The Correlation between the Precipitation and the Amount of ^{137}Cs in Milk in Norway.

Authors:

Madshus, Kjell, M. Sc. Engineering Physics N.T.H.
Norsk Hydros Institute for Cancer Research,
Oslo.
Chief: Director R. Eker, Dr. Med.

Strømme, Aksel, M. D. Contract with U.S. AEC.
The Norwegian Radium Hospital,
Oslo.
Chief: Professor E. Poppe, Dr. Med.

Contributions from:

The State Institute of Radiation Hygiene,
Oslo.

Øgland, P. The Norwegian Meteorological Institute,
Oslo.

Høien, D. Norwegian Computing Center,
Oslo.

LEGAL NOTICE

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:

A. Makes any warranty or representation, expressed or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or

B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission, or employee of such contractor, to the extent that such employee or contractor of the Commission, or employee of such contractor prepares, disseminates, or provides access to, any information pursuant to his employment or contract with the Commission, or his employment with such contractor.

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

The Correlation between the Precipitation and the Amount of ^{137}Cs in Milk in Norway.

The global distribution of the radioactive fallout from nuclear weapon tests has been essentially non-uniform. Due to atmospheric movements, turbulence and diffusion in the stratosphere and prevailing west-east winds in the troposphere, most of the fallout descends on the hemisphere in which the bomb has been tested, and the northern hemisphere is therefore the most contaminated. The radioactive particles will, to a certain extent, come down as a dry debris[1], but the greater part will be brought down with rain or snow. The climate, the precipitation type and rate and the topographical peculiarities of a certain district will to a high degree determine the amount of fallout.

Among the various radioactive isotopes present in the fallout, ^{137}Cs is one of the most important from a genetic point of view. The main routes of the radioactive particles from the atmosphere and the soil to man are through plants and animal products. It is often considered that about half of the body burden of ^{137}Cs is due to consumption of milk and dairy products, but as shown [2], [3], this is not always true, although a considerable part of the body burden of ^{137}Cs in Western Europe is due to the intake of milk. The concentration of radioactive elements in milk is at a minimum in spring, when the cows are kept in sheds and partly fed upon supplementary fodder. The biological half-life of ^{137}Cs in cows is only about 20 days [4], i.e. the body burden will rapidly be reduced if the cows are fed upon uncontaminated fodder.

From 1958 until the autumn of 1961 there were no nuclear bomb tests. It therefore seemed reasonable to assume that in the spring of 1962 we should find the lowest ^{137}Cs body burden in cows and consequently the lowest ^{137}Cs concentration in milk for the next few years, if no more nuclear weapons were tested in the atmosphere. At that time the cows were fed upon supplementary fodder and grass gathered before the bomb tests were resumed in the autumn of 1961. We therefore started a systematical analysis of milk with regard to the ^{137}Cs content, and these analyses were repeated on the same scale during the spring of 1963 and the spring of 1964. Spring, means, in this connection, the months of March and April although a few of the milk samples were gathered in February and May.

The total number of dairies in Norway and the number of dairies from which milk was sampled each year is shown in Table 1. It will be seen that practically all of the dairies were included in the investigation. Milk from 30 of these dairies has been examined regularly every month since the spring of 1963. These 30 dairies, or 10% of the total number, were chosen so that they were spaced as evenly as was considered practical. Fig. 1 shows the location of these 30 dairies. Fig. 2 shows that at least in the period March 1963 to March 1964 the lowest concentration of ^{137}Cs in milk occurred during springtime (for the significance of the numbers I, II and III see below).

Fig. 3 shows a map of Norway where the county borders are drawn and where the counties have been given numbers from 1 to 18. A line is drawn on the map dividing the country into three zones. This line follows the borders of the counties except in Sør-Trøndelag (14) and Nord-Trøndelag (15), where it divides these counties in a part near to the coast, included in zone II, and an eastern part, included in zone I. This division of the country into three zones is due to meteorological conditions which will be described later. Except in (14) and (15), no dairies are situated near the zone line, as this part of the country is very mountainous.

Zone I : 1 Østfold, 2 Akershus, 3 Hedmark, 4 Oppland, 5 Buskerud, 6 Vestfold, 7 Telemark, 14 (a) eastern part of Sør-Trøndelag, 15 (a) eastern part of Nord-Trøndelag.

Zone II : 8 Aust-Agder, 9 Vest-Agder, 10 Rogaland, 11 Hordaland 12 Sogn og Fjordane, 13 Møre og Romsdal, 14 (b) western part of Sør-Trøndelag, 15 (b) western part of Nord-Trøndelag.

Zone III : 16 Nordland, 17 Troms, 18 Finnmark.

Fig. 4 shows the average concentration of ^{137}Cs in the milk in each county in the three zones in the spring of 1962, 1963 and 1964. It can be seen from this figure that concentrations of ^{137}Cs are different in zone I and II and usually much higher in the latter. Fig. 5 shows the average concentration of ^{137}Cs in the milk in the three zones each spring. As discussed later, the precipitation rate and form are rather different in the three zones. It seemed to be of interest to investigate whether there was any correlation between the precipitation and the concentration of ^{137}Cs in milk.

