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Discussion

The Chairman, opening the discussion, said that engineers would be grateful to Sir George McNaughton, of the Ministry of Housing and Local Government, for having anticipated several years ago the situation which would arise and for having taken the necessary steps in advance to deal with it by creating the appointment which the Author now held at the Ministry.

57. The Paper which Dr Key and the Author had presented in 1952,[1] had given the general impression that the Ministry was studying the whole question and watching conditions throughout Britain to see that no trouble occurred anywhere. The Chairman thought that he detected a slight change in the attitude adopted in the present Paper, the Author taking the view that each case had to be treated on its merits—a doctrine on which engineers had been brought up—and that conditions would vary from place to place. That attitude seemed to be applied to the subject of radioactivity, and the Author had referred to the need to watch the conditions at various points in sewers and disposal works and even to measure the activity. The Author gave reasons for complete confidence that at the moment there was no danger, but there might be one day, owing to the increasing use of isotopes as time went on. The impression remained, however, that the Ministry was fully alert to possibilities of future danger and prepared to take the necessary precautions.

Mr R. H. Burns (Chief Industrial Chemist, A.E.R.E., Harwell) said that a great deal had been written in the past which gave the impression that the use of radioisotopes, whilst bringing undoubted benefits could also give rise to many hazards. The Author had helped to dispel some of those fears.

59. Mr Burns then referred to § 3, where it was stated that one works of the United Kingdom Atomic Energy Authority (U.K.A.E.A.) disposed of its effluent to a local sewer. That was the Radiochemical Centre at Amersham, which discharged to a sewer owned by the Colne Valley Sewerage Board. Since the Author had not dealt with that case, Mr Burns thought it of interest to see how it compared with the general picture drawn in the rest of the Paper. It was remarkable to suppose that the Radiochemical Centre at Amersham would be discharging more radioactive material to the sewer than any other users of isotopes discharging to sewers. Under the Atomic Energy Authority Act of 1954 no

radioactive waste could be discharged from any establishment of the Authority without the prior authorization of two Ministers: the Minister of Housing and Local Government and the Minister of Agriculture, Fisheries and Food. Every establishment of the U.K.A.E.A. had those authorizations, and that at Amersham was authorized to discharge to the Colne Valley sewer.

60. Some idea of the levels involved could be given by a few figures. The centre at Amersham was allowed to discharge to the sewer in any one month 0·0028 c of radium, which was equivalent to 0·0028 g/month, or 0·017 c of other alpha emitters, or 0·14 c of radiocalcium or radiostrontium, or 7·0 c of other beta emitters. Those were considered as mutually exclusive, which meant that if, for instance, the permitted amount of radium was discharged, the discharge of anything else would not be allowed.

61. He would assume that Amersham discharged up to its limit each month and would refer only to the radiostrontium group and assume that all the activity discharged arose from radiostrontium. He chose that because it was generally recognized that strontium was the most toxic of the beta-emitters. On the assumption that Amersham was discharging to the Colne Valley sewer 0·14 c of strontium per month, then from recent figures which he had been able to obtain for sewage arising in the Colne Valley sewage works the maximum concentration in the crude sewage worked out to 1×10^{-7} μc/cc. The internationally agreed maximum permissible level in water for strontium 90 was 8×10^{-7} μc/cc, so that if Amersham discharged up to its limit of radiostrontium the crude sewage would be at only one-eighth of the permitted level, which it was considered safe for occupational workers to drink at the rate of approximately 4½ pints/day. At the moment Amersham was discharging only about 22% of the authorized amount. The figure he had given related to crude sewage. There would be, of course, a purification of the effluent in the sewage works and a further dilution in the Colne before it joined the Thames. It would be seen, therefore, that although Amersham was probably the biggest user of sewers for that purpose there was still no possibility of hazard arising.

