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Progress Report Concerning International Atomic Energy Agency Research Contract

No.: 37

June 1961 - April 1962.

Report by:

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F O R E W O R D

This progress report, the fourth report concerning the International Atomic Energy Agency Research Contract No. 37, covers the period June 1, 1961 - May 1, 1962.

The paper gives in outline a description of the work performed during the period. A discussion of the most important results obtained from the experiments in the model recipient during the first summer with continuous operation, was given in the third report to the International Atomic Energy Agency, dated November 25, 1961.

The present report contains an account of the work performed in the experimental plant during the summer and autumn 1961 not previously reported, together with information about the experimental part of the investigation carried out in the laboratories throughout the winter months 1961 - 1962.

We feel free to stress that the report has an informative character, and does not comprise final discussions of the results obtained or concluding treatment of the problems under consideration.

The accomplishment of the research work on the present project has - as in the previous periods reported - been done in cooperation between the Institute for Atomic Energy and the Norwegian Institute for Water Research.

We extend gratitude to the International Atomic Energy Agency for the financial aid and the superintendence of the research project.

Blindern, June 22 , 1962

Olav Skulberg

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1. A BRIEF REVIEW OF THE ACTIVITIES DURING THE PERIOD

The investigations in the experimental plant were entered upon on April 19, 1961, (see second progress report, covering the period August 1960 - June 1961).

During May and the first half of June the regular observations of the development of biota in the throughflow channel systems were performed together with the preparations for the summer programme of investigations.

The study of organism development and the changes of communities in the model recipient formed the base for the experiments of synecological type. The experiments have been performed with the radioisotopes:

P^{32}, Cs^{134}, Sr^{89}, Ru^{106}, I^{131}, U (nat.)

The major organisms in the throughflow channel system which were objects for measurements comprise:

Spirogyra cf. formosa, Spirogyra cf. porticalis, Fragilaria capucina var. mesolepta, Vaucheria sp., Oedogonium sp., Eurycercus lamellatus, Anodonta cygnea.

The aim with the experiments was to describe the behaviour of the radioisotopes with respect to distribution and uptake among organisms and sediments in the throughflow channel biotopes. The accumulation of the radioisotopes by major species in situ in their respective communities have been given attention.

The following list enumerates the experiments and observations performed during the operation of the model recipient in 1961.

1. Uptake of P^{32} by major species in the algal communities. Throughflow channel No. 4. Spirogyra sp., Oedogonium sp. (June 16 - June 17, 1961).

2. Experiments with Phoxinus phoxinus and Salmo trutta. Radioisotope P^{32} (June 21 - August 10, 1961).

3. Uptake of P^{32} by major species in the algal communities. Throughflow channel No. 2. _Spirogyra sp._, _Oedogonium sp._, _Fragilaria sp._, _Vaucheria sp._ (June 22 - June 23, 1961).

4. Sudden versus continuous dosing of radioisotopes (June 28, 1961).

5. Experiment in the recirculation channel with P^{32} and uptake by _Callitriche verna_, _Scirpus acicularis_, _Alisma Plantago-aquatica_, _Chara Braunii_, _Astacus fluviatilis_, _Anodonda cygnea_ (July 5 - July 14, 1961).

6. The variation in electrolytic conductivity during passage of water through the experimental plant (July 11, 1961).

7. Uptake of Cs^{134} by organisms in the throughflow channel No. 4. _Spirogyra sp._, _Oedogonium sp._, _Eurycercus lamellatus_ (July 20 - July 24, 1961).

8. Uptake of P^{32} by organisms in the throughflow channel No. 2. _Spirogyra sp._, _Oedogonium sp._, _Eurycercus lamellatus_ (July 20 - July 24, 1961).

9. The use of _Anodonta cygnea_ as a test organism for biological reconcentration of radioactive wastes in a river recipient. (July 25 - August 15, 1961).

10. Flow rate and flow pattern studies (August 16 - August 25, 1961).

11. Investigations on hydrobiological conditions in the retention pond (August 25 - September 3, 1961).

12. Uptake of Sr^{89} by organisms in the throughflow channel No. 4. _Spirogyra sp._, _Oedogonium sp._, _Anodonta cygnea_ (September 5 - September 12, 1961).

13. Uptake of Sr^{89} by major species in the algal communities. Throughflow channel No. 4. _Spirogyra sp._, _Oedogonium sp._ (September 20 - September 25, 1961).

14. Uptake of Ru^{106} by major species in the algal communities. Throughflow channel No. 3. Spirogyra sp., Oedogonium sp. (October 3 - October 4, 1961).

15. Uptake of I^{131} by major species in the algal communities. Throughflow channel No. 3. Spirogyra sp., Oedogonium sp. (October 16 - October 17, 1961).

16. Uptake of U(nat.) by major species in the algal communities. Throughflow channel No. 3. Spirogyra sp., Oedogonium sp. (October 18 - October 19, 1961).

17. Variation pattern of turbidity and electrolytic conductivity in the river water during a heavy rainfall in the drainage basin. (October 16 - October 20, 1961).

The results obtained from most of the experiments are previously discussed (see report dated November 25, 1961). As an addendum (appendix 1) the data obtained from the undertakings in the model recipient are concentrated as documentation. In the present report an account of the work carried out concerning the numbers 6, 10, 11, and 17 in the list above is given.

The study of water movement in the model recipient was brought to an end during the period under consideration. Important knowledge was gained through this work, and the information obtained prove necessary for the operation of the experimental plant.

The floristic investigation of the communities of the retention pond was finished. Vegetation was recorded on the bathygraphical map. The specific purpose of the recording of vegetation is to give a base for the description of the change of contamination level in the water in response to biological activity.

The study of seasonal and daily variations of electrolytic conductivity, pH, and turbidity in the river water described in the second progress report, was completed during the present period. The interesting relationship between the variations of these factors and the meteorological conditions and the character of the drainage basin, were given particular attention in a separate set of observations.

The last observations in the experimental plant for the season was done on November 3, 1961. The frost situasion then made it necessary to prepare the experimental plant for the winter condition. The winter lasted during the rest of the period covered by the present report.

During the winter months our activities have been concentrated upon laboratory work. The studies on water - sediments - algae interrelationships are continued. Further investigations on sorption phenomena have been carried out, together with work on accumulation of radioisotopes by algae. The experiments will give information about the role of radionuclides sorbed to particles, how they may be mobilized for the metabolism of algae and therewith enter the food chain.

On January 16, 1962, there was a conference to discuss the status and progress of the work concerning International Atomic Energy Agency Research Contract No. 37. Participants were:

Erik Eriksson	Doctor, International Atomic Energy Agency.
Kjell Baalsrud	Director, Norwegian Institute for Water Research.
Gudbrand Jenssen	Senior Scientist, Institute for Atomic Energy.
Eivind Stedje	Chief of Health Physics Department, Institute for Atomic Energy.
Karen Halvorsen	Radiochemist, Institute for Atomic Energy
Olav Skulberg	Botanist, Norwegian Institute for Water Research.

During the conference, the scientific scope of the International Atomic Energy Agency Research Contract No. 37 was recapitulated by Kjell Baalsrud. The most important results obtained from the work carried out were presented by Karen Halvorsen and Olav Skulberg. During the afterwards discussions the research programme for 1962 was handled.

In connection with this conference there was an excursion to the field station, and demonstrations of laboratory experiments.

The detailed programme for the experimental work with the model recipient during the summer of 1962 was drafted on the colloquium March 19 - March 21, 1962. Participants were:

Kjell Baalsrud	Director, Norwegian Institute for Water Research.
Theodore Olson	Professor of Public Health Biology, University of Minnesota, USA.
Gudbrand Jenssen	Senior Scientist, Institute for Atomic Energy.
Eivind Stedje	Chief of Health Physics Department Institute for Atomic Energy.
Karen Halvorsen	Radiochemist, Institute for Atomic Energy.
Magne Grande	Zoologist, Norwegian Institute for Water Research.
Olav Skulberg	Botanist, Norwegian Institute for Water Research.

A small demonstration was arranged in connection with the meeting to visualize aspects of the relation between the landscape as environment and the actual problems studied, together with some of the experimental objects from the model recipient. The programme for the experimental work in the model recipient during the summer of 1962 is shown in Appendix 2.

2. THE STUDY OF HYDRAULIC RELATION IN THE MODEL RECIPIENT, AND INFORMATION ABOUT VARIATIONS OF WATER QUALITY

The work on these topics is quite necessary in order to give background knowledge for the experiments in the model recipient. The data obtained from the study of distribution and uptake of radionuclides by major species of the organism-communities in the throughflow channels are to be discussed on basis of the flow rate and flow pattern of the water masses. During the period of time reported the necessary observations to describe the hydraulic properties of the throughflow channels were collected.

Experimental data on flow in open channels are generally difficult to obtain. The defined geometry of the channels, and the use of radiotracers made the work in this case easier. The procedure followed was described in the progress report covering the period August 1960 - June 1961. The data reproduced in table 1 are the results of fifty single experiments. The accuracy of the observations of the throughflow time is ± 0,1 minute. The diagram in figure 1 represents the graphical interpretation of the results.

The type of flow in the throughflow channels is classified as a steady flow i.e. with time as a criterion, the depth of flow does not change during the time interval under consideration. With space as the criterion, the depth of flow changes along the length of the channel, and the flow is therefore classified as varied. The state of flow is turbulent.

The experiments with variation of water flow demonstrated that the velocity of the water in a throughflow channel does not vary direct proportionately with the discharge of water. The volume of the streaming water is changing correspondingly during these operations. This effect is shown on the diagram for the inclination of water level in the throughflow channels as a function of flow rate, in figure 2. The slope of the water surface corresponds to 1 : 3960, 1 : 4160, 1 - 5410, 1 : 6270, and 1 : 10810 respectively by 1.50, 1.25, 1.00, 0.75, and 0.50 l/sec. of water discharge.

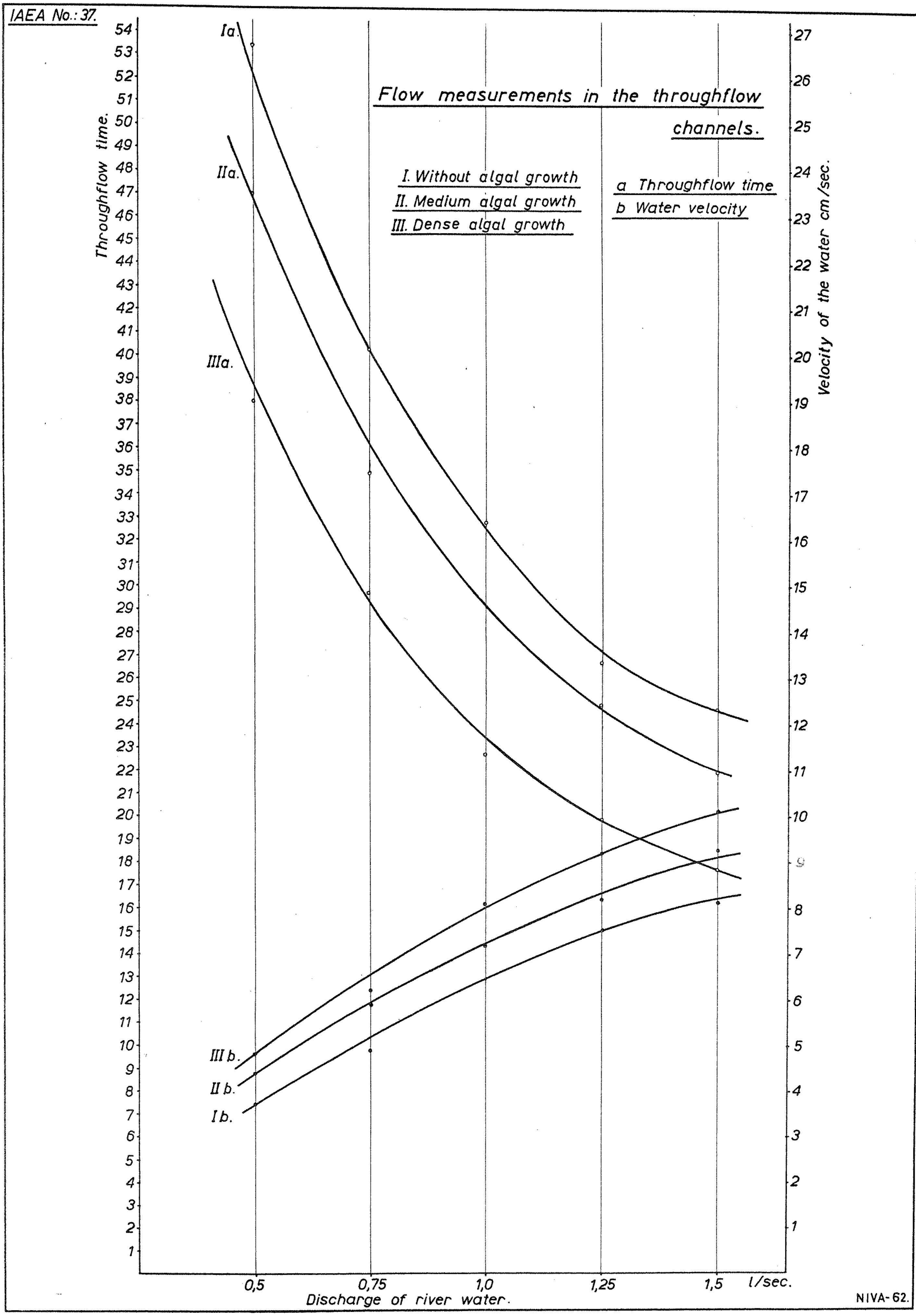
Table 1

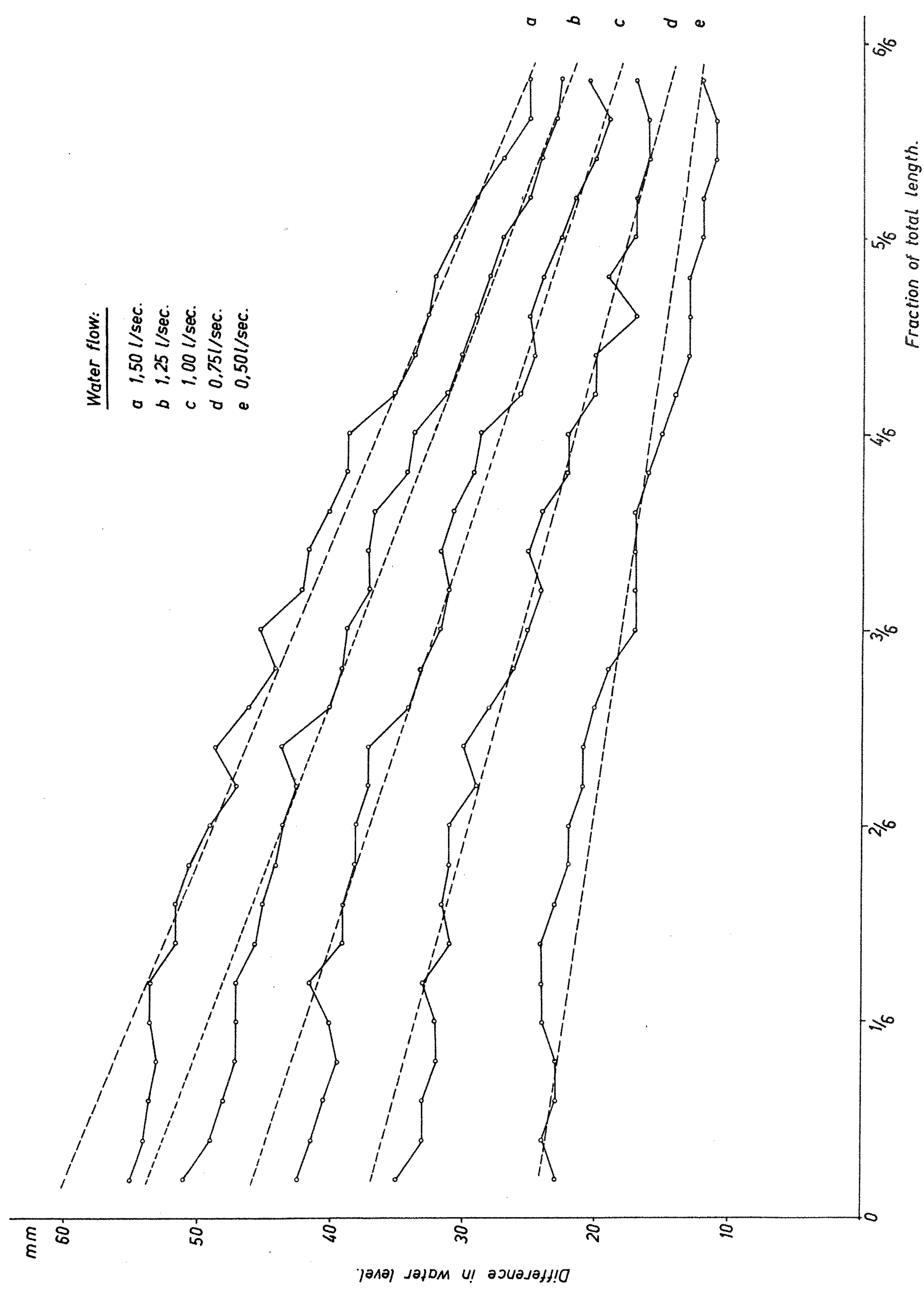
Experimental data describing hydraulic properties of the throughflow channels

1. Without algal growth.
2. Medium algal growth.
3. Dense algal growth.

Discharge of water litre/sec.	Observed throughflow time. min.	Calculated velocity of water cm/sec.	Calculated volume of streaming water. litre
1.			
0,50	53,4	3,7	1701
0,75	40,3	4,9	1900
1,00	32,8	6,1	2053
1,25	26,7	7,5	2177
1,50	25,6	8,1	2304
2.			
0,50	47,0	4,4	1586
0,75	34,9	6,9	1664
1,00	28,4	7,2	1797
1,25	24,9	8,2	1914
1,50	21,9	9,3	2061
3.			
0,50	38,0	4,8	1316
0,75	29,8	6,2	1517
1,00	22,8	8,1	1544
1,25	19,9	9,2	1669
1,50	17,7	10,1	1765

Figure 1.