From gammaspectroscopic measurements performed by us in our laboratory, we knew the amount of ^{137}Cs in the milk from the same dairies at the same time of the year for 3 consecutive years. It was presumed that the ^{137}Cs which was deposited in the soil until the nuclear weapon test series in the autumn 1961, would give the same contribution to the milk's content of ^{137}Cs in 1962, 1963 and 1964 due to the long physical half-life of ^{137}Cs - 30 years - compared to the time of observation - 3 years. ^{137}Cs is strongly bound in the soil and diminishes very slowly [5]. Besides, most of the ^{137}Cs ingested by cows originates from ^{137}Cs deposited directly from the air to the leaves and to a far lesser degree from the soil via the roots [6]. The increase of the ^{137}Cs content of milk therefore ought to be exclusively due to increased fallout.

The year, 1961, is therefore used as the basic year and to minimize local variations in the precipitation for that year, we have used the average precipitation for 1959, 1960 and 1961 instead of the precipitation in 1961 only.

These facts are important when considering the precipitation in the various districts from which the dairies receive their milk supplies : The precipitation rate in Norway varies considerably from one county to another and is measured by a large number of stations. Apart from exceptional occurrences such as local squalls, stations situated near each other in a small, not too mountainous area at some distance from the coast will record only slight differences in the amount of precipitation, Stations, however, situated on the leeside of mountains or mountain ranges. commonly record considerably less precipitation than stations situated where the geological formations force moist air upwards. Where moist air is forced upwards due to topographical conditions, one will find that the precipitation usually increases with the height above the sea. These conditions very often apply to regions in Western and Northern Norway where stations are situated rather close to each other, but have very different precipitation rates. Observations from single stations are therefore not representative for their districts, and in the present study the average precipitation rates from several stations in and around the district in question have been used. The precipitation rate in the district from which the dairy receives its milk has therefore been estimated as the average, probable precipitation rate measured by meteorological stations in and around the district. Differences from the true precipitation will be reduced by this method of averaging.

Figs. 6, 7 and 8 show the specific concentration of ^{137}Cs in spring milk versus precipitation the preceeding year. In fig. 6 the average precipitation in the three years 1959, 1960 and 1961 has been used, whereas in fig. 7 and fig. 8 the precipitation in 1962 and 1963 has been used respectively.

In Norway, the grass which is to be cut for hay is usually grown during May, June and July. Besides finding the correlation between the yearly precipitation and the ^{137}Cs concentration in milk, it is of interest to correlate the amount of precipitation in this period with the ^{137}Cs concentration in the milk next spring. Statistical analyses show no such correlation in any of the three zones.

However, in zone II and III there are statistically significant correlations between the yearly precipitation and the concentration of ^{137}Cs in the milk the following spring. These correlations are significant in zone II for all three years, and in zone III for the last two years.

In zone I no significant correlation has been found. The coefficients of correlation are shown in Table II. Several of these amount to statistically significant correlations, but only those which are underlined are used, as only those are consecutive. In fig. 9, with respect to zone II and fig. 10, with respect to zone III, the relationship between precipitation and ^{137}Cs is shown as lines of regression together with their 95% confidence limits (in all of the calculations we have tried equations of first degree as well as equations of second degree but the curves turned out to be so similar that only equations of first degree have been used.).

Discussion :

The prevailing winds in Norway blow from west to east. At a distance from the coast, mountains force these masses of moist air upwards where the temperature is lower, causing them to condense and fall as rain or snow, favouring an increase of radioactive fallout. Fig. 11 shows the total, yearly precipitation in Norway averaged over a 30 year period. In zone I a greater part of the precipitation falls in summer as rain. A considerable part of the remaining precipitation in this zone comes down as snow, bringing the fallout down with the snow particles. A certain amount of this snow melts and together with its content of radioactive particles flows away without contaminating the soil while the earth is still frozen. In this way some of the radioactive particles will be carried to the rivers and can not contribute to the contamination of milk. In zone II most of the precipitation falls in winter, but even then it falls mostly as rain i.e.

in districts where cows are grazing or hay collected. In the counties Aust-Agder (8), Vest-Agder (9), and the southern part of Rogaland (10) some distance from the coast, the precipitation is more evenly distributed over summer and winter. In zone III by far the greater part of the dairies and also the districts where the milk is collected are situated along the coast. Here, too, most of the precipitation falls in winter, but a greater percentage than in zone II will fall as snow instead of as rain. The precipitation decreases as one goes north and in the interior of Finnmark (18) the climate is rather dry; here most of the precipitation falls in summer and as rain. The precipitation in zone II and partly in zone III is greater than in zone I and will therefore presumably wash out larger amounts of fallout from the atmosphere.

Summary and Conclusions.

The prevailing winds in Norway blow from the Atlantic towards the east. Along the west coast the peculiar topographical conditions will favour a greater precipitation and also a greater deposition of radioactive fallout than in the eastern part of the country. The precipitation in several districts in Norway has been estimated for three consecutive years (1961, 1962 and 1963) and the concentration of ^{137}Cs in milk from about 90% of the dairies in Norway has been measured during the following spring (1962, 1963 and 1964 respectively). Along the coast statistically significant correlations between the precipitation one year and the amount of ^{137}Cs in milk the following spring have been demonstrated for three consecutive years. In the eastern part of Norway there is no such systematic correlation. Neither is any such correlation found between the precipitation during the months when grass for storage is grown (May, June and July) and the amount of ^{137}Cs in the milk the following spring in any district any year.

