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Sir Gethin Jones

WASHINGTON CONFERENCE ON STRONTIUM PROJECT

16th - 19th October 1956

Present:

Dr. Libby	U.S.A.E.C. (first hour only)
Dr. Dunham	Dept. of Biology and Medicine, U.S.A.E.C.
Dr. Claus	" " " " " "
Dr. Western	" " " " " "
Mr. Eisenbud	New York Operations Office, U.S.A.E.C.
Dr. Harley	" " " " "
Dr. Hardy	" " " " "
Dr. Martell	formerly at Chicago, now at Cambridge Air Force Research Centre
Dr. Kulp	Lamont Geological Observatory
Dr. Eckelman	" " "
Dr. Alexander	U.S. Dept. of Agriculture, Beltsville
Dr. Menzel	" " " "
Dr. Mawson	Chalk River
Dr. Crummit	" "
Dr. Sowby	Dept. of Health, Ottawa
Mr. Smales	A.E.R.E.
Mr. Stewart	"
Mr. Chamberlain	"
Dr. Bryant	"
Mr. A. Morgan	"
Col. Walklyn	U.K. Ministry of Defence
Dr. Machta	U.S. Weather Bureau

Radiological Health Hazards - Strontium 90

0144. II.

Points arising from Conference

1. ANALYTICAL METHODS

1.1 Strontium

Determination of Sr^{90} from ash or leachings is satisfactory in all laboratories, as shown by interchange of samples. Methods of extracting strontium and calcium from soils are still at variance.

U.S. soils are mostly collected by Alexander and the initial treatment done at Beltsville. Originally ammonium acetate leaching was used, now electrodialysis. Both methods leave behind unknown fractions of both Sr and Ca. Sr/Ca ratio is higher in first fraction than subsequently. Recovery depends also on size of sample. Comparison of results obtained in U.S. (Ref.4) by electrodialysis of UK 1955 soils with U.K. determination in the same soils are as follows:-

TABLE I

U.S. and U.K. determinations on U.K. 1955 soils

Lab	Method	Welsh soils	Suffolk soils
		$\mu\mu c/m^2$	$\mu\mu c/m^2$
Woolwich	Fusion	2500	830
"	HCl	2500	860
"	NH_4Ac	1400	540
U.S.	Electrodialysis	2000	400

Assuming that fusion removes 100% of the Sr^{90} activity, the percentage removed by other methods are:-

TABLE II

Percentage removal of Sr^{90}

Method	Welsh soils	Suffolk soils
Fusion	100	100
HCl	100	103
NH_4Ac	64	65
Electrodialysis	80	48

It appears that the American method of electrodialysis when used as an indicator of total fallout will give low results on calcareous soils. Private communication with Harley indicates that he is unhappy about the U.S. soil analysis methods and would prefer HCl leaching.

1.2 Caesium

Gamma ray spectroscopy as a method of estimating Cs in milk and other foods and in human bodies was briefly discussed. By comparison of results on milk from U.K. and U.S. (different samples) it appears that gross overall accuracy is obtained.

There is considerable advantage in the use of the crystal scintillator as used at Harwell over the liquid scintillator used by Anderson in the better resolution of different gamma energies.

2. METHODS OF SAMPLING

U.K. stressed importance of recording area from which vegetation sample is taken so that results can be expressed in $\mu\mu c/m^2$ and thus compared with fallout rates, but this evolved little response from U.S. Canada thinks only milk and human bone would be sampled. Canadian milk sampling is very thorough and includes Sr^{89} measurements (Ref. 6).

U.S. (Kulp) expressed preference for rib or human bone, but U.K. prefer femur as giving larger sample and also sample of major bone.

3. COMPARISON OF U.K., U.S., AND CANADIAN RESULTS

3.1 Soils

The intercomparison sample from Ithaca, N.Y. gave a fairly reproducable result of 17 to 22 S.U. in all laboratories and by methods ranging from fusion to electrodialysis (Table 9 of Ref. 4).

The agreement between laboratories is less good when routine samples are compared in terms of activity per unit area. The low extraction of Sr^{90} by electrodialysis at Beltsville from Suffolk soils has already been referred to (Tables 1 and 2 above). The mean result from 5 samples(1) was 81 dpm/ft^2 ($\simeq$400 $\mu\mu c/m^2$ = 1.0 mc/m^2) with one sample as low as 12 dpm/ft^2 (= 59 $\mu\mu c/mi^2$ = 0.16 mc/mi^2). The Woolwich result on this last sample was 310 $\mu\mu c/m^2$ by NH_4Ac, and 690 $\mu\mu c/m^2$ by HCl leach.