62. At Harwell there was a normal sewage system and a normal sewage works. Steps were taken to prevent activity getting into the works and these were usually successful, but at times activity had got in by accident. On some occasions when that had happened the level in the purified sewage effluent had been of the order of $1{\cdot}5 \times 10^{-7}$ μc/cc, or, in other words, of the same order as could be expected in the crude sewage in the Colne Valley works. Regular surveys were carried out of the works, of the men, and of the men's clothing, and at no time had they found any hazard arising from that occasional discharge of activity to their sewage. He emphasized that he referred to the sewage effluent after treatment. It was very difficult, if not impossible, to relate that to the activity in a particular batch of sludge with that in the purified effluent, but it seemed from the results, however, that the activitiy in the sewage sludge was of the order of 100 times $1{\cdot}5 \times 10^{-7}$ μc/cc, and that might be of interest as indicating practical experience of the concentrating effect in sewage sludge.

63. At Harwell there was also an active drainage system which dealt with the known active waste arisings, and in that the levels were usually considerably higher—they were of the order of $1{\cdot}5 \times 10^{-6}$ μc/cc of alpha emitters and $7{\cdot}5 \times 10^{-6}$ μc/cc of beta emitters. They treated that effluent by chemical precipitation and coagulation, which gave rise to active sludges. The level in the sludge varied, but averaged out at about $1{\cdot}4 \times 10^{-3}$ μc/cc of alpha emitters and $6{\cdot}0 \times 10^{-3}$ μc/cc of beta emitters—in other words, very much higher figures than were ever likely to be found in sewage sludge. That active sludge had to be handled and filtered, and the tanks cleaned out periodically. In the 8 or 9 years for which Harwell had been operating no hazard to the men thus employed had arisen; there had been no contamination or radiation hazard as a result of dealing with those relatively high levels of active sludges. Admittedly precautions were taken, but they were reasonable—neither extensive nor time-consuming. That statement was based on the record of examination of the film monitoring badges which all the men wore and which were examined periodically. The Health Physics Division also carried out surveys of the tanks, drains, and pipes, and even at the levels mentioned there had been no significant build-up of activity in the drainage system or in the tanks.

64. Mr Burns asked the Author if he could state what measurement ought to be carried out, on the activity of these sludges and whether or not those measurements should be taken regularly by local authorities.

Mr G. E. Eden (Water Pollution Research Laboratory, D.S.I.R.) said that the Water Pollution Research Laboratory had just embarked on a fairly large programme of investigation into the fate of radioactive materials in natural watercourses, rivers, streams, lakes and so on, and he was sure that the information obtained would have a considerable bearing on what happened in sewage treatment, particularly if discharge into a river of normal sewage effluent and the processes of self-purification in the stream were regarded as a natural continuation of the processes of purification of sewage.

66. He then referred to the Author's remarks on the results obtained on the treatment of sewage containing radioiodine. Very widely varying results had been obtained by investigators. It had been found on occasion that the uptake of iodine from sewage could vary between 0 and nearly 100% for no apparent reason. The Author suggested that the iodine content of the sewage might have something to do with that but might not be the whole story. The Laboratory had recently had occasion to measure iodine contents of a number of waters. There was a good deal of literature on the iodine content of water, mostly obtained for medical purposes in relation to goitre. The methods of analysis, unfortunately, returned only total iodine. The Water Pollution Research Laboratory had recently made measurements using more refined methods of analysis and had been able to determine the iodine present as iodide separately from the other iodine compounds. It appeared that in waters a very large proportion of the iodine was not present as iodide at all, but as iodate and other compounds. The proportion present as iodide was very variable. That might eventually shed some light on the position, but at the moment it was an additional complication.