IAEA No.: 37.
Flow measurements in the throughflow channels.
I. Without algal growth
II. Medium algal growth
III. Dense algal growth
a Throughflow time
b Water velocity
Throughflow time.
Velocity of the water cm/sec.
Ia.
IIa.
IIIa.
IIIb.
IIb.
Ib.
0,5
0,75
1,0
1,25
1,5
l/sec.
Discharge of river water.
NIVA-62.



Inclination of water level in the throughflow channels as a function of flow rate, using river water.

The effect of the algal growth on the hydraulic relations in the throughflow channels appears on the diagram in figure 1. The biomass occupies at times considerable volume of the channels, and influences also directly the friction coefficient. This condition results in smaller values for the detention time of water when algae are growing in the channels, compared with the situation when algae are not developed.

The hydraulic relations of special interest in the present investigation are the detention time (T), the average water velocity (V) and the loss of head per length of channel (Δh). If Q denotes water discharge, and L is the length of the throughflow channel, the following functions are applying:

$$T = e(Q)$$
$$V = f(Q)$$
$$\Delta h = g(L)$$

To consider these functions, the formulae mentioned below are employed:

1. $Q = V \cdot A_m.$

2. $Q = \frac{2}{3} \cdot B \cdot \sqrt{2g} \cdot h^{3/2}$

3. $V = K \cdot R^{2/3} \cdot (\frac{\Delta h}{L})^{1/2}$

4. $A_m = B(H + h + \frac{\Delta h}{2})$

5. $T = \frac{A_m \cdot L}{Q}$

The symbols used indicate:

A_m, mean cross-sectional area
B , the channel width
g , the constant of gravitation
h , head of discharge weir
K , friction factor
R , means hydraulic depth
H , water depth at zero discharge.

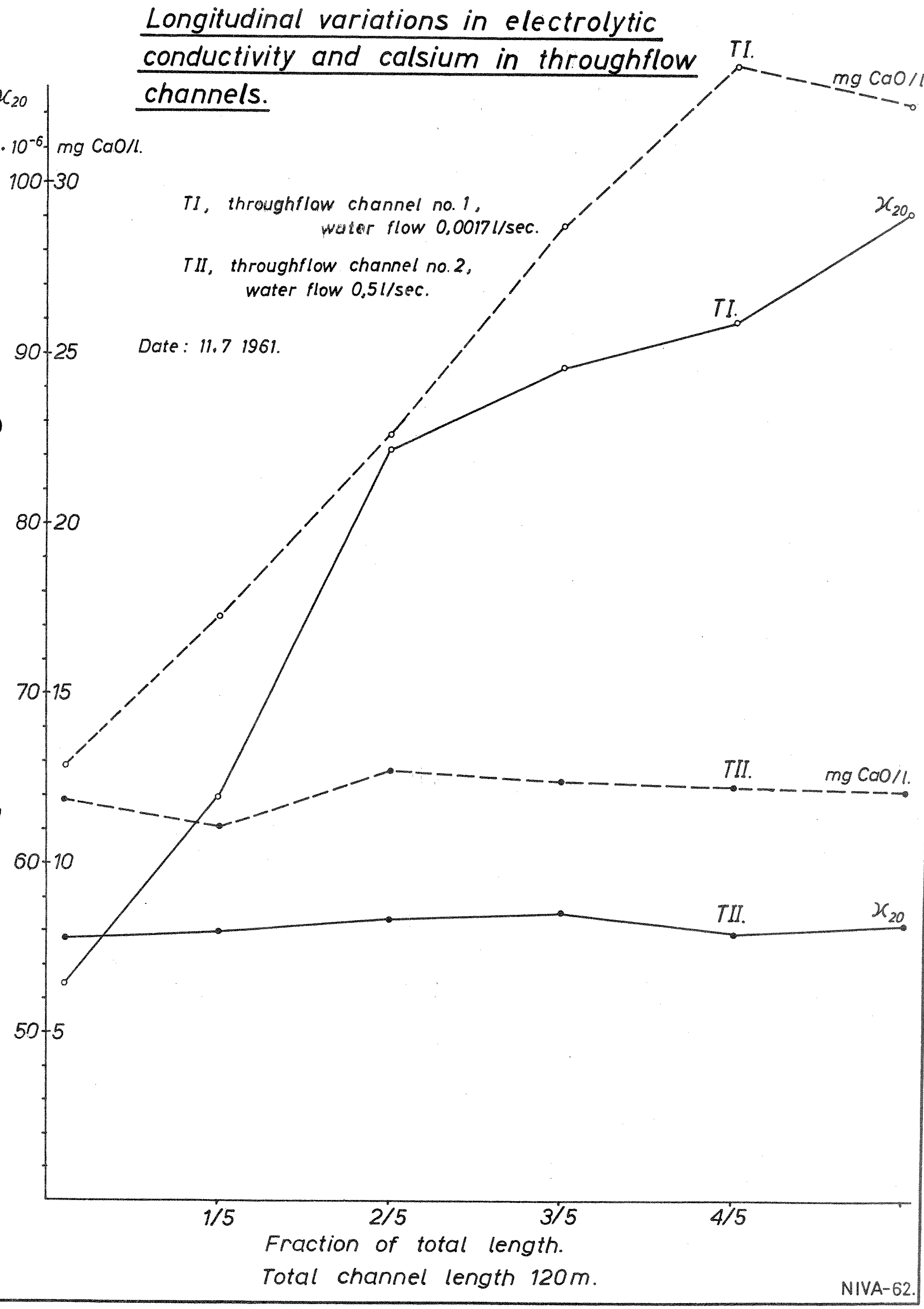
Formula 2 gives the discharge over the rectangular weir at the end of the throughflow channel. The frictional loss in the channel is represented by formula 3, the Manning - Strickler formula.

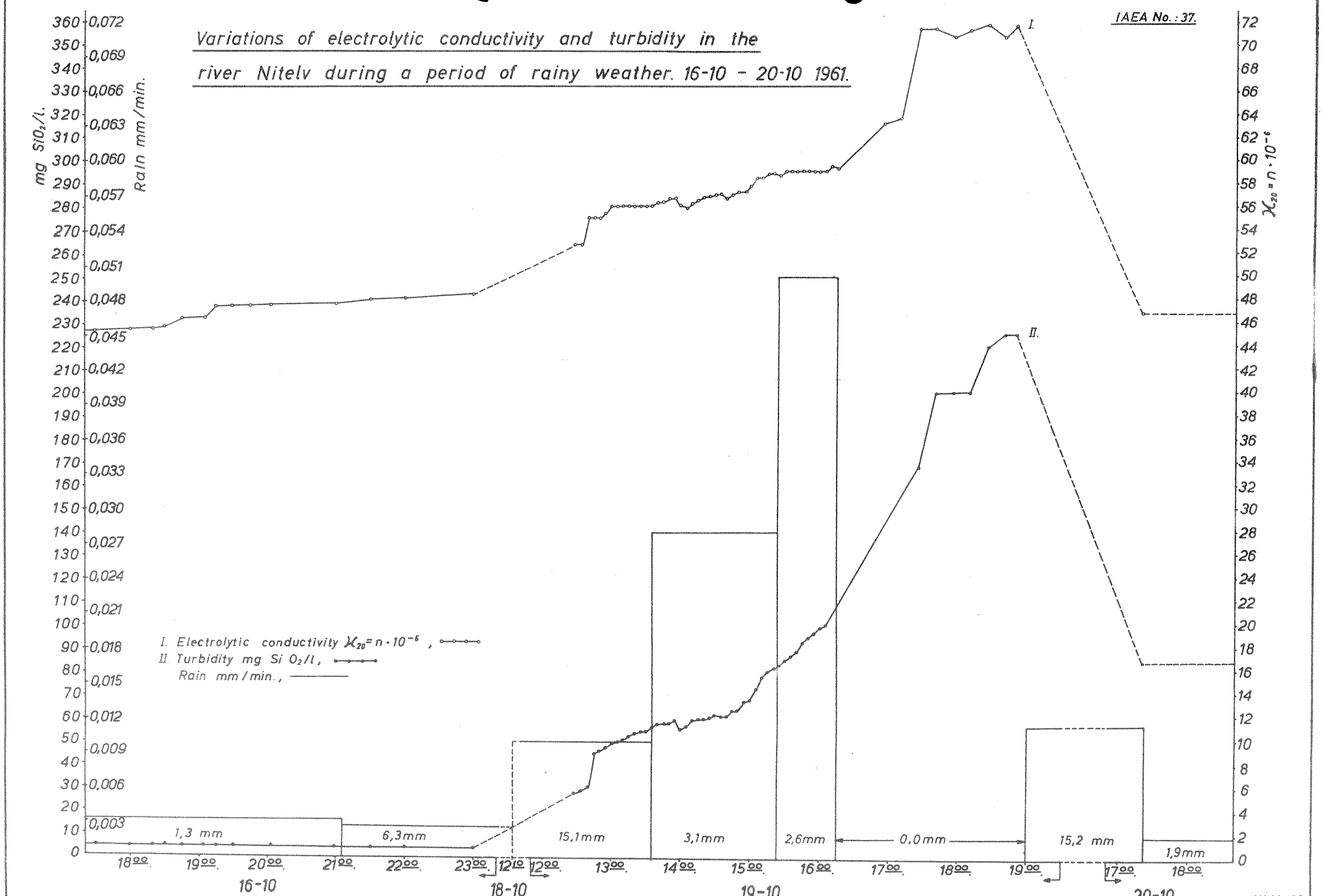
The solution of the equations is to be done after an empirical method. The discussion of the theoretical aspect of the hydraulic relations in the model recipient is in progress.

In the preparations for the building of the model recipient the influence of the building materials on chemical and biological conditions of water was tested. The testing was done in the laboratory. To ascertain that the results were applicable for the circumstances existing in the model recipient itself, determinations of the variations of chemical properties of water during the passage in the throughflow channels were now carried out. The data obtained are given in figure 3. The variation of the concentration of calcium and the electrolytic conductivity in the water shows that the effect of the channel material on chemical properties of the water is negligible during the ordinary operation of the model recipient. But for very small amounts of water discharge i.e. long detention times, the effect can be of considerable significance. This underlines the importance of the surface painting of the recirculation channel.

In the progress report covering the period August 1960 - June 1961 it was pointed out that the daily variation in the values of electrolytic conductivity and turbidity in the river Nitelva is of considerable magnitude. During a period of rainy weather in the autumn 1961, we had the opportunity to measure the variations of precipitation and the corresponding changes in water quality. The observations are reproduced in figure 4. Immediately after the onset of rain, an increase of the electrolytic conductivity of the river water was registered. The turbidity of the water also increased, and the situation was characterized by high values og electrolytic conductivity in the river water, combined with high values of turbidity.

EA No.: 37.


Longitudinal variations in electrolytic conductivity and calsium in throughflow channels.
TI, throughflow channel no. 1, water flow 0,0017 l/sec.
TII, throughflow channel no. 2, water flow 0,5 l/sec.
Date: 11.7 1961.
mg CaO/l.
100
90
80
70
60
50
30
25
20
15
10
5
TI.
TII.
1/5
2/5
3/5
4/5
Fraction of total length.
Total channel length 120 m.
NIVA-62.


IAEA No.: 37.
Variations of electrolytic conductivity and turbidity in the river Nitelv during a period of rainy weather. 16-10 - 20-10 1961.
mg SiO₂/l.
Rain mm/min.
$\mathcal{X}_{20} = n \cdot 10^{-6}$
I. Electrolytic conductivity $\mathcal{X}_{20} = n \cdot 10^{-6}$,
II. Turbidity mg Si O₂/l,
Rain mm/min.,
I.
II.
1,3 mm
6,3mm
15,1mm
3,1mm
2,6mm
0,0mm
15,2 mm
1,9mm
16-10
18-10
19-10
20-10

The state of high electrolytic conductivity in the water was of short duration, and soon after the termination of the rain, the values decreased to the level present before the onset of rain. The high value of turbidity lasted for several days. These data are in good agreement with previous observations demonstrating the relationship between the character of the drainage basin, the meteorological conditions and the hydrographic factors in the river water.

3. INVESTIGATIONS OF VEGETATION IN THE RETENTION POND

Knowledge of the plant and animal communities in the retention pond is needed for the description of the change of contamination level in the water in response to the biological processes. Our particular aim is to show how the aquatic vegetation may act as a reservoir for radionuclides, holding them in the biomass and releasing them to herbivores and water.

A grid map of the vegetation of the pond was prepared during the months July - September 1961. The batygraphical map was used for the recording of the results (figure 5). The pattern of distribution for the major plant populations are shown in figure 6 . Dominant and subdominant species are included. Two profiles of the retention pond; through the deepest point, one east - west, the other north - south; are given in figure 7 . The change of vegetation and its zonation is here illustrated.

The water masses of the retention pond is characterized by the following data which represent winter and summer averages:

Table 2

<u>Chemical characteristics of the pond water</u>

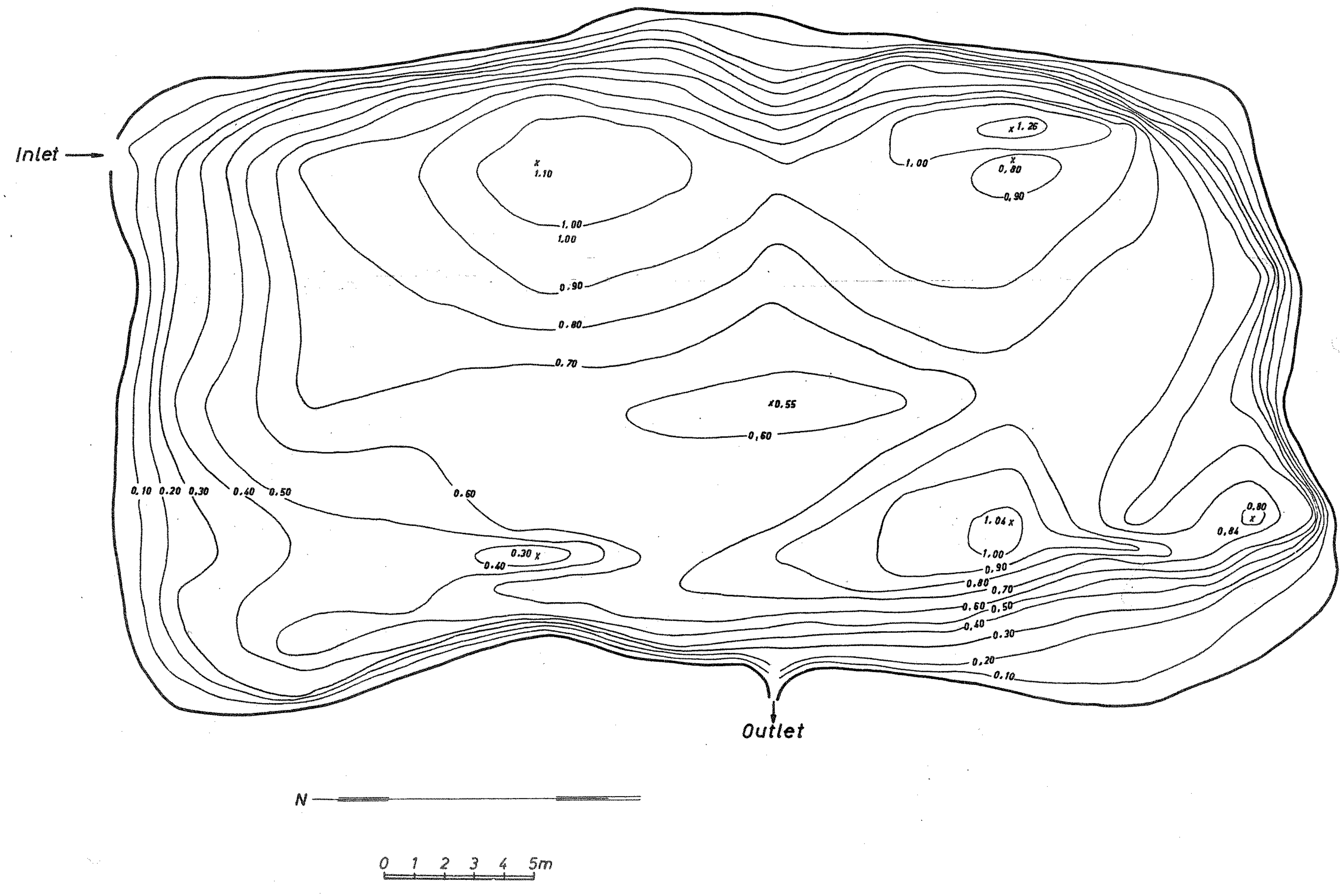
Factor:	Winter conditions:	Summer conditions:
κ_{20}	60 - 160 · 10^{-6}	50 - 110 · 10^{-6}
H_3O^+	6,2 - 6,7 pH	6,7 - 7,6 pH
Permanganate value	15 - 20 mg O/l	8 - 16 mg O/l

The great difference between the summer and winter observations is partly due to the operation of the experimental plant during the summer. The volume of the water in the pond is usually only 50 m^3. The extreme stagnation of the water masses under a thick ice cover during winter time, has also a considerable effect on the hydrographic conditions. The winter season demonstrates marked oxygen deficit with production of hydrogen-sulfide, poisoning the water in all depths.

IAEA No.: 67

Bathygraphical map of the pond.