It appears that electrodialysis results from calcareous soils cannot be used as an index of total fallout. Realization of this fact might prevent some erroneous conclusions on geographical variation being drawn from soil data obtained by this method.

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(1) Table 2c of Ref. 4. The figure 174 dpm/ft^2 assigned to Wales in that table is actually a measurement on a Suffolk soil.

The results of the U.K. survey of welsh soils (Ref.1) the HASL survey of U.S. soils (Ref.2) and the Chicago survey of Wisconsin/Illinois soils (Ref.3) all give results in the range 8 - 10 mc/mi^2 for total fallout referred to date 1.10.55, and are in reasonable agreement with estimates of total rainfall activity at that date.

Ten 1955 soils from the New York area collected by Lamont and extracted by HCl gave an inexplicably low average of 2.0 mc/mi^2. (Table 2a of Ref.4).

3.2 Vegetation

Agreement between U.S. and U.K. is now very good with 1955 averages of 41 S.U. and 35 S.U. respectively (Refs. 2 and 1).

3.3 Milk

1955 mean S.U. values are as follows:-

U.K.	3.9	(Ref. 1, with additional data)
Canada	4.5	(Ref. 6)
New York	2.8	(Ref. 2)
Chicago	2.4	(Refs 3 and 5)

High values of about 10 S.U. have been found in milk from British Columbia by Canadians and in milk from North Dakota by U.S. The former is explained by Canada in terms of low calcium soil, but high rainfall may be important.

Highest U.K. sample is 6.4 S.U. in June 1955.

The increase in milk levels with time was discussed. The Canadians report good correlation with total fallout, but have not tabled figures for earlier years. U.S. (New York) and U.K. find only slight increase in levels from 1955-6.

3.4 Animal bone

Good agreement between 1955 U.S. average (12 S.U.) from HASL data (Ref. 2) and U.K. lowlands average (14 S.U.). U.K. hill sheep show range 16 to 150 S.U. with high values from Pennines and Dartmoor as well as Wales, whereas highest value reported from U.S. is 24 S.U.

3.5 Human bone

Good agreement in levels between U.K. and U.S. U.S. have found 3 S.U. in one 50 year old man but this figure is not supported by others from adults. Maximum U.S. level in child about 2 S.U. are compared with U.K. 1.3 S.U.

FOLIAR AND ROOT UPTAKE OF RADIOSTRONTIUM

No agreement found on dominant mode of uptake, evidence as follows:-

(a) Canadians consider trend of their milk levels consistent with proportionality to cumulative fallout in soil. However, they report (Ref. 6) Sr^{89}:Sr^{90} ratios in milk as high as 9:1 (Dec 1955), suggesting foliar uptake.

(b) U.K. and New York milk levels fairly stable, increasing apparently le. rapidly than cumulative fallout.

(c) U.K find that in chalk soils available Sr is about 1 S.U. whereas vegetation shows about 50 S.U. This suggest foliar uptake dominant on these soils.

(d) Welsh hill vegetation has recorded 510 S.U. with soil over 100 S.U. On this soil root uptake, including effects of retention on peaty mat under vegetation, may be important. Welsh sheep bones have increased by factor 2.5 in each comparison 1955:1954 and 1956:1955, animals being taken from same flock in each instance.

(e) U.S. data on beans gives following results in S.U. (Appendix I). Stalks 81, Leaf 78, Pods 57, Beans 2.2. Factor of 30 reductions in bean activity relative to other parts of plant suggest effect of shielding by pods from foliar uptake.

The conclusion may be that foliar absorption is dominant at present on normal soils, but root uptake may be important on very low calcium soils.

5. EXPERIMENTAL APPROACH

Work in U.S. on elucidating factors determining the mode of entry of fallout Sr into food chains and into human bone was reported as follows:-

(a) Kulp reported work on investigation of distribution of single shots of Sr^{85} given to terminal patients before death. Kulp uses this data, with doubtful justification to normalise Sr^{90} results on different bones.

