APPLICATIONS

During the year under review the use of radioisotopes as well as of Soreq's large Co^{60} radiation source for applications in both industry and agriculture has been greatly extended. Most of the work was carried out within the framework of contracts with private and public institutions.

A new company, "ISORAD" Ltd., was set up to promote the use of radiation in industry. ISORAD is a private company owned jointly by the Israel Government and NUMEC - Nuclear Materials and Equipment Corporation, Apollo, Pennsylvania. Two meetings of the company took place, in June and October 1965.

The National Research Council has set up a steering committee to coordinate a national irradiation program. An extensive program has been drawn up, in cooperation with the Ministry of Agriculture and the Ministry of Commerce, for the irradiation of foods and agricultural products and for the use of irradiation in pest control.

The scope and versatility of the Co^{60} facility used in the above irradiation programs have been greatly increased by the incorporation of several improvements (see p. 311).

Steps have been taken to obtain official authorization for the use of irradiated food products for human consumption. As a test case, an application has been submitted to the Israel Ministry of Health for authorization to use radiation for sprouting control of potatoes and onions, and for insect eradication in wheat. The application was based mainly on

the corresponding petitions submitted in the U.S. and Canada to the respective Food and Drug Administrations, as well as on the permission granted in the Soviet Union to use irradiated potatoes, and on the report of the working group of the U.K. Ministry of Health on food irradiation.

In a campaign to promote the use of radiation and radioisotopes, numerous lectures were delivered at many institutions, and a number of seminars were held at Soreq for administrative and technical directors in the food, wood, plastics and ceramics industries, as well as for scientists, technicians and agriculturalists.

Dr. Ch. Miller of Applied Nucleonics Consultants, Los Angeles, U.S., joined the Department at the beginning of August 1965, on an Israel A.E.C. fellowship for the academic year 1965/66.

A. INDUSTRIAL APPLICATIONS OF RADIOISOTOPES

A Laboratory Apparatus for the Study of Reactions in Sprays[1]*

: E. Foa M. Konigsbuch**, S. Lask, O. Schächter** and Z. Stuhl

In the studies already reported[2] on the reactions occurring in an Aman Spray Reactor, a laboratory apparatus specially built for the purpose was used. The apparatus has been modified and improved over the past three years, and its present form and characteristics are described in this report[1]. A schematic representation is given in Fig. 46.

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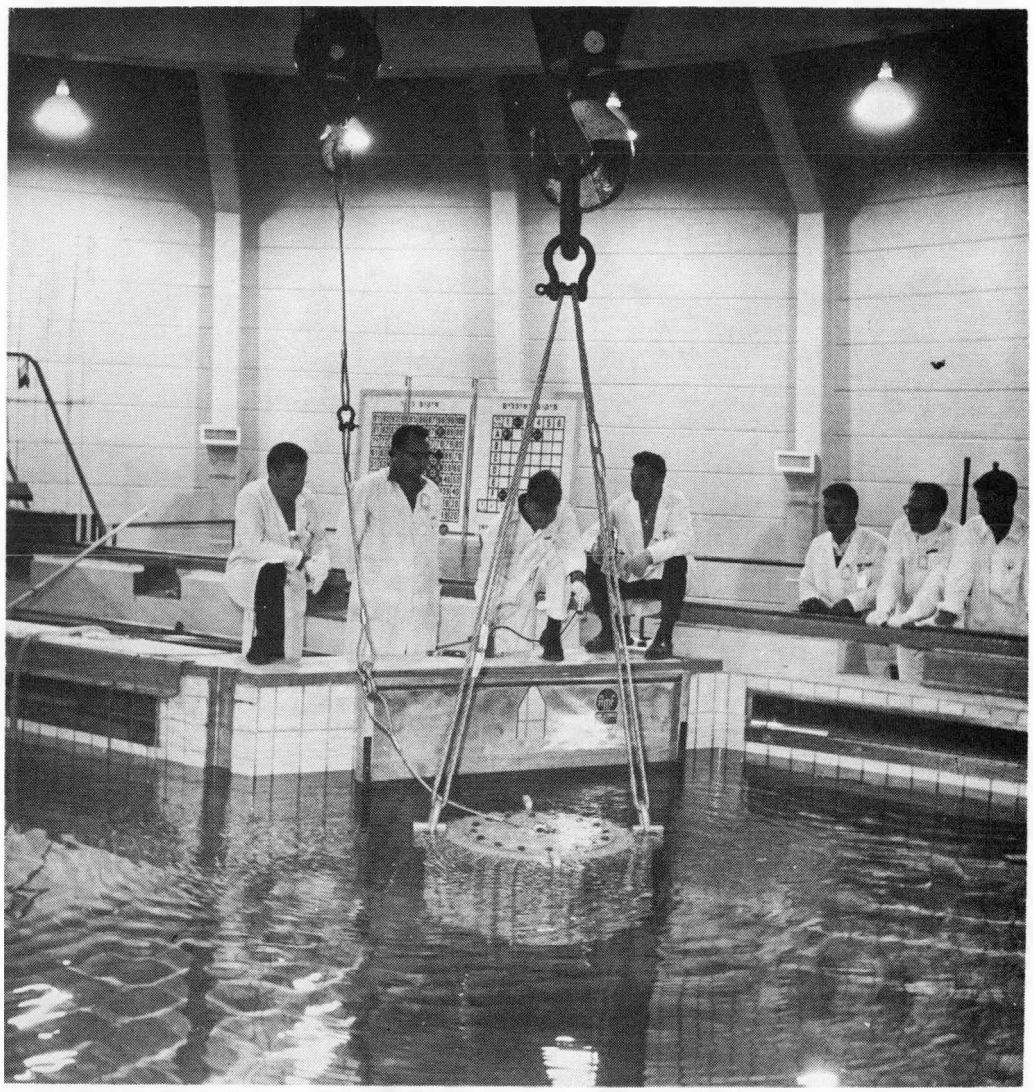
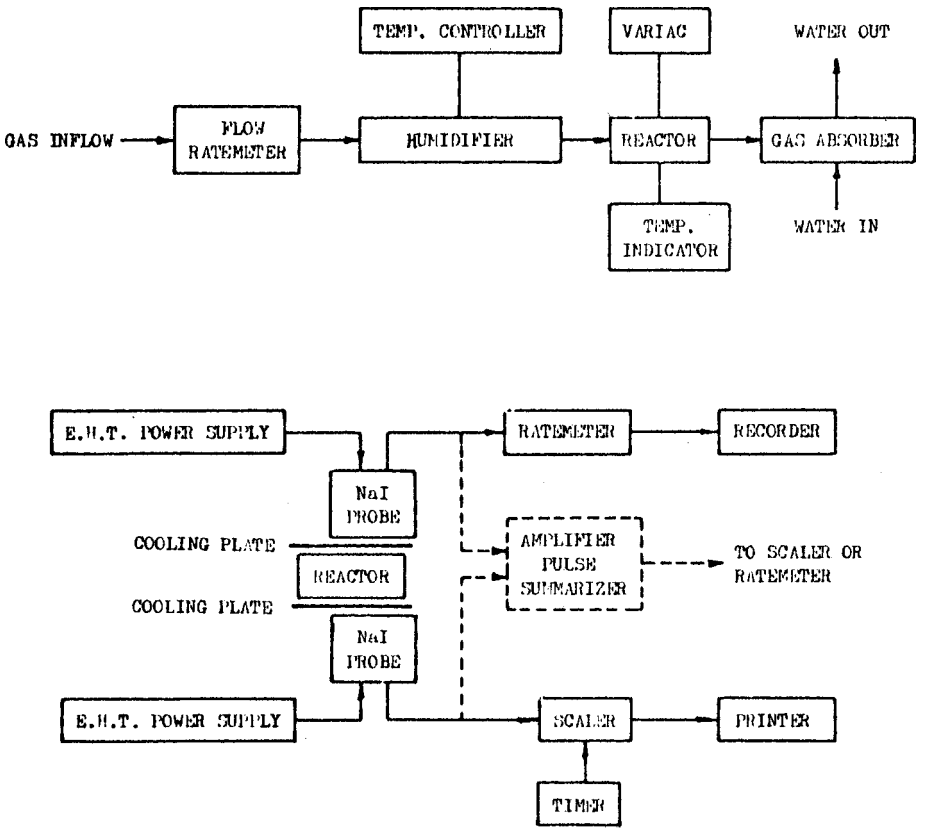
* Work performed under a grant from the Ministry of Development

** Bar Ilan University



Co^{60} source in its cask being lowered into the reactor swimming pool



b

Fig. 46

Scheme of laboratory apparatus for studying reactions in sprays
a) the reactor b) the detection apparatus

The apparatus was designed to simulate as closely as possible the conditions prevailing in the commercial reactor. An important feature is that the detection system, which is based on the use of radioactive tracers, can record the concentrations of the radioactive species continuously. Reactions are studied by examining what occurs in a stationary drop. In particular, reactions in which hydrogen chloride is formed as a product have been investigated. The technique is based on the use of Cl^{38}-labelled chlorides which are heated in the form of a single droplet in a current of gas. Changes in activity are measured both in the droplet and in the escaping gases, which are absorbed in a filter impregnated with alkali. This arrangement permits the study of the influence of the most

important variables: temperature, drop size, rate of flow and composition of gas, and concentration of the solutions.