67. In certain circumstances the discharge of activity to sewers might actually be beneficial to the civil engineer. The Laboratory had recently been asked on two occasions to measure rates of flow of crude sewage in somewhat inaccessible sewers. That was not particularly easy by conventional methods, but it lent itself admirably to some very simple tracer techniques. The principle involved was nearly 100 years old: the so-called salt dilution technique. The method was to feed into the sewer at a constant rate of flow a solution of tracer of known strength, and, after mixing, to take samples downstream, when from the concentration of the tracer in the sewage the rate of flow could be calculated by simple proportion. Originally brine had been used for that purpose, but by the use of a radioactive tracer (active bromide) the operations were done quickly and simply and very accurate results obtained. The concentration required to give results need not be higher than 10^{-4} μc/cc.

Mr H. J. Dunster (Health Physics Division, A.E.R.E., Harwell) stated, that in any waterway or sewer, there was always some quantity of radioactivity which it was reasonable to put in. There was no situation in which no discharge was acceptable at all. The reason for that was fairly straightforward. It was that we ourselves were radioactive, the land on which we lived was radioactive, our building materials were radioactive and even the air which we breathed was radioactive, so that there was a constant background against which to compare the situation created by the addition of further radioactivity. The question to be asked, therefore, was not whether or not radioactivity could be discharged into a sewer, but what was the safe limit.

69. Much of what the Author had said had emphasized that at the moment that safe limit was an unknown quantity in a very large number of circumstances. All that could be said at the present time was that it was demonstrable that the amount being put in was well below that limit. It was very costly to find out the realistic limit in those situations, because it required a long period of study and usually involved working with radioactive materials; in other words doing experimental discharges over a long period at levels which could be followed up by measurement. At the moment extreme caution was being exercised, perhaps to such an extent as to be uneconomic.

Mr J. Griffiths (Chief Chemist, Main Drainage Department, Middlesex County Council) said that he had been connected with the Colne Valley Sewerage Board but could not recollect any information being received about what was happening at Amersham. He was interested to know that there was very little risk attached to working at the Colne Valley works. He noted, however, that nothing had been done about the examination of the sludge and dusts in the sludge treatment plant. Those in charge of the Colne Valley works would facilitate the examination of the dusts, the men, and the surroundings. The sludge treatment plant had now been in operation for about 5½ years. The men were examined regularly for dust hazard and so on, but it would be helpful to determine what was happening in that plant which was likely to have the highest concentration of radioactive materials, since the surplus activated sludge was withdrawn from the plant and passed to the sludge treatment plant immediately. He suggested also that tests should be carried out at sewage works over long periods.

71. When at Colne Valley, having had the assurance that everything was perfectly safe he had simply left it to the Ministries concerned to look after them, but he thought that those in charge of sewage works could help a great deal in investigating that problem over a long period of time. That appeared to be important in view of the possibility of marked increases in the quantities of the radioactive materials used.

72. It seemed to Mr Griffiths that perhaps one of the greatest hazards might be at a small sewage plant connected with some remote institution at which radioactive materials might have to be used. There might be very high local concentrations at such sewage works, where one man might be employed for the whole of his working life. Those, he considered, were the places which might give rise to trouble in the future.

Mr H. R. Oakley (Partner, J. D. & D. M. Watson, Consulting Engineers, London) wished to sound two faint notes of alarm amidst all the reassurances which had been given in the Paper and the discussion. He referred first to the very considerable discrepancies in the experimental work which had been done on the fate of radioactive material discharged to sewage disposal works. Much more ought to be known about the fate of those particular materials and the reasons for the discrepancies would have to be discovered.

74. He then asked about the possibility of accidental discharges in excess of any permitted limit. The extreme caution with which radioactive materials were dealt with and the wastes handled at the various atomic establishments was common knowledge, but as radioisotopes became more widely used the possibility might arise of their getting into the hands of people with less sense of responsibility and possibly with less appreciation of the inherent dangers.

75. As a comparison (but not an exact parallel) it was well known that cyanide was a very virulent poison which was subject to very strict regulations regarding acquisition and discharge, but accidental discharges of cyanide were not unknown. Fortunately a safeguard was provided by the fact that the effect of cyanide in a river was such as to draw attention to its presence; but radioisotopes and radioactive materials generally did not show such visible effects. It was possible that local concentrations of material which could hazard the health of the individual might arise purely from one man's carelessness and lack of responsibility.