(b) It was reported that Comar had found differences in the retention in the cow of Ca^{45} and Sr^{89} according as the activity was given with milk or with hay and grain, as follows:-

Age of cow	Food	Retention (percent) Ca^{45}	Sr^{89}
2 days	Milk	99	95
2 months	Milk	86	89
"	Hay & grain	69	77
5 months	Milk	79	84
"	Hay & grain	15	13

Human patients also were found to absorb more Ca^{45} activity when given with milk than when given as $CaCl_2$.

No work on adding Sr activity to soils similar to that of Scott Russell was reported, nor was there mention of any further work like that reported by Rettemeier at the SPAR Conference. It is possible however, that work of this nature may be going on at UCLA, which was not represented.

SUMMARY OF IMPRESSIONS LEFT BY CONFERENCE

The lack of unified direction of the U.S. effort was noticeable. HASL exert some supervision over methods and standards, but are very cautious in calling attention to discrepancies in their own and other's data. For example in Ref. 2 data on the fallout in rain in New York for 1955 and 1956 is given. The total for the 2 years is left for the reader to add up, and it is left for him to observe the wide gap between this total (24 mc/mi^2) and the data from the sticky paper surveys.

HASL are aware of the shortcomings of the present U.S. methods of sampling soil and vegetation and of estimating Sr90 from the former.

The U.S. milk sampling, both in Chicago and New York has been well and carefully done and provides the best base line for comparing trends and geographic variations of biological uptake.

The bone sampling programme of Lamont is extensive, 400 samples having been done. These results will be published shortly.

The U.S. are set up to do world wide sampling. In respect of vegetation, milk and bone we need not duplicate their work in the U.K. The electrodialysis method of extracting soil is unproven and it is desirable for the U.K. to continue to get soil samples from the Commonwealth for HCl and fusion analysis.

7. REFERENCES

1. Radiostrontium fallout in biological materials in Britain. HP/R.2056
2. Summary of analytical results from the HASL strontium programme to June 1956, USAEC NYOO, 475[1].
3. University of Chicago Project Sunshine Bulletin No. 12
4. Evaluation of strontium soil studies USAEC HASL report 56-10
5. Current research findings on radioactive fallout. USAEC press release of 12.10.56 (W. F. Libby)
6. Candian report to U.N. Scientific Committee

APPENDIX I

SNAP BEAN PLANT EXPERIMENT

(H.A.S.L.)

Section	Dry Weight Grams	Ash Weight Grams	% Ash of Dry Weight	% Ca in Ash		Sr^{90} d/m/Total Sample	Sr^{90} d/m/g Ash	Strontium Units			Sr^{90}/Ca^{90}	
					Ave.				Ave.			Ave.
Stalk	535	61.4	12	14	14	1535	25 ± 0.47	82 ± 1.5	81		1.2	1.2
				15			26 ± 0.47	80 ± 1.4			1.1	
Leaf	591	189	32	12	12	3780	20 ± 0.45	76 ± 1.7	78		3.0	3.0
				11			19 ± 0.45	80 ± 1.8			2.9	
Pods	210	19.3	9.2	9.3	8.6	212	11 ± 0.37	53 ± 1.7	57		1.6	1.5
				8.0			11 ± 0.55	61 ± 3.1			1.4	
Beans	407	17.2	4.2	42	38	34	2.0 ± 0.18	2.2 ± 0.20	2.2		0.87	0.83
				35			1.6 ± 0.26	2.1 ± 0.34			0.79	
TOTAL PLANT	1743	287	16		14	5561		19		62		

On C-Date 10-15-56

RE: Letter of August 27, 1956 from Alexander to Harley

APPENDIX II

Notes on work proceeding under Dr. Menzel at U.S. Dept. of Agriculture, Beltsville (visited by A. Morgan)

---

1. Experiments are in progress to determine the rate at which activity (strontium^{89}) can be leached through soil columns by distilled water and N/5000 solutions of NaCl and $CaCl_2$. The activity is added $\frac{1}{4}$" below the surface of 8" columns of different soils and the columns eluted until break through of activity occurs.

Movement was fairly rapid with the $CaCl_2$ solution, break through being observed with all soils. It appeared that the volume of eluate required was directly proportional to the available calcium in the soil. No break through was observed with distilled wate and NaCl solution, so the columns were extruded, cut into sections and the sections assayed for activity. Little difference in movement was discovered. It was estimated that about 10 years rainfall (300") would be required to move the activity through 2".