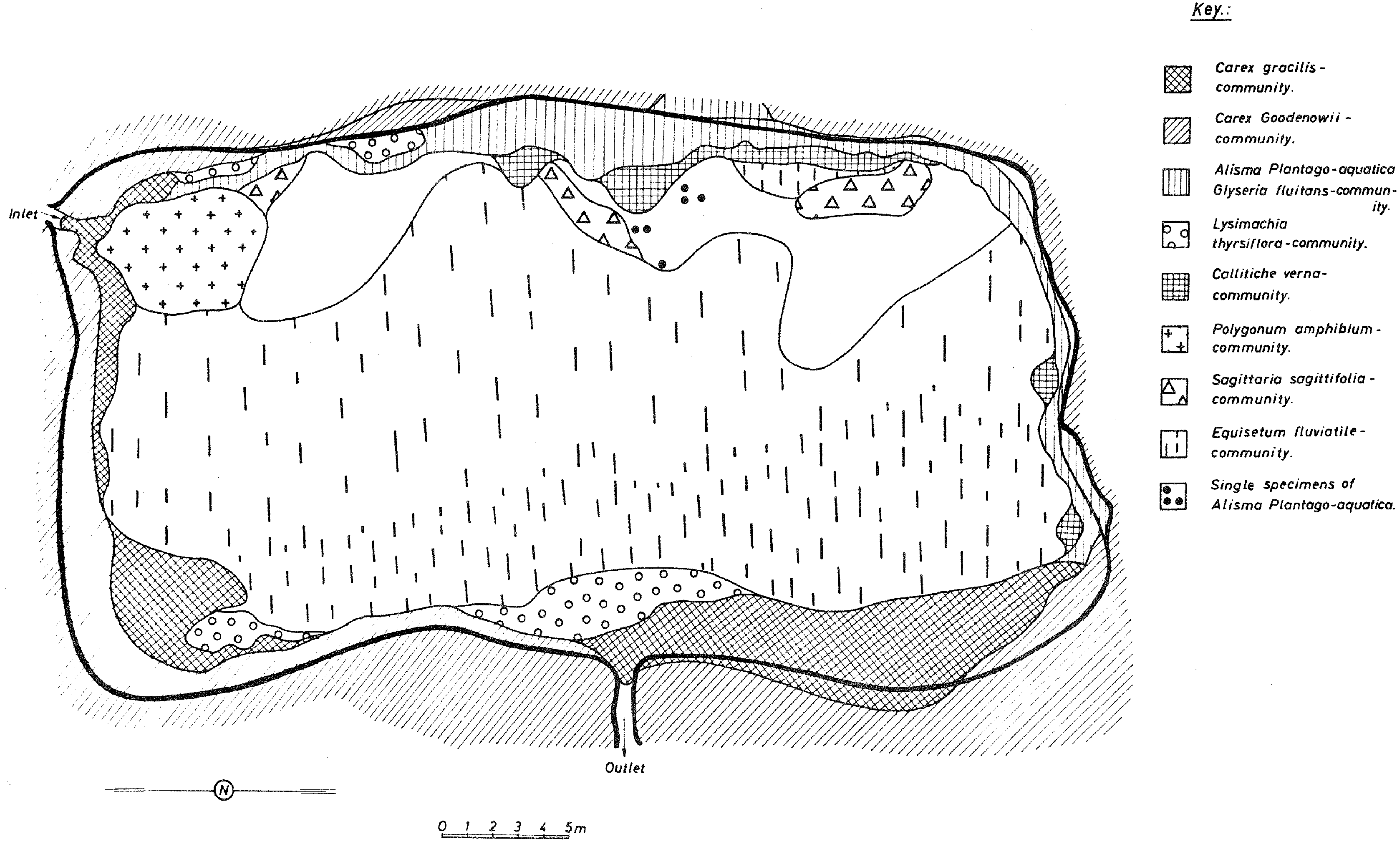
Equidistance of depth curves 0,1m.



NIVA-1961.

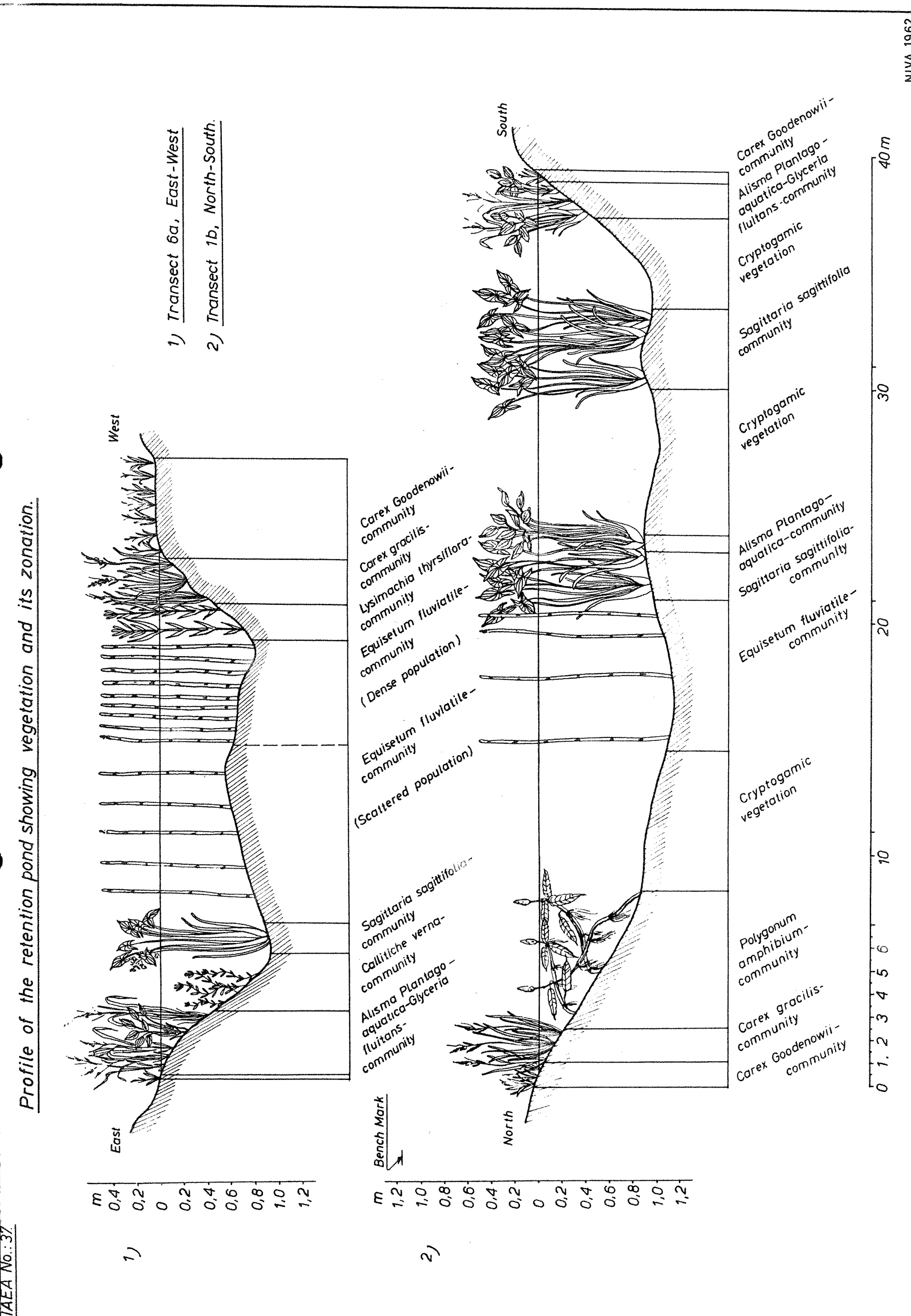
IAEA No.: 37.

Distribution of vegetation in the retention pond. Surveyed: July – September 1961.



NIVA 1962.

Figure 7.


IAEA No.: 37
Profile of the retention pond showing vegetation and its zonation.
NIVA 1962.
1) Transect 6a, East-West
2) Transect 1b, North-South.
1)
m
0,4
0,2
0
0,2
0,4
0,6
0,8
1,0
1,2
East
West
Carex Goodenowii-community
Carex gracilis-community
Lysimachia thyrsiflora-community
Equisetum fluviatile-community
(Dense population)
Equisetum fluviatile-community
(Scattered population)
Sagittaria sagittifolia-community
Callitiche verna-community
Alisma Plantago-aquatica-Glyceria fluitans-community
2)
m
1,2
1,0
0,8
0,6
0,4
0,2
0
0,2
0,4
0,6
0,8
1,0
1,2
Bench Mark
North
South
Carex Goodenowii-community
Carex gracilis-community
Polygonum amphibium-community
Cryptogamic vegetation
Equisetum fluviatile-community
Sagittaria sagittifolia-community
Alisma Plantago-aquatica-community
Cryptogamic vegetation
Sagittaria sagittifolia community
Cryptogamic vegetation
Alisma Plantago-aquatica-Glyceria fluitans-community
Carex Goodenowii-community
0
1.
2
3
4
5
6
10
20
30
40 m

Besides the chemical composition of the water masses, the geological substratum and the morphology of the basin are giving the vegetation distinct features. The vegetation in the pond is composed of specialized species typical for clayish bottoms and an aquatic milieu rather rich on plant nutrients. Table 3 presents the results of the floristic analysis of macrovegetation. A low number of species, not present in the pond as discrete communities, are not included, these species are herbs of small covering.

Table 3

Species of macrovegetation in the retention pond

CHAROPHYCEAE

Chara Braunii Gmel.
Nitella cf. mucronata Miq.

BRYOPHYTA

Calliergonella cuspidata (Hedw.) Loeske.
Drepanocladus aduncus (Hedw.) Moenkem.
Drepanocladus exannulatus (Gumb.) Warnst.
Fontinalis dalecarlica Bruch & Schimp.
Philonotis fontana (Hedw.) Brid.

PTERIDOPHYTA

Equisetum fluviatile L.

MONOCOTYLEDONEAE

Alisma Plantago-aquatica L.
Carex Goodenowii Gay.
Carex gracilis Curt.
Carex livida Wahlenb.
Carex vesicaria L.
Deschampsia caespitosa (L.) P.B.
Eriophorum angustifolium Honck.
Glyceria fluitans (L.) R.Br.
Juncus articulatus L.
Juncus bufonis L.
Juncus filiformis L.
Lemna minor L.
Potamogeton perfoliatus L.
Sagittaria sagittifolia L.
Scirpus acicularis L.
Scirpus mamillatus H. Lindb.
Scirpus palustris L.

DICOTYLEDONEAE

Bidens tripartita L.
Cardamine pratensis L.
Epilobium palustre L.
Galium palustre L.
Lysmachia thyrsiflora L.
Polygonum amphibium L.

The communities of vegetation in the pond are classified in sociations of potametalia (Koch 1926) and phragmitetalia (Koch 1926). The littoral zone is relatively large, and the benthic plants give the most important contribution to the biomass of the pond. The border between the supralittoral and the eulittoral zone is distinguisable by the Carex Goodenowii-community, which have occurrence all around the pond. A profundal region is absent, the areas of the bottom without macrophytes are colonized by cryptogamic species. Algae living in the water-mud interface belong partly to an epipythmenio formation. The periphyton component of microphytes in the pond have not been examined.

The vegetation map is required for the recording of fauna, and it will be used as a basis for the field work with collection of samples for the radiological determinations.

4. THE BIOLOGICAL SYSTEM STUDIED IN THE MODEL RECIPIENT

The descriptive study of the qualitative and quantitative composition of the communities of biota in the throughflow channels is an intricate task. The species of the biocoenoses represent many taxonomic groups, each of them demanding specialists for species diagnosis with high claims on reliability. In the present study it has been necessary to emphasize dominating organisms only, i.e. a relatively few species exerting a major controlling influence by virtue of their biomass in the actual community. The development of benthic algae was given particular attention during the first period of regular observations in the model recipient. The algae represent several important entrance possibilities for transfer of radionuclides into the food chain, and being of a considerable biomass, they have to be regarded as experimental objects of much interest in the present investigation.

Before the throughflow channels were put into operation in August 1960, a layer of pebbles was placed on the bottom of the channels. The stony layer was of an even thickness of about three centimetres. The pebbles were of common Norwegian bed-rock stones, and taken from a natural gravel-pit in a moraine.

Operation period August 1 - November 1, 1960

Already one week of continuous dosing of river water to the throughflow channels resulted in visual growth of benthic organisms on all surfaces in contact with the water. The first invaders were Charchesium polypinum, Cladothrix dichotoma, and a range of bacteria. This first development of heterotrophic species is reasonable, considering the pollution by sewage of the river water. Charchesium polypinum was an ecological dominant, and the walls and the bottoms of the throughflow channels were partly coloured grey by this ciliate.

A development of algal communities of importance with respect to biomass, was noted round about ten days after the starting date. Blue-green algae (species of the genus Oscillatoria) and diatoms (representatives of the genera Navicula, Nitzschia, Achnantes, Synedra, and Cymbella) then growing and forming larger or smaller patches on the pebbles of the bottom. Charchesium polypinum was also present in abundance during this stage of development. Besides the protozoans, only one species of the rotatorian genus Philodina was observed of the other invertebrates.

A vegetation of trichale green algae appeared during the first week of September, the water having then been dosed to the throughflow channels for about three weeks. The algae dominating were just the species of Spirogyra which later have characterized the communities of green algae in the throughflow channels. Even if it is necessary to make reservations regarding our species diagnosis, there is reason to underline the close accordance between the actual systematic characteristica observed and those described for Spirogyra formosa respectively Spirogyra porticalis. In the samples examined, there were also other species of Spirogyra present, but they were quite in inferior quantity. The longitudinal variation of algal communities in the throughflow channels demonstrated that sections dominated by Spirogyra cf. formosa were followed by sections where Spirogyra cf. porticalis was a major constituent of the community. Towards the middle of the throughflow channels in longitudinal direction, the green algae communities were gradually disappearing, and communities dominated by species of diatoms replaced them. Fragilaria capucina var. mesolepta was here the most common species, but a varied selection of species of the genera at the same time present in the interface of mud and water in the river Nitelva, were represented in the samples of vegetation from these sections of the throughflow channels. Of typical species may be mentioned Stauroneis phoenicenteron, Gyrosigma acuminatum, Surirella ovata, and Ceratoneis arcus.

The advancing autumn situation resulted in changes in the communities. The diatom component of the biota in the throughflow channels constituted more and more of the biomass, at the same time as the green algae decreased in frequency. This seasonal periodicity in community succession was parallelled by development of Anthophysa vegetans and Leptothrix ochracea. The situation, with the vegetation of the throughflow channels characterized by diatoms and iron organisms, remained until winter put a stop to the operation of the model recipient on October 31, 1960.

Operation period April 18 - November 3, 1961

The water was again led into the throughflow channels on April 18, 1961.

During the first week of May benthic communities were distinctly developing. Visually they consisted of brown and yellow-green specks and green tufts. Three main components of organisms were established in these pioneer communities, schizophyceans, bacillariophyceans and chlorophyceans. Major species were respectively Oscillatoria cf. chlorina, Navicula rhynchocephala, Ceratoneis arcus, Nitzschia acicularis, and Ulothrix sp. together with Hormidium sp.

An interesting phenomenon took place in the throughflow channel number 1, these first weeks after the model recipient was put into operation. This throughflow channel had been given a water flow of about 100 millilitres per minute, and had got an organism development which completely distinguished it from the others. A mass occurrence of Haematococcus pluvialis was established in the whole length of the throughflow channel, and for several days the stones at the bottom were almost continuously coloured red. These growths of algae were grazed away by a species of Chironominae which was not further identified.

About May 20, the Spirogyra-communities were again completely developed. From this data until the middle of the month of July the following vegetation was characteristic: The first half of the throughflow channels in longitudinal direction was dominated by growths of Spirogyra cf. formosa and Spirogyra cf. porticalis. These communities were in the last half of the throughflow channels replaced by communities where Fragilaria capucina var. mesolepta was a major species.

Sexual reproduction of species of Spirogyra was watched in the period June 15 - 25. These observations among others demonstrate the usefulness of a model recipient for recording of microphenological courses of development. The photographs in the figures 8 and 9 reproduce two examples of the microscopical observations on the conjugation process.

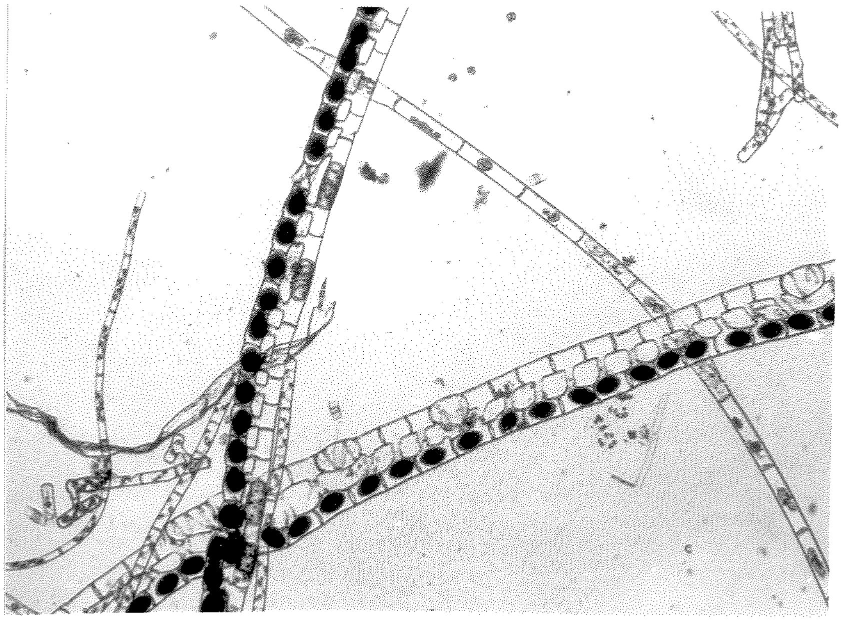


Figure 8

The scalariform conjugation of Spirogyra.