76. The authorities would perhaps be wise to give a little wider scope to those who were at the receiving end. The time might well come when it would be necessary for sewage and water works managers to be trained in those matters and to have means at their disposal for the detection of possible accidental discharges.

Mr H. D. Manning said that he had recently read in *The Times* a report of a conference dealing with radioactivity and similar matters with the heading "No Safe Limit"; or words to that effect. Several speakers had stated that there was no danger in anything that was being done today. He asked the Authors to comment on that.

The Chairman referred to the statement in § 12 that it was thought undesirable to

allow the general public to be irradiated to the same level as occupation workers; that for the general public being only one-tenth of that allowed for occupational workers, and asked the reason for this. Was it an additional factor of safety, or did the bodies of the occupational workers become accustomed to irradiation?

78. Whilst having complete confidence in the Author's calculations, there were one or two points which seemed to the Chairman a little doubtful. For example, in § 26 the calculation was based on a discharge of 70 mc. That had been stated to be the dose obtained from the urine of, presumably, one patient being treated for cancer of the thyroid. It seemed conceivable, however, that a number of patients would be discharging at the same time. The Author might say that there was a factor of safety of 100 or 1,000 so that it did not matter, but it seemed dangerous to base the calculation on one patient.

79. A similar point arose in § 41, where the present use of isotopes in the London area was estimated at 70 c per 6 months, and a calculation followed which was based on an average. In ordinary sewage-treatment practice there could easily be a variation of 3 to 1 between day and night, or three times the average volume of sewage in the middle of the day, and a strength of twice the average could be obtained at times. The impurity rate coming on to the works might vary by as much as 3 to 1, and in small works the difference could be considerably greater, so that there was a danger in working on averages. If a momentarily higher-than-average discharge killed all the fish in a river it would be no use the sewage works manager claiming that his average strength was satisfactory. There were those very big variations in ordinary sewage works practice, and some variations might be expected in the discharge of radioactive substances when they were reasonably spread over the entire district. Where that was not so, and they came from isolated hospitals and the like, from which the maximum discharge might take place at, say, 10 a.m., there might be a much greater variation and a much greater peak in the discharge. It was possible, of course, that the factor of safety was so great that that did not matter.

80. In § 34 it was stated that the ionizing radiations from tritium were "soft." What did that mean? It was said that they were so soft that they would not reach any worker at the plant. Did that mean that they would not travel very far?

81. It seemed that a trend towards even greater mechanization in sewage works might be inevitable. Many steps had been taken in that direction already, but with dangerous substances in sewage a greater rate of mechanization, leading to more and more automation seemed probable; and, finally, the use of the remote control apparatus which was being developed in the atomic stations themselves. He hoped that that would never come, but was it possible?

The Author, in reply, referred to the bibliography at the end of the Paper and said that the U.S.A.E.C. reports, such as No. 24, were available to the general public. There were, for example, some in the Patent Office Library and others in the Library of Imperial College.

83. On the question of taking measurements of sewage and sewage sludge, he said that like most experimental chemists—and, in spite of the fact that he had not done any experiments for 5 or 6 years, he still liked to regard himself as an experimental chemist—he had far more confidence in actual measurements than in theoretical calculations, despite the fact that there were big factors of safety in the calculations. It was easy in making calculations to forget something, and one or two measurements were worth far more than all the calculations. He did not think that the measurements need be taken regularly, so long as they were chosen properly, so as to yield significant results.