The apparatus is composed of two main parts:

a) The reactor proper, with provision for heating, temperature control and measurement, thermal insulation, and gas flow control.

b) Detecting apparatus, which includes two crystal scintillation counters, a ratemeter and automatic recorder unit, a scaler and printer system, and an attachment for measuring the activity of the gaseous reaction products.

The temperature can be controlled to within ± 1%. The size of the droplets investigated is between 0.5 and 5 microliters and the radioactivity from 1 to 5 microcuries.

References:

1. FOA, E., KONIGSBUCH, M., LASK, S., SCHACHTER, O. and STUHL, Z., Israel AEC Report, IA-1078 (in press)
2. FOA, E., KONIGSBUCH, M., LASK, S., SCHACHTER, O. and STUHL, Z., Israel AEC Semi-Annual Reports, Jan.-June 1963, IA-900, p.131; July-Dec. 1963, IA-920, p.134; Jan.-June 1964, IA-984, p.155; July-Dec.1964, IA-1021, p.144

Determination of Polyelectrolyte Residuals after Flocculation, Using a Radioactive Tracer[1]: Z. Stuhl and Ch. Gilath

Flocculation with polyelectrolytes is widely used in processes of solid-liquid separation and is finding application in the field of water treatment. One of the problems in this technique is to determine the polyelectrolyte residuals after completion of the flocculation process and separation of the flocs. In the case of treatment of water for drinking purposes, data on residuals is of great importance from the point of view

of public health. Also, a better understanding of the mechanism of flocculation, such as its relation to absorption, could be gained from this data.

Flocculation experiments with polyectrolytes are being carried out at the Sanitary Engineering Laboratories of the Technion, Israel Institute of Technology. Existing methods for determining polyelectrolyte concentrations[2] are not suitable for the very low residual concentrations encountered in water treatment. Experiments were thus carried out with a C^{14}-labelled cationic polyelectrolyte, namely cationic quaternized polyvinylpyridonium polymer. An easy way of preparing the labelled polymer was found to be the use of C^{14}-labelled CH_3I for quaternization of inactive polyvinylpyridonium. 100 microcuries of $C^{14}H_3I$ (specific activity 5 mc/millimole), contained in a glass ampoule, were cooled with a dry-ice acetone mixture. 1 cc of a solution of polyvinylpyridonium in nitromethane, containing 20 mg of the polymer, was added. An excess of inactive CH_3I was added and the quaternized polymer precipitated. The precipitate was separated by filtration, yielding 30 mg of active polymer of a specific activity of 1.2 μc/mg.

In the flocculation experiments the residual concentration of the polymer was determined by measuring the activity of the solution by the liquid scintillation technique (in dioxane solution). As is known, quenching problems arise when working in aqueous solutions; a mixture of 3.5 ml of the solution to be analysed and 16.5 ml of scintillator was found to give the best conditions for the measurements. No quenching was found due to the polymer itself. The system was calibrated at a known concentration of active polymer.

By this easy and rapid method residual labelled polymer could be determined down to a concentration of 0.005 mg/ml.

Reference :

1. Paper Presented at the XXXV Meeting of the Israel Chem. Soc., Feb.1966
2. FUOSS, R. M. and SADEK, H., Science 110, 552 (1949)

Studies of Sand Movement on the Sea Bed Using Radioactive Tracers* :

Z. Stuhl, Ch. Gilath and P. Pfeffer

There is today considerable interest in sand movement studies. Geologists and oceanographists need experimental methods for checking theories and models of sand transport, and information is required on the rates at which harbours fill with sand. Sand for building is dug from the sea bottom and the holes formed are expected to fill in again. It is important to avoid shore erosion and therefore to know the mechanism of hole filling.

In Israel several authorities such as the Geological Institute, the Ports Authority and the Committee for Shore Preservation are interested in sand movement studies along the Mediterranean coast. Lately work in this field was undertaken jointly by the Israel AEC and the Geological Institute. The immediate aim of the project is to develop a method for tracing sand movement by using radioactively tagged sand. A sample of labelled sand is introduced at a known place on the sea bed, and the spread of the activity is mapped after various time intervals.

(i) Labelling of the sand

The choice of the radioisotope to be used was governed by the requirement that the half-life should be of the order of a few days or longer and the energy of the emitted gamma rays sufficiently high for effective detection.

Activities of a few curies must be injected in order to allow for a detectable activity of 1 $\mu c/m^2$ after dispersal of the active grains over an area of about 1 km^2. About 100 active grains/m^2 are necessary for a reliable measurement. The grain size in our case is in the range of 100-200 microns, requiring the use of a few kg of labelled sand.

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* Work performed in collaboration with the Israel Geological Institute, the Ports Authority and the Committee for Shore Preservation, under a grant from the Ministry of Development.

Several methods of labelling the sand were considered. Activation of the sand by irradiation in the IRR-1 reactor at a flux of 2.5×10^{13} n/cm^2.sec for 1 - 24 h was found to give inadequate specific activities and half-lives. The use of irradiated glass particles was rejected because of recent publications mentioning the great difference in the hydrodynamic behaviour of glass and sand grains. The method finally chosen was surface labelling with Au^{198} or Cr^{51}.

The sand is first treated with 10% nitric acid to decompose carbonates and any organic materials. It is neutralized and then boiled with NaOH (30%) for 1.5 h and washed with water. The sand surface is then ready for labelling by one of the following methods:

a) Redox System. The sand is treated with an acidic (HCl) solution of $SnCl_2$, then washed to remove unadsorbed $SnCl_2$, and treated with $AgNO_3$ solution. A solution containing hydrazine sulphate and pyridine is added while stirring. The silver-coated sand is washed to remove traces of Ag^+. Up to this stage only non-radioactive substances are handled. The prepared sand is now ready for reduction of gold on it. This is easily done by addition of an acidic (HCl) $Au^{198}Cl_3$ solution and labelling is complete within a few minutes. The yield is higher than 95%. The great advantage of this method lies in the fate that all preliminary work can be done in the laboratory and the final work with radioactive gold in the injection container itself. Specific activities of 1 curie/kg and higher are easily obtained.

b) Formation of sesquioxides. Activated chromium powder is dissolved in HCl (1:3), and an excess of NaOH is added to obtain a chromite solution. The sand is boiled with the chromite solution for 1.5 h. After washing, the activity is fixed on the surface by drying at 200°C for 12 h. The maximum labelling yield was 50% at a chromium-to-sand weight ratio of 0.1%. With the available flux of 2.5×10^{13} n/cm^2.sec and irradiation for 4 weeks, a specific activity of about 2 curies/kg sand could be produced. The idea of labelling with non-radioactive chromium and irradiating the labelled sand is also being considered.

(ii) Injection of the labelled sand.

An injection vessel was designed in the Technical Services Department, by Mr. Ch. Gavish. The vessel has a volume of about 15 liters, which allows about 5 kg labelled sand to be prepared at a time. The injection vessel is lowered to about 1.5 meters below the surface of the sea (for shielding purposes) and is partly filled with water. A glass ampoule containing 20 cc of the $Au^{198}Cl_3$ solution is dropped into the vessel and crushed. Air is bubbled into the solution and the sand sample poured in gradually. This labelling can be done conveniently in a harbour. The vessel opens upon contact with the sea bottom and the labelled sand pours out of it.

