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STUDIORUM PROGRESSUS

A Statistical Study on the Possible Influence of Soil and Other Geological Conditions on Cancer

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I.–*Reasons for Study*

There have been a great number of publications in the orthodox medical literature, suggesting the influence of soil and topography on the development and distribution of carcinoma. Several physicians have reported so-called "cancer houses" or "cancer districts" in towns, which would suggest that high cancer incidence is related to a particular location of a house or district. The reported examples could be explained in part by greater concentrations of elderly people in certain houses or districts, but many instances are known in which this explanation is unsatisfactory.

An extensive review of these problems has already been given by TROMP and DIEHL[2], the most important features of which will be summarized below.

One of the first contributions to the problem of the possible influence of soil on cancer was made at the end of the 19th century by HAVILAND[3], formerly lecturer at St. Thomas's Hospital Medical School in London. The 625 registration districts of England and Wales were traced on a geological map of Great Britain, each district being coloured differently to designate the various degrees of annual cancer mortality per 10,000 inhabitants during the period 1851–1860.

HAVILAND concluded that districts with high cancer mortality coincide with low-lying clay areas, sheltered from the direct influence of prevailing winds, and traversed by large rivers which seasonally flood the surrounding areas. Elevated districts which are the source of these rivers have low cancer mortalities. Chalk countries are remarkably free from cancer. Water partings of catchment basins where hard rocks occur, especially limestones, also have low cancer mortalities. In river basine with high cancer death rates, locally outcropping chalk areas are characterized by low cancer frequencies. Areas above the floodline have lower cancer frequencies than areas immediately bordering the rivers.

HAVILAND's observations were supported in Great Britain by BRAND (formerly president of the North Lincoln Branch of the British Medical Association)[4], BUTLIN (surgeon at St. Bartholomews Hospital)[1], WEBB and JACKSON (formerly presidents of the Wales Branch of the British Medical Association)[2] and in France by FIESSINGER[3], FOUCAULT, GUEILLOT[4], MOLLIÈRE, and others.

In 1951 LEGON (Dept. of Geography at the London School of Economics and Political Science)[5], reported on the high frequencies for gastric cancer in certain parts of Wales, characterized by specific geological conditions. High cancer frequencies seem to be related to soils rich in peat and other organic substances and with poor drainage, whereas low mortality ratios are found where peat soils are not present and where a relatively good drainage occurs, either because of the porous nature of the subsoil (sandstones, certain limestones), presence of subsoil fractures, dipping strata, or sloping topography.

There have been a number of publications in France (apart from those of FIESSINGER) suggesting an influence of soil or groundwater on cancer[6]. According to DURAND, Physician at Courville, gastric cancer is less common in France in areas with very deep ground water.

A particularly interesting statistical study was carried out by ROBINET[7] on the possible relationship between cancer and magnesium content of soil. His observations were supported by the studies of DELBET[8] and SCHRUMPF-PIERRON[9]. ROBINET compared the geological maps of France and England with the cancer mortality figures of villages of less than 5,000 inhabitants. A striking resemblance was found between areas with *high cancer frequency and low magnesium content*, and vice versa.

The above mentioned publications suggest that carcinoma is either activated or counteracted by certain geological conditions, and they stimulated the authors to study for the period 1900–1940 the possible influence of soil and other geological conditions on cancer mortality in the Netherlands. For reasons explained[1], only the total cancer mortality (from malignant tumours) could be considered for the time being. In the near future our studies will be extended to each of the cancer localizations separately. The results of our preliminary investigations support the general conclusion of the previously mentioned studies that certain activating and counteracting factors related to the soil conditions in a particular area, seem to influence the distribution and development of carcinoma mortality. It is quite conceivable that a study of the cancer localizations separately may demonstrate that the soil-cancer relationship applies only to certain types of carcinoma.

[1] Oegstgeest (Leiden), Holland.

[2] S. W. TROMP and J. C. DIEHL, First Report on the Geographical and Geological Distribution of Carcinoma in the Netherlands (Published by the Foundation for the Study of Psycho-Physics, Oegstgeest, Holland, February 12, 1954).

[3] A. HAVILAND, The Geographical Distribution of Cancer (Med. Soc., London, 1868); Brit. Med. J. 537 (November 26, 1870); *On the Influence of Clays and Limestones on the Medical Geography*, illustrated by the Geographical Distribution of Cancer among Females in England and Wales (7th Int. Congr. Hyg. Demography, London, August 12, 1891); The practitioner *400* (1899); The Lancet *314*, 365, 412, 467 (1888).

[4] A. T. BRAND, Brit. Med. J. 238 (July 26, 1902).

[1] H. T. BUTLIN, Brit. Med. J. (February 26, 1887).

[2] A. JACKSON, Brit. med. J. *11*, 1465 (1899).

[3] FIESSINGER, Gaz. Med. Paris *10*, 109 (March 5, 1892); Rev. Med. *17*, (1893).