84. The discharge of the Radiochemical Centre, Amersham, to the Colne Valley Sewerage Board had not been discussed in the Paper because it was very unrepresentative, and he had wanted to concentrate on the situation which sewage works managers would find in their own communities. The first official information which the Colne Valley sewage works had received had been in July 1954, when the Atomic Energy Authority had been set up as an independent authority. Previously it had been under the Ministry of Supply, and, as was usual between Government departments (Crown property not being subject to normal law), he had consulted the appropriate Government department on what should

be done; but Mr Fillingham Brown had been told previously about the discharges by Dr Key and the Author, and the assurances which they had given had been accepted.

85. Mr Griffiths had mentioned the readiness of sewage works to give facilities for taking measurements, and the Author thought that in the near future such offers would be accepted and arrangements made for measurements to be done. Although the future use of radioisotopes might not create a hazardous level in the sewage, it would be desirable to make measurements: one experimental fact was worth more than any reassurances.

86. He agreed that small sewage works were more vulnerable, and that was why in quoting the figure 10^{-4} μc/cc he had emphasized that it assumed a dilution of about 100 times. There was a reference in § 15 to the records of isotope deliveries kept at Harwell and Amersham. The Author went there periodically to inspect the records and to make sure that there was in fact no small sewage works which at the moment was receiving very large quantities of activity. At present the main use of radioisotopes was in the large hospitals and most of those were in the big cities situated on the coast, so that the bulk of the activity was going almost directly into the sea and very little was receiving treatment at a sewage works in the full sense. There was not at the present time a small sewage works which was receiving large quantities of radioactivity, but it was a point which had to be watched and which was being watched.

87. Comments had been made on the discrepancies in the behaviour of iodine. It was certainly desirable that the reasons for that should be known. There was something curious about the behaviour of iodine both in water and in sewage, as Mr Eden had emphasized, and it would be a fascinating task to elucidate the idiosyncrasies of its behaviour. It was by no means certain that iodine in different chemical forms, and particularly if present in an organic molecule in drinking water, would be incorporated in the body metabolism in the same way, and there might be thyroid deficiency implications.

88. With regard to the possibility of accidents, it had to be remembered that figures such as those for strontium-90 referred to life-long drinking of water contaminated to the level in question. If it were a case of drinking it for one day only, the level would be higher, perhaps 10^4 times as high. In fact, 1 μc/cc corresponded to 4,500 c per million gallons. If it were accepted that 0·1 μc/cc was safe for immersion, then on an average 450 c per million gallons or 450 mc per thousand gallons could be discharged by accident without causing harm. In fact 450 mc was three times the dose of 150 mc of radioiodine, or radiogold, giving as a maximum in hospital, and above the amounts normally present in universities and research establishments. It seemed likely that before reaching a sewer worker, an accidental discharge of this order would receive sufficient dilution. Although Mr Oakley's remarks were true in general, and might be very pertinent in future when the use of radioisotopes became very much greater than it was today, at the moment it was difficult to conceive of danger from the accidental discharge of isotopes from premises using amounts of radioisotopes of this order.

89. On the question of there being no safe limit, the Author was glad that Mr Manning had provided the opportunity for something to be said about that. There were two things to be kept in mind. First, it was possible so to arrange things in the atomic age that no individual was harmed except by accident. The Author did not believe that it would ever be possible, by legislation or other means, to prevent the occasional accident. In fact, the development of atomic energy had been accompanied by far fewer accidents than the development of any other major industry in the United Kingdom. So far the record was good, and everything possible should be done to keep it so.

90. Any irradiation of the reproductive organs of the male or female by ionizing radiations resulted in a slight change, or the probability of a slight change, in those organs. If that change were transmitted to posterity, if the organs producing the cells which human beings passed to their offspring (and which formed the minute spark from which they grew) were changed, so that those cells were changed, then in a very small respect the offspring would be slightly different from the parents, not exactly of the stuff from which the parents were made. Such changes were generally deleterious. From that point of view it was asserted that there was no safe limit, in other words, that any irradiation of the gonads of any individual in the population was undesirable.