(iii) Mapping the activity on the sea bed

The detector is towed along the sea bed behind a boat, and thus it must be robust and stable, as well as well as highly sensitive. Its hydrodynamic properties must be such that it does not rise from the bottom when towed at a velocity of 1 m/sec. The Littoral Drift Probe made by the Danish Isotope Centre was chosen. The count rate at the sea bottom will be continuously recorded and the location of the boat determined at different times by navigational measurements.

The results obtained will be converted into isoactivity curves, as a function of time, from which it will be possible to determine the direction and velocity of the sand movement under the given experimental conditions (winds, currents and wave direction, strength and frequency).

The first experiments will be conducted with Au^{198}-labelled sand, but if the half-life proves too short, work will continue with Cr^{51}.

References:

1. CURTOIS, G., private communication
2. PETERSEN, B.R., Ingeniøren International Edition, 4, 3, 99 (1960)

Method for Determining Movement of Silt in a Wadi : Z. Stuhl and Ch. Gilath

During rain periods the wadis (dry watercourses) suddenly fill up with flood waters which bring down large amounts of silt. If reservoirs are built to catch the rain water the silt will be deposited in them, gradually filling them up. It is thus of great practical importance to estimate the amount of silt brought down by floods. Recently the Geomorphological Laboratory of the Geography Department of the Hebrew University began measurements of silt movement along the Nahal Soreq Wadi, using dyed particles. However particles of less than 500 microns cannot be traced in this way, and it is just this fraction of particles that is of greatest importance in the determination of silt movement. The problem can be solved by radioactive labelling.

Labelling of the silt was carried out by using the cation exchange properties of clay. Cr^{51} with a half-life of 27.8 days was chosen. A well defined fraction of silt (88 - 120 microns) was treated with HNO_3 to destroy the carbonates and organic materials present. This treatment also replaced the exchangeable cations with H^+. After washing the residue to pH 7, a solution of $Cr^{51}Cl_3$ was added to the silt suspension, with shaking. The exchange was complete in a few minutes and a specific activity of 1 curie/kg silt was obtained. Three kilograms of labelled silt was divided into 20 portions and the portions buried along a 10 meter length of the wadi bed. The aim of such a distribution was to get a good average picture of the movement and to reduce any insignificant displacement. The rate of silt movement will be investigated as a function of the flooding conditions.

Mixing Conditions in Pulp Chests in a Paper Mill : Ch. Gilath, S. Lask, Z. Stuhl, E. Foa, M. Finkel*, D. Schiffer*

Experiments were performed to check the effectiveness of pulp mixing in chests at the American-Israel Paper Mill, Hadera. The

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* American-Israel Paper Mill, Hadera.

technological process in this mill starts with a batch operation, namely slushing of the dry pulp with water. Batches are discharged into a chest and the process becomes continuous from there on. The pulp is pumped through two additional chests, connected in series, and finally to the paper machine.

The chests are agitated, but a certain amount of channeling, which interferes with homogenisation of the pulp, was suspected. The matter had been investigated by using dyed pulp to trace the movement of material through the chests. These tests showed qualitatively that the mixing conditions were fairly good under the particular flow conditions of the test. However, this type of test is not entirely satisfactory. Each grade of paper requires different flow conditions, and the mixing must be examined for each case. Since most grades of paper are spoiled by adding dye, the production losses would be considerable. A better tracing method, which would also give more quantitative results, was thus needed.

The residence time distribution technique, using a radioactive tracer, was employed to determine the mixing conditions in one of the mixing chests. A pulse of Na^{24} (as an aqueous solution of Na_2CO_3) was injected into the feed stream to the chest. The activity of the outlet stream was measured with a scintillation detector placed in contact with the exit pipe and connected to a ratemeter and recorder. The curve obtained was corrected for recirculated activity (determined by means of a detector placed at the inlet stream to the chest), and thus the concentration versus time curve was obtained.

The function $F(t/\theta)$ representing the residence time distribution gives the fraction of the injected tracer activity which leaves the system up to the time t/θ . Here θ is the mean residence time, obtained by dividing the volume of the vessel by the flow rate; t/θ is the reduced time. If S^* is the whole area beneath the activity concentration curve, and S the area up to a certain time t/θ, when $F(t/\theta) = \frac{S}{S^*}$.

A mathematical model of the chest as a vessel composed of three regions - dead volume, plug flow and perfect mixing - connected in series, was considered. According to Ref.2, for this case

$$1 - F = e - \frac{1}{(1-p)(1-m)} \left[\frac{t}{\theta} - p(1-m) \right]$$

where p is the fraction of the vessel volume which acts as an ideal plug flow region, m is the fraction acting as dead volume, and 1 - (p+m) is the fraction working in ideal mixing conditions.

The parameters p, m and 1 - (p+m) were determined by plotting (1-F) against t/θ. In the experiment performed there was found to be 12% dead volume, 5% plug flow and 83% perfect mixing. No channeling was found in the system.

The use of radioactive tracers to obtain residence time distribution curves of flow systems provides valuable continuous information about the system, in an easy way, without disturbing the normal production process.

References:

1. Paper presented at the XXXV Meeting of the Israel Chemical Society, Feb. 1966
2. REBHUN, M. and ARGAMAN, A., Technion Report C V 106, 1963

Use of Radioactive Tracers for Corrosion Studies: S. Lask and Ch. Gilath

A study of the mechanism of halogen ion migration through passivation layers on stainless steel is being undertaken at the Corrosion Laboratories of the Israel Metal Institute. Preliminary experiments were performed to evaluate the use of radioactive tracers for this study. Two kinds of information can be obtained by radioisotope tracer techniques:
a) the general surface concentration of the halogen ions,
b) a microscopic picture of the halogen concentration distribution on the surface, as obtained from autoradiographs.

Chlorine-38, produced by irradiating NH_4Cl in the IRR-1 reactor, was used for the first experiments. Aqueous solutions of HCl^{38} (obtained by decomposition of NH_4Cl^{38}) were used to establish the sensitivity of the above techniques. At a maximum concentration of 3000 ppm Cl^-, the specific activity of the HCl solution was about 700 μc/ml.

Counting for 1 min on a 1 cm^2 surface using a GM counter, the sensitivity was about 0.1 mμc/cm^2 (based on twice the standard deviation). This corresponds to 3×10^{-2} micrograms of Cl^-/cm^2 for a solution of the above specific activity.

Autoradiographs were taken with a medium grain size Kodak X-ray microtex film and exposures of a few hours, up to practically complete decay of the Cl^{38}. Satisfactory darkening was obtained for a specific activity of about 1 mμc Cl^{38}/cm^2, but the resolution obtained was not better than 30 microns. A much better resolution of about 2 microns was obtained with Kodalith Ortho film, but the very low sensitivity of this film necessitates the use of specific activities of about 100 mμc/cm^2. Experiments will be continued with the Kodirex X-ray film, which is expected to give a good resolution at a reasonably low specific activity.

Thus, both counting and autoradiography are suitable for use in the corrosion study.

Radioactive Tracer Method for Determining the Weight Distribution of Carbon Black in Rubber: Z. Stuhl and Ch. Gilath

In the making of rubber, the carbon black incorporated is dispersed in the form of grains of submicron dimensions. However these grains may coalesce to form agglomerates, which impairs the quality of the rubber. It is accepted practice to check the degree of agglomeration by counting the number of agglomerates larger than 6 × 6 microns, under the microscope.

The present work was undertaken to ascertain if there is any detectable inhomogeneity in the weight distribution of the carbon black, and if so, whether this is related to the degree of agglomeration. There are no simple chemical methods for this determination and thus a radioactive tracer method was tried. A 150 g quantity of carbon black (IPC, type FIAF) was irradiated for 5 minutes in the IRR-1 reactor at a flux of 7×10^{12} n/cm^2 sec. The trace amount (about 0.1%) of sodium present was converted to radioactive Na^{24} (half-life 15 h). The irradiated carbon black was used to make a batch of 500 g of rubber. Prior to vulcanizing the rubber sheet, three samples - of 10, 100 and 1000 mg - were taken from each of 24 points on the sheet. The activity of the samples was measured with a scintillation counter. The count rates were corrected for the decay of radioactivity and the results converted into the weight of carbon black per sample.