2. In connection with the concept of available calcium, work is being done to see if an isotopic exchange method could be used to give a true measure of this.

3. The results published in a paper by Menzel and Heald (Soil Science 80, 287, (1955) are interesting. The relative uptakes of chemically similar elements into plants from nutrient solutions were measured. It was found that caesium was absorbed only 0.2 times as rapidly as potassium. Strontium and calcium were absorbed in a ratio 1.1 x the ratio of their concentrations in the nutrient solutions, but strontium was concentrated in the roots and the Sr/Ca ratio became progressively lower in the stems, petioles and leaves.

UK U/C
20. 25/1/85

COPY

Copies also sent to
DD., CR., Mr Dawson.
Hill. 27/3/57.

~~SECRET~~

UNCLASSIFIED

Illiam Penney.

This relates to the memorandum I handed to you in London last Friday. A. M. A.
20. 3. 57.

19th March, 1957.

Radiological Health Hazards - Strontium 90.
0144 II

Dear Marley,

May I refer to my background memorandum about "The Internal Radiation Hazard from Strontium 90, Etc.", which was agreed with you, and of which I sent you a copy on 14th March.

The memorandum as typed said, in paragrapn 9(ii), that Dr. Libby estimated that

> "as a result of the explosions to date (including the future fall-out still to come from them), the "body burden" of strontium 90 in the United States by early 1970s will reach 4 units."

The figure of 4 units was taken from the report of Libby's article in "The Times", but, as you know, I have since been told that, to report Libby correctly, it should read "4 to 10 units". I have amended the Lord President's copy accordingly and should be grateful if the recipients of this letter would amend theirs.

Noted Hill. 27.3.

I am writing, after speaking to Dr. Cohen of the M. R. C., to say that I think it would be very helpful if you could give us some appreciation of what you think are the implications of Dr. Libby's figure of 4 to 10 units by 1970, from explosions to date. I believe you feel that Libby's finding is still not inconsistent with the M. R. C's indication that the present level "may be increased tenfold (i.e. 10 units) in the course of several decades", if the present rate of firing continues. Could you at the same time say whether you think Libby's argument, leading up to the 4 to 10 units by 1970, is sound based or not?

We are asking you for this further help because it seems likely that Ministers will continue to be pressed to say whether or not there is any need to revise the M. R. C's findings in the light of Dr. Libby's report.

I am sending copies of this letter to Allen, How and Cohen at the M. R. C.

Yours sincerely,

R. N. QUIRK.

Dr W. G. Marley,
AERE, Harwell.

UK U/K. Tel. 2x/1/55

27/3/57

Reference

Radiological Health Hazards Strontium 90 0144 II.

Mr. HUDDLE

An earlier version of Mr.Quirk's brief on Internal Radiation Hazard went to Aldermaston and Sir William Penney arranged for copies to be made for Mr.Cook, Mr.Adams and Dr.Dawson.

Mr.Quirk has now sent us a revised version. We have had it copied and I attach three copies, which perhaps you would be kind enough to circulate.

A.H.HUDDLE

DOWNGRADED TO UNCLASSIFIED

2nd April, 1957

Additional copy made for Mr. Adams.
Copies sent to Dr. Dawson & Mr Cook.

MK. 8/4.

~~SECRET~~ COPY

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UK U/C to U.K.A.E.A. Def. Nuc. Tech. Hqs.
26 25/1/58

Radiological Health Hazards - Strontium 90.
0144 II.

241/4/57

18th April, 1957

When we were with Edwin the other day we were wondering whether it would be possible to get the Royal Society to sponsor a Discussion on Strontium 90 both as regards the physical measurements of fall-out from weapons and the medical side including the whole chain of events between fall-out and the Strontium 90 doing damage in the human body. I think that this would be well worth doing, but it will take several months to get it organised, and I suppose that October or November is the earliest that the Society could manage. If you are in agreement with the suggestion you may wish to think it out more fully.

For example, I would think it would be a good idea for the Society to invite Libby and perhaps another member of the A.E.C. on the medical side. The Society might also wish to invite the Russian Academy to send a couple of people.

While it is necessary to press on with our thoughts about the Discussion, I think it is also necessary to get something done much more urgently in a more public and open way; something of the form of newspaper articles or an article in "Nature" where the publication is quick is what we want. Could Harwell do anything along these lines?