References :

1) Blifford et al. : U. S. Naval Res. Lab., report 4607 (1955).

2) Lidén, K. : Acta Radiol. 56, 237 (1961).

3) Madshus, Strømme, Koren : Nature, vol. 200, No. 4903 (1963).

4) Vohra et al. : Health Physics, vol. 6 pp. 142-148 (1961).

5) Eisenbud : Environmental Radioactivity pp. 104-105 McGraw-Hill, New York (1963).

6) W. M. Myers : Symposium on Radioisotopes in the Biosphere, pp. 210-211 (1960).

	1962	1963	1964
No. of dairies	342	342	327
No. of samples	272	297	292

Table I

Table 1. The number of dairies and the number of samples in 1962, 1963 and 1964.

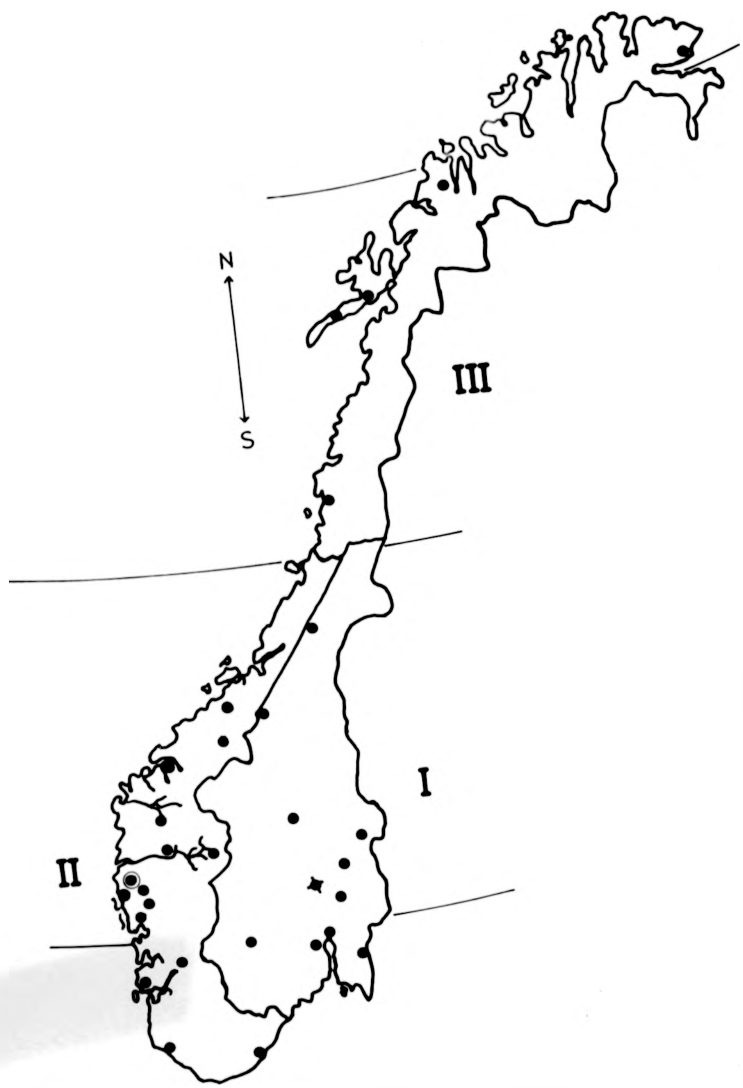

Fig. 1. The location of 30 dairies examined every month.