The standard deviation of the counts was calculated separately for the 10, 100 and 1000 mg sample groups. There was no significant difference between the standard deviations of the three groups, it being less than $\pm$ 2.5% in all cases. Of this, the standard error due to counting statistics (square root of the count) was about $\pm$ 1%, leaving an error of less than $\pm$ 2% from all other sources including changes in counting geometry and inhomogeneity of the neutron flux. Thus it can be stated that the weight distribution of carbon black has a standard deviation which does not exceed $\pm$ 2%, i.e. no significant inhomogeneity was detected.

The method described above is simple, fast and reliable, and can be used on samples down to 1 mg.

Investigation of the Flow of a Submerged Radioactive Spring (Radioisotope Training Center): C. Braudo, E. Mazor*, F. Mero**

A considerable part of the salinity of Lake Kinereth arises from springs flowing up through the bed of the lake. Many of these highly

* Isotope Department, Weizmann Institute of Science
** Tahal, Water Planning for Israel Ltd.

saline springs are also radioactive and it has been suggested that the radioactivity of the water might be used as a sensitive indicator to aid in the location of such sources, the final purpose being either to contain the water or to pump it away.

The water issuing from the springs is diluted almost immediately in the large volume of lake water, and thus any measurement of salinity, temperature or radioactivity must be carried out in the immediate vicinity of the source with submersible detectors. A submersible probe was designed containing a scintillation detector consisting of a 2" dia × 4" NaI crystal viewed by a type 6292 photomultiplier. The signal was conducted via a 50 meter coaxial cable to a portable battery-operated scaler ratemeter. Attenuation in the cable was compensated by a preamplifier operating in a mixed current and voltage mode, as suggested by Miwa and Tohyama[1] and suitably modified in our electronic workshop.

The preliminary tests were conducted at a spring whose characteristics are well known, not far from the inlet to the National Water Carrier. The increased salinity and higher temperature associated with the spring water were accompanied by activity about 100 times the normal background activity of the water measured some distance from the spring. The mud on the bed of the lake in the vicinity of the spring was even more active (more than 150 times the background activity). This preliminary series of tests was brought to an end by a fault in the cable to the probe.

Subsequently a further series of tests was carried out at a spring (Ma'agan 2) which has the physical form of a conical crater some 20 meters deep in the lake bed. At this point the bed is covered by 21 meters of water. The activity profiles measured are shown in Fig. 47. Simultaneous measurements of temperature and conductivity showed that the radioactivity correlated fairly well with the salinity and temperature of the water, and visual observation by a diver established that the water of the spring (high activity and salinity) also carried with it a large quantity of suspended solids.

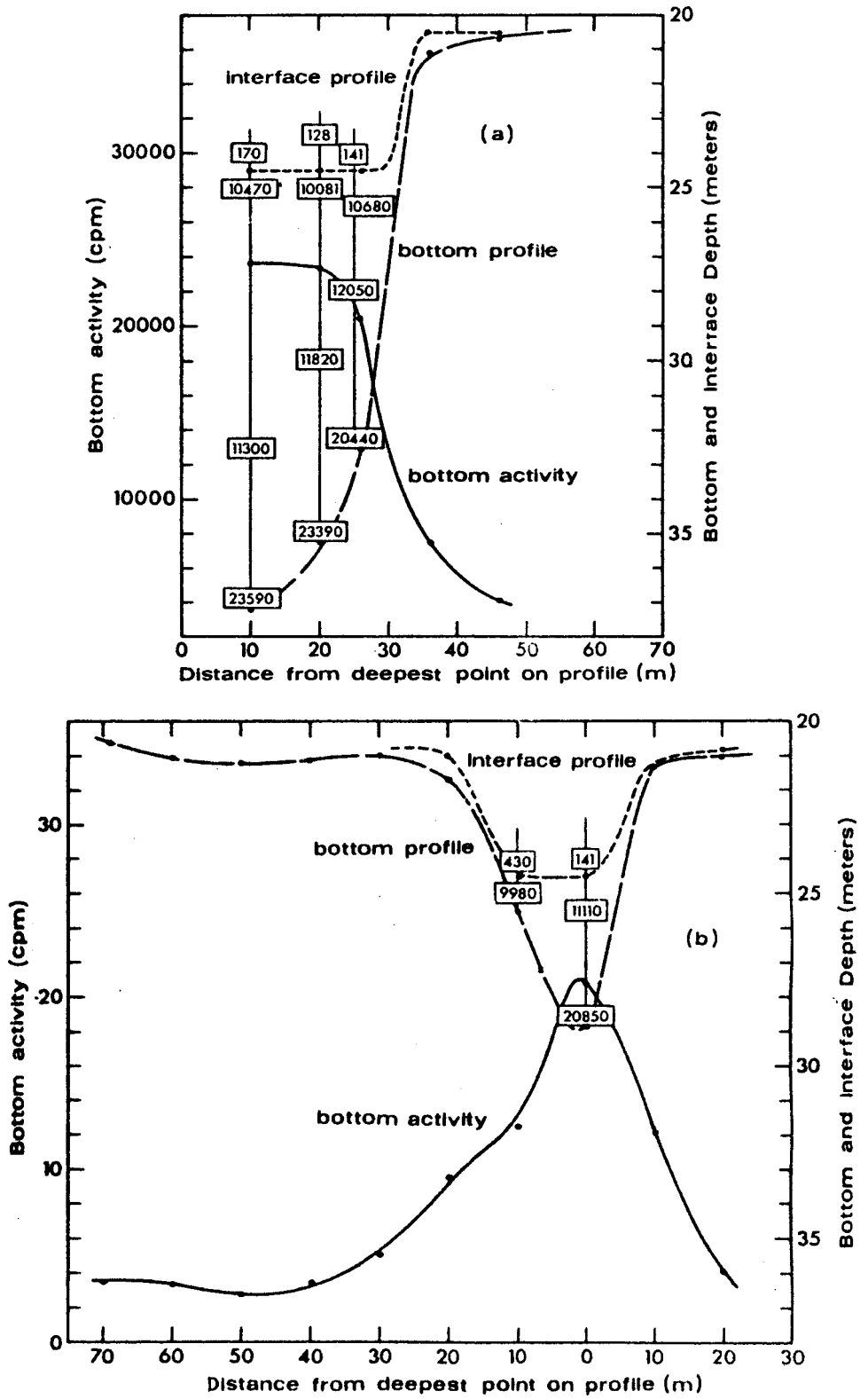

Fig. 47

Radioactivity of Ma'agan II. Figures in boxes give the activity at the particular location in c.p.m.

a) East-West profile b) North-South profile.

Inspection of the activity profiles shows that there is a well defined lake - spring interface. The activity is constant below the interface and negligible above it, arguing fast and thorough dilution. The activity of the mud on the bed of the lake seems to rise as one approaches the throat of the crater. Further tests are being carried out to investigate the speed and mechanism of dilution of the spring water.

Reference:

1. MIWA, H. and TOHYAMA, T., Nuclear Electronics II, p.421, I.A.E.A., Vienna 1962

B. IRRADIATION OF AGRICULTURAL PRODUCTS

Effect of Irradiation in Delaying Sucrose Decomposition in Sugar Beets:

E. Eisenberg, R. S. Kahan, A. Heller* and A. Perlman*

This experiment was planned in collaboration with the Sugar Beet Growers Association and the sugar factory "Sugat Ltd".

One of the problems of the local industry is the need to store sugar beets for one to three days in order to permit continuous plant operation on Saturdays (no crops are harvested on Saturdays). When the green top is removed and the beet stored, the sugar concentration diminishes, the loss increasing with temperature.

A preliminary experiment was carried out to test the effect of different radiation doses on sucrose concentration during storage under normal plant conditions. The beet was treated with doses in the range 1 - 100 krad, applied during the first 24 hours of storage. The batch size was about 25 kg. The sugar content was measured after storage for 1 - 13 days. A single analysis was performed per batch, under normal industrial analytical conditions at the sugar factory.