Titterton is coming here next week in his capacity as Chairman of the Australian Safety Committee and I am going to suggest to him that a series of newspaper articles be put out in

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Titterton is coming here next week in his capacity as Chairman of the Australian Safety Committee and I am going to suggest to him that a series of newspaper articles be put out in Australia about weapon testing. The first article in my view should be one by a distinguished retired General or somebody of that sort (if a Britisher is required then Slessor would be a good choice, but there are one or two retired Australian Chiefs of Staff who would probably be better for Australian purposes). This article would explain what a dangerous world we live in and what the risks of war are and so on, and would lead to the conclusion that it is better to accept the very mild risks of fall-out from weapon tests than it is to be confronted by the enormous conventional forces of our possible opponents without any defence at all.

/The rest of.....

Sir John Cockcroft, O.M., K.C.B., C.B.E., F.R.S.,
Director,
A.E.R.E.,
Harwell,
Nr. Didcot,
Berkshire.

Copy to:- Dr. B.F.J. Schonland

UK o/c Feb. 26/1/55

F

Radiological Health Hazards - Strontium 90.

255/5/57

0144 II

6th May, 1957

Dear

The Australian Safety Committee are going to put a lot of pressure on us to take more samples of Sr.90 in Australia, particularly in the region of the Range. Harwell has already promised to do about 20 samples a year and I think that this will have to go up to perhaps 80 samples a year.

When I spoke to Marley the other day on the 'phone, he seemed to think that this work could be undertaken, but it might need another man or two at Woolwich. Would you please give me a firm statement that Harwell could undertake this work, because if you can't do it then I shall have to make other arrangements.

I should like an answer by the time that Titterton is back from America; that is to say within a week.

Yours

Sir John Cockcroft, O.M., K.C.B., C.B.E., F.R.S.,
Director,
A.E.R.E.,
Harwell,
Nr. Didcot,
Berks.

Copies to:- Dr. B.F.J. Schonland
Dr. W. G. Marley

Copy on D/41/01 "Australian Safety Committee"

(1) DD
(2) ADD

~~SECRET~~

COPY

UK O/C. w.r.t Def. Nuc. Tech. Info.
25/1/85

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Office of the Lord President of the Council,
Privy Council Office,
WHITEHALL, S. W. 1.

14th March, 1957

Radiological Health Hazards – Strontium 90.
0144 II.

Dear Allen,

In connection with the current batch of P. Qs on this subject, we have been preparing a confidential background note for the Lord President and others who may be concerned. The attached note has been discussed and agreed in detail with the M. R. C. (Sir H. Himsworth) and with Dr. Marley and we are sending it to the Lord President in connection with the P. Q. on Monday by Mrs. Joyce Butler.

Plowden may like to have the enclosed copy, and I am also sending copies to How and Marley.

Yours sincerely,

(Sgd.) R. N. Quirk

A. M. Allen, Esq.

COPY

~~Secret~~

The Internal Radiation Hazard from fall-out of strontium 90, etc.

Most of the discussion about possible medical effects of radiation has been related to external radiation, i.e., radiation received at the surface of the body from all sources, including natural sources such as cosmic rays, the "appurtenances of civilisation" such as X-rays, and the fall-out.

2. The M.R.C. Report of last Summer (Cmd. 9780) was disturbing in bringing out the considerable increase which is taking place in external radiation received during an average life-time from the increasing use of X-rays and other "appurtenances of civilisation". This situation if allowed to develop might become serious, particularly as regards genetic hazards. On the other hand, the Report made it clear that the contribution to the total amount of external radiation from the fall-out from the test explosions of nuclear weapons, fired at the present rate and in the present proportion of the different kinds, was small and that the hazards from external radiation, from this source in isolation, could be regarded as negligible (Conclusion 4 (a) on page 80).

3. The present note is concerned with the hazard from internal radiation. Insofar as the general population is concerned this hazard, in contrast with that of external radiation, is particularly a problem resulting from the fall-out. Certain constituents of the fall-out, which are entirely new chemical elements - such as the element strontium 90 - non-existent in the world before atomic fission, may be absorbed into the body through food. For instance, strontium 90 deposited on grass may be eaten by cows, find its way into milk and hence into the human body. This particular element is chemically similar to calcium and may likewise be incorporated in bones, particularly the bones of young children. Its accumulation as a source of continuously emitted internal radiation, may in time produce bone cancers (sarcomata) and possibly leukaemia (cancer of the blood).