[4] GEUILLOT, Union Méd. Nord-Est (February 15, 1891).

[5] C. D. LEGON, Brit. J. Cancer *5*, 175 (1951); Brit. Med. J. 700 (September 27, 1952).

[6] ARNAUDET, Normandie Méd. Rouen (February 1, 1889, April 1, 1890, February 15, 1892). – BRUNON, Normandie Méd. Rouen *1*, 23, 46 (1893); Rev. Hyg. 244 (1893). – L. NOEL, *Sur la Topographie et la Contagion du Cancer* (Paris, 1897). – REBULLET, Normandie Méd. Rouen (1st and 15th April, 1890).

[7] L. ROBINET, Acad. Méd. 440 (April 29, 1930; April 10, 1934).

[8] P. DELBET, Acad. Méd. 393 (March 20, 1934). – P. DELBET and L. ROBINET, Acad. Méd. 415 (March 20, 1934).

[9] P. SCHRUMPF-PIERRON, Bull. Ass. Franç. Etude Cancer *20*, 307 (1931); Acad. Méd. *106*, 235 (1931); Z. Krebsforschung *36*, 145 (1932).

II.–*Geological distribution of carcinoma in the Netherlands*

Statistical studies carried out by DIEHL and TROMP revealed that unknown factors, activating or counteracting the development of cancer, create the situation in which two areas close together, with similar age group structures and without racial, social or professional differences, may differ considerably in cancer mortality.

Municipalities (i.e. the smallest regional administrative unit in the Netherlands) with cancer death rates above the average for the country were designated by DIEL as *Plus Municipalities*, those below the average as *Minus municipalities*. The result of our analyses was that there are well defined conglomerations of such similar municipalities in the Netherlands (either "plus" or "minus"), which were designated by DIEHL as *plus and minus Areas* and are represented in plate no. 3[1]. A detailed discussion of these areas was presented in the same publication.

Apart from the possible influence of soil, a study was made of the possible correlation between hygienic conditions, degree of geographical isolation of an area, size of municipalities, main character of municipalities (agricultural, industrial, and fishery, and the contrasting urban and rural types), growing speed of municipal population, water system (both chemical composition of drinking water and source of supply) and cancer mortality on the basis of population above the age of 50[2]. A brief summary of these analyses, discussed by TROMP and DIEHL[2] will be given below. They support the assumption that the correlation found between type of soil and cancer is not only an apparent one (because, for example, certain professions, etc. might dominate on certain soils) but seems a real one.

The correlation between soil and cancer was estabished by using two different methods:

(1) *Iso-carcinoma maps.* "Iso-carcinoma map" is a name introduced by the first author to indicate maps on which, similar to certain topographical maps, curved lines connect points marking locations with the same number of cancer deaths (per municipality, per year, per 10,000 or 100,000 inhabitants). The spaces between those lines, representing certain intervals, can be coloured, the darkest colours (usually red) used for high cancer death rates, the lightest colours (white and yellow) for the lowest values.

As a basis for the iso-carcinoma map, a municipality map is used, in which the town hall is considered the centre of the municipality, and the cancer mortality figure (per year per 10,000 or 100,000 inhabitants) is written next to each municipal centre. The advantage of this method is that artificial municipal boundaries are not used, since they represent a rather irregular picture when coloured. On the basis of this chart, with figures attached to each municipality on the map, an iso-carcinoma map is made similar to a topographical map, on which iso-hypses connect points of equal elevation and on which intermediary points are established by interpolation. Although it is fully realized that in the case of cancer maps (in contrast with topographic maps) no linear change in cancer mortality occurs between two municipal values, it was still considered the preferable way to trace the iso-carcinoma lines, otherwise a personal factor of preference might be introduced into the drawing of those lines.

The examination of the attached tentative iso-carcinoma map of the Netherlands (for the period 1930–1939) reveals the following interesting features:

(a) There are four large areas with high cancer frequencies (more than 16 per 10,000 inhabitants): the provinces of Friesland, Groningen, Zeeland, and the northern part of Noord Holland.
(b) Several smaller areas with high cancer frequencies were found in the province of Utrecht and in the northern parts of Noord Brabant and Limburg.
(c) Very low cancer death rates were observed particularly in the southern parts of the provinces of Noord Brabant and Limburg, and in the eastern border area with Germany (in the provinces of Gelderland, Overijsel and Drente).
(d) Large cities scarcely influence the shape of the iso-carcinoma lines.
(e) Large industrial areas such as Twenthe (east Overijsel) with its textile and machine industries are characterized by low cancer death rates.
(f) The areas with high cancer death rates mentioned in (a) are geologically characterized by a high percentage of sea-clay, peat and reclaimed peat soils. Those with low cancer death rates are characterized by sandy soils and calcareous soils (South Limburg). This general conclusion is supported by a detailed statistical soil analysis.