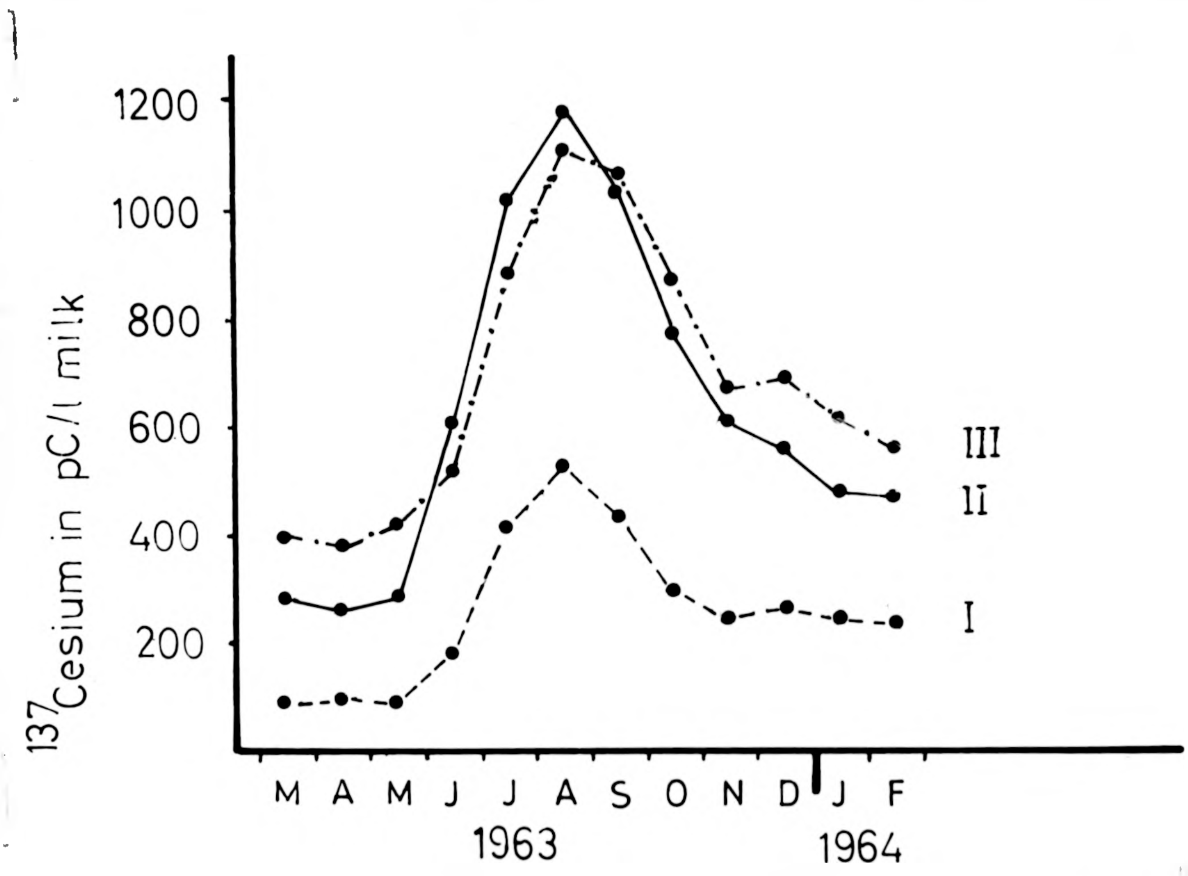

Fig. 2. The average concentration of ^{137}Cs in milk in each zone in the period March 1963 to February 1964.

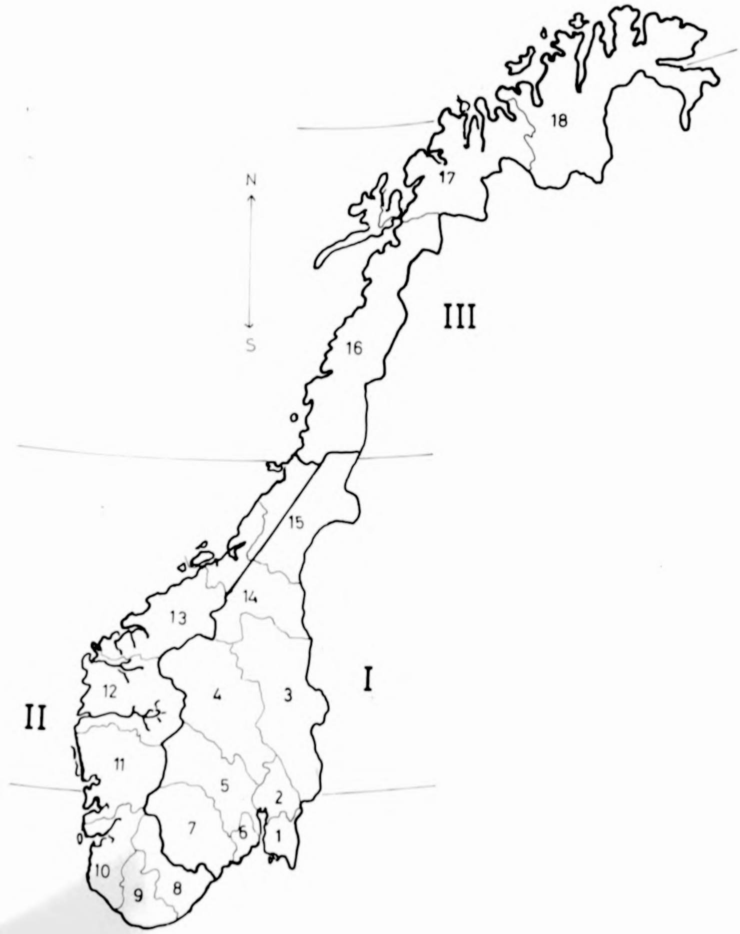

Fig. 3. The borders of the counties and the division of Norway into 3 zones.

