

Y.I. Sorokin

# Radioisotopic Methods in Hydrobiology

With 97 Figures and 14 Tables



Springer

# Contents

<b>1</b>	<b>General Features of Radioisotopic Methodology and Measurement of Radioactivity</b>	<b>1</b>
1.1	Physical Background	1
1.2	Measurement of Radioactivity	6
1.2.1	General Considerations	6
1.2.2	Liquid Scintillation Counting	7
1.2.2.1	Basic Principles	7
1.2.2.2	Practical Use of Liquid Scintillation Counting	10
1.2.2.3	Quenching and Quench Correction	13
1.2.2.4	The Effect of Chemoluminescence	17
1.2.3	Application of Radioisotopic Methods in Hydrobiology	18
<b>2</b>	<b>The Radiocarbon Method to Estimate Primary Production in Aquatic Environments</b>	<b>21</b>
2.1	Introduction	21
2.2	Historical Proceedings	22
2.3	Technique of Measuring Phytoplankton Primary Production	26
2.3.1	General Principles	26
2.3.2	Practical Use of the $^{14}\text{C}$ -Methodology to Estimate $C_{ps}$	27
2.3.2.1	Preparation of $^{14}\text{C}$ -Carbonate Working Solution and Determination of its Radioactivity ( $R_i$ )	27
2.3.2.2	Estimation of Total Hydrocarbonate Carbon Contents in Water ( $C_i$ )	31
2.3.2.3	Selection of Bottles for Experiments and Their Preparation	32
2.3.2.4	Sampling Technique	34
2.3.2.5	Experiments to Measure the Absolute Photosynthesis Rate ( $C_p$ ) and Primary Production ( $C_{ps}$ ) in the Surface Water Layer	35
2.3.2.6	Practical Problems of Filtration and Measuring Radioactivity of Filters	40
2.3.2.7	Estimating correction Coefficients ( $K_f$ , $K_c$ )	42
2.3.3	Estimating Integrated Pelagic Primary Production in the Water Column ( $C_{pt}$ )	48
2.3.3.1	The $C_{pd}$ Method	50

2.3.3.2	$K_p$ Calculative Method .....	54
2.3.3.3	Conversion from Daily Rates to the Whole Basin and Annual Primary Production .....	61
2.4	Faults in the Radiocarbon Method and Problems in its Calibration .....	64
2.5	Use of the Radiocarbon Method to Determine Primary Production by Benthic Hydrophytes and Their Associations ....	74
2.5.1	General Principles in the Use of $^{14}\text{C}$ – Methods .....	76
2.5.2	Experimental Vessels and Enclosures .....	78
2.5.3	Preparation of Working Solution of $^{14}\text{C}$ – Carbonate .....	82
2.5.4	Incubation Procedures .....	85
2.5.5	Estimation of Radioactivity in Plant Material .....	94
2.5.6	Calculation of Results; Comparison with Alternative Methods ..	97
<b>3</b>	<b>Radioisotopic Methods for the Study of Nutrition in Aquatic Animals .....</b>	<b>100</b>
3.1	Introduction. Alternative Methods .....	100
3.2	General Principles .....	104
3.3	Preparation of Labeled Food .....	107
3.3.1	Labeling Algae and Plant Detritus .....	107
3.4	Analyses of Basic Values Needed for the Calculation of Intensity and Efficiency of Nutrition .....	112
3.4.1	Estimation of $C_r$ .....	112
3.4.2	Determination of Radioactivity in Consumers' Bodies ( $R_o$ ) ....	115
3.4.3	Determination of Radioactivity of Respired $\text{CO}_2$ and Feces ....	118
3.4.4	Estimation of the Inverse Specific Radioactivity of $\text{CO}_2$ Respired by Labeled Animals ( $C_q$ ) .....	119
3.5	Use of $^{14}\text{C}$ for Assessment of Nutritional Problems in the Ecology and Physiology of Aquatic Animals .....	120
3.5.1	Assessing the Duration of Digestion .....	121
3.5.2	Assessing Comparative Rates of Food Ingestion and Assimilation .....	121
3.5.3	Radiocarbon Estimation of the Relative Rate of Respiration ...	126
3.5.4	Evaluation of Food Spectrum and Selectivity .....	127
3.5.5	Dependence of Nutrition Rate upon Food Concentration .....	129
3.5.6	Experimental Evaluation of Other Factors Influencing Nutrition Rate .....	132
3.5.7	Determining Filtration Rates in Filter Feeders .....	135
3.5.7.1	General Considerations .....	135
3.5.7.2	Technique for $F_r$ Determination .....	136
3.6	Measurements of Absolute Rates of Feeding, Food Assimilability, and Respiration .....	138
3.6.1	General Considerations .....	138