(2) *Detailed statistical soil analysis.* Through the kind intermediary of the Agricultural Soil Survey Institute at Wageningen, the principal soil type (in the centre of the municipality) was determined for each municipality. On the basis of these data, the number of municipalities located on each type of soil and the total number of cancer deaths in the population above the age of 50 (for these municipalities) was determined, enabling the author to calculate the average cancer death rate per municipality (per year on the basis of 100,000 inhabitants above the age of 50) for each type of soil.

Large cities are usually located on several types of soil, the geological boundaries of which are often not satisfactorily known. Unless an accurate percentage estimate could be made, those cities were eliminated from our statistics. As the population in large cities migrates more than in smaller rural or provincial towns, the elimination of large cities is, four our purpose, even to be recommended.

It was fully realized that even if a relationship between soil and carcinoma could be established, several other factors undoubtedly also have an important influence which could easily obscure the effect of soil. The fact in itself that certain municipalities on "minus" soils have very high cancer frequencies, indicates that other activating factors, apart from soil, must exist.

Some of the general disturbing factors in our soil analyses were the following:

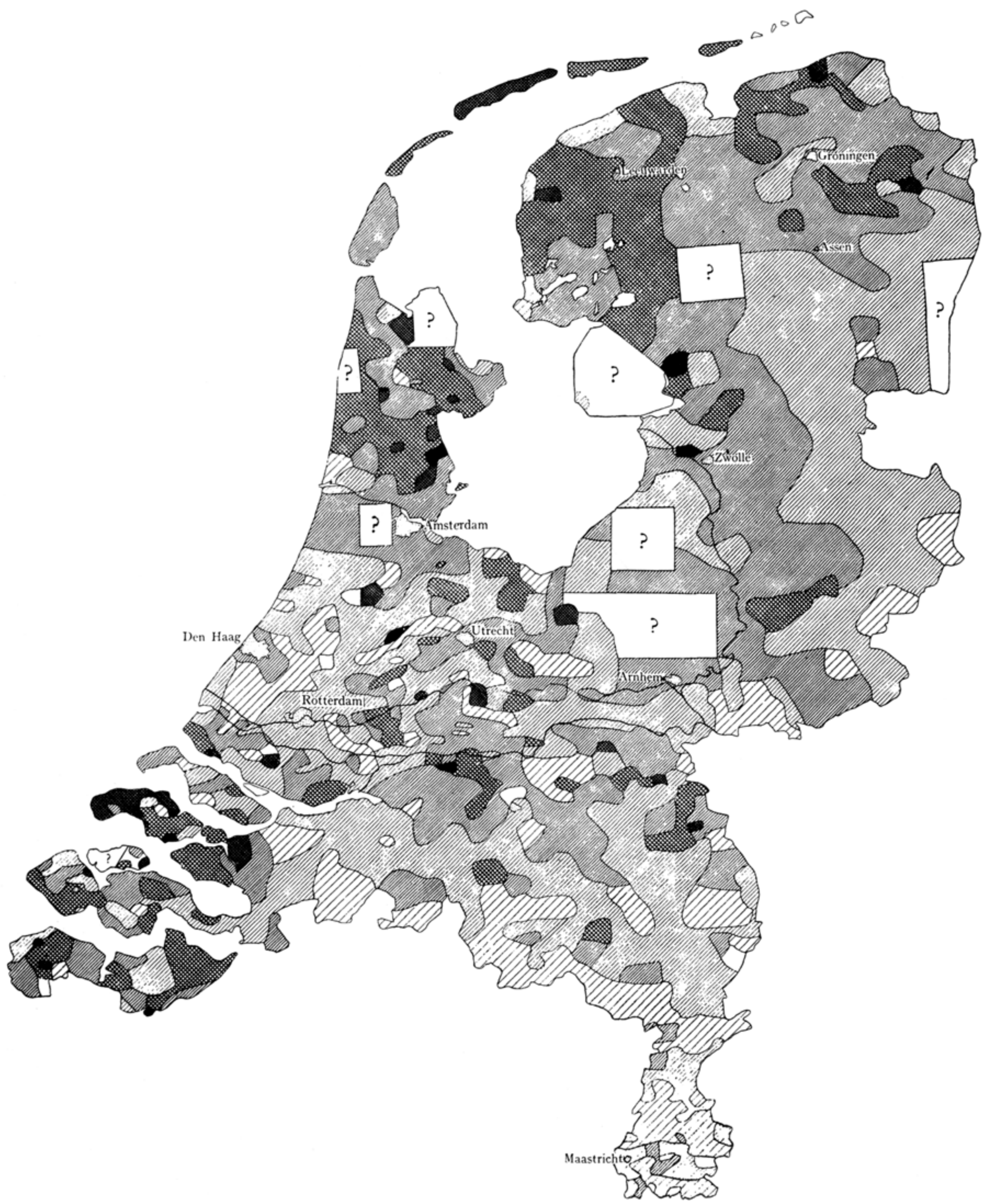
(a) The general increase (and sometimes decrease) of carcinoma during the period 1900–1940, the rate varying for the different provinces, municipalities and soils.

