sci. Occ. Publ. **1**, 625 pp., Alaska.

LIEBEZEIT, G., 1980. Aminosäuren und Zucker im marinen Milieu – neuere analytische Methoden und ihre Anwendung. Diss. Univ. Kiel, 195 pp.

LIEBEZEIT, G., M. BÖLTER, R. DAWSON and F. BROWN, 1980. Dissolved free amino acids and carbohydrates at pycnocline boundaries in the Sargasso Sea and related microbial activity. Oceanol. Acta **3**, 357–362.

MOPPER, K., V. ITTEKOT, R. DAWSON and G. LIEBEZEIT, 1980. The monosaccharide spectra of natural waters. Mar. Chem. **10**, 55–66.

PARSONS, T. R. and J.D.H. STRICKLAND, 1962. On the production of particulate organic carbon by heterotrophic processes in sea water. Deep-Sea Res. **8**, 211–222.

SADJADI, S.A.S., 1980. Sauerstoffbilanz der Kieler Bucht. Diss. Univ. Kiel, 106 pp.

SALTZMANN, H. A., 1980. Untersuchungen über die Veränderungen der Mikroflora beim Durchgang von Brackwasser durch die Kühlanlagen von Kraftwerken. Diss. Univ. Kiel, 124 pp.

SHARP, J. H., 1973. Total organic carbon in sea water – composition of measurements using persulfate oxidation and high temperature combustion. Mar. Chem. **1**, 211–230.

WILLIAMS, P. J. LeB., 1975. Biological and chemical aspects of dissolved organic material in sea water. In: J.P. Riley and G. Skirrow (eds.): Chemical oceanography, Vol. 2, 301–363, Academic Press, N.Y.

WOLTER, K., 1980. Untersuchungen zur Exsudation organischer Substanz und deren Aufnahme durch natürliche Bakterienpopulationen. Diss. Univ. Kiel, 127 pp.