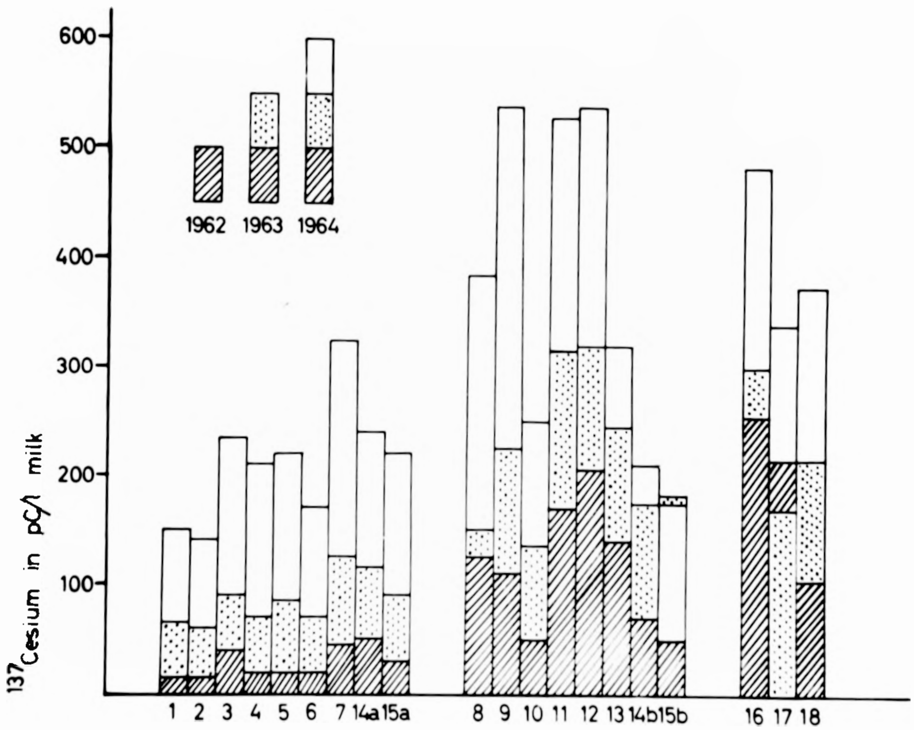

Fig. 4. The average concentration of ^{137}Cs in the milk from each county in the spring of 1962, 1963 and 1964. Zone I is represented by the group of columns 1 to 15 a, zone II by the group 8 to 15 b and zone III by the group 16 to 18.

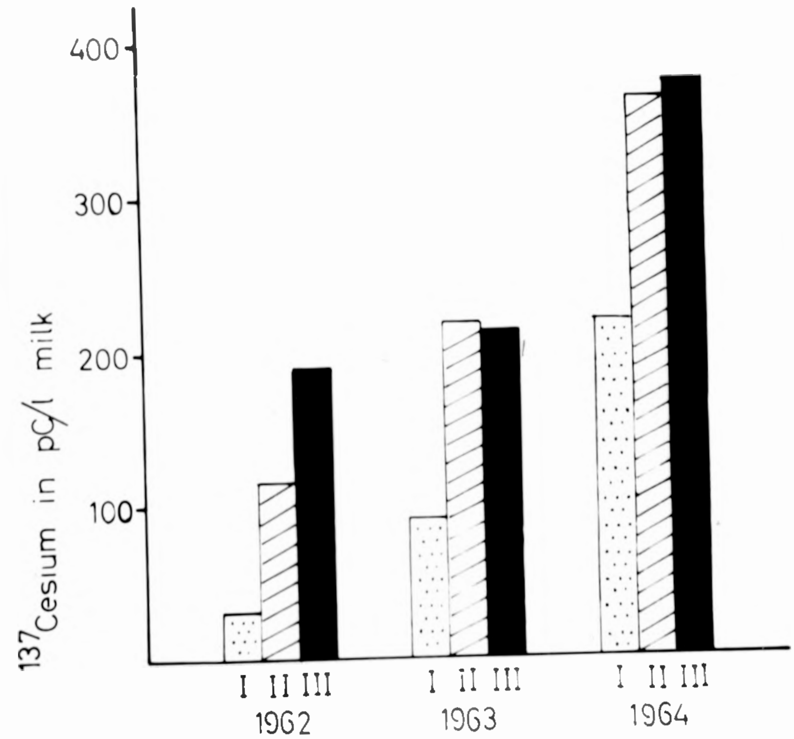

Fig. 5. The average concentration of ^{137}Cs in the milk in the three zones each spring of observation.