[1] S. W. TROMP and J. C. DIEHL, First Report on the Geographical and Geological Distribution of Carcinoma in the Netherlands (Published by the Foundation for the Study of Psycho-Physics. Oegstgeest, Holland, February 12, 1954).

[2] In order to reduce the influence of the age factor, the total number of cancer deaths per municipality during a period of 10 years was calculated on a basis of a population of 50 years and older and for a standard population of 10,000 inhabitants. The figure obtained was divided by 10 in order to obtain the average yearly cancer death rate during that particuliar decade. Age groups of 60 years and older or 70 years and older were unsatisfactory because in most municipalities the number of data was too meager for a accurate statistical analysis (5 to 6 times less than for the 50 years and older group). It has been suggested that despite the fact that only the population above the age of 50 is taken into consideration, the geographical differences in cancer still might be due to local differences in age group structure above the age of 50. Statistical studies by the authors indicate that this factor explains only a small part of the observed differences.

Tentative Iso-Carcinoma map of the Netherlands.
Compiled by J. KANIS and Dr. S. W. TROMP.
Based on data of the Central Bureau of Statistics.

Foundation for the Study of Psychical Physics.



0–5 deaths (0–5·5 included)
6–9 deaths
10–12 deaths
13–15 deaths
16–19 deaths
20–25 deaths
more than 25 deaths

Number of Carcinoma deceased per municipality, per year, per 10,000 inhabitants, during the period 1930–1939.

? Areas left open for shortage of data.

Scale: 1:400,000

Table I

Type of soil* No.	Name	Number of municipalities	Character of municipalities** R %	M %	U %	Total number of Carcinoma deaths per year, per 100,000 inhabitants above the age of 50, for the period 1900–1940
1	Beachbank soils	20	50	35	15	688
2	Loamy river soil	21	94	6	—	664
3	*Reclaimed peat soils*	11	20	80	—	662
4	Permanently moist sandy soils	56	83	17	—	661
5	Young beach sands	27	88	8	4	658
6	*Peat soils*	70	83	15	2	657
7	*Sea-clay soils*	275	91	8	0·5	652
8	*Dry sandy soils* (part of year moist)	56	61	24	15	635
9	Dune sands	15	46	46	8	617
10	*River-clay soils*	193	90	7	3	605
11	Cover sand soils	191	82	16	2	603
12	Sand on peat	2	77	23	—	585
13	River sand soils	3	100	—	—	578
14	Inland dune sand	6	100	—	—	505
15	*Loess* and other old soils rich in lime	large (not exactly known)	100	—	—	485
16	Brook soils	4	100	—	—	455

* *Beachbank soils* are sandy ridges in the "old dune landscape", the upper part of which is often rich in humus. *Reclaimed peat soils* are peat soils from which the surface peat has been removed, and of which the 80 cm thick top layer covering the peat has been mixed with the old underlying sandy subsoil. *Cover sand soils* are rather fine, well sorted sands deposited by wind action at the end of the Würm Glacial period. *Loess Soils* are calcareous deposits formed by wind action during the Würm Glacial period. *Brook Soils* are sandy soils along rivers and brooks with varying amounts of silt.

** *R* = Rural communities (less than 5,000 inhabitants); *M* = Mixed communities (5,000–20,000 inhabitants); *U* = Urban communities (more than 20,000 inhabitants).

(b) The influence of growth of municipalities since 1900.
(c) The influence of changing character of municipalities since 1900.

The fact that, despite these disturbing factors, the soil influence, as indicated by our analysis, is statistically significant (also in a mathematical analysis), suggests an influence of the soil even greater than actually demonstrated by the statistical figures (unless we assume that all disturbing factors were only strengthening the observed soil influence).

The original soil classification used by the Soil Survey Institute consisted of 64 soil units. These were united into 16 larger soil groups because the statistical numbers would otherwise be too small, and therefore unreliable (see Table I). But despite this, some soil types were represented by only a small number of municipalities. The average cancer figures for those soils should be accepted with the greatest caution. It is for this reason that a still broader classification was introduced, using only 6 soil groups, as indicated in Table II.

It is remarkable that the so-called "*Plus*" *Soils* (reclaimed peat soils, peat soils, and sea-clay soils) have higher cancer death rates and higher percentages of "plus" municipalities than the "*Minus*" *Soils* (sandy soils, river-clay and loess soils) for each decade separately and for the periods 1900–1930 and 1900–1940.