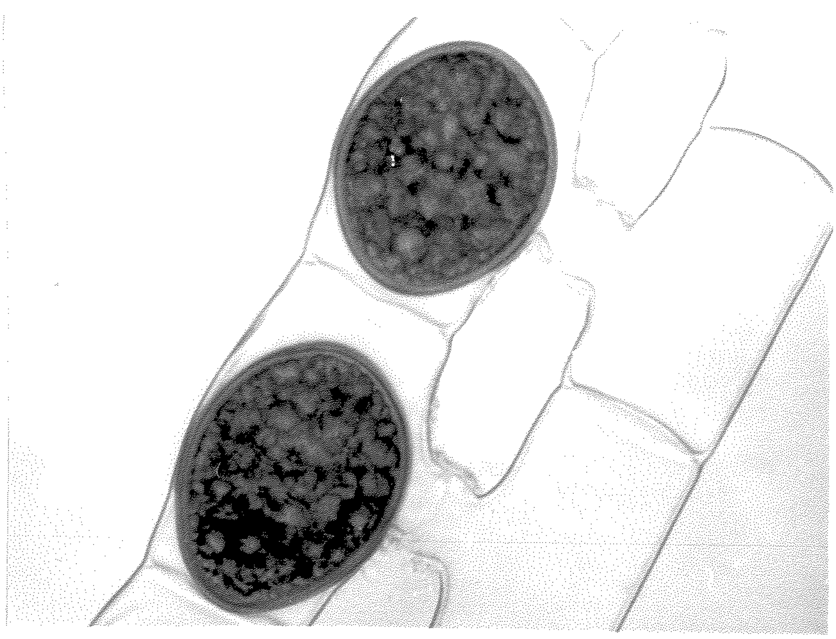


Figure 9

Details of Spirogyra - zygotes.

Passing phenomena in the month of July was a large occurrence of Ophrydium versatile in the first sections of the throughflow channels, and a mass development of Hydra vulgaris which lasted during one week and was manifested in all the channels along their whole lengths.

In the course of July crustaceans developed in considerable population number. Eurycercus lamellatus, especially, occurred in large amounts. The distinct retrogression of the population of Fragilaria capucina var. mesolepta, which took place towards the beginning of August, seemed directly to have a connection with the grazing by the animal. During August Fragilaria capucina var. mesolepta was present with a few specimens only in the samples collected from the throughflow channels. The communities of Spirogyra cf. formosa and Spirogyra cf. porticalis still dominated the algal vegetation in the first half of the throughflow channels, while a species of Oedogonium gradually replaced Fragilaria capucina var. mesolepta.

Examples of the change in community structure mentioned above, are recorded on the photographs in figure 10 and 11 . Figure 10 shows the Spirogyra-community on July 11; together with the two dominant species of Spirogyra is the winding bends of Fragilaria capucina var. mesolepta. Figure 11 gives an impression of the Spirogyra-community on August 21; a species of Oedogonium (densely populated with epiphytic diatoms) is dominant together with Spirogyra cf. porticalis.

The algal communities which were developed during the last part of July were outstandingly stable, and the situation established remained almost unchanged during the autumn months. Major species of the communities were then:

Algae	:	Spirogyra cf. formosa.
		Spirogyra cf. porticalis.
		Oedogonium sp.
Invertebrates	:	Eurycercus lamellatus.
		Philodina sp.
		Psectrocladinus (?) sp.
		Ephemera vulgata.
		Baetis sp.

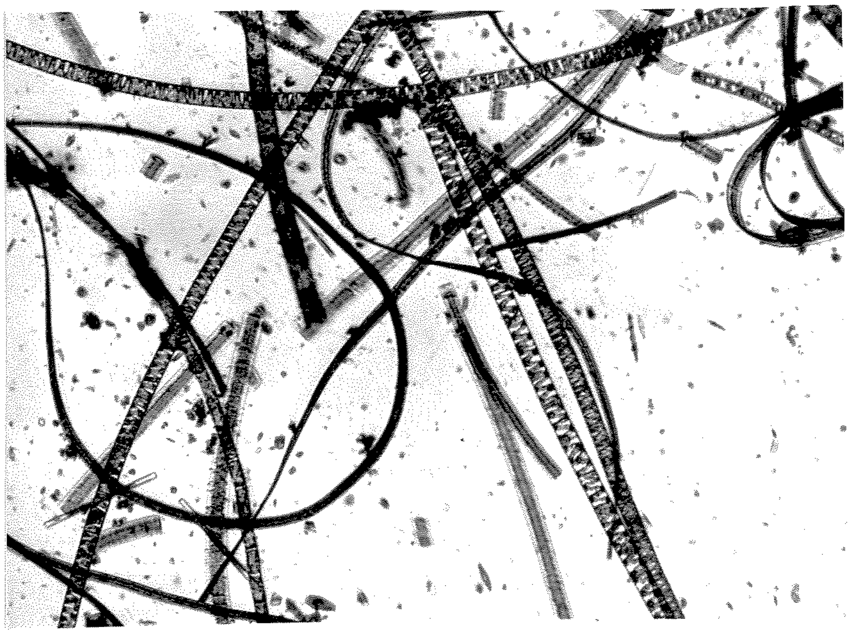


Figure 10

Spirogyra-community on July 11, 1961

Figure 11

Spirogyra-community on August 21, 1961

During the month of October Leptothrix ochreacea and Anthophysa vegetans were developing in the same way as the preceding year. The diatoms, on the contrary, did not come to any marked mass occurrence this autumn.

On November 3, 1961, the water was turned off from the model recipient.

The observations of the development of algal communities in the model recipient are summed up in the following particulars:

1. The succession of organism communities with respect to time, shows that when water from the river Nitelva is lead into a system of channels, communities of bacteria and protozoans are first established. These communities are succeeded by new, where blue-green algae and diatoms with several species are dominating in the biomass. These first autotrophic communities are also unstable and are followed by communities of green algae with species of the genera Spirogyra and Oedogonium in dominant quantity.

2. Longitudinal zonation of communities in the throughflow channels is prominently demonstrated. This effect reflects the self-purification process of the river water.

3. Throughflow channels operated in the ame manner demonstrate parallel development of organism communities.

4. The amount of river water discharged to the throughflow channels has a considerable effect on the orderly process of organism community change.

The study of the biological system in the model recipient makes out an important part of the work with this project. The current observations of the organism development and the changes of communities in the throughflow channels form a base for the experimental investigation. In addition information about the role of microorganisms in shaping community structures is provided. Knowledge about the course of microphenological phenomenons is very scarce, information of this kind is gathered through the study of biota in the model recipient.

An index of species identified in samples from the river water and the benthic growths of the model recipient are given in table 4 .

TABLE 4

Species of plankton and benthos

SCHIZOMYCETES

Beggiatoa cf. alba (Vaucher) Trevis.
Cladothrix dichotoma Cohn.
Leptothrix ochracea Kützing.
Siderocapsa Molisch sp.
Sphaerotilus natans Kützing.

SCHIZOPHYCEAE

Achroonema Skuja sp.
Anabaena subcylindrica Borge.
Anabaena Bory sp.
Cylindrospermum Kützing sp.
Lyngbya Agardh sp.
Merismopedia glauca (E.) Näg.
Merismopedia punctata Meyen.
Merismopedia tenuissima Lemm.
Merismopedia Meyen sp.
Oscillatoria cf. chlorina Kützing.
Oscillatoria limosa Agardh.
Oscillatoria Vaucher sp.
Phormidium uncinatum Gom.
Phormidium Kützing sp.
Pseudanabaena Lauterborn sp.

CHLOROPHYCEAE

Ankistrodesmus falcatus (Corda) Ralfs.
Ankistrodesmus Corda sp.
Bulbochaete Agardh sp.
Chlamydomonas Ehrenberg sp.
Cladophora Kützing sp.
Closterium cf. acerosum (Schrank) Ehrenberg.
Closterium Leibleinii Kützing.
Coelastrum microporum Naegeli.
Cosmarium Corda spp.
Crucigenia rectangularis (A. Braun) Gay.
Crucigenia Tetrapedia (Kirchner) W. et. G.S. West.
Desmidium Swartzii Agardh.
Desmidium Agardh sp.
Draparnaldia glomerata (Vauch.) Agardh.
Elakatothrix gelatinosa Wille.
Euastrum bidentatum Naegeli.
Haematococcus pluvialis Flot. em. Wille.
Hormidium Klebs sp.
Hyalotheca dissiliens (Sm.) Brebisson.
Hyalotheca mucosa (Mert.) Ehrenberg.
Micrasterias Agardh sp.
Mougeotia Agardh sp.
Nephrocytium lunatum W.West

CHLOROPHYCEAE (continued)

Oedogonium Link sp.
Oocystis Naegeli sp.
Pediastrum Boryanum (Turpin) Menegh.
Pediastrum Tetras (Ehrenberg) Ralfs.
Pleurotaenium Naegeli sp.
Quadrigula closterioides (Bohlin) Printz.
Scenedesmus acutus Meyen.
Scenedesmus bijugatus (Turpin) Kützing.
Scenedesmus obliquus (Turpin) Kützing.
Scenedesmus quadricauda (Turpin) Brebisson.
Scenedesmus Meyen spp.
Selenastrum capricornutum Printz.
Sphaerozosma Corda spp.
Spirogyra cf. formosa (Transeau) Czurda.
Spirogyra cf. porticalis (Müller) Cleve.
Spirogyra Link spp.
Spondylosium planum (Wolle) W. et G.S. West.
Staurastrum Meyen spp.
Tetraspora Link sp.
Ulothrix Kützing sp.
Volvox aureus Ehrenberg.
Xanthidium antilopaeum (Breb.) Kützing.
Zygnema Agardh sp.

BACILLARIOPHYCEAE

Achnantes Bory spp.
Asterionella formosa Hassall.
Ceratoneis arcus Kützing.
Cocconeis cf. pediculus Ehrenberg.
Cymatopleura solea (Breb.) W. Smith.
Cymbella cf. affinis Kützing.
Cymbella lanceolata (Ehr.) v. Heurck.
Cymbella Agardh spp.
Diatoma elongatum Agardh.
Diatoma vulgare Bory.
Fragilaria capucina Desmazieres.
Fragilaria capucina var. mesolepta (Rabh.) Grun.
Fragilaria crotonensis Kitton.
Fragilaria Lyngbye spp.
Frustulia rhomboides (Ehr.) de Toni.
Gomphonema Agardh sp.
Gyrosigma acuminatum (Kütz.) Rabh.
Melosira ambigua (Grun.) O. Müller.
Melosira varians C.A. Ag.
Meridion circulare Agardh.
Navicula rhynchocephala Kützing.
Navicula Bory spp.
Nitzschia acicularis W. Smith.
Nitzschia dissipata (Kütz.) Grun.
Nitzschia Hassall spp.
Pinnularia Ehrenberg spp.
Stauroneis phoenicenteron Ehrenberg.

BACILLARIOPHYCEAE (continued)

Surirella ovata Kützing.
Surirella Turpin sp.
Synedra ulna (Nitzsch) Ehrenberg.
Tabellaria fenestrata (Lyngb.) Kützing.
Tabellaria flocculosa (Roth) Kützing.

CHRYSOPHYCEAE

Anthophysa vegetans (O.F.M.) Stein.
Chrysococcus Klebs sp.
Dinobryon sertularia Ehrenberg.
Dinobryon spirale Iwanoff.
Dinobryon Ehrenberg sp.
Hyalobryon Lauterborn sp.
Kephyrion Rubri-claustri Conrad.
Kephyrion spirale (Lack.) Conrad.
Kephyrion Pascher spp.
Synura uvella Ehrenberg.

XANTHOPHYCEAE

Botryococcus Braunii Kützing.
Tribonema Derbes et Solier sp.
Vaucheria De Candolle sp.

DINOPHYCEAE

Glenodinium (Ehrbg.) Stein.
Gymnodinium Stein emend., Kofoid et Swezy sp.
Peridinium (?) aciculiferum (Lemm.) Lemm.
Peridinium cf. Willei Huitf.-Kaas.
Peridinium Ehrenberg sp.

CRYPTOPHYCEAE

Cryptomonas caudata Shiller.
Cryptomonas Ehrenberg sp.

EUGLENOPHYCEAE

Euglena Ehrenberg sp.
Trachelomonas Ehrenberg emend. Deflandre sp.

FUNGI

Asterothrix raphidioides (Reinsch spec.) Printz.

PORIFERA

Euspongilla lacustris Aut.

CILIATA

Carchesium cf. polypinum (Linnaeus).
Coleps hirtus (Müller).
Ophrydium versatile Müller.
Tintinnidium Stein sp.
Vorticella Linnaeus spp.

RHIZOPODA

Amoeba Ehrenberg sp.
Arcella cf. vulgaris Ehrenberg.
Difflugia Taranek sp.

COELENTERATA

Hydra vulgaris Pall.

BRYOZOA

Plumatella fruticosa Allman.

GASTROTRICHA

Chaetonotus Ehrenberg sp.

OLIGOCHAETA

Stylaria lacustris (Linnaeus).

ROTATORIA

Keratella quadrata (Müll.)
Philodina Ehrenberg sp.
Polyarthra vulgaris Carlin.
Trichotria Bory de St. Vincent sp.

CRUSTACEA

Bosmina longirostris (O.F. Müller).
Chydorus sphaericus O.F. Müller.
Cyclops O.F. Müller sp.
Diaphanosoma brachyurum (Lievin).
Eurycercus lamellatus (O.F. Müller).
Holopedium gibberum Zaddach.
Notodromas cf. monacha O.F. Müller.
Polyphemus pediculus (Linne).

ARACHNIDA

Hydrachnellae Latreille.

MOLLUSCA

Lymnea ovata Drap.
Lymnea pereger (Müll.)
Pisidium Pfeiffer sp.
Planorbis carinatus Müll.
Sphaerium corneum (Linn.).
Valvata piscinalis (Müll.).

INSECTA

Anopheles Meigen sp.
Baetis Leach sp.
Chironomus thummi Kieffer.
Corixa Geoffr. sp.
Culex Linnaeus sp.
Dytiscus marginalis L.
Ephemera vulgata Linn.
Gerris najas De Geer.
Nepa cinerea L.
Notonecta glauca Linn.
Phryganea striata Linn.
Phryganea Linnaeus sp.
Psectrocladinus ?.
Simulium Latr. sp.

5. WEIGHT RELATIONS OF EXPERIMENTAL OBJECTS

The biological objects sampled for radiological examinations are regularly weighed, wet weight, dry weight, and ash weight being determined. The data are applied for the interpretation and description of the phenomena studied.

The concentration factor is a parameter used in several of the experiments performed in the model recipient. The calculation of the concentration factor is based upon a wet weight determination of the biological material treated. Wet weight determinations of organisms are subject to considerable uncertainty. The main error involved is the varying amount of water attached to the organisms. Besides, it is difficult to define the conditions during the collection of the samples.

After wet weight determinations, the biological materials are used for dry weight and ash weight analyses. The procedure is the following one:

The porcelain crucible with the biological sample is transferred to a heating stove. The temperature in the stove is 100 - 105°C, and the material is staying here till complete dryness occurs. This usually takes 24 hours. After dry weight determination, the sample undergoes incineration in a muffle-oven. The temperature during this process is 500°C, and the duration of the treatment is round about 20 - 24 hours.

Besides being a necessary tool for the present investigation, the information provided by these determinations is of some interest as mere facts. Table 5 contains the figures obtained by the work.

A comparison between the values representing the different taxonomic groups reveals some general features. The mineral fraction of the algal material is relatively high. The species *Fragilaria capucina var. mesolepta*, with its silicious frustules, and *Selenastrum capricornutum*, a planktonic species, are to be regarded as exceptions. The vascular plants demonstrate middle and low figures of ash content. *Equisetum fluviatile* and *Lysimachia thyrsiflora*, both helophytes, are extremes in the present selection of species. In regard to the animal species, it is of interest to note that the invertebrates examined have a relatively higher content of minerals than the species of fish considered.

Table 5

Weight relations of some organisms [1)]

Species	Dry weight in per cent of wet weight	Ash weight in per cent of wet weight	Ash weight in per cent of dry weight	Number of samples
Algae[2)]				
Chara Braunii	5,0	1,3	27	6
Fragilaria capucina var. mesolepta	13	10	76	9
Oedogonium sp.	2,8	0,5	19	8
Selenastrum capricornutum	2,0	0,13	7	8
Spirogyra cf. formosa	3,5	0,7	21	4
Spirogyra cf. porticalis	3,3	0,6	17	12
Vascular plants				
Alisma Plantago - aquatica	9,8	1,1	11	6
Callitriche verna	3,8	0,6	16	7
Carex gracilis	29	2,5	9,1	3
Equisetum fluviatile	22	4,2	19	6
Glyceria fluitans	72	5,1	7,2	8
Juncus bufonis	13	1,9	14	2
Lysimachia thyrsiflora	21	1,0	4,9	2
Polygonum amphibium	80	9,5	12	2
Scirpus acicularis	6,6	1,1	16	6
Scirpus palustris	19	2,1	11	2
Invertebrates				
Anodonta cygnea:				
Soft tissue	12	2,1	18	35
Shell	95	90	95	35
Eurycercus lamellatus	11	2,6	25	5
Astacus fluviatilis	34	9,2	28	3
Vertebrates				
Perca fluviatilis	24	4,2	18	2
Leuciscus rutilus	23	4,3	19	3
Phoxinus phoxinus	21	3,1	15	7
Salmo trutta	26	2,8	11	7

1) The figures have reference to the whole organism, with the exception of the vascular plants for which the roots are not included.

2) The samples of algae showed a higher degree of weight variance than the other objects sampled. The values used are considered the most representative.

6. EXPERIMENTS WITH ALGAE

The laboratory investigations of the uptake of radionuclides by algae have continued during the period reported. The experiments have been performed with Selenastrum capricornutum.

In the present investigation the previous work on this topic has been carried out using closed systems. It was considered important to study the problems in an open system, and a simple continuous culture plant was constructed for this purpose. Three glass aquaria were connected by glass tubings functioning as siphons. Conditions for growth of the algae in the aquaria were maintained by introducing fresh medium continuously to the first aquarium in the series. The detention time of the culture solution in the system was about one month.

Three series of this type were operated. The culture solution used was the standard medium of 10% concentration, with exception of the content of phosphorus which was varied in the following way:

Series 1,	concentration of phosphorus	70 γ P/l
Series 2,	" " "	140 γ P/l
Series 3,	" " "	280 γ P/l

The radiotracer P^{32} was added to the medium.

The fresh medium was continuously dosed in the amount of 0,7 ml/min. (around 1 litre/24 hours).

At regular intervals observations on the uptake of the radionuclides and growth of algae were performed.

The data obtained are reproduced in the diagrams in figures 12, 13, 14, and 15.