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* Sugar Beet Growers Association

The sugar content in the irradiated samples appeared to be 10% - 20% higher than in the controls during the whole period of storage. The lowest dose tested (1 krad) seemed to give the best results. However it should be noted that the sugar content of beets harvested in the same field may vary by the amounts observed, and that our results are based on analyses of single batches only. Nevertheless the results obtained justify further investigation during the 1966 harvest season.

Extension of the Ripening Period of Stored Avocado Pears : R. S. Kahan, G. Zaubermann*, E. Eisenberg

Several varieties of avocado pears are grown in Israel. The fruit is picked while still green and then allowed to ripen. The ripening period is fairly short, and towards the end of it the fruit becomes discoloured and a fungal growth (colletotrichum) develops.

Preliminary experiments during the 1964/65 season showed that the ripening period of the main variety grown (Fuerte) could be extended by relatively low radiation doses. Doses in the 5-200 krad range were tested at 2 dose rates (250 krads/h and 430 krads/h) using the Gamma Cell-200 source. In one experiment, 20 krads extended the ripening period from 7 days (control) to 12-18 days. Similar results have been reported recently from California[1].

Experiments on this and other varieties are being carried out during the 1965/66 season.

Reference:

1. YOUNG, R. E., Nature 205, 1113-14 (1965)

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* Dept. of Fruit and Vegetable Storage - Volcani Institute of Agricultural Research

Inhibition of Sprouting in Stored Potatoes: R.S. Kahan, N. Temkin-Gorodeiski* and E. Eisenberg

Experiments conducted abroad have demonstrated the efficacy of irradiation in inhibiting sprouting and extending the storage life of potatoes. It has also been shown that such irradiated potatoes retain their wholesomeness, and in Canada, the U.S.A. and U.S.S.R. the use of these potatoes for human consumption has been approved.

The present experiments were conducted to confirm the results obtained abroad for the local varieties of potatoes. The project was planned in cooperation with the Vegetable Crops Dept. of the Ministry of Agriculture and is being executed in collaboration with the Volcani Institute of Agricultural Research.

Tests are being carried out on the "Up-to-Date" variety of potatoes, which is the main type grown in Israel. Some work on this variety has been reported from India[1,2]. In the present experiments, potatoes harvested during May-June 1965 from fields that had not been treated with chemical sprays were irradiated. After storage for 3 months under ambient conditions, non-irradiated controls were shrivelled and soft and had sprouts 10-30 mm long. Batches that had been irradiated with 7.5 - 15 krads showed very little sprouting (1-2 mm sprouts), while those irradiated with 15 krads gave sprouts 3-5 mm long. All the irradiated lots were of good appearance and firm.

A large scale experiment is now being conducted to investigate the effect of temperature on the storage life of irradiated potatoes. Loss in weight, losses due to rot, chemical changes, and the culinary quality of the stored potatoes will be observed over a period of 12 months. The potatoes taken for the experiment are of commercial origin and had been in storage at 8° for several weeks. They were thus close to the end of their natural dormancy period. They were kept for a further

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* Volcani Institute of Agricultural Research

10 days at ambient conditions and then irradiated, without regrading. Part were treated in their original commercial 45 kg sacks; the rest were transferred to small containers for irradiation and returned to sacks for storage. A total of about 6 tons were irradiated.

Doses of 6, 10 and 14 krads (± 17%) were applied at 2 dose rates (20 and 100 krads/h). The irradiated potatoes and controls are being stored at 4 temperatures: at 4° and 8°C in commercial storage, and at 14° and ambient temperature in darkened rooms. The effect of irradiation is being compared with that of 2 chemical treatments for sprouting control. Sample sacks are withdrawn from storage every 4-8 weeks, and after preliminary evaluation are stored for a further 4 weeks under ambient conditions to simulate marketing and consumer handling.

References:

1. MATHUR , P.B., Nature 198, 99 (1963)
2. MATHUR , P.B., Nature 199, 1007 (1963

Comparison of the Effects of Gamma Radiation and other Treatments on the Storage Qualities of "Lassen" Strawberries

It has been reported from abroad that irradiation is effective in delaying spoilage in strawberries. Experiments were conducted* to check the response of the local variety and to compare the results with those of other treatments of commercial interest. The treatments tested were:

a) irradiation with 100 and 200 krads, at a dose rate of 100 krads/h.
b) keeping at 10°-15° from the time of picking until irradiated after 18 hours ("precooling").
c) dipping in 0.1% Captan

The fruit was picked towards the end of the season, at two stages of ripening, namely pinkish-red and red-ripe. Except in the case of

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* By S. Ben-Yehoshua (Volcani Inst. of Agricultural Research), R. S. Kahan and E. Eisenberg

treatment b) above it was kept at ambient conditions (26-27°C) for 18 hours before treatment and storage. The experimental unit was 100 fruits, packed in 4 commercial plastic baskets. The storage temperatures tested were 2°-3° and 20°C.

Table 34 gives the incidence of rot for storage at 20°. Irradiation with 200 krads was the best single treatment (16% and 45% rot in pink-hard and red-ripe fruits respectively, versus 76% and 96% for the controls). A combination of immediate precooling, dipping in Captan and 100 krads reduced rot to zero for pink-hard fruits. Table 35 shows that storage at 2°-3° after irradiation gave a marked improvement for fruit stored for 2-7 days, but had little or no effect on fruit stored for 14 days, especially if it was kept for an additional day at 23°C. The effect of storing at 2°-3° was less marked for the other types of treatment.

The fruit picked at the pink-hard stage did not ripen uniformly, the stem end frequently remaining pink and hard while the bulk of the strawberry became red and ripe. Irradiation intensified the red colour of the pulp.

Organoleptic tests, based on triangular comparison by a panel of 5 persons, showed a distinct reduction in the aroma of the pulp of fruit treated with 200 krads. The flavour and texture of the fruit were not affected.

The effects of precooling were poor, possibly because the portable equipment used was inadequate. In preliminary experiments it was found that increasing the CO_2 content to 10% of the atmosphere during precooling gave greatly improved storage qualities.

In another series of tests* the effect of dipping the fruit in 0.2% dehydroacetic acid (DHA) was compared with that of irradiation. These experiments were conducted under rather unfavourable weather conditions, the day of picking being a sharav (hot and dry). After treatment the fruit was stored at 0° or 17°C. The red-ripe fruit spoiled immediately.

* By N. Temkin-Gorodeiski (Volcani Inst. of Agricultural Research), E. Eisenberg and R. S. Kahan

TABLE 34

Effect of various treatments on the spoilage of strawberries stored for 2 days at 20°C

Treatment \ State at picking	% Spoilage	
	Pink-hard	Red-ripe
none	76	96
0.1% Captan	45	61
precooling to 10-15°C	35	60
100 krads	30	90
200 krads	16	45
precooling + 0.1% Captan + 100 krads	0	30

TABLE 35

Effect of irradiation on spoilage of fruit stored at 2°-3°C

Storage time →	2 days		7 days		14 days		14 days plus 1 day at 23°C	
Treatment \ State at picking	Pink-hard	Red-ripe	Pink-hard	Red-ripe	Pink-hard	Red-ripe	Pink-hard	Red-ripe
none	0	25	13	43	49	66	67	84
100 krads	0	15	10	17	25	75	52	75
200 krads	0	10	6	15	36	58	60	89

The pink-hard responded as follows. With 100 krads (dose rate 217 krads/h) spoilage after 4 days at 17° was 17%, versus 65% for the untreated controls. The spoilage increased to 35% on the 5th day. For storage at 0° the spoilage was 18% after 7 days, compared with 33% for the controls. However after storage for an additional day at 17° there was as much spoilage in the irradiated as in the control fruit. Essentially the same results were obtained with 200 krads. The action of DHA was rather similar. Fruit treated with DHA and stored at 17° had the better appearance. On the other hand, for fruit stored at 0°, 100 krads irradiation gave better results.

Effect of Co^{60} Radiation in Extending the Storage Life of Shamouti Oranges Inoculated with Fungal Spores of Penicillium Digitatum and Penicillium Italicum[1] : R. S. Kahan and R. Barkai-Golan *

Radiation was found to delay the appearance of rot in Shamouti oranges inoculated with fungi. However the radiation caused peel damage.