In addition, the succession in detail is perfect for the three "minus" soils (for each decade and for the periods 1900–1930 and 1900–1940); the same succession was found for the "plus" soils for the decades 1900–1910, 1910–1920, and for the periods 1900–1930 and 1900–1940. This result is so striking that it is difficult to believe that

Table II

Name of soil group	Number of municipalities on which data are based	Period 1900–1910	1910–1920	1920–1930	1930–1940	Average 1900–1930	Average 1900–1940
Reclaimed peat soils	11	658 (82)**	706 (82)	661 (55)	689 (82)	675	678
Peat soils	70	607 (63)	667 (60)	667 (53)	688 (57)	647	657
Sea clay soils	275	595 (56)	654 (54)	667 (50)	693 (58)	639	652
Sandy soils	385	562 (48)	622 (49)	653 (50)	651 (55)	612	622
Cover sand soils	191	544 (43)	611 (47)	653 (50)	603 (49)	603	603
River clay soils	193	551 (43·5)	603 (40)	635 (46)	631 (41)	596	605
Loess and other old soils rich in $CaCO_3$	large*	350	479	578	533	469	485

* The number is large, but not exactly known.

** ( ) indicates the percentage of "plus" municipalities.

it could be only coincidence, particularly if we realize how many factors disturb the effect of an actual soil influence. The conclusion seems justified, therefore, that a certain activating or counteracting influence exists, particularly since a mathematical study of our statistical data confirmed the significance of our results.

The observed difference between *River-Clay* and *Sea-Clay Soils* also shows up in a difference in increase in cancer death rate since 1900. In the case of *Sea-Clay Soils* (on which 275 municipalities are located) the average increase per municipality during a period of 30 years amounted to 97, or an average yearly increase of 3·7 per municipality. In the case of *River-Clay Soils* (on which 193 municipalities are located) these figures are 80 and 2·7 respectively. One would be inclined to assume, therefore, that certain conditions connected with the location of municipalities on sea-clay soils have a greater activating effect on the development of carcinoma than in the case of river-clay soils, and also that the factors causing increase in carcinoma during the last decades seem more active on sea-clay soils than on river-clays.

DIEHL rightly pointed out that if a real soil influence existed, one would expect a high percentage of "plus" municipalities on "plus" soils, despite the fact that in a province as a whole the cancer mortality might be below average. On "minus" soils the percentage of "plus" municipalities should be low even in provinces with high cancer death rates. A statistical analysis carried out by DIEHL confirmed this assumption.

Further evidence of the reality of the observed soil-cancer relationship was found by DIEHL by analyzing the influence of a number of factors mentioned above:

(1) *Influence of Size of Municipality.* It has often been stated that geographical differences in cancer mortality could be explained by variations in size of municipality, in other words, by differences in the availability of various means of diagnosing carcinoma during the different decades and in different parts of the Netherlands, and also the inclination to take advantage of these different means. However, a statistical analysis of the influence of the size of municipalities clearly indicates that this factor can not be of great importance because during the period 1900–1930 the cancer death rate and the percentage of "plus" municipalities decreased with increasing size of municipality, whereas the reverse would have been expected.

(2) *Influence of Principal Character of Municipality.* DIEHL statistically demonstrated the following correlations:

(a) Total cancer death rates in municipalities of the agricultural or industrial type do not differ markedly. The same is true for rural and urban municipalities.

(b) However, the percentage of "plus" municipalities is considerably higher for the agricultural and rural type of municipality than for the industrial and urban type (agricultural type 31·9% against 11·4% in the industrial type).

Of 275 municipalities located on sea-clay soils, 91% belong to the rural type (i.e. less than 5,000 inhabitants), 0·5% to the urban type (i.e. more than 20,000 inhabitants); of the 193 municipalities located on river-clay soils, 90% belong to the rural type, 3% to the urban type. In other words, the general structure is practically the same for both soil groups. The river-clay soils have only a slightly higher percentage of the urban type, thus a slightly better means of diagnosing cancer. Yet, areas on sea-clay soils in the Netherlands possess considerably higher average yearly cancer death rates than river-clay soils. Loess soils with a much higher percentage of rural municipalities than peat soils (see Table I) differ strikingly in cancer mortality, contrary to what would be expected on the basis of the possible influence of agricultural professions.

(3) *Influence of Hygienic Conditions and Degree of Geographical Isolation of an Area.* One could assume that the soil-cancer relationship was due to a peculiar distribution of these factors on the different types of soil.

(a) DIEL demonstrated that the total number of deaths from all diseases in the municipalities and provinces differ so greatly from the distribution of cancer deaths (the curves are in parts even contrary to each other), that considerable influence of hygienic conditions on cancer development does not seem likely, at least not in the Netherlands. The highest death rates were found in the northern province of Friesland, the lowest in the southern province of Limburg, whereas hygienic conditions were almost the same, even slightly better in Friesland.

(b) DIEHL found no statistical evidence suggesting that isolated areas in the Netherlands taken together (i.e. islands in the rivers and sea) have cancer death rates differing from the average figures for the whole country.