M.R.C.'s recommendations on levels of strontium in bone

4. On page 68 of Cmd. 9780 the M.R.C. provided the following important figures:-

	Units*
Maximum permissible level of strontium 90 for adults in special occupations	1,000
Maximum allowable concentration in the bones of individuals in the general population	100
Level at present being reached in human bones in this country	about 1
Immediate consideration required if concentration in human bones "showed signs of rising greatly beyond"	10

*Micro-micro curies per gramme of calcium

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5. The M.R.C.'s detailed views as regards these figures are set out in paragraphs 281 to 284 of Cmd. 9780. The figure of 1,000 units, at present accepted by the International Commission on Radiological Protection, is the maximum permissible level for adults in special occupations. The M.R.C. considered that for individuals in the general population the maximum allowable concentration should be 100 units. The figure of 1 unit (more precisely 1.2 units: see page 125) of Cmd. 9780 was the maximum concentration actually measured in the U.K. in human bone at the time of the Report. As to the possible future rise in the figure in bone, the M.R.C. said that

> "calculation of the fall-out likely to come, if the present rate of firing continues, suggests that this level may be increased ten-fold in the course of several decades. The present level would produce no detectable increase in the incidence of ill-effects. It is evident, however, that we are now accumulating radiostrontium at an appreciable rate and that a close watch will need to be kept on this increase. 283. In the light of knowledge at present available, we should feel that immediate consideration were required if the concentration in human bones showed signs of rising greatly beyond one-hundredth of that corresponding to the maximum possible occupational level."

In other words, if the figure in bone showed signs of rising greatly above 10 units, "immediate consideration" would, in the M.R.C.'s view, be required.

Figures for the level of strontium 90 in bones measured since the M.R.C Report

6. Questions have been asked in Parliament about the highest levels of strontium 90 observed in bone samples since the publication of the M.R.C. Report. It is considered that importance should only be attached to the general picture provided by large numbers of observations, particularly those made on the bones of young children. It is scientifically unsatisfactory to give undue emphasis to individual high readings which may be unrepresentative or may reflect an occasional experimental error.

7. The following is the latest information on the subject:-

(i) In this country the average level of strontium 90 found during 1956 in the bones of children under 5 years of age was 0.67 units. The highest single level observed was 1.3 units, a level which does not differ significantly from the maximum of 1.2 units given in the M.R.C. Report (page 125 of Cmd. 9780).

(ii) The average figure of 0.12 units, given by Kulp and others ("Science", 8th February 1957), was derived from samples from all over the world. This figure was based on data from all age groups and for this reason is considered to be misleading, since the figures for children, who are the most vulnerable group, are on the average bound to be higher than those for adults.

(iii) A very few isolated cases, outside the U.K., giving figures from 1.7 to 2.5 units, have been reported, but for the reasons given above they cannot be considered to be of great significance. A single figure of 6.65 units (corresponding to a skeletal average of 9.1 units) from a 49-year old person in Vancouver, British Columbia, is reported in "Science" of 8th February 1957. This reading falls out of line with all other observations so far reported.

8. The position therefore about measurements in bone, compared with those when the M.R.C. Report was published, show for this country no significant change, but for the free world as a whole there are a few isolated reports of higher levels that the U.K. maximum. It was on the basis of the above figures that the Prime Minister, on the advice of the

M.R.C., said in answer to a P.Q. on 5th March that:-

> "the Medical Research Council have no evidence that the amount of strontium 90 and other radioactive particles released by hydrogen bomb explosions which may become sources of internal radiation has reached a potentially dangerous level."

Varying views as to future rate of increase

9. There appear to be considerable differences of opinion as to the rate at which concentrations of strontium 90 in bone are likely to incre in the future. This variation in view can be illustrated as follows:-

(i) The M.R.C. As indicated above, the M.R.C. state, in paragraph 282 of their Report, that "calculation of the fall-out likely to come, if the present rate of firing continues, suggest that this level (i.e. the figure of 1 unit in bone) may be increas ten-fold (i.e. to 10 units) in the course of several decades."