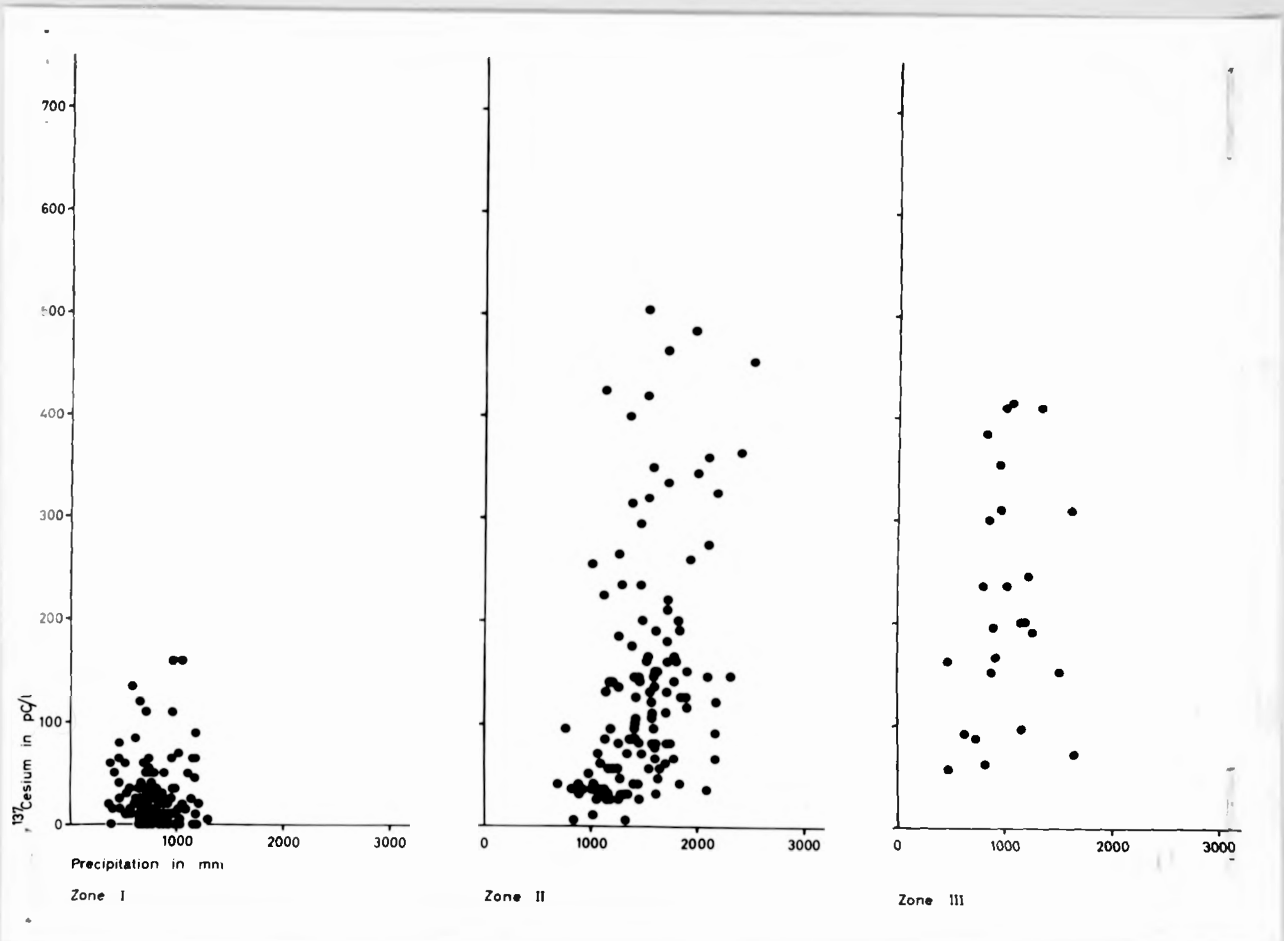

Fig. 6. ^{137}Cs in milk from the spring 1962 versus the average precipitation in 1959, 1960 and 1961.