(4) *Influence of Growing Speed of Municipal Population.* DIEHL demonstrated statistically that with increasing growing speed of the population (usually accompanied by extended means of diagnosing cancer), the percentage of cancer deaths and the percentage of "plus" municipalities decreases continuously, whereas a more or less continuous increase is observed in the "minus" municipalities; here again we have a result opposed to our expectations, if geographical differences were due only to differences in means of diagnosing.

(5) *Influence of Chemical Compounds in Soil and Drinking Water.*

(a) *Influence of $CaCO_3$ in soil.* The influence of soil could be related to the abundance of one or more chemical elements in the different soil units. Unfortunately, despite the tremendous amount of work carried out in the Netherlands by agricultural institutes on the composition and structure of agricultural soils, it is not possible to give for each of the 64 soil units the accurate distribution of the various chemical elements. In recent years it has become even more difficult due to the annual artificial manuring of soils with different quantities and kinds of chemical fertilizers, and the application of weed-killers, insecticides, and fungicides. Despite these difficulties, it is possible to classify clay soils, to a certain extent, on the basis of their $CaCO_3$ content.

To *Calcareous sea-Clay Soils* belong young, light, silty sea-clays; young, very light, silty sea-clays; silty sea-clays; young, light sea-clays on dune sand; young, heavy sea-clays; and calcareous old sea-clays.

To *Non-Calcareous Sea-Clay Soils* (or at least very poor in $CaCO_3$) belong sticky sea-clay soils; older, heavy sea-clay soils; older, heavy sea-clay soils on peat; young, heavy sea-clay soils on peat; non-calcareous sea-clay soils; sea-clay soils on peat; soap-clay soils; and soap-clay soils on acid sub-soil.

To *Calcareous River-Clay Soils* belong light river-clay soils.

To *Non-Calcareous River-Clay Soils* (or at least very poor in $CaCO_3$) belong light, non-calcareous river-clay soils; heavy river-clay soils; river-clay soils on peat soils; and river-clay soils on wood peat soils.

In Table III a summary is given of the cancer death rates for each of the four above mentioned soil groups during each of the four decades since 1900. The table reveals that, except for the decades 1930–1939 in the case of sea-clays, and 1920–1929 for river-clays, the

Table III

Type of soil	Period				Average 1900–1930	Average 1900–1940	Number of municipalities
	1900–1909	1910–1919	1920–1929	1930–1939			
Calcareous sea-clays	580 (51)	643 (49)	631 (43)	690 (52)	618	636	130
Non-calcareous sea-clays	599 (55)	665 (60)	695 (59)	677 (57)	653	659	100
Calcareous river-clays.	541 (41)	579 (36)	627 (46)	642 (41)	578	597	126
Non-calcareous river-clays. . . .	588 (55)	648 (45)	624 (39·5)	650 (53)	619	627	38

calcareous clays are always characterized by lower cancer death rates and lower percentages of "plus" municipalities than the non-calcareous clays, during each decade and during the periods 1900–1930 and 1900–1940. In other words, the results suggest the existence of a retarding effect on carcinoma development when soils are rich in lime. This result is supported by our general analysis (loess soils have the lowest cancer frequency, see Table II), and by the observations of HAVILAND and others that limestone areas are characterized by low cancer frequencies.

Amongst the sea-clay soils it is particularly interesting to study more in detail the *Sticky Sea-Clay Soils*, represented by 38 municipalities. These heavy sea-clay soils, poor in $CaCO_3$, belong to the soils with almost the highest cancer death rates for the four decades since 1900 and for the averages of the periods 1900–1930 and 1900–1940. These death rates are 638, 650, 742, 721, 677, 688 (see Table I for comparison).

In connection with the problems discussed, it is interesting to refer to the previously mentioned studies of Robinet in France, which suggest that *Low Cancer Frequency* is related to *Areas with high Magnesium Content of Soils* and vice versa. Without further extensive research it would be difficult to decide whether one particular chemical element or the interaction of a group of closely associated elements is responsible for the activating effect of certain types of soils (either a real activating effect or a depressing effect on certain counteracting factors). For example, high SiO_2 content parallels low $CaCO_3$ percentage in many soils, and the problem thus arises whether the high SiO_2 or the low $CaCO_3$ content is the primary activating factor. The same applies to other chemical elements. ROBINET concluded, that the high Mg content of the Liassic, Triassic, and Permocarboniferous areas of France is responsible for the low cancer death rates in those areas; the high degree of dolomitization of those limestone areas (dolomite = $CaCO_3 \cdot MgCO_3$; pure limestone consisting of calcite = $CaCO_3$) could be the cause; on the other hand, it may simply be due to the high $CaCO_3$ content of the soils[1].