(ii) Dr. Libby of the U.S. Atomic Energy Commission (in a report quoted in the "Times" of 22nd February) estimates tha as a result of the explosions to date (including the future fall-out still to come from them), the "body burden" of strontium 90 in the United States by the early 1970s will reach 4 ~~units~~. (See the Qu Dr. Libby

(iii) Messrs. Kulp, etc., in "Science" of 8th February, wh give a large number of figures of measurements in bone to date, reported that the present world wide average level of strontium 90 in human bone was about 0.12 units. But they considered that, with the present burden of strontium 90 (i.e. from the explosions to date, excluding future ones), this average level should rise to a figure of 1 to 2 units by 1 As indicated in paragraph 7 (ii) above, these figures may be unduly reassuring because the results are averaged over al the figures for young children being on the everage higher t those for adults.

(iv) Mr. Eisenbud, of the U.S. Atomic Energy Commis published some calculations indicating that from the fall-

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(i) The M.R.C. As indicated above, the M.R.C. state, in paragraph 282 of their Report, that "calculation of the fall-out likely to come, if the present rate of firing continues, suggests that this level (i.e. the figure of 1 unit in bone) may be increased ten-fold (i.e. to 10 units) in the course of several decades."

(ii) Dr. Libby of the U.S. Atomic Energy Commission (in a report quoted in the "Times" of 22nd February) estimates that, as a result of the explosions to date (including the future fall-out still to come from them), the "body burden" of strontium 90 in the United States by the early 1970s will reach 4 ~~units~~. to 10 units. (See Mr. Quirk's letter to Dr. Norbert - 9.3.57)

(iii) Messrs. Kulp, etc., in "Science" of 8th February, who give a large number of figures of measurements in bone to date, reported that the present world wide average level of strontium 90 in human bone was about 0.12 units. But they considered that, with the present burden of strontium 90 (i.e. from the explosions to date, excluding future ones), this average level should rise to a figure of 1 to 2 units by 1970. As indicated in paragraph 7 (ii) above, these figures may be unduly reassuring because the results are averaged over all ages - the figures for young children being on the average higher than those for adults.

(iv) Mr. Eisenbud, of the U.S. Atomic Energy Commission, has published some calculations indicating that, from the fall-out to date (excluding future explosions), the ultimate figure for radio strontium in bone could not be expected, anywhere in the United States, to exceed 25 units, and 8 units in New York. But Mr. Eisenbud said that his figure might over-estimate the true value by a factor of ten.

Uncertainty regarding the induction of leukaemia

10. It must be realised that there are bound to be many uncertainties and differences of opinion among responsible scientists about the deductions which may be drawn from the very limited evidence relating to the effects of radiation on human beings. Considerable press publicity has recently been given to the views expressed by Professor A. Haddow (Director of the Chester

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Beatty Research Institute), who was a member of the M.R.C. Committee. Professor Haddow is reported to have stated that in his view no "threshold" dose of radiation exists below which leukaemia is not induced, i.e., that there is no dose of radiation too small to produce leukaemia. He appears to have been referring to the possible dangers from exposure to external radiation, which were discussed in the M.R.C. Report. There is in fact no direct evidence regarding the effect of exposure to very low doses, but similar views to those expressed by Professor Haddow are held by some other scientists. (The subject will be fully discussed in a report by Dr. W. M. Court Brown and Dr. R. Doll on Leukaemia and Aplastic Anaemia in Patients Irradiated for Ankylosing Spondylitis, shortly to be issued in the M.R.C's series of scientific publications).

11. The possibility that there is no threshold below which strontium 90 may not have an effect in producing bone tumours was discussed in the M.R.C. Report (Appendix N. p.127). The possibility that strontium 90 can give rise to leukaemia in human beings must be borne in mind, but there is still insufficient evidence for the question of "threshold" dose to be discussed in this connection.

Conclusions

12. The following general conclusions can be drawn:-

(1) The present measurements for strontium 90 in the U.K. do not differ significantly from those of last year. On the other hand certain higher figures have been noted elsewhere in the world and the figures must clearly be very carefully watched.

(2) In view of the varying opinions as to the possible future rate of rise in strontium 90 content in bone, and the scientific uncertainties of the whole matter, it seems wise to adopt a cautious attitude to the possible long-term danger from strontium 90. The danger should be neither exaggerated nor underrated.