Fruit picked at the beginning of the main Shamouti harvest season was cleaned and inoculated with suspensions containing either P.digitatum or P.italicum spores. Three concentrations were used for each pathogen (100, 1000 and 10,000 spores per inoculum). The inoculated fruits were irradiated with doses of 50-250 krads, applied at 390 krads/h, and then stored for 80 days at 23°C. The experimental unit was 20 oranges.

The results are given in Table 36 . Doses above 50 krads delayed the appearance of rot, the effect being more marked when the initial spore concentration was lower. A dose of 200 krads was usually sufficient to delay rot for at least a month, while 250 krads usually prevented development of the pathogen entirely.

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* Dept. of Fruit and Vegetable Storage, Volcani Inst. of Agricultural Research

TABLE 36

Effect of radiation in delaying the appearance of visible rot in inoculated oranges stored at 23°C

Fungus	Dose (krads)	Days before appearance of rot		
		100 spores per inoculum	1000 spores per inoculum	100,000 spores per inoculum
P. digitatum	0	3	3	3
	50	3	4	3
	100	5	4	3.5
	150	23	-	10
	200	27	-	26
	250	no rot	no rot	30
P. italicum	0	3	3	3
	50	8	5	4
	100	20	9	5
	150	29	-	23
	200	no rot	35	40
	250	no rot	no rot	no rot

Slight radiation damage to the peel was observed in some of the fruit treated with 50 and 100 krads. All the fruit receiving 150 krads or more showed marked peel damage, in the form of surface pitting which appeared 3 days after irradiation and darkened and spread with time. Similar peel damage has been observed in non-inoculated Shamouti fruits[2].

References:

1. BARKAI-GOLAN, Rivka, and KAHAN, R.S., Volcani Inst. of Agr. Research Bulletin No. 91, p.19 (1965) (in Hebrew)

2. KAHAN, R.S., Israel AEC Semi-Annual Report July-Dec. 1964, IA-1021, p.149

Effects of Gamma Irradiation on Valencia-Type (Jaffa Late) Oranges :

R.S. Kahan, S.P. Monselise*, E. Eisenberg and C. Satchy

Studies on the effects of radiation on Shamouti oranges[1] were extended to the Valencia variety. The Co^{60} plate source was used, and the effects of 4 doses (50, 100, 150, 200 krads) at 4 dose rates in the range 50-300 krads/h were investigated. External damage and chemical and enzymatic changes were examined in fruit stored in a cellar at ambient conditions (20-30°) for 13 and 90 days. Only a limited number of replicate analyses were performed so that the results must be regarded as preliminary.

Visible damage to the peel was far less marked than in the case of Shamouti oranges. The damage appeared 5-10 days after irradiation and spread during the next 20-30 days to an area 2-3 times as large as that initially affected. After this there was no spread of the damage up to the end of the 90-days storage period. The extent of visible peel damage appeared to be affected by the dose rate (least damage at 200 krads/h and most at 50 krads/h). Such effects were also observed in regard to weight loss during storage (least loss at 200 krads/h in most cases, and most loss at 300 krads/h). There were no clear cut effects of the dose rate on the chemical constituents and enzymatic activity of the skin. These factors were in any case not greatly influenced by radiation.

The increased damage observed at low rates may have been due not so much to the dose rate itself as to ozone in the irradiation chamber during the prolonged exposure.

Reference:

1. KAHAN, R.S., Israel AEC Semi-Annual Report, July-Dec. 1964 IA-1021, p.149

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* Dept. of Citriculture, Hebrew University, Rehovoth

Determination of the Radiation Required for 90% - 100% Lethality in Penicillium Italicum Spore Suspensions[1] : R S. Kahan and R. Barkai-Golan*

P. italicum amd P. digitatum are the common rot-causing fungi attacking stored citrus fruit in Israel. The need to combat these fungi is of special importance in the export of citrus, since the fruit takes several weeks to reach its destination. An in vitro study was made to determine the radiation dose required for 100% destruction of the spores in various spore populations. Beraha et al.[2] determined some sublethal and supra-lethal doses for these fungi, and Sommer and Maxie[3] determined the C.I.D.80 (the dose required to inactivate 80% of the spore population) for various populations. However these doses cannot be extrapolated since the response to radiation is not linear.

P. italicum spores were prepared in suspensions containing 10^2, 10^3, 10^4, 10^5, and 10^6 spores per ml. The suspensions were irradiated with doses of 100-300 krads, and after suitable dilution they were incubated on normal potato-dextrose agar medium at 23°C. The number of spores which formed colonies are given in Fig. 48 . All the doses used inactivated over 99% of all the spore populations tested, but the dose required for 100% lethality varied with the initial spore concentration. 100 krads did not cause 100% lethality even in the smallest population tested (100 spores/ml); 150 and 200 krads gave 100% lethality in populations of 100 spores/ml; 300 krads caused 100% lethality in populations of 10^2 - 10^5 spores/ml. Doses of 150 krads or higher inactivated at least 99.95% of all the populations tested.

It seems probable that doses of 100 krads would be adequate for commercially packed fruit in which the residual spore concentrations are far less than those used in this experiment. Similar experiments will be carried out for P. digitatum.

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* Dept. of Fruit and Vegetable Storage, Volcani Inst. of Agricultural Research

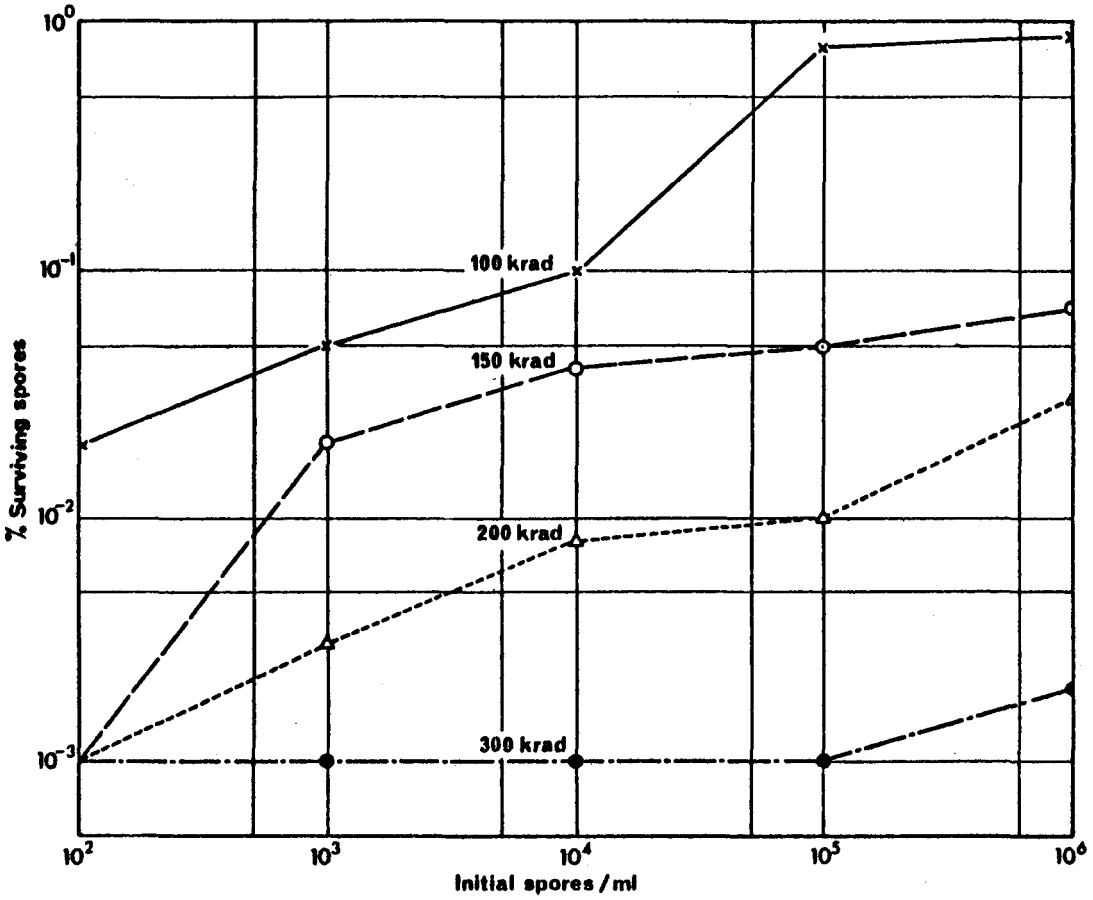

Fig. 48

Effect of gamma radiation on the percentage of viable spores surviving from various initial concentrations