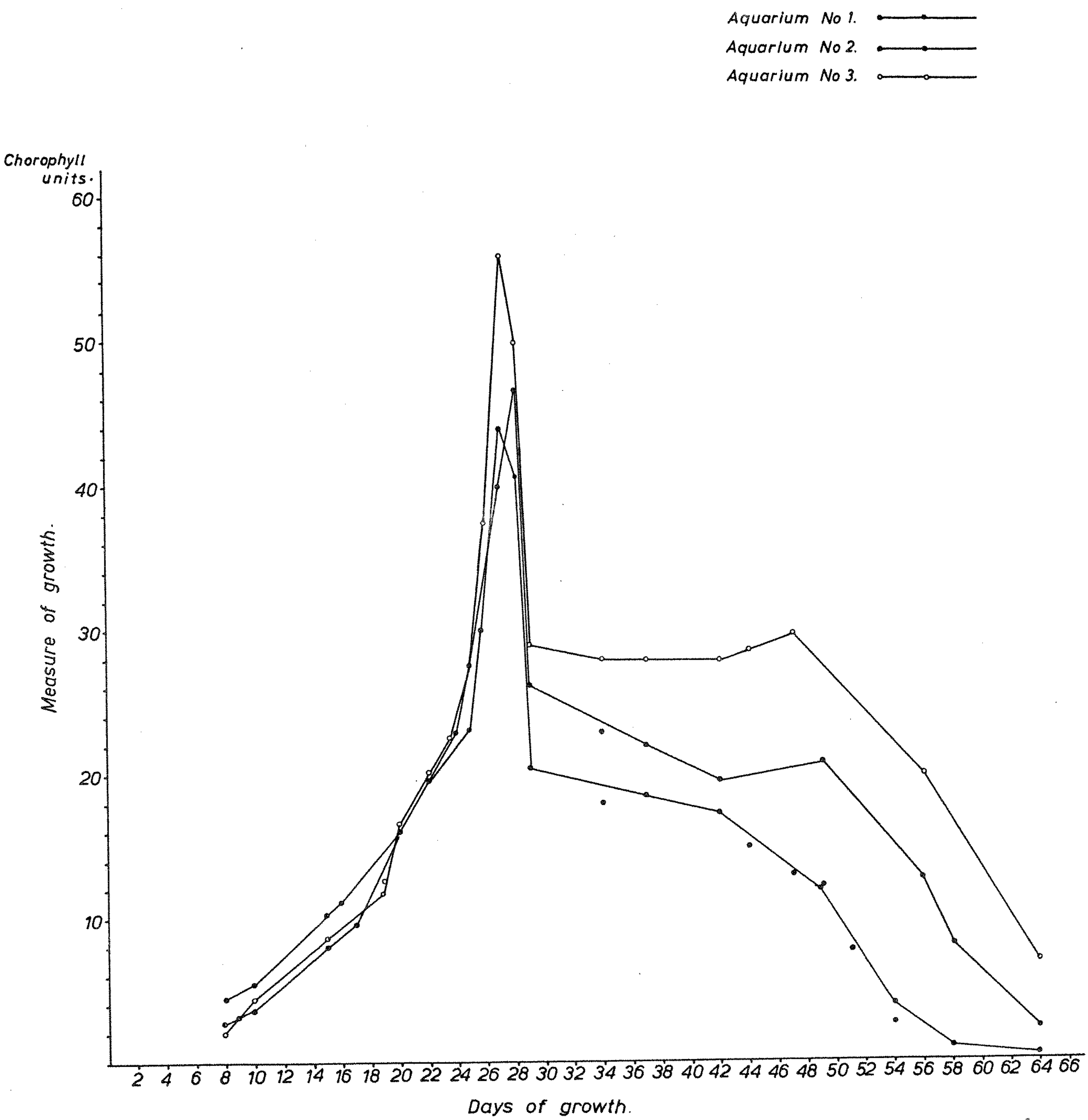
The growth curves for the algae in the series 1 (figure 12) showed a maximum 28 days after the inocculation. During the first period of fourteen days with growth, the radioactivity in the solution of the three aquaria decreased to a very low level. During the last part of the experimental period the level of radioactivity was almost constant (fig. 13).

IAEA No.: 37.

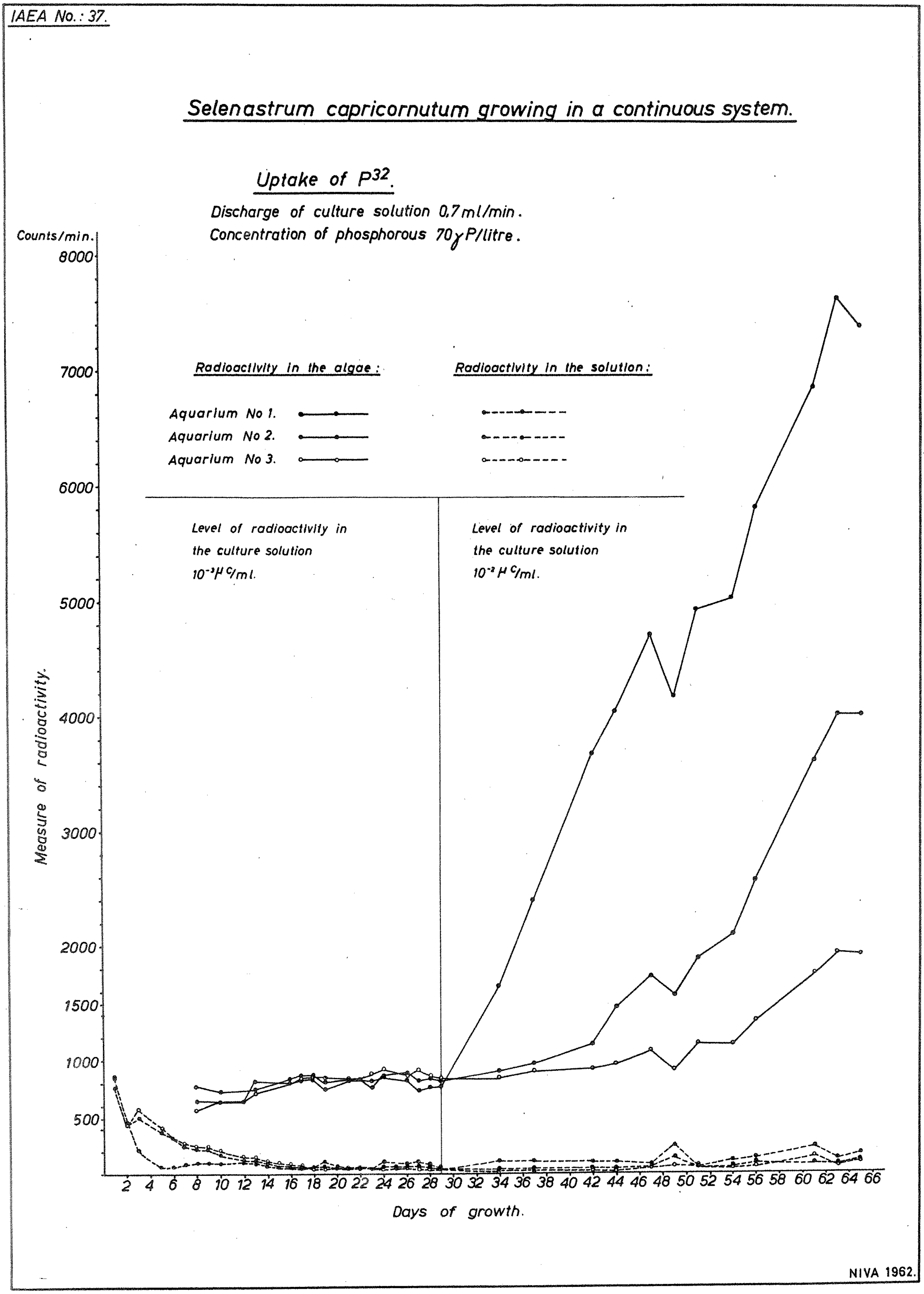
Selenastrum capricornutum growing in a continuous system.

Growth curves.

Discharge of culture solution 0,7 ml/min
Concentration of phosphorous 70 γ P/litre.



NIVA 1962.


IAEA No.: 37.
Selenastrum capricornutum growing in a continuous system.
Uptake of P32.
Discharge of culture solution 0,7 ml/min.
Concentration of phosphorous 70 γ P/litre.
Counts/min.
8000
7000
6000
5000
4000
3000
2000
1500
1000
500
Measure of radioactivity.
Radioactivity in the algae:
Radioactivity in the solution:
Aquarium No 1.
Aquarium No 2.
Aquarium No 3.
Level of radioactivity in the culture solution 10⁻³ μC/ml.
Level of radioactivity in the culture solution 10⁻² μC/ml.
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50 52 54 56 58 60 62 64 66
Days of growth.
NIVA 1962.

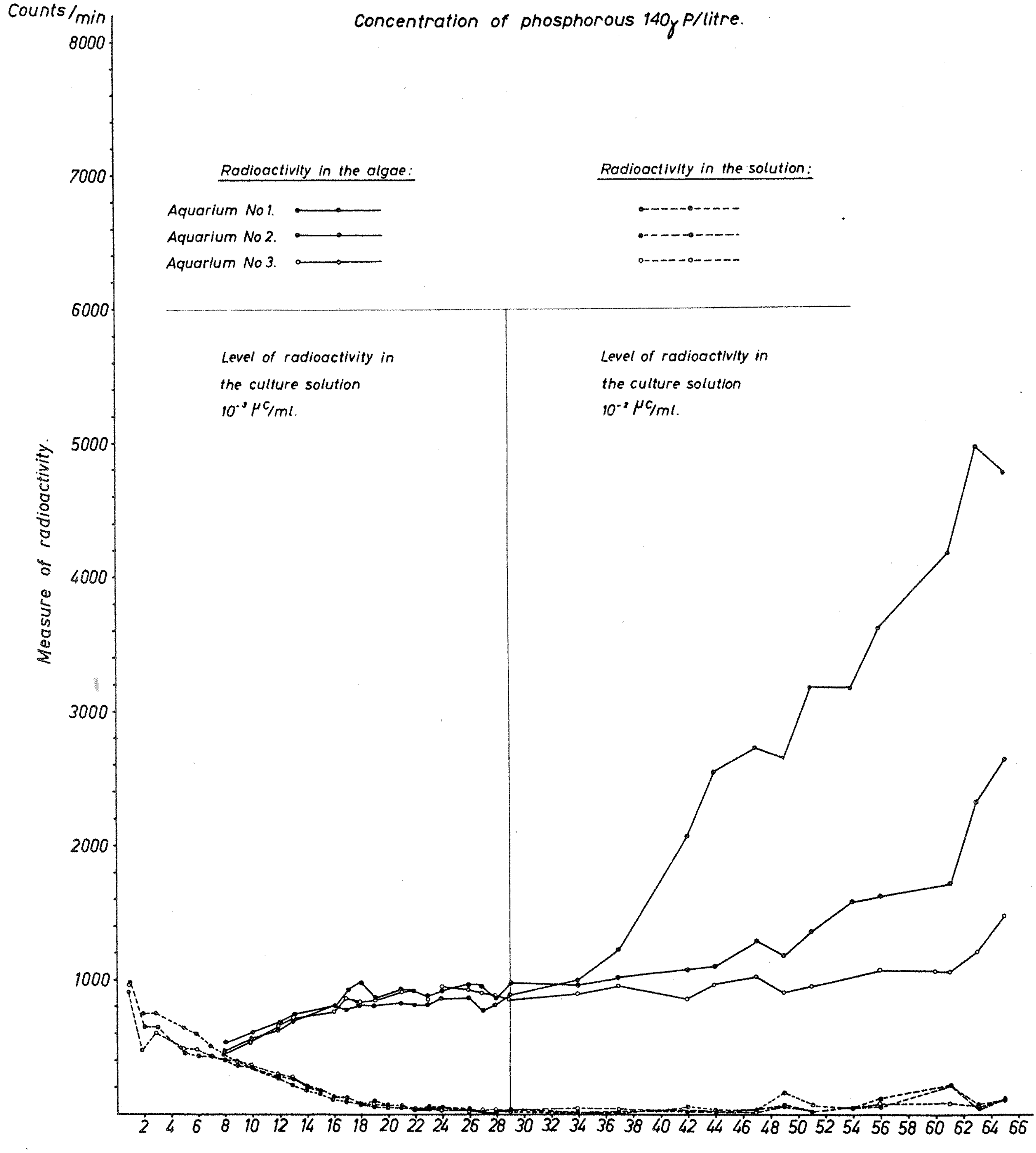
IAEA No.: 37.

Selenastrum capricornutum growing in a continuous system.

Uptake of P^{32}.

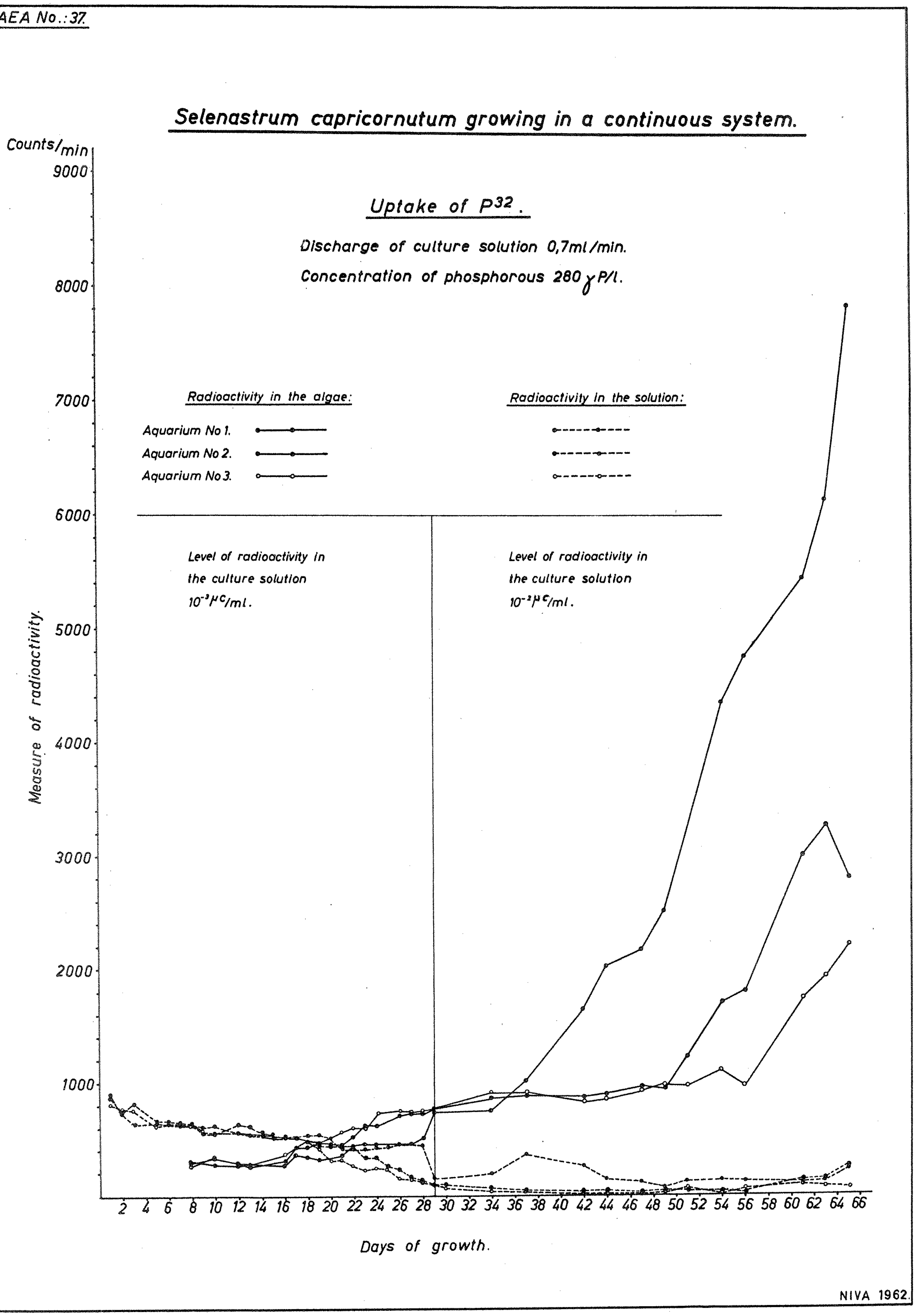
Discharge of culture solution 0,7 ml/min.

Concentration of phosphorous 140γ P/litre.



NIVA 1962.

Figure 15.


AEA No.: 37.
Selenastrum capricornutum growing in a continuous system.
Uptake of P^{32}.
Discharge of culture solution 0,7ml/min.
Concentration of phosphorous 280 γ P/l.
Counts/min
Measure of radioactivity.
Radioactivity in the algae:
Radioactivity in the solution:
Aquarium No 1.
Aquarium No 2.
Aquarium No 3.
Level of radioactivity in the culture solution 10^{-3} μc/ml.
Level of radioactivity in the culture solution 10^{-2} μc/ml.
9000
8000
7000
6000
5000
4000
3000
2000
1000
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50 52 54 56 58 60 62 64 66
Days of growth.
NIVA 1962.

Phosphorus, being the essential element at minimum concentration, limited the growth in the aquaria. When the critical minimum was reached, the uptake of radiophosphorus by the algae in the first aquarium was very effective, and only small amounts of phosphorus were transported further to the second and the third aquarium.

A bio-assay method has been developed for studying the uptake by algae of radionuclides sorped to the component of particles in the free water masses. When solutions of radionuclides are mixed with river water, a considerable fraction of the radionuclides will be associated with the suspended particles. It is important to know the possibilities for these radioactive substances to be assimilated by algae in the plankton population, and enter the food chain in this way. The method used to investigate these processes and their extent, involves the following procedure:

1. The algae Selenastrum capricornutum is grown in Pyrex-glass flasks. The flasks are shaken slowly and illuminated by fluorescent lamps. Temperature is constant. The culture solution used is the previous described standard medium. The radionuclide studied is added to the culture, and the distribution of the radionuclide between the solution and the algae growing is observed.