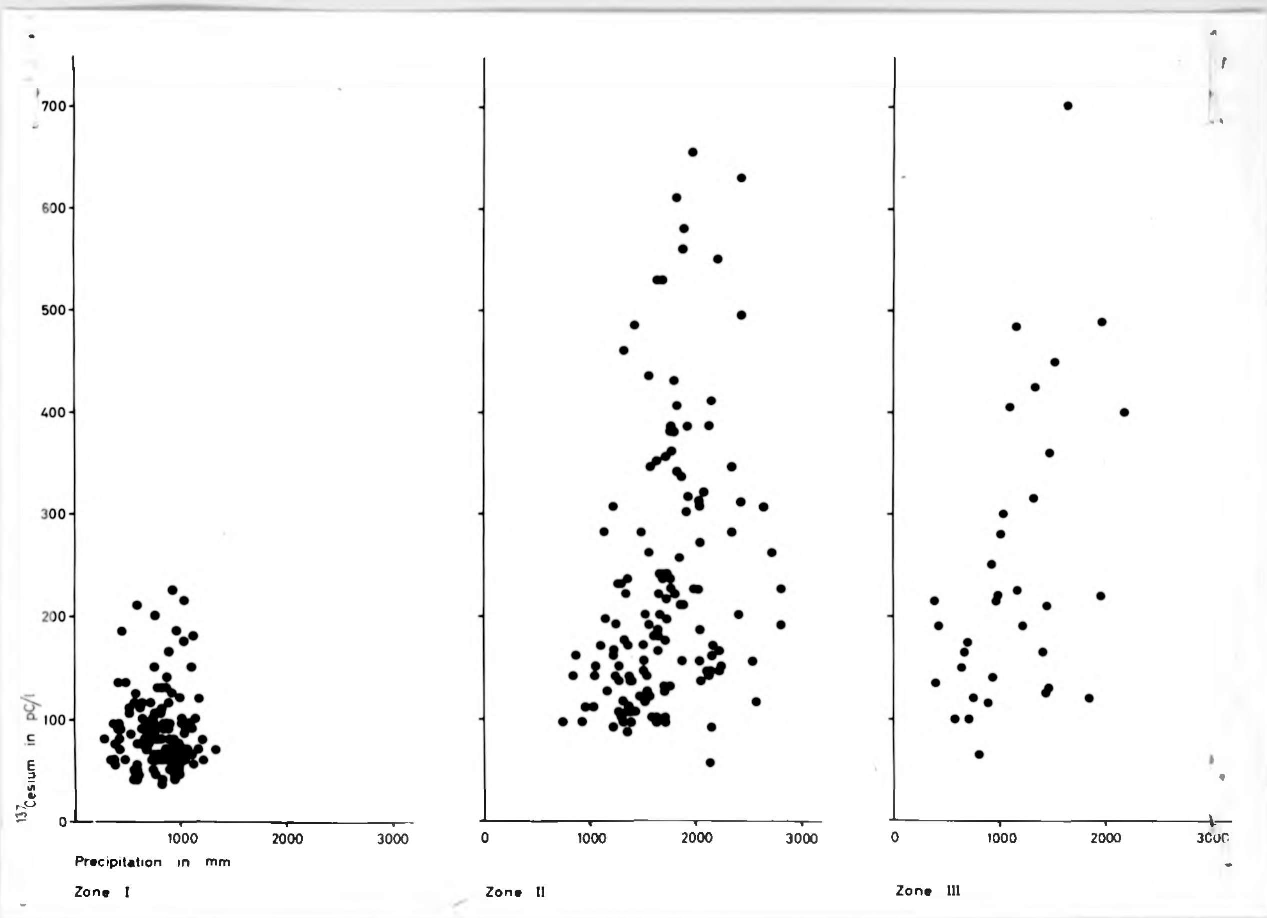

Fig. 7. ^{137}Cs in milk from the spring 1963 versus the precipitation in 1962.

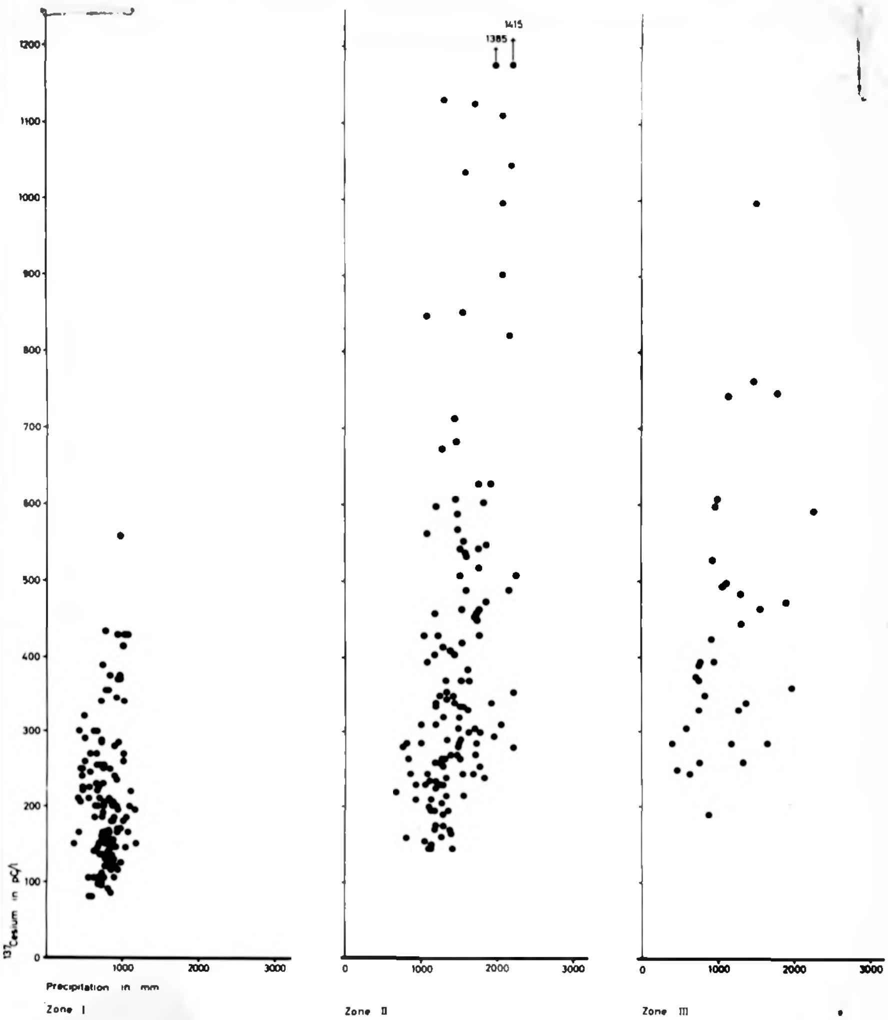

Fig. 8. ^{137}Cs in milk from the spring 1964 versus the precipitation in 1963.

	Zone	1962	1963	1964
Precipitation May-June-July	I	.310	.008	.360
	II	.312	.182	.373
	III	.011	.466	.273
Precipitation Per year	I	.009	.011	-.002
	II	.413	.395	.500
	III	.299	.496	.436

Table 2. The coefficients of correlation.