——— 100 krad - - - - 150 krad
- - - - 200 krad —·—·— 300 krad

References:

1. BARKAI-GOLAN, Rivka and KAHAN, R.S., Inst. of Agricultural Res. Bull. No. 91, 27-28 (1965) in Hebrew

2. BERAHA, L., RAMSEY, G.B., SMITH, M.A. and WRIGHT, W.R., Phytopathology 49, 91 (1959); 56 474-(1960)

Control of the Mediterranean Fruit Fly (C. Capita Wied) by Mass Irradiation Sterilisation of Laboratory-Bred Flies: I. Cohen*, D. Nadel**, B.A. Peleg**, R.S. Kahan and E. Eisenberg

Tests are being carried out under field conditions in three selected areas in order to evaluate the efficacy of fly control by the release of large numbers of laboratory-bred flies sterilised by irradiation. The flies, which are bred at the Biological Control Institute, Rehovoth, are irradiated during the pupal stage, on the last day before emergence of the adults. The dose is 5-8 krads, which produces a lethal mutant in the spermatozoa of the mature male flies, and renders the mature female sterile and unable to ovipósit and damage fruit. Currently about 7 million pupae are being irradiated and released per week. A total of 80 million pupae have been treated since the project was begun in April 1965.

This large-scale project is based on the results of successful small-scale experiments which solved the following problems:

a) Determination of the dose which would produce a lethal mutant in the males but leave them sufficiently active to compete effectively with wild-type males.

b) Determination of the optimum stage at which to irradiate the pupae.

c) Development of a suitable container for irradiating liter quantities of pupae (60,000 pupae per liter).

d) Development of a rapid method for confirming the sterility of both male and female flies before their release.

e) Testing of various methods of release under field conditions.

f) Investigation of the efficacy of the treatment under field conditions.

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* Agro-Technical Division, Citrus Marketing Board, Tel Aviv
** Biological Control Institute (C.M.B.) Rehovoth

Radiation Susceptibility of Various Developmental Stages of the Mediterranean Fruit Fly (Ceratitis Capita Wied) : R. S. Kahan, B. A. Peleg* and E. Eisenberg

An experiment is being carried out to determine the lethal dose of gamma radiation for laboratory-bred flies at various stages of the development cycle. The insects are dispersed in a suitable synthetic food medium and irradiated with the Co^{60} plate source. A dose of 10 krads was found to kill all immature stages of the fly. This dose also rendered the adult fly sterile. Thus 10 krads may be sufficient for quarantine control of citrus and other fruits against this fly.

Tests are now being carried out with lower doses and in vivo conditions, and eventually the wild type flies will be studied.

Preliminary Experiments on the Use of Radiation in Agriculture and Related Fields

Several experiments have been carried out or are in progress to explore new applications of irradiation. These experiments have been undertaken in collaboration with various other institutions and will be reported on at a later stage. The following topics are being studied:

a) Delay of sprouting in stored gladiolus bulbs. (R. Shiloh, Dept. of Floriculture, Volcani Institute of Agricultural Research).

b) Control of growth of microflora in experimental soils used in soil studies. (A. Geron, Dept. of Soil Science, Volcani Institute of Agricultural Research).

c) Control of rots in "Hayani" soft dates. (S. Ben-Yehoshua, Volcani Institute of Agricultural Research).

d) Preliminary tests on Beit-Alpha variety of winter-harvested onion bulbs. (M. Avidov, Dept. of Vegetable Crops, Ministry of Agriculture and N. Temkin - Gorodeiski, Volcani Institute of Agricultural Research).

e) Changing the time required for onion bulbs to reach maturity. (M. Avidov, Dept. of Vegetable Crops, Ministry of Agriculture).

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* Biological Control Institute, Agrotechnical Division, Citrus Marketing Board of Israel, Rehovoth

f) Control of ticks causing cave-fever and disease-bearing mosquitoes (R. Galon, Israel Institute for Biological Research, Ness Ziona).

g) Formation of visible mutants in plants from irradiated potato tubers. (Y. Natav (Reves) Dept. of Vegetable Crops, Ministry of Agriculture).

h) The effect of irradiation on the phytotoxic fungi attacking table-grape varieties (Queen of the Vineyards, Alphonse Levallec, and Sultanina) and on rot-causing pathogens in grapes. (R. Barkai-Golan and S. Reich, Dept. of Fruit and Vegetable Storage, Volcani Institute of Agricultural Research).

i) Disinfection of dried egg albumin against Salmonella (Tomaz Ltd.,Hedera).

j) Disinfestation and disinfection of bran. (D. Nadel Biological Control Institute of Citrus Marketing Board, Rehovoth).

k) Disinfestation of contaminated filled chocolate confectionery. (D. Mor, Ministry of Commerce and M. Calderon, Ministry of Agriculture).

l) The effect of irradiation on stored melon pathogens. (R. Barkai-Golan, Dept. of Fruit and Vegetable Storage, Volcani Institute of Agricultural Research).

m) Preservation of peeled sliced grapefruit in plastic packages. (R. Beck, Dept. of Food Technology, Technion, Haifa).

n) The effect of irradiation on the pathogen Phytophtera citrophthora causing brown rot in citrus fruit. (M. Shiffmann - Nadel and E. Cohen, Dept. of Fruit and Vegetable Storage, Volcani Inst. of Agricultural Research).

o) Effects on the development of rot-causing pathogens in strawberries. (R. Barkai-Golan, Dept. of Fruit and Vegetable Storage, Volcani Institute of Agricultural Research).

p) Preliminary experiments to compare the effects of diphenyl and gamma radiation on artificially inoculated Shamouti oranges. (R. Barkai-Golan, Dept. of Fruit and Vegetable Storage, Volcani Inst. of Agricultural Research).

Determination of Ozone in the Gamma Cell : M. Lapidot and A. Algave

Measurements were carried out to calibrate the "Ozonomat" apparatus which has been installed for continuous monitoring of the ozone concentration in the air of the gamma cell. For the calibration the air was absorbed into an alkaline solution of fluoresceine (zinc-reduced fluorescine)[1] and the ozone present determined from the change in colour

produced by the oxidation of the fluoresceine. The amount of fluoerescine obtained was measured spectrophotometrically at 4900 Å, and the ozone concentration calculated by the method of Egorow[2].

Air was pumped from the gamma cell, at a spot about 20 cm from the source, and passed successively through two absorption bottles containing the fluoresceine solution. The following table gives the ozone concentration in the gamma cell as a function of irradiation time for a dose of rate of 200 krads/h.

TABLE 37

Ozone concentration in gamma cell

Time of irradiation hours	Ozone concentration ppm (by wt)
0.5	0.644
1	0.752
2	1.17
3	6.12

References:

1. WALTHER Deckert, Z. Annl. Chemie 150, 421 (1956)
2. KERTESZ, Z.I. and PARSONS, Grace F., Science, 142, 1289 (1963)

Calibration of the Gamma Cell and Dosimetric Development Work :

Carmela Satchy

Measurements were made to map the radiation field in the gamma cell when the 30,000 curie Co^{60} source is in operating position. Silver phosphate glass dosimeters were used. These were calibrated at different wavelengths, against the Fricke $FeSO_4$ dosimeter, using the Gamma-Cell 200 source at a flux of 400 krad/h. Fading curves of the glass dosimeter were prepared and conditions of accelerated fading were established. The additivity of fractionated doses was determined and the accuracy and reproducibility of calibration by the dosimeter established. For the mapping

measurements dosimeters were positioned on plastic sheets stretched on wooden frames and arranged at different distances from the source. The depth-dose curves obtained are shown in Figs. 49, 50 and 51.