2. The same experiment is performed with a known concentration of clay in the culture solution, and with autoclaved river water as culture medium.

3. The distribution of the radionuclide between the component of clay and the water phase without algal growth is determined.

By comparing and discussing the results obtained it is possible to assess the availability of the radionuclides sorped to the particle fraction for the algae in the recipient plankton. So far we have only carried out this experiment with favourable issue using P^{32}.

Experiments of this kind are for the first time performed, as far as reported in the literature studied. We hope that the application of this method can be a supplement to others in the evaluation of biological processes responsible for the reconcentration of radionuclides in the aquatic environment.

7. SORPTION OF RADIONUCLIDES TO RIVER SEDIMENTS

The investigations on sorption of radionuclides to river sediments have been continued. The radionuclides Ce^{144}, Zr^{95}-Nb^{95}, and Y^{91} have been included in the tests. The sorption of P^{32} to sediments have been subject to a more comprehensive study.

The materials used in the experiments are the same as described in a previous report, i.e. a postglacial clay from the river Nitelva. (O. Skulberg: Progress Report, I.A.E.A. Research Contract No. 37, August 1960 - June 1961).

An analysis of the clay material has been performed by the Norwegian Geotechnical Institute. The analysis comprises X-ray diffraction and differential thermic analysis, and determination of the base-exchange capacity. The result of the analysis shows that the clay consists of quartz and feltspar, and the clay-minerals, chlorite, micas, and hydrous micas (Illit.).

The total content of clay minerals is about 20 per cent, the rest being quartz and feltspar in equal amounts. The base-exchange capacity of the clay is 6,8 mcq./100 g.

Preparation of the sediments and testing procedure

The sediments were dried at room temperature, organic material was destroyed with hydrogen peroxide and the sediments were passed through a 200 mesh sieve. Suspensions of the sediments were made by adding a known weight of sediments to the solution of the radionuclides in distilled water.

Sorption of Ce^{144}, Zr^{95} - Nb^{95}, and Y^{91}

The sorption of these radionuclides to the sediments was tested at the concentration of 16, 32, 64, 128, and 256 ppm of sediments.

Table 6, 7 and 8 show the average percentage of Ce, Zr-Nb and Y sorbed by the sediments. The affinity of the sediments to sorb the radioactivity has also been expressed as the distribution coefficient, Kd.

$$(K_d = \frac{fc/M}{fs/V})$$

where

fc = fraction of activity sorbed by the sediments
fs = fraction of activity left in solution
M = weight of sediments in grams
V = volume of solution in ml.

The results show that the Kd values are effected by the sediment-concentration and are decreasing with increasing concentration of the sediments.

These results are in agreement with the previous tests on sorption of Cs^{134}, Sr^{89}, Ca^{45}, P^{32}, and Ru^{106} to river sediments.

These findings imply that the sediment concentration always have to be taken into consideration when evaluating the Kd-values.

Sorption of P^{32} to sediments

Experiments on sorption of P^{32} to sediments have been reported previously. Further tests showed, however, that the sorption mechanism of phosphate is much more complex than the sorption mechanism of cations. Results obtained with the same method as above were not reproducible, and the obtained data were inconclusive.

In ecological considerations the sorption of phosphate is an important factor, therefore a more comprehensive study of the phosphate sorption has been performed.

This includes a fractionation of the sediments, pretreatment of the sediments and sorption experiments with various phosphate-concentrations and various sediment concentrations.

Table 6

Sorption of Zr^{95}-Nb^{95} to various concentrations of sediments

Concentration of sediments	Per cent activity sorped	Kd
16 ppm	8,0 ± 1,0	5.400
32 ppm	12,7 ± 1,2	4.500
64 ppm	19,5 ± 1,5	3.800
128 ppm	30,0 ± 2,5	2.350
256 ppm	38,3 ± 3,3	2.400

Table 7

Sorption of Y^{91} to various concentrations of sediments

Concentration of sediments	Per cent activity sorped	Kd
16 ppm	6,7 ± 0,8	4.500
32 ppm	8,0 ± 1,0	2.700
64 ppm	14,3 ± 1,5	2.600
128 ppm	26,7 ± 1,8	2.800
256 ppm	35,0 ± 1,8	2.100

Table 8

Sorption of Ce^{144} to
various concentrations of sediments

Concentration of sediments	Per cent activity sorped	Kd
16 ppm	18,5 ± 1,1	14.200
32 ppm	29,5 ± 1,5	13.200
64 ppm	33,5 ± 1,6	7.800
128 ppm	39,5 ± 1,8	5.100
256 ppm	54,0 ± 2,2	4.600

Pretreatment of the sediments

All the experiments has been carried out with sediments pretreated with hydrogenperoxide as described above.

Experiments were also made to evaluate the effect of ammoniumcarbonate-treatment of the sediments. The sediments were suspended in a solution containing 100 g pr. litre of ammoniumcarbonate for 5 minutes and then centrifuged at 3400 rpm for 10 minutes. This was repeated five times, and the sediments were then dried at 90^{o}C for 24 hours.

The treatment with ammoniumcarbonate seemed to have little effect on the sediments. Sediments prepared in this way were used for the phosphate sorption tests.

Fractionation of the sediments

A portion of the sediments was suspended in distilled water and separated in three different fractions by sedimentation, centrifugations and filtration.

1. Sedimented fraction, This is the fraction which is sedimented from the suspension in five minutes. This fraction contains particles of the approximate size 100 μ - 30 μ.

2. Centrifuged fraction. This fraction is separated from the remaining suspension by centrifugation at 3400 rpm for 10 minutes. The fra-tion contains particles of the size 30 μ - 1 μ.

3. Filtrated fraction. Ammoniumcarbonate was added to the supernate after centrifugation, and the suspension was filtered through membrane-filter. The addition of ammoniumcarbonate was necessary to obtain a complete separation. The particle size of this fraction is less than 1 μ.

The sedimented and centrifuged fractions were microscopical identical and consisted of quartz and feltspar. The filtrated fraction contains probably most of the clay-minerals.

The sedimented and the centrifuged fractions contain a relatively large amount of iron and phosphate. This was tested by washing out the sediments with 10 per cent HCl, none of the iron and phosphate was removed with distilled water. The filtrated fraction contained less iron and phosphate.

Experimental procedure

The sediments were added to 100 ml of solution containing phosphate as K_2HPO_4 and 0,01 μC of carrier free P^{32}. The suspensions were shaked on a shaking tabel for 24 hours. The suspensions were then filtered through membrane filters, and the activity was measured in the filtrate. Samples were prepared containing various concentrations of phosphate and various sediment concentrations. One parallel set of samples were run on sediments treated with ammoniumcarbonate before fractionation.

Results

Sorption of P^{32} to sediments at various concentrations of phosphate is shown in table 9 and 10. The ammoniumcarbonate treatment of the sediments appears to have no significant effect on the sorption capacity for phosphate. At low phosphateconcentrations the filtered fraction has the highest sorption capacity.

In the concentration range of 10-100 μg.P/litre the sorption is proportional with the phosphate concentration, but at higher concentrations the sorption is approaching a saturation level. The sedimented and centrifuged fractions have a lower sorption capacity at the lower phosphate concentrations.

The results of the measurement of phosphate sorption to various concentrations of the sediments are given in table 11 and 12 .

Table 9

Sorption of P^{32} to sediments

Concentration of sediments 500 ppm.

Concentration of phosphate	Per cent activity sorbed to sediments			
	Unfractionated sediments	Sedimented fraction	Centrifuged fraction	Filtered fraction
25 µg P/l				80,8
50 µg P/l				88,6
75 µg P/l				88,6
100 µg P/l	41,8	18,4	31,6	88,5
1 mg P/l	16,4	16,3	14,4	27,0
1 g P/l	19,0	7,3	8,2	5

Table 10

Sorption of P^{32} to sediments

Sediments treated with ammoniumcarbonate 500 ppm

Concentration of phosphate	Unfractionated sediments	Sedimented fraction	Centrifuged fraction	Filtered fraction
100 µg P/l	30,6	7,2	19,4	70,4
1 mg P/l	7,7	11,5	5,0	32,7
1 g P/l	5	12,7	6,3	5

Table 11

Sorption of P^{32} to sediments

Concentration of phosphate, 500 µg P/l

Concentration of sediments	Per cent activity sorbed to sediments: Unfractionated sediments	Sedimented fraction	Centrifuged fraction	Filtered fraction
10 mg/l	5,4	5	22,8	8,2
100 mg/l	5	7,2	13,4	7,2
1000 mg/l	21,7	26,8	14,4	56,0

Table 12

Sorption of P^{32} to sediments

Sediments treated with ammoniumcarbonate
Concentration of phosphate, 500 µg P/l

Concentration of sediments	Per cent activity sorbed to sediments: Unfractionated sediments	Sedimented fraction	Centrifuged fraction	Filtered fraction
10 mg/l	5	17,4	22,8	17,4
100 mg/l	7,2	18,5	6,2	8,2
1000 mg/l	25,8	10,3	17,3	60,0

FIELD EXPERIMENTS ON SORPTION OF RADIONUCLIDES TO RIVER SEDIMENTS

The laboratory experiments on sorption of radionuclides to river sediments have been supplemented with experiments in the recipient model. The experiments have been performed in the recirculation channel, and the river water containing its natural turbidity has been used.

Experimental procedure

The recirculation channel was filled with 2400 litres of water from the river Nitelva. The velocity of the water during the experiments was approximately 9 cm/sec. Radionuclides were added to the water and samples were collected at various time intervals. The samples were filtered through membrane filters and the activity measured in the water and in the particle fraction, (turbidity was measured as ppm SiO_2).

Sorption of P^{32}

The results of the experiments are shown in figure 16.

The initial turbidity in the water was 36 ppm., at the end of the experiment the turbidity was 15 ppm.

The figure shows that after a few hours about 90 per cent of the P^{32} is accosiated with the particle fraction. During the experiment some sedimentation of the particles accurred, and at the end of the experiment only about 50 per cent of the initial activity was retained in the system: particles - water phase.

These data are in agreement with the data from the laboratory experiments, at low phosphate concentration the phosphate is readily sorbed to the sediments.

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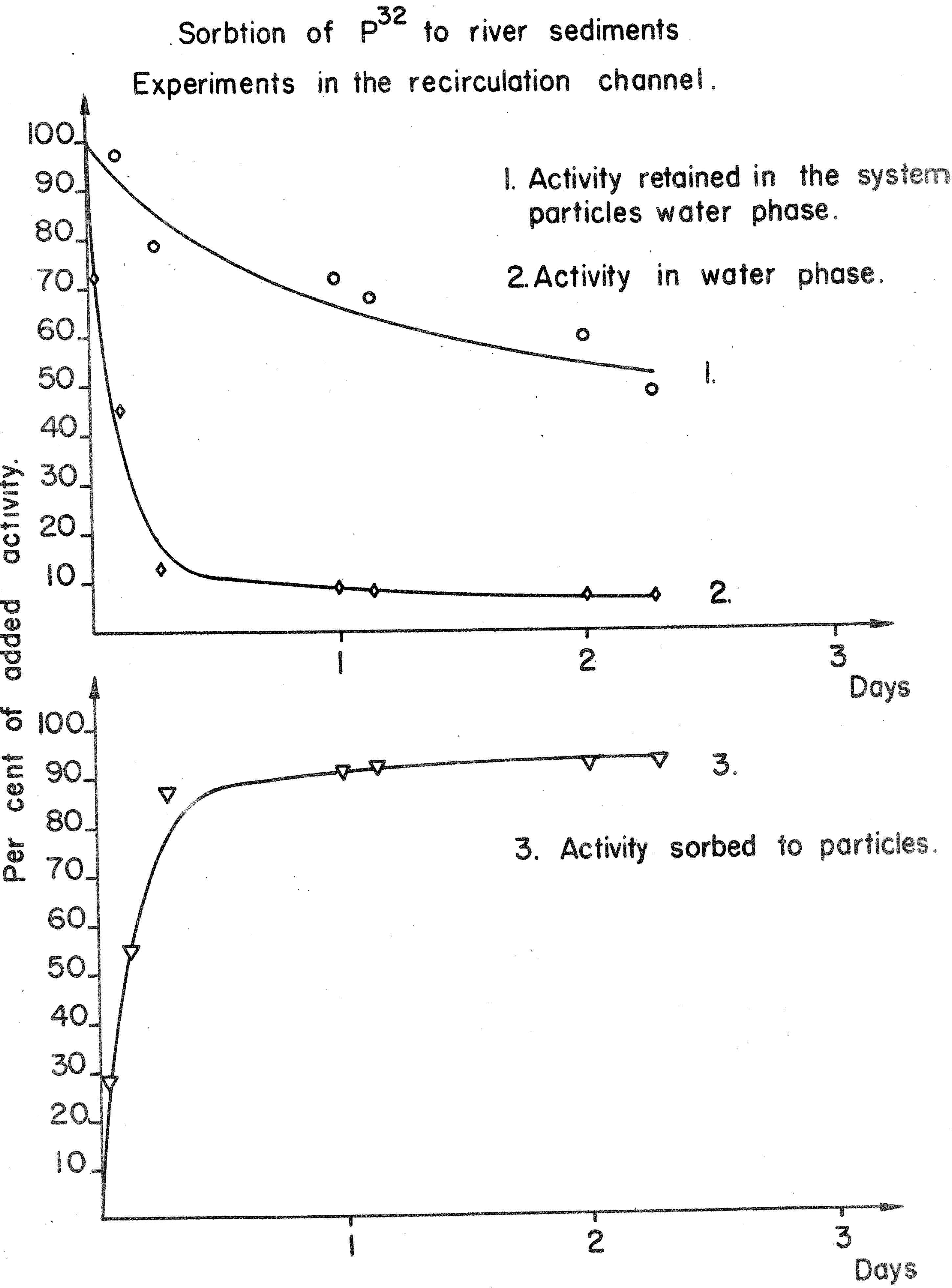
Sorbtion of P32 to river sediments
Experiments in the recirculation channel.
1. Activity retained in the system particles water phase.
2. Activity in water phase.
3. Activity sorbed to particles.
Per cent of added activity.
100
90
80
70
60
50
40
30
20
10
1.
2.
3.
1
2
3
Days

Sorption of Cs^{134}

Figure 17 shows the sorption of Cs^{134} to the particle-fraction. The experimental conditions were the same as above, but the initial turbidity of the water was 130 ppm.

Cs^{134} is activity sorbed to the particles, but even after 8 days the sorption is not completed, similar results were obtained in the laboratory experiments. The amount of Cs^{134} sorbed to the particle fraction compares with the sorption measured in the laboratory experiments.

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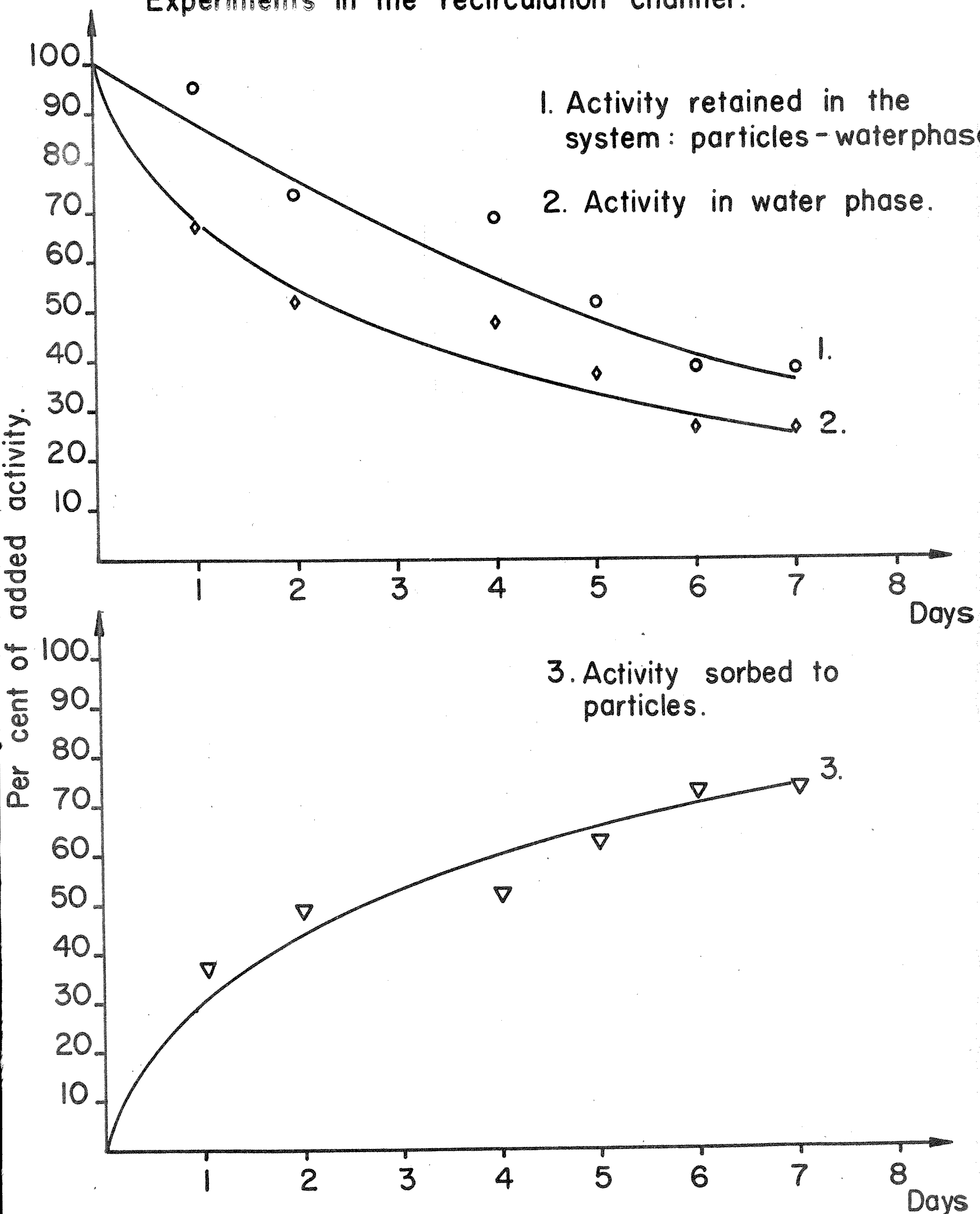
Sorbtion of Cs^{134} to river sediments

Experiments in the recirculation channel.