(b) *Influence of Moisture.* A number of factors determine the moisture content of soil, some of which are meteorological factors. Variations in moisture content of soil seem to influence both the chemical and physical fields of the soil. If a relationship between moisture content of soil and cancer frequency could be established, this relationship would be a direct one or apparent one depending on a possible relationship between carcinoma frequency and meteorological conditions (a relationship which was discussed at length by TROMP and DIEHL[2]). It is also possible that both factors together cause the observed correlation. In view of these various considerations, a study of the influence of moisture content of soil on cancer frequency was made.

In Table IV the cancer death rates for municipalities located on dry, moist and wet soils are compared.

It is interesting that except in one case (period 1910–1919, moist to wet), all figures indicate the increase in cancer death rates with increasing moisture. This conclusion seems supported by the cancer mortality for cover sand soils. The *Cover Sand Soils* vary considerably in their cancer frequencies. Four main types of cover sands are distinguished: dry, moist, very moist to wet, and loamy cover sand soils, which can be briefly designated as D, M, W, and L cover sands. The carcinoma frequencies for the cover sands in the 5 provinces in which they occur are given in Table V for the period 1930–1939.

Table V reveals that the presence of loamy cover sand soils does not seem to influence considerably the cancer frequency figures in the provinces of Limburg and Noord Brabant. However, one has the impression that the high figures for the provinces of Drente, Utrecht and

[1] The influence of calcium on cancer has been discussed by A. I. LANSING in a paper *Calcium and Growth in Aging and Cancer*, Science *106*, no. 2748, 187 (1947). According to LANSING, cancer cells are characterized by a markedly low calcium content which would decrease their adhesiveness and increase their invasiveness. According to C. GURCHOT, Science *106*, ... (1947), however decreased adhesiveness of cancer cells would not explain their *destructive* invasiveness as a cause of malignancy (see also publications by J. CASPER and A. ELKELES on the apparent antagonism between Carcinoma and arteriosclerosis).

[2] S. W. TROMP and J. C. DIEHL, First Report on the Geographical and Geological Distribution of Carcinoma in the Netherlands (Published by the Foundation for the Study of Psycho-Physics, Oegstgeest, Holland, February 12, 1954).

Table IV

Type of soil: Sandy soil	Number of municipalities	Period				Average 1900–1939
		1900–1909	1910–1919	1920–1929	1930–1939	
Dry	56	591	631	633	686	635
Moist	42	597	642	671	692	650
Wet	14	678	626	747	718	692

Table V

Province	Number of municipalities	Carcinoma deaths	Type of cover sands (and % of municipalities for each type)
Drente	29	706	D (38%), M (48%), W (14%)
Utrecht	16	679	D (62·5%), M (25%), W (12·5%)
Friesland	11	676	D (18%), M (73%), W (9%)
Limburg	29	586	D (38%), M (7%), L (55%)
	(13)	586	D M
Noord Brabant	106	560	D (67%), M (13%), L (20%)
	(85)	541	D M
Total	191	603	D, M, W, and L
	184	597	D, M, and L

2 figures are given for the provinces of Limburg and Noord Brabant: one including the loam cover sands and one (between parentheses) without.

Friesland may be due, at least partly, to the high percentage of moist and wet cover sands, which could explain the relatively high cancer frequencies for the cover sands as a whole, in contrast with other sandy soils.

(c) *Influence of Drinking water.* This problem was discussed extensively by DIEHL and TROMP[1]. The influence of potable water can be studied as a function of the source of supply and of the physico-chemical properties of the water.

Influence of the Source of Supply. DIEHL divided the water supply systems in the Netherlands into 4 groups: Municipalities supplied with water from dune areas, from heath areas, from wells, and from rivers. The data on hand, based on 96 water systems, suggest:

(1) that the highest cancer death rates are in municipalities supplied with river water (606), followed by heath water (594), dune water (585), and well water (568).

(2) That if the number of "plus" municipalities supplied by each of the four sources of supply are taken into consideration, the highest percentages (21%) are again found amongst municipalities supplied with river water.

These observations seem supported by the studies of STOCKS[2] in Greater London. A carcinoma map of London reveals uniformly high ratios for cancer, other than stomach, in the northwestern corner of the city. On the other hand, the southeastern boroughs have high ratios for stomach cancer and low ratios for other sites. Stocks could not explain this contrast by age groups or differences in social conditions. Greater London is supplied by four main sources of water: the Thames, Lea and New Rivers, and by wells. A comparison between water supplies in the different boroughs and cancer death rates revealed the following: The four London boroughs supplied largely by well water had lower cancer mortalities than most of the boroughs supplied by river water.

For stomach cancer, on the other hand, the wells group is 105 in contrast with 89 for the Thames group.

For all other sites the Thames group has higher mortality figures than the wells group.