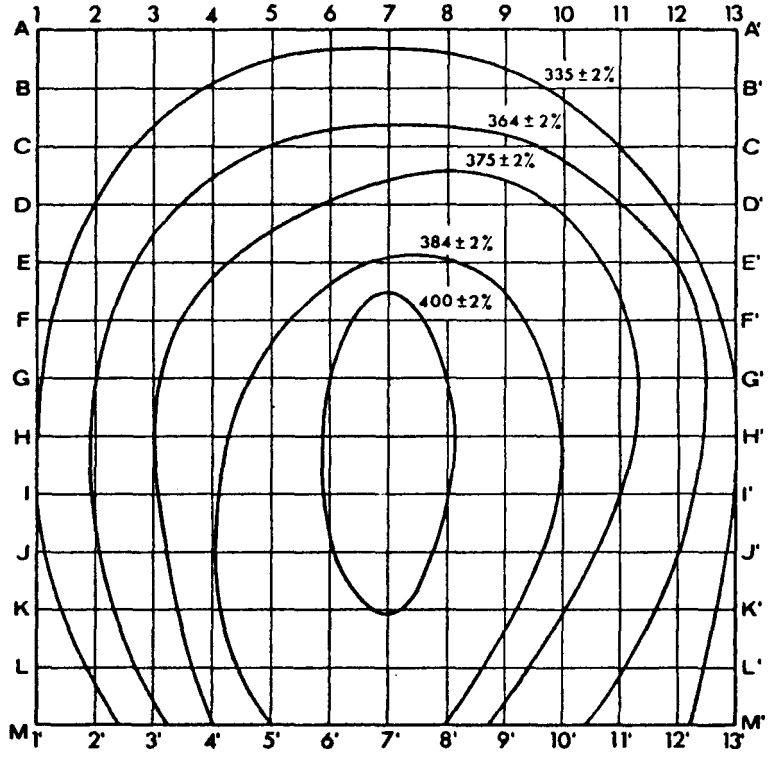

Fig. 49

Isodose curves at the window of the gamma cell, with the 30,000 curie Co^{60} source in operating position. Dose rates are given in krads/h. A vertical section is shown, representing a quarter of the cell. The doses are symmetrical upon reflection about M-M' and 13-13'

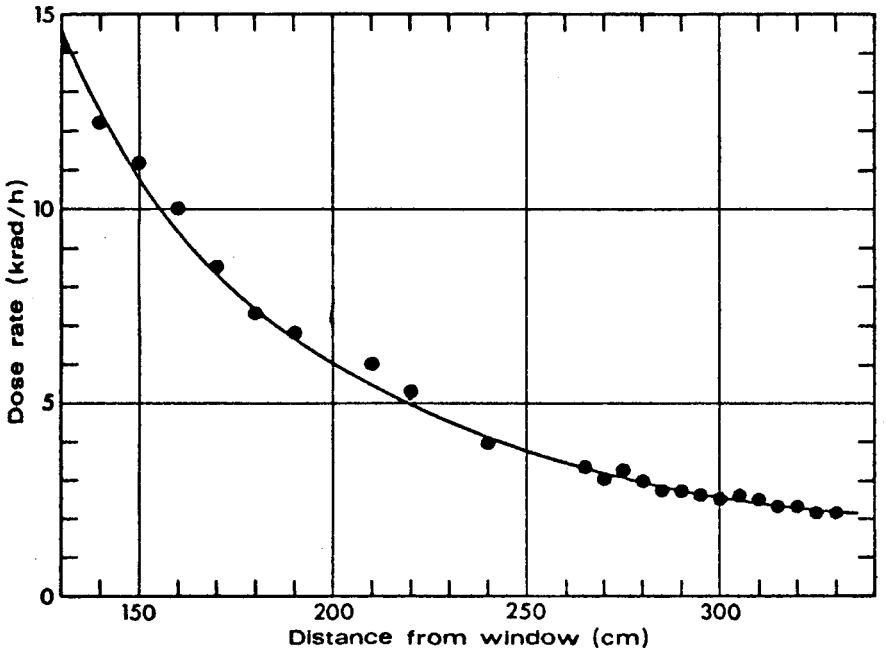

Fig. 50

Dose rate as a function of distance from the window. Location K13, at a height of 37 cms above the floor.

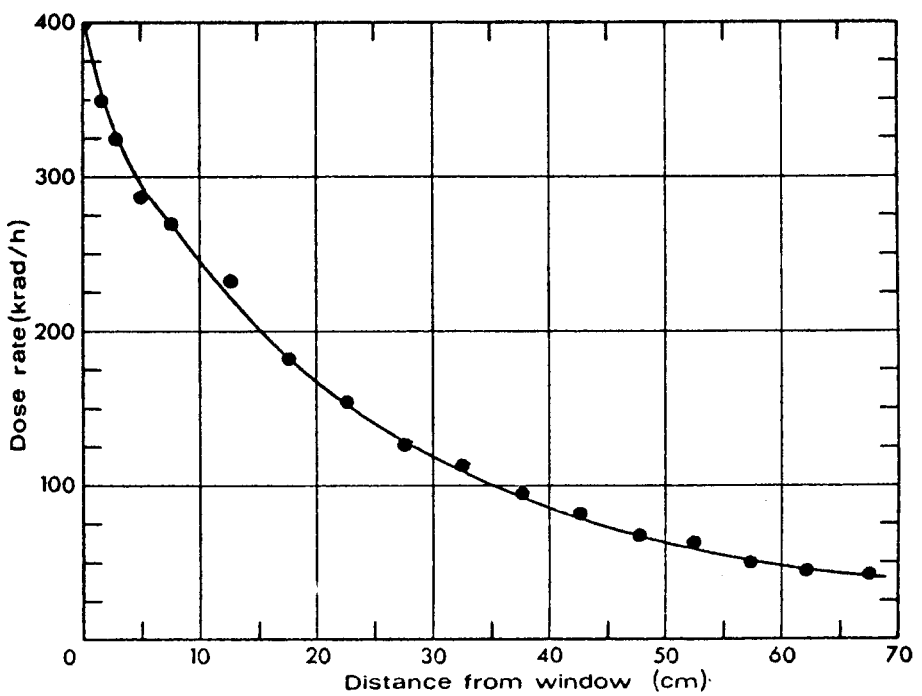

Fig. 51

Dose rate as a function of distance from the window. Location Q7, at a height of 37 cms above the floor.

Routine dosimetry was performed in order to determine the following factors for items of different densities and geometries:

a) The appropriate location and time of irradiation for various dose-rates and doses.

b) The distribution of the absorbed dose.

Various dosimeters were compared, namely Fricke ampoules[2,8], silver metaphosphate activated glass plates[1,3,5] and cobalt glass plates[4]. The glass dosimeters, which are too expensive for routine work, were regenerated by heating at 470° for 15 minutes[1,5]; this results in the disappearance of the colour centers. Both kinds of glass were subjected to 5 successive identical exposure-regeneration cycles, with doses over the range 120-180 krad and dose-rates of 160-250 krad/h. One hour after each irradiation the optical density at 400 mμ was measured with a Spectronic 20 Colourimeter. The response of the glass was found to remain essentially constant over the whole treatment. The error was ± 12% for the cobalt glass and ± 10% for the silver metaphosphate glass.

Some specimens of glass were found to retain a certain amount of colouration after the thermal regeneration procedure. Those having an optical density of over 0.1 (about 15-20% of the cases) were chemically treated to ensure complete bleaching. Several processes were tried, the most efficient for silver metaphosphate glass being soaking in NaOH solution (4 min in 10% NaOH or 10 min in 5% NaOH) followed by rinsing in water and reheating. The chemically treated specimens were irradiated in parallel with new specimens and their response was found to be similar to that of heat-regenerated glasses.

The modified Fricke dosimeter[2,6,7] (based on cupric-ferrous sulphate) was chosen for the higher range of doses, up to 10^6 rads.

A review of world literature on new dosimeters was prepared. Photographic films, print-out-papers, X-ray films, cellophane dyes, chlorinated hydrocarbons and similar materials were investigated as possible cheap dosimeters.

Research has started on the development of new dosimeters based on the decrease in the fluorescence of organic compounds. Azo or diazo compounds dissolved in solvents like benzene (for the lower dose range) or polystyrene (for the higher dose range) will be irradiated and the changes measured by gasometric or fluorimetric means.

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