A P P E N D I X I.

Experimental data obtained from the
undertakings in the model recipient
during the operation period
April 19 - November 3, 1961.

EXPERIMENTS ON UPTAKE OF P^{32} IN THE THROUGHFLOW CHANNELS

16th June, 1961

EXPERIMENTAL CONDITIONS

Water flow	:	1 l/sec.
Water velocity	:	7 cm/sec.
Water temperature	:	16 - 18°C
Exposure time	:	13 minutes
Total amount of activity added	:	760 μc
Theoretical concentration of radioactivity in water at starting point	:	$1{,}0 \cdot 10^{-3}$ μc/ml
Objects studied	:	Spirogyra cf. formosa, Spirogyra cf. porticalis, Bottom deposits.

RESULTS OF MEASUREMENTS

TABLE 1

Species \ Date	P^{32} μc/mg ash weight $\cdot 10^{-5}$		
	Background	16/6	17/6
Sampling point 1			
Spirogyra cf. formosa		840	808
Spirogyra cf. porticalis	0,33	1240	970
			970
Bottom deposits		4,0	0,28
			1,6

KH/MB

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EXPERIMENTS ON UPTAKE OF P^{32} IN THE THROUGHFLOW CHANNELS

22nd June, 1961

EXPERIMENTAL CONDITIONS

Water flow	:	1 l/sec.
Water velocity	:	7 cm/sec.
Water temperature	:	15 - 18°C
Exposure time	:	35 minutes
Total amount of activity added	:	122 µc
Theoretical concentration of radioactivity in water at starting point	:	$5,8 \cdot 10^{-5}$ µc/ml
Objects studied	:	Spirogyra cf. formosa, Fragilària capucina var. mesolepta, Vaucheria sp., Bottom deposits.

RESULTS OF MEASUREMENTS

TABLE 1

Water samples

Sampling point	µc per ml water $\cdot 10^{-6}$	µc per ml filter $\cdot 10^{-6}$	Total µc per ml $\cdot 10^{-6}$	Turbidity mg/l SiO_2
1 - 10 minutes	19,1	4,3	23,4	20,4
1 - 10 - 20 minutes	28,4	8,6	37,0	24,2
1 - 20 - 30 minutes	31,2	8,3	39,5	20,2
6 - 10 minutes	5,6	1,5	7,5	23,8
6 - 10 - 20 minutes	23,9	8,2	32,1	20,5
6 - 20 - 30 minutes	26,2	7,3	33,5	21,5
12 - 10 minutes	2,3	0,16	2,5	20,4
12 - 10 - 20 minutes	7,1	2,20	9,3	20,0
12 - 20 - 30 minutes	16,2	5,5	21,7	20,0

TABLE 2

Experimental objects

P^{32} μc/mg ash weight · 10^{-5}

Species \ Date	S.point 1		S.point 3		S.point 6		S.point 9		S.point 12	
	22/6	23/6	22/6	23/6	22/6	23/6	22/6	23/6	22/6	23/6
Spirogyra cf. formosa	16 23 8,5 21 32	16	12	20	4,6	0,7	6,5 4,9	2,8	5,6	4,9
Fragilaria capucina var. mesolepta			1,2	3,2	1,0	1,9	1,0	1,8	1,5 0,9	0,9
Vaucheria sp.	1,6 3,5									
Bottom deposits	0,09	0,05	0,15	0,28	0,20	0,13	0,28	0,21	0,33 0,33 0,26 0,35	0,30

Sampling points 1, 3, 6, 9, 12 represent the points at 1/12, 3/12, 6/12, 9/12, 12/12 of the total channel length.

KH/MB

EXPERIMENTS ON UPTAKE OF P^{32} IN THE THROUGHFLOW CHANNELS

20th July, 1961

EXPERIMENTAL CONDITIONS

Water flow	:	0,5 l/sec.
Water velocity	:	4,5 cm/sec.
Water temperature	:	19 - 22°C
Exposure time	:	30 minutes
Total amount of activity added	:	123,5 μc
Theoretical concentration of radioactivity in water at starting point	:	$1,4 \cdot 10^{-4}$ μc/ml
Objects studied	:	Spirogyra cf. porticalis, Oedogonium sp., Eurycercus lamellatus, Bottom deposits.

RESULTS OF MEASUREMENTS

TABLE 1

Water samples

Sampling point	Activity in water $\mu c/ml \cdot 10^{-5}$	Activity in filter $\mu c/ml \cdot 10^{-6}$	pH	κ_{20}	Turbidity mg/l SiO_2
Start background	0,4	0,5	7,1	$58 \cdot 10^{-6}$	96,0
End background	0,4	0,6	8,0	$58 \cdot 10^{-6}$	52,8
1	1,7	4,0	7,8	$58 \cdot 10^{-6}$	72,0
6	1,6	0,7	7,8	$58 \cdot 10^{-6}$	65,2
12	1,4	2,2	7,8	$60 \cdot 10^{-6}$	60,4

IAEA Research Contract No. 37
20th July, 1961

TABLE 2

Experimental objects

P^{32} μc/mg ash weight · 10^{-5}

Species / Date	Sampling point 1			Sampling point 6			Sampling point 12		
	20/7	22/7	24/7	20/7	22/7	24/7	20/7	22/7	24/7
Spirogyra cf. porticalis	429,0	186,0	42,1	191,0	93,5	39,0	-	-	-
Oedogonium sp.	17,4	12,6	8,4	13,1	13,5	7,2	-	-	-
Bottom deposits	0,09	0,13	0,10	0,16	-	-	0,15	0,18	0,12
Eurycercus lamellatus	6,42	-	-	3,40	-	-	1,07		

Sampling points 1, 6, 12 represent the points at 1/12, 6/12, 12/12 of the total channel length.

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EXPERIMENTS ON UPTAKE OF Cs^{134} IN THE THROUGHFLOW CHANNELS

20th July, 1961

EXPERIMENTAL CONDITIONS

Water flow	:	1 l/sec.
Water velocity	:	7 cm/sec.
Water temperature	:	19 - 22°C
Exposure time	:	41 minutes
Total amount of activity added	:	304 μc
Theoretical concentration of radioactivity in water at starting point	:	$1,2 \cdot 10^{-4}$ μc/ml
Objects studied	:	Spirogyra cf. porticalis, Oedogonium sp., Eurycercus lamellatus, Bottom deposits.

RESULTS OF MEASUREMENTS

TABLE 1

Water samples

Sampling point	Activity in water $\mu c/ml \cdot 10^{-5}$	Activity in filter $\mu c/ml \cdot 10^{-6}$	pH	κ_{20}	Turbidity mg/l SiO_2
Background	0,2	0,63	7,8	$58,4 \cdot 10^{-6}$	58,0
1	8,6	12,4	7,5	$58,0 \cdot 10^{-6}$	72,0
6	9,9	9,3	7,6	$58,4 \cdot 10^{-6}$	58,4
12	5,8	7,7	8,0	$58,0 \cdot 10^{-6}$	69,6

TABLE 2

Experimental objects

Cs^{134} µc/mg ash weight • 10^{-5}

Species \ Date	Sampling point 1			Sampling point 6			Sampling point 12		
	20/7	22/7	24/7	20/7	22/7	24/7	20/7	22/7	24/7
Spirogyra cf. porticalis	2,94	1,40	0,48	3,04	10,9	0,55	-	-	-
Oedogonium sp.	2,90	1,02	0,61	3,94	1,67	0,82	-	-	-
Bottom deposits	0,25	0,61	0,49	0,25	-	-	0,27	0,44	0,23
Eurycercus lamellatus	0,59	-	-	0,27	-	-	0,45		

Sampling points 1, 6, 12 represent the points at 1/12, 6/12, 12/12 of the total channel length.

KH/MB

EXPERIMENTS ON UPTAKE OF Sr^{89} IN THE THROUGHFLOW CHANNELS

5th September, 1961

EXPERIMENTAL CONDITIONS

Water flow	:	0,5 l/sec.
Water velocity	:	4,5 cm/sec.
Water temperature	:	10 - 15°C
Exposure time	:	30 minutes
Total amount of activity added	:	37,8 μc
Theoretical concentration of radioactivity in water at starting point	:	$4,0 \cdot 10^{-5}$ μc/ml
Objects studied	:	Spirogyra cf. formosa, Spirogyra cf. porticalis, Oedogonium sp., Anodonta cygnea, Bottom deposits.

RESULTS OF MEASUREMENTS

TABLE 1

Water samples

Sampling point	Activity in water $\mu c/ml \cdot 10^{-6}$	Activity in filter $\mu c/ml \cdot 10^{-6}$	pH	κ 20	Turbidity mg/l SiO_2
Background Nitelva	0,10				
Background channel	0,06		9,8	$62,2 \cdot 10^{-6}$	27,8
1	47	1,9			
12	22	3,3			
12 1 hour after starting exposure	10	2,7			
12 during exposure	24	0,8			
12 during exposure	23	1,8			

IAEA Research Contract No. 37
5th September, 1961

TABLE 2
Experimental objects

Sr^{89} µc/mg ash weight • 10^{-6}

Sampling points	1			3			6		9		12	
Species	Back-ground	5/9	7/9	Back-ground	5/9	7/9	5/9	7/9	5/9	7/9	5/9	7/9
Spirogyra cf. formosa	1,1	1,4	0,25									
Spirogyra cf. porticalis				0,37	1,3	0,29	2,3	0,31				
Oedogonium sp.									3,2	0,70	3,1	0,80
Bottom deposits	0,02	0,41	0,41	0,08	1,3	0,49						

ANODONTA CYGNEA

Date	5/9		7/9	
Specimen	Soft Tissue	Shell	Soft Tissue	Shell
1	0,99	0,042	0,70	0,014
2	0,21	0,045	0,77	0,021

Sampling points 1, 3, 6, 9, 12 represent the points at 1/12, 3/12, 6/12, 9/12, 12/12 of the total channel length.

KH/MB

EXPERIMENTS ON UPTAKE OF Sr^{89} IN THE THROUGHFLOW CHANNELS

12th September, 1961

EXPERIMENTAL CONDITIONS

Water flow	:	0,5 l/sec.
Water velocity	:	4,5 cm/sec.
Water temperature	:	10 - 15°C

Three experiments.

Experiment 1

Exposure time	:	20 minutes
Total amount of activity added	:	55,4 μc
Theoretical concentration of radioactivity in water at starting point	:	$9{,}2 \cdot 10^{-5}$ μc/ml

Experiment 2

Exposure time	:	19 minutes
Total amount of activity added	:	52,5 μc
Theoretical concentration of radioactivity in water at starting point	:	$9{,}2 \cdot 10^{-5}$ μc/ml

Experiment 3

Exposure time	:	15 minutes
Total amount of activity added	:	41,5 μc
Theoretical concentration of radioactivity in water at starting point	:	$9{,}2 \cdot 10^{-5}$ μc/ml
Objects studied	:	Spirogyra cf. formosa, Spirogyra cf. porticalis, Oedogonium sp., Anodonta cygnea, Bottom deposits.

RESULTS OF MEASUREMENTS (See the following tables)

IAEA Research Contract No. 37
12th September, 1961

TABLE 1

Water samples

Sr^{89} μc/mg ash weight • 10^{-5}

	Time	Activity in water μc/ml • 10^{-6}	Activity in filter μc/ml • 10^{-6}	pH	κ_{20}	Turbidity mg/l SiO_2
Experiment 1	3.00 p.m.	21	2,3	9,2	$5C,3 \cdot 10^{-6}$	31,0
Experiment 1	3.15 "	35	3,6	9,1		
Experiment 2	5.37 "	13	4,8	8,8		

The samples are taken from sampling point 12.

KH/MB

TABLE 2

Experimental objects

Species \ Sampling point	Sr^{89} µc/mg ash weight · 10^{-6}					
	0,5	1	3	6	9	12
Experiment 1						
Spirogyra cf. formosa	1,7	2,2				
Spirogyra cf. porticalis			4,9	3,6		
Oedogonium sp.					4,5	13,3
Bottom deposits	0,19	0,38	0,36	0,97	0,63	0,73
Experiment 2						
Spirogyra cf. formosa	3,3	7,8				
Spirogyra cf. porticalis			13,8	11,7		
Oedogonium sp.					36,7	43,9
Bottom deposits	0,22	0,74	0,74	1,6	0,81	0,89
Experiment 3						
Spirogyra cf. formosa	2,6					
Spirogyra cf. porticalis			4,2			
Oedogonium sp.					3,5	4,0
Bottom deposits	0,41		0,60		0,80	0,63

ANODONTA CYGNEA

Sr^{89} µc/mg ash weight · 10^{-6}		
Sample No.	Soft Tissue	Shell
1	0,22	0,023
2	0,59	0,065
1	0,13	0,11
2	0,63	0,055
1	1,19	0,047
2	0,80	0,037

Sampling points at 0,5, 1, 3, 6, 9, 12 represent the points at 0,5/12, 1/12, 3/12, 6/12, 9/12, 12/12 of the total channel length.

KH/MB

EXPERIMENTS ON UPTAKE OF Sr^{89} IN THE THROUGHFLOW CHANNELS

20th September, 1961

EXPERIMENTAL CONDITIONS

Water flow	:	0,5 l/sec.
Water velocity	:	4,5 cm/sec.
Water temperature	:	12 - 14°C
Exposure time	:	60 minutes
Total amount of activity added	:	150 µc
Theoretical concentration of radioactivity in water at starting point	:	$8{,}3 \cdot 10^{-5}$ µc/ml
Objects studied	:	Spirogyra cf. formosa, Spirogyra cf. porticalis, Oedogonium sp., Anodonta cygnea, Bottom deposits.

RESULTS OF MEASUREMENTS

TABLE 1

Experimental objects

Species \ Sampling point	Sr^{89} µc/mg ash weight $\cdot 10^{-6}$					
	0,5	1	3	6	9	12
Background						
Spirogyra cf. formosa	0,82	0,84				
Spirogyra cf. porticalis			0,64	0,60		
Oedogonium sp.					1,03	0,42
Bottom deposits	0,21	0,20	0,47	1,39	0,49	0,36
After exposure						
Spirogyra cf. formosa	4,6	5,6				
Spirogyra cf. porticalis			17,0	8,1		
Oedogonium sp.					14,9	11,9
Bottom deposits	0,50	0,61	1,14	1,7	6,0	4,7

ANODONTA CYGNEA

Sr^{89} µc/mg ash weight • 10^{-6}		
	Soft Tissue	Shell
Background	0,81	0,06
After exposure	3,7	0,05

KH/MB
15.3.1962

IAEA Research Contract No. 37

EXPERIMENTS ON UPTAKE OF Ru^{106} IN THE THROUGHFLOW CHANNELS

3rd October, 1961

EXPERIMENTAL CONDITIONS

Water flow	:	0,5 l/sec.
Water velocity	:	4,5 cm/sec.
Water temperature	:	9 - 10°C

Three experiments.

Experiment 1

Exposure time	:	17 minutes
Total amount of activity added	:	47,5 μc
Theoretical concentration of radioactivity in water at starting point	:	$9{,}3 \cdot 10^{-5}$ μc/ml

Experiment 2

Exposure time	:	26 minutes
Total amount of activity added	:	95 μc
Theoretical concentration of radioactivity in water at starting point	:	$1{,}2 \cdot 10^{-4}$ μc/ml

Experiment 3

Exposure time	:	14 minutes
Total amount of activity added	:	190 μc
Theoretical concentration of radioactivity in water at starting point	:	$4{,}5 \cdot 10^{-4}$ μc/ml

Objects studied : Spirogyra cf. formosa, Oedogonium sp., Anodonta cygnea, Bottom deposits.

RESULTS OF MEASUREMENTS (See the following tables)

IAEA Research Contract No. 37
3rd October, 1961

TABLE 1

Water samples

Ru^{106} μc/mg ash weight • 10^{-5}

	Time	Activity in water μc/ml • 10^{-6}	Activity in filter μc/ml • 10^{-6}	pH	κ_{20}	Turbidity mg/l SiO_2
Background		0,013				
Experiment 1	2.30 p.m.	21,8	0,41	8,7	$57{,}5 \cdot 10^{-6}$	39,0
Experiment 1	2.32 "	29,2	0,39			
Experiment 1	2.37 "	43,1	0,83			
Background	4.00 "	0,11	0,13			
Experiment 2	5.13 "	53	0,34	7,7		
Experiment 2	5.17 "	71	0,43			
Background	6.42 "	0,22	0,13			
Experiment 3	8.15 "	166	0,98			
Experiment 3	8.50 "	18	0,28	7,1	$56{,}5 \cdot 10^{-6}$	43,2

The samples are taken from sampling point 12.

KH/MB

TABLE 2

Experimental objects

Species \ Sampling point	Ru^{106} μc/mg ash weight • 10^{-6}		
	1	6	12
<u>Background</u>			
Spirogyra cf. formosa	3,6		
Oedogonium sp.		3,1	2,6
Bottom deposits	0,05	0,04	0,08
<u>Experiment 1</u>			
Spirogyra cf. formosa	3,9		
Oedogonium sp.		5,6	5,7
Bottom deposits	0,10	0,16	0,15
<u>Experiment 2</u>			
Spirogyra cf. formosa	5,3		
Oedogonium sp.		7,1	8,8
Bottom deposits	0,12	0,16	0,20
<u>Experiment 3</u>			
Spirogyra cf. formosa	12,8		
Oedogonium sp.		14,1	15,2
Bottom deposits	0,16	0,26	0,50

ANODONTA CYGNEA

Ru^{106} μc/mg ask weight • 10^{-6}		
Sample No.	Soft Tissue	Shell
1	0,17	0,015
2	0,17	0,004
1	0,032	0,016
2	0,092	0,004
1	0,14	0,016
2	0,13	0,004
1	0,20	0,016
2	0,20	0,025

Sampling points at 1, 6, 12 represent the points at 1/12, 6/12, 12/12 of the total channel length.