91. No one, the Author thought, would quarrel with that assertion. He had indicated that in the case of water supplies no great population, so far as he could tell, was being irradiated, but undoubtedly a few members of the public (as distinct from atomic energy workers), perhaps a few hundreds, were being irradiated at levels below 30 ergs/gram as a result of the operations of the atomic energy industry and there was a genetic effect as a result.

92. The choice before Britain, it seemed to the Author, was either not to develop atomic energy, in which case there could be no genetic effect at all, or to develop atomic energy keeping the irradiation of the public to as low a level as could be achieved. That brought up Mr Dunster's comment that the levels adopted might be uneconomically low. The country had to decide how much it was prepared to spend to keep the genetic effect as low as it was possible to keep it. That was the crux of the matter. If Britain did not develop atomic energy it would not have a problem to worry about. But its fuel reserves were running out and it might be subject to attack by another power which had made use of atomic energy. The development of atomic energy was vital for Britain and for the future of the race, but it could not be done without some slight irradiation of the gonads of the population and some slight genetic effect in future. That was what was meant by there being no safe limit.

93. With regard to the factor of 10 between the public and workers occupationally exposed, it was felt to be undesirable to irradiate the public to a level which was believed to be safe (30 ergs/gram/week) and so that was reduced by a factor of 10 to be on the safe side. The workers in atomic energy factories were continually being examined medically, so that it might be hoped that any effects would be seen. That was not a very sanguine hope, because the effects did not manifest themselves at an early stage, and when they did they were such that very little if anything could be done about them, so that in the atomic-energy industry everything was done to keep down the level and the workers were kept under control. There was not the same strict control over the public, and it had been suggested at a very early stage that for the public the level should be reduced by a factor of 10. That was one reason for it. The other reason was that in thinking of irradiating the public one had large populations in mind, and owing to the genetic effect the level had to be kept as low as possible. So far as he knew, there was no question of getting used to irradiation.

94. The Chairman had referred to § 26. The disease which was treated by radioiodine using 100 mc was cancer of the thyroid; a rare condition. Not all cancers of the thyroid could be treated by radioiodine; he believed that only about one-fifth could be successfully treated in that way, so that it was not likely that in a hospital there would be more than one or two patients receiving such treatment. They would have to discharge their urine at the same time to double the figure of 70 mc given in § 26. It was possible that that might happen, but there was a sufficient margin in hand to make it unnecessary to worry about it.

95. The Author had made some remarks about the average level in answering Mr Oakley. In the case of London, which was discussed in § 41, he had shown that even though the sewage was discharged to the estuary of the Thames and not used as drinking-water supply it was down to drinking-water level. It was a rather foolish comparison to make, because the water was not drunk in any case; it would be better to take the level for swimming in. A level had been suggested of 0·1 μc/cc for immersion for half an hour. Because of that it would not matter in the case of London if an average was taken, because quite big fluctuations from the average could be tolerated before any trouble would arise. However, that was a question which had to be borne in mind, and, as the Chairman had emphasized, each case had to be treated on its merits. The Chairman had pointed out that that was normal engineering practice. Eventually, as a later speaker had said, those at the receiving end would have to educate themselves or be educated in the subject and work out their problems. At the moment the situation was so safe that it hardly seemed worth spending the money to do that, but it was not possible to tell what would happen in the future.

96. On the question of discharge to rivers and the effect on fish, with the discharge of

cyanide the average level in the effluent might be safe but the momentary concentration would kill the fish. There was not the same effect with radioactivity. The hazard to the fish depended on a continuous build-up in the body, similar to that which occurred when water containing lead was drunk and the lead slowly built up. It would not matter if one drank water containing ten times the permissible level of lead so long as one evened it up later. That was the analogy for radioactivity, not the analogy of cyanide.

97. The word "soft" was used to describe weak radiations, those possessing so little energy or momentum that they travel no appreciable distance.

The closing date for correspondence on this Paper was 15 May, 1957. No contribution received after that date will be published in the Proceedings.—SEC.