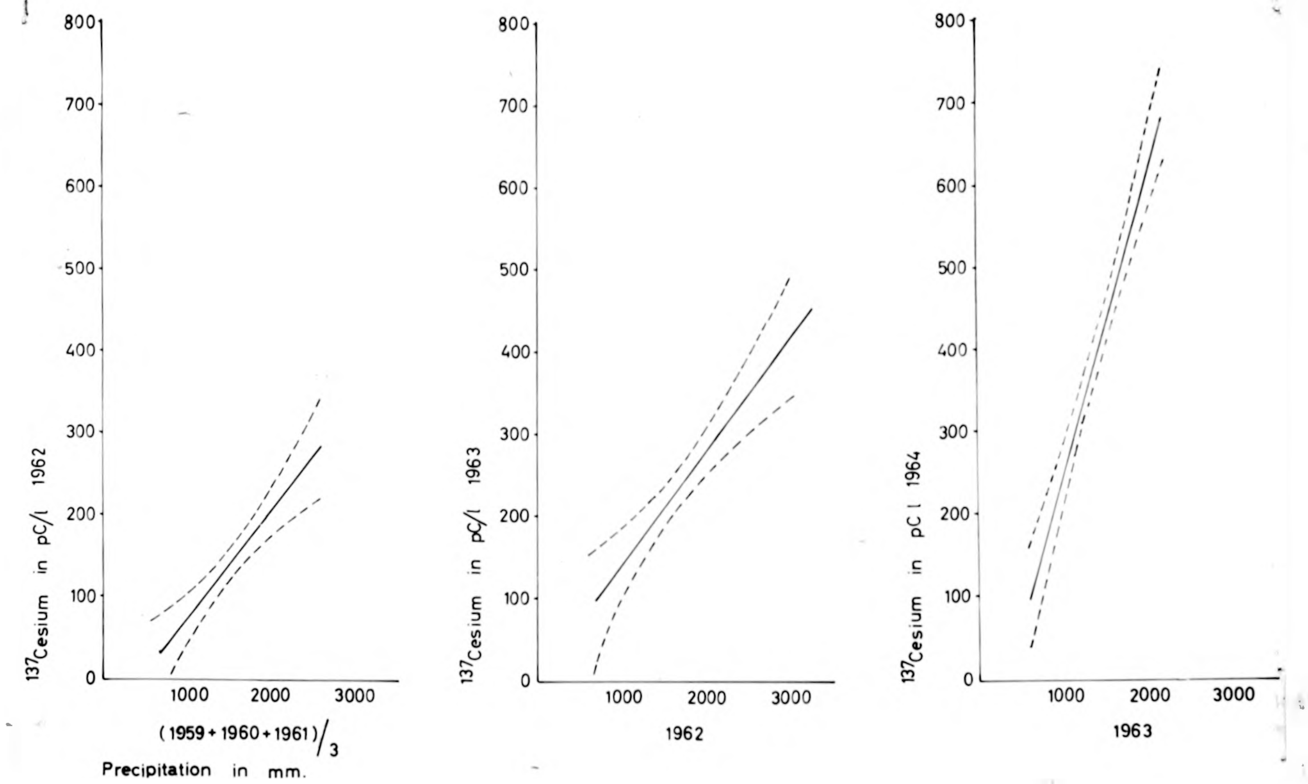

Fig. 9. The lines of regression each year and the corresponding 95% confidence limits in zone II.

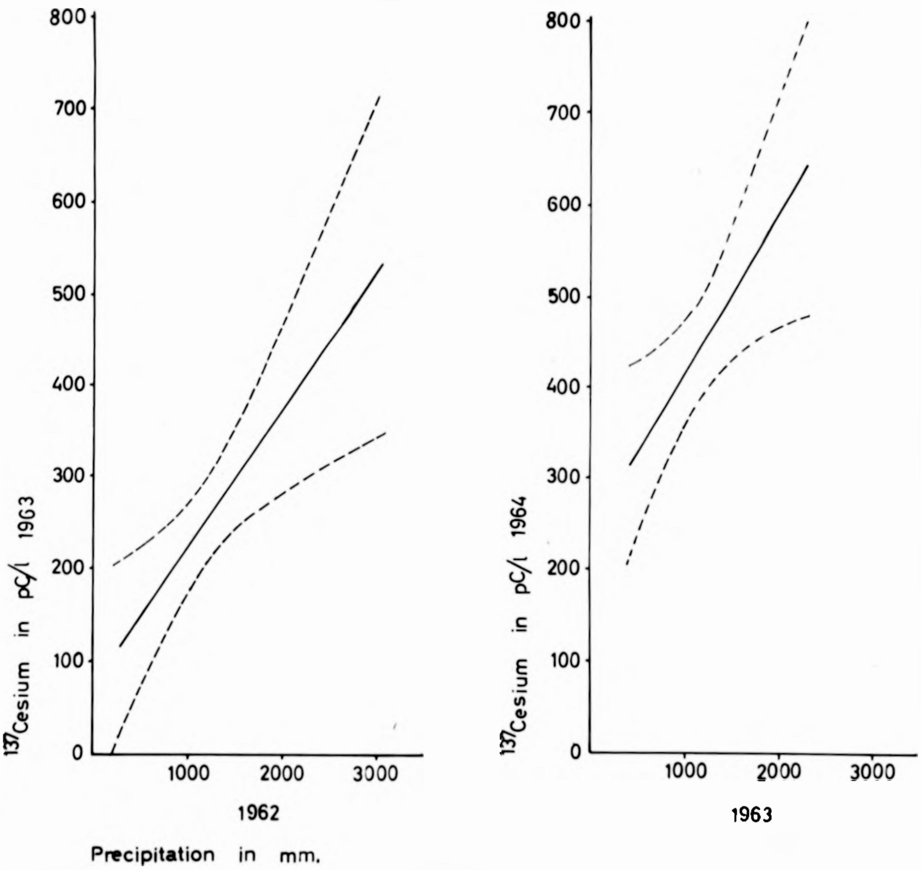

Fig. 10. The lines of regression the two last years and the corresponding 95% confidence limits in zone III.

Fig. 11. The total yearly precipitation in Norway averaged over a 30 years period. The curves are drawn for every 200 mm precipitation, and show the gross distribution and amount of precipitation.