3.6.2	Technique of the Balance Experiment .....	139
3.6.3	Estimations of Aquatic Animal Nutrition with Dissolved Organic Matter .....	143
3.6.3.1	General Remarks .....	143
3.6.3.2	Technique for Measurement of DOM Uptake .....	146
3.6.4	Radiocarbon Method of Measurement of Absolute Rates of Respiration .....	149
3.7	Concluding Remarks .....	151
<b>4</b>	<b>Use of Radioisotopic Methodology in Aquatic Microbial Ecology .....</b>	<b>154</b>
4.1	Introduction .....	154
4.2	Estimation of Relative Microbial Activity in Aquatic Habitats .....	156
4.2.1	General Remarks .....	156
4.2.2	The Technique of Microradioautography .....	159
4.2.3	A Study of the Spatial Distribution of Metabolically Active Heterotrophic Microbial Populations .....	160
4.2.3.1	General Remarks .....	160
4.2.3.2	Practical Implementation .....	165
4.3	Determination of the in situ Decomposition Rates .....	171
4.3.1	General Remarks .....	171
4.3.2	Practical Implementation .....	174
4.4	Determination of Microbial Production .....	177
4.4.1	Introduction .....	177
4.4.2	Application of $^{14}\text{CO}_2$ Dark Uptake for Estimation of Heterotrophic and Chemoautotrophic Microbial Production .....	183
4.4.2.1	Introduction .....	183
4.4.2.2	Measuring Production of Heterotrophic Bacteria .....	186
4.4.2.3	Estimating Chemosynthetic and the Overall Bacterial Production in the Redox Zones Within the Water Column .....	194
4.4.2.4	Determination of Anoxygenic Bacterial Photosynthesis .....	197
4.4.3	The Thymidine Method .....	199
4.4.3.1	General Considerations .....	199
4.4.3.2	Practical Procedure .....	210
4.4.3.3	Measuring Bacterial Production in Bottom Sediments .....	214
4.4.4	The Labeled $\text{PO}_4\text{P}$ – Uptake Method .....	217
<b>5</b>	<b>Use of Radioisotopes to Study Biogeochemical Cycling of Elements in Aquatic Environments .....</b>	<b>220</b>
5.1	Introduction .....	220
5.2	Study of Microbial Methane Oxidation Using $^{14}\text{C}$ .....	221

5.2.1	General Remarks .....	221
5.2.2	Practical Procedures .....	223
5.3	Estimation of in situ Methane Production Rates .....	228
5.4	Measurement of Nitrification Rate with the $^{14}\text{CO}_2$ Dark Uptake Method .....	229
5.5	Studying Sulfur Cycling with the Aid of $^{35}\text{S}$ .....	230
5.5.1	Introduction .....	230
5.5.2	Measuring the Rate of Sulfide Oxidation .....	232
5.5.2.1	Preparation of the Working Solution of Labeled Sulfide .....	234
5.5.2.2	Experimental Procedure .....	237
5.5.3	Oxidation Rates of Thiosulfate and Elemental Sulfur .....	240
5.6	Study of Sulfate Reduction .....	242
5.6.1	General Remarks .....	242
5.6.2	Practical Implementation: Bottom Sediments .....	248
5.6.2.1	Preparation of the Working Solution of Labeled Sulfate .....	248
5.6.2.2	The Slurry Method .....	249
5.6.2.3	The Core Method .....	252
5.6.3	Practical Implementation: Water Column .....	253
5.6.4	Location of Active Populations of Sulfate-Reduction Bacteria ..	255
5.7	Study of the Dynamics of Phosphorus .....	256
5.7.1	General Remarks .....	256
5.7.2	Measuring $\text{PO}_4\text{P}$ Uptake Rates by Microplankton .....	263
5.7.2.1	Preparation of the Isotope Working Solution .....	263
5.7.2.2	Estimation of the Total $\text{PO}_4\text{-P}$ -Uptake by Microplankton .....	265
5.7.3	Estimation of the Share of Bacterioplankton in Total $\text{PO}_4\text{-P}$ Consumption by Microplankton .....	265
5.7.4	Estimation of in situ $\text{PO}_4\text{-P}$ Regeneration Rates .....	267
5.7.5	Consumption of $\text{PO}_4\text{-P}$ from the Water Column by the Elements of Bottom Biotopes .....	268
<b>6</b>	<b>Assay of Some Common Hydrobiological Techniques .....</b>	<b>272</b>
6.1	Techniques for the Quantification Density of Microplankton Populations .....	272
6.1.1	Phytoplankton .....	272
6.1.2	Heterotrophic Microplankton .....	281
6.1.2.1	Bacterioplankton .....	281
6.1.2.2	Nanoheterotrophs .....	282
6.1.2.3	Planktonic Ciliates .....	283
6.1.2.4	Multicellular Microzooplankton .....	285
6.2	Quantification of Mesozooplankton .....	286
6.3	Total Plankton Respiration, Stock of Labile Organic Matter, and its Turnover Time .....	289

6.4	Determination of Free H <sub>2</sub> S and Labile Sulfides in Bottom Sediments .....	292
6.5	Conclusion .....	294
<b>References .....</b>		<b>296</b>