KH/MB

EXPERIMENTS ON UPTAKE OF I^{131} IN THE THROUGHFLOW CHANNELS

16th October, 1961

EXPERIMENTAL CONDITIONS

Water flow	:	0,5 l/sec.
Water velocity	:	4,5 cm/sec.
Water temperature	:	7 - 10°C

Three experiments.

Experiment 1

Exposure time	:	14 minutes
Total amount of activity added	:	52 μc
Theoretical concentration of radioactivity in water at starting point	:	$1,2 \cdot 10^{-4}$ μc/ml

Experiment 2

Exposure time	:	15 minutes
Total amount of activity added	:	104 μc
Theoretical concentration of radioactivity in water at starting point	:	$2,3 \cdot 10^{-4}$ μc/ml

Experiment 3

Exposure time	:	15 minutes
Total amount of activity added	:	208 μc
Theoretical concentration of radioactivity in water at starting point	:	$4,6 \cdot 10^{-4}$ μc/ml

Objects studied	:	Spirogyra cf. formosa, Oedogonium sp., Anodonta cygnea, Bottom deposits.

RESULTS OF MEASUREMENTS (See the following tables)

TABLE 2
Experimental objects

Species \ Sampling point	I^{131} µc/mg ash weight · 10^{-6}		
	1	6	12
Background			
Spirogyra cf. formosa	1,1		
Oedogonium sp.		0,45	0,38
Bottom deposits	0,19	0,28	0,43
Experiment 1			
Spirogyra cf. formosa	4,9		
Oedogonium sp.		20,2	18,4
Bottom deposits	0,14	0,10	0,33
Experiment 2			
Spirogyra cf. formosa	8,8		
Oedogonium sp.		25,4	49,2
Bottom deposits	0,27	0,68	0,36
Experiment 3			
Spirogyra cf. formosa	31,7		
Oedogonium sp.		86,0	95,2
Bottom deposits	0,65	0,49	1,4

ANODONTA CYGNEA

I^{131} µc/mg ash weight · 10^{-6}		
Sample No.	Soft Tissue	Shell
1	0,49	0,019
2	0,58	0,014
1	0,70	0,034
2	1,08	0,035
1	1,87	0,039
2	1,76	0,010
1	2,78	0,072
2	3,24	0,087

Sampling points at 1, 6, 12 represents the points at 1/12, 6/12, 12/12 of the total channel length.

KH/MB

EXPERIMENTS ON UPTAKE OF NAT. URANIUM IN THE THROUGHFLOW CHANNELS

18th October, 1961

EXPERIMENTAL CONDITIONS

Water flow	:	0,5 l/sec.
Water velocity	:	4,5 cm/sec.
Water temperature	:	6 - 9°C

Three experiments.

Experiment 1

Exposure time	:	14 minutes
Total amount of activity added	:	6,35 μc
Theoretical concentration of radioactivity in water at starting point	:	$1{,}5 \cdot 10^{-5}$ μc/ml

Experiment 2

Exposure time	:	14 minutes
Total amount of activity added	:	12,7 μc
Theoretical concentration of radioactivity in water at starting point	:	$3{,}0 \cdot 10^{-5}$ μc/ml

Experiment 3

Exposure time	:	14 minutes
Total amount of activity added	:	25,4 μc
Theoretical concentration of radioactivity in water at starting point	:	$6{,}0 \cdot 10^{-5}$ μc/ml
Objects studied	:	Spirogyra cf. formosa, Oedogonium sp., Anodonta cygnea, Bottom deposits.

RESULTS OF MEASUREMENTS (See the following tables)

IAEA Research Contract No. 37
18th October, 1961

TABLE 1

Nat. U

Sampling point	1		6		12	
Water samples	Activity in water μc/ml • 10^{-6}	Activity in filter μc/ml • 10^{-6}	Activity in water μc/ml • 10^{-6}	Activity in filter μc/ml • 10^{-5}	Activity in water μc/ml • 10^{-6}	Activity in filter μc/ml • 10^{-6}
1st exposure	40	0,9	64	1,5	59	2,1
2nd exposure	121	3,5	91	2,5	35	2,1
3rd exposure	176	6,7	136	4,6	44	5,3

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TABLE 2

Experimental objects

Species / Sampling point	Nat.U μc/mg ash weight · 10^{-6}		
	1	6	12
Background			
Spirogyra cf. formosa	4,3		
Oedogonium sp.		2,5	3,9
Bottom deposits	0,29	0,47	0,58
Experiment 1			
Spirogyra cf. formosa	6,1		
Oedogonium sp.		8,4	15,9
Bottom deposits	0,37	0,74	0,67
Experiment 2			
Spirogyra cf. formosa	11,3		
Oedogonium sp.		26,9	13,8
Bottom deposits	0,41	0,49	0,71
Experiment 3			
Spirogyra cf. formosa	19,6		
Oedogonium sp.		27,8	33,5
Bottom deposits	0,47	0,81	1,58

ANODONTA CYGNEA

Nat.U μc/mg ash weight · 10^{-6}		
Sample No.	Soft Tissue	Shell
1	0,56	0,03
2	0,94	0,03
1	1,41	0,06
2	1,71	0,05
1	1,78	0,03
2	1,23	0,04
1	5,3	0,03
2	1,75	0,03

Sampling points at 1, 6, 12 represent the points at 1/12, 6/12, 12/12 of the total channel length.

KH/MB

A P P E N D I X II.

Research programme for the period

April - December 1962.

DRAFT

International Atomic Energy Agency
Research Contract No. 37

PROGRAMME FOR THE EXPERIMENTAL WORK WITH THE MODEL RECIPIENT
THE SUMMER OF 1962

The aim of the experimental investigations with the model recipient this summer is to collect items of information which makes the completion of the Research Contract No. 37 possible.

The work will include experiments and observations in the throughflow channels, the recirculation channel, the well system, and the retention pond. The biological systems studied and the methods used will be the same as previously.

It will be taken advantage of the experience gained from the experiments performed in the field station during the last summer.

The synopsis of the experiments which follows is divided in two parts after the time aspect of their performance. Extensive investigations comprise work being in progress during the whole experimental period in the field station, intensive investigations includes experiments of short duration to be performed at intervals during the summer works.

1. EXTENSIVE INVESTIGATIONS

1.1 Biological observations of flora and fauna in the channel biotopes and the retention pond.

1.2 Experiments on chromic exposure of the organisms - communities in the channel biotopes.

Radionucleides: P^{32}, Cs^{137}, Sr^{89}, Ru^{103}, Ce^{144}, Zr^{95}.

1.3 Descriptive investigations of the contamination in the retention pond.

1.4 Measurements of backgroundactivity due to fall out.

2. I N T E N S I V E I N V E S T I G A T I O N S

2.1 Field experiments on sorbtion to river sediments.

Radionucleides: Sr^{89}, Ru^{103}, Ce^{144}, Zr^{95}.

2.2 Experiments on acute exposure of organisms communities in the channel biotopes.

Radionucleides: P^{32}, Cs^{137}, Sr^{89}, Ru^{103}, Ce^{144}, Zr^{95}.

2.3 A comparative study of species of helophytes, elodeids and nymphaeids with respect to uptake of radionucleides.

Radionucleides: P^{32}, Cs^{137}, Sr^{89}.

2.4 A test of several species from the river Nitelva on their accumulation of radionucleides.

Radionucleides: P^{32}, Cs^{137}, Sr^{89}.

2.5 Experiments on uptake of radionucleides by fish.

Radionucleides: P^{32}, Cs^{137}.

1.1 BIOLOGICAL OBSERVATIONS OF FLORA AND FAUNA IN THE CHANNEL BIOTOPES AND THE RETENTION POND

This is a study in order to describe the communities in the model recipient.

The field work will include:

Collection of biological samples.

Regular photographing of typical stages in the development of the communities in the throughflow channels and the retention pond.

Monthly determinations of weight of organisms and sediments in the throughflow channels.

Measurements of the increase in height of the dominant species of macrophytes in the communities of the retention pond.

Supplementary work on weight relations of experimental objects.

The following topics have to be considered:

The changing phases of vegetation and fauna during the experimental period.

The longitudinal succession of communities in the throughflow channels.

A comparison of the development of biota in the throughflow channels with river water and with tap water.

The influence of different types of bottom materials in the channels.

The influence of various water flows.

Observations on the sexual periods of selected species in the model recipient.

Phenological observations in the retention pond.

1.2 EXPERIMENTS ON CHROMIC EXPOSURE OF THE ORGANISMS-COMMUNITIES IN THE CHANNEL BIOTOPES

The purpose of the experiment is to investigate the uptake and distribution of radionucleides to biota and sediments in the through-flow channels under conditions of chromic exposure.

Two channels will be used for this experiments. The radionucleides combination will be:

a. P^{32}, Cs^{137} and Ce^{144}

b. Sr^{89}, Ru^{103} and Zr^{95}

Weekly observations in the channels are intended.

Programme for the field work:

Collection of water samples. Water samples representative for one week are obtained by collection of daily samples and perserving with formalin.

Harvest of algae (2 major species) and invertebrates (2 major species).

Sampling of bottom deposits.

The objects will be samples at three channel intervals.

It is intended to combine this experiment with exposure of Anodonta Cygnea, and possibly Astacus fluviatilis at the end of the channels.

1.3 DESCRIPTIVE INVESTIGATIONS OF THE CONTAMINATION IN THE RETENTION POND

The descriptive study of the biota in the retention pond during last summer will be continued with an investigation of the contamination levels in the water, selected species of organisms and bottom deposits.

A detailed journal of the radionucleid discharge to the pond will be maintained.

Monthly observations in the retention pond are intended.

Programme for the field work:

Collection of water samples (the same procedure as 1.2).

Objects to be examined:

6 species of macrophytes
3 species of invertebrates
2 species of algae
3 samples of bottom deposits

This investigation will also form the basis of the field experiment with fish (See 2.5).

It is necessary to perform, at monthly intervals, determinations of the background radioactivity in the same biological objects from the river Nitelva (See 1.4).

1.4 MEASUREMENT OF BACKGROUND RADIOACTIVITY DUE TO FALL-OUT

The present situation with a high rate of radioactive fall-out makes it necessary to perform measurement of fall-out activity in various media.

Besides being a necessary supplement to our investigations, the obtained results will also be of general interest.

Weekly observations in a separate throughflow channel are planned.

The measurements will include analysis of Sr^{89}, Sr^{90}-Y^{90} and gamma spectrometric analysis.

Programme for the field work:

Collection of water samples (the same procedure as 1.2).

Objects to be examined:

2 species of algae
1 sample of bottom deposits.

Specimens of organisms, comprising the same species as under observation in the retention pond, will be collected from the river Nitelva each month.

In connection with this field work samples of Phoxinus phoxinus and Salmo trutta, and the species of helophytes, elodeids and nyphaeids will be collected. This biological material will be analysed for the chief chemical components.

2.1 FIELD EXPERIMENTS ON SORBTION TO RIVER SEDIMENTS

In order to complete the investigation on sorbtion of radionucleides to river sediments, the laboratory experiments will be supplemented with experiments in the recirculation channel.

The experiments will be carried out with natural river water.

The radionucleides to be tested are: Sr^{89}, Ru^{103}, Ce^{144}, Zr^{95} (Cs^{137}, P^{32}).

A total number of 6 experiments are planned, each experiment will last for 3 days.

The factors to be analysed are: Turbidity, electrolytic conductivity, pH, and radioactivity in the particle fraction and the water phase.

It is considered of interest to perform X-ray spectrometric analysis of the clay minerals and electron-microphotographing for determination of particle size distribution.

2.2 EXPERIMENTS ON ACUTE EXPOSURE OF ORGANISMS-COMMUNITIES IN THE CHANNEL BIOTOPES

The results of former experiments of this type show that the following matters have to be considered:

a. The amount of uptake of radionucleides as a function of time.

b. The rate of elimination of radionucleides from the organisms.

c. A comparison between river water and tap water in order to evaluate the influence of turbidity on the distribution of radionucleides.

d. The self purification process, with respect to water decontamination.

Radionucleides to be tested are:

P^{32}, Cs^{137}, Sr^{89}, Ru^{103}, Ce^{144}, and Zr^{95}.

The experiments will be repeated three times during the summer season, preferably in June, July, and September. Two of the through-flow channels are to be used for this purpose. The experiments will be performed with one single isotope each time.

Experimental procedure.

a. The radionucleides to be tested will be dosed continuously for several hours (for example 6 hours). Collection of samples will be carried out at defined intervals in the channel. Algae and invertebrates are to be sampled. The sampling are to be carried out after 10 minutes, 30 minutes, 60 minutes, and 2, 3, 4, 5, and 6 hours.

b. A study of the loss of radionucleides from the biological objects is planned to follow each experiment of type a. The same species are under observation and samples will be collected after 15 minutes, 30 minutes, 1, 2, 4, 8, 16 hours and 2 days.

c. These experiments will follow the same procedure as described in a. and b. The radionucleides to be used are restricted to P^{32}, Cs^{137}, Sr^{89}.

d. The data obtained from the experiments a. and b. will give the information necessary to evaluate this problem. A few experiments are, however, planned specially for this purpose.

2.3 A COMPARATIVE STUDY OF HELOPHYTES, ELODEIDS, AND NYMPHAEIDS WITH RESPECT TO UPTAKE OF RADIONUCLEIDES

A few organisms, representing the littoral and sublittoral zone, possessing different physiological properties will be examined with respect to their ability to concentrate radionucleides.

The radionucleides to be tested are:

P^{32}, Cs^{137}, and Sr^{89}.

The experiments will be conducted two times.

Each experiment will last for 14 days, with collection of samples every second day.

The samples are to be analysed for:

Water	:	Turbidity, electrolytic conductivity, pH, and radioactivity in water phase and particle phase.
Plant materials	:	Radioactivity and weight.

It is also found of interest to perform a field experiment with *Potamogeton perfoliatus* in situ on a river locality.

2.4 A TEST OF SEVERAL SPECIES FROM THE RIVER NITELVA ON THEIR ACCUMULATION OF RADIONUCLEIDES

The autecological investigations on uptake of radionucleides by selected species will be extended to include several other important organisms from the river Nitelva.

The collection of organisms for these tests will be combined with the sampling of materials for measurement of background activity (see 1.4).

The organisms will be exposed to the radionucleides in the recirculation channel for 14 days.

The experimental procedure will follow the procedure described in 2.3.

Radionucleides to be tested are: P^{32}, Cs^{137}, Sr^{89}.

2.5 EXPERIMENTS ON UPTAKE OF RADIONUCLEIDES BY FISH

The different types of dispensing radionucleides to fish in the present investigation will be continued by feeding experiments with contaminated food.

A field experiment which is intended to give information on food chain transfer to fish will be conducted in the retention pond.

The experimental procedure will be the same as previously used in this project.

Species of fish: *Phoxinus phoxinus* and *Salmo trutta*.

REMARKS

The programme for the work in the recipient model the summer of 1962 formulated in the preceding pages considers the scientific part only.

It should, however, be realized that a considerable effort has to be put into the regular maintenance and management of a biological field station.

LIST OF RADIONUCLEIDES TO BE USED IN THE EXPERIMENTS

Radionucleides		Half-lives	Gamma energy+	Beta energy+
Phosphorus	P^{32}	14,2 d.	-	1,71 Mev.
Caesium	Cs^{137}	30 y.	0,66 Mev.	0,51 "
Strontium	Sr^{89}	51 d.	-	1,46 "
Ruthenium	Ru^{103}	40 d.	0,50 "	0,21 "
Cerium	Ce^{144}-Pr^{144}	285 d.	0,133 "	2,98 "
Zirconium	Zr^{95}-Nb^{95}	65 d.	0,73 " 0,76 "	0,36 " 0,40

+The beta and gamma energies listed are the energies of highest abundance.

Figure 18.

Research Programme for the Periode April - December 1962.

Experiments planned:	April	May	June	July	August	September	October	November	December	Required personnel and time. person	month
Laboratory work.										L: 4,0	1
Biological observations of flora and fauna in the channel biotopes and the retention pond.										F: 0,35	6
Experiments on chronic exposure of the organisms - communities in the channel biotopes. Radionucleids: P^{32}, Cs^{137}, Sr^{89}, Ru^{103}, Ce^{144}, Zr^{95}.										F: 0,35 L: 2,0	6 6
Descriptive investigations of the contaminaton in the retention pond.										F: 0,25 L: 0,25	6 6
Measurement of background-activity due to fall-out.										F: 0,1 L: 0,25	6 6
Field experiments on sorbtion to river sediments. Radionucleids: Sr^{89}, Ru^{103}, Ce^{144}, Zr^{95}.										F: 0,25 L: 0,25	1 1
Experiments on acute exposure of organisms - communities in the channel biotopes. Radionucleids: P^{32}, Cs^{137}, Sr^{89}, Ru^{103}, Ce^{144}, Zr^{95}										F: 0,35 L: 1,0	3 3
A comparative study of helophytes, elodeids and nymphaeids with respect to uptake of radionucleids. Radionucleids: P^{32}, Cs^{137}, Sr^{89}.										F: 0,5 L: 0,25	2 2
A test of several species from the river Nitelva on their accumulation of radionucleids. Radionucleids: P^{32}, Cs^{137}, Sr^{89}.										F: 0,5 L: 0,5	1 1
Experiments on uptake of radionucleids by fish. Radionucleids: P^{32}, Cs^{137}.										F: 1,0 L: 0,1	4 4
Conclusion, preparation of report.										L: 4,0	2
Required personnel:	 L:4,0	F: 2,30 L: 2,85	F: 2,65 L: 3,73	F: 1,65 L: 3,63	F: 1,55 L: 3,0	F: 2,90 L: 3,85	F: 2,05 L: 2,60	 L: 4,0	 L: 4,0	13,1 person month 31,6 person month	

F: Field work

L: Laboratory work

1 cm : 1 person.

4 cm : 1 month.