The observation by DIEHL, if confirmed by further studies, is of great practical importance, because an activating effect of river water may be due to a number of inorganic and organic compounds dissolved in river water, as a result of water discharged by large factories, e.g. in the Rhine district in Germany and Holland, and also in other industrial areas in the Netherlands located near rivers and lakes[1]. In view of the general shortage of supply of potable water in the Netherlands due to the increased consumption of water per family (more than 25% increase since 1939), the increase in the number of houses connected with water systems, the rapidly expanding population, the increasing industrialization of the country, and several other factors, there is a general tendency to augment the water supply by using river water.

Influence of Chemical Compounds. (1) *Studies by* J. C. DIEHL. The average composition of potable water used in the water systems (since 1915) was determined by DIEHL, using the chemical analysis published in the statistical summary of water systems in the Netherlands as a basis, over a period of 6 years for the following compounds: solids, Cl_2, NO_2, No_3, So_4. HCO_3, free CO_2, PO_4, SiO_2, organic NH_4, Fe, Mn, H_2S, Ca, Mg, Na, and for the total hardness and consumption of $KMnO_4$. The various averages were compared for the "plus", "zero", and "minus" municipalities which have had water systems since 1915. For each of these groups of municipalities a chemical average was calculated. The only chemical compounds which might have a certain influence on the cancer death rate because of a regular increase or decrease from "plus" through "zero" to "minus" municipalities are the following:

SiO_2 : 20–16·8–13·9 (milligrams per liter water)
Mn : 0– 0·01– 0·04
Na : 28–47·5–52·1

In other words, if these data can be confirmed, *Silica would seem to have an Activating Effect and Manganese and Natron a Counteracting Influence.*

DIEHL also divided the water systems into three groups (Si, Mn, Na), each subdivided into "plus", "zero", and "minus" groups (i.e. above, equal to or below the average Si, Mn, and Na content of all water systems). Here again it was found that with *decreasing* SiO_2 *Content, the Percentage of "plus" Municipalities decreases continuously* (from 42% to 25%), *while the "minus" Municipalities in creaseregularly* (from 20% to 43%).

[1] S. W. TROMP and J. C. DIEHL, First Report on the Geographical and Geological Distribution of Carcinoma in the Netherlands (Published by the Foundation for the Study of Psycho-Physics, Oegstgeest, Holland, February 12, 1954).

[2] P. STOCKS, *Regional and Local Differences in Cancer Death Rates* (Gen. Registrar Office, London, 1947).

[1] Recent studies in the U.S.A. suggest carcinogenic properties of certain carbon adsorbates of various sources of drinking water supplies depending upon the type of industrial wastes released into the water (written information from Editor of "Cancer Research").

It must be kept in mind, however, that the amount of data on which these preliminary conclusions were based is small, and that the need for continuing these studies in other countries in order to increase the statistical data and the validity of the conclusions is clearly indicated.

(2) *Studies by* TROMP. Tromp compared soil types, average chemical composition of drinking water of municipalities located on those types of soil, and the average cancer frequency of those municipalities. For this purpose all municipalities were classified into 64 soil units (see page 513). The amount each of four chemical compounds (CaO, SiO_2, MgO, Mn) present in drinking water was calculated for the municipalities of the same soil unit. The result of this analysis is compiled in annex no. 3 of TROMP and DIEHL[1]. All analyses were based on the data published in the "Statistisch Overzicht der Waterleidingen in Nederland over de jaren 1946 en 1947", pp. 88–109. Only those municipalities of which more than 50% of the houses were connected with the main water systems were taken into account. Municipalities where the quantities and types of water received from various water systems vary considerably, and where conditions are not adequately known were omitted from our statistics. For municipalities receiving water from more than one pumping station, the average chemical composition of all stations together was used. The author fully realizes that all these conditions influence unfavourably the final conclusions of our statistical analyses yet, for the time being, and for lack of better data, the present analysis was considered the only means of studying the problem of the possible influence of the chemical composition of potable water on cancer frequency.

Similar to Table I, the 64 soil units were united into 16 larger groups. The tables suggest the following:

(a) No simple relationship (e.g. continuous decrease or increase) can be found between CaO, SiO_2, MgO and Mn content and the soil units (classified according to cancer death rate), perhaps due to the fact that the differences in chemical composition of the water supplied by water systems do not adequately reflect the differences in chemical composition of the soil. This assumption is supported by the following observations: Brook soils and loess soils have the same CaO content of drinking water, whereas a pronounced difference exists in the CaO content of these soils. These and other discrepancies suggest that other factors apart from drinking water determine the soil influence.

(b) *Influence of* CaO. On page 514 it was demonstrated that in both sea-clay and river-clay soils high $CaCO_3$ content seems related to relatively low cancer frequencies and viceversa. In the present analysis this is true only for peat soils, beach bank soils, sea-clay soils, and loess soils, with 95, 104, 106, and 136 mg CaO per liter water respectively, but does not apply to other soils. Here again one is inclined to assume that it is not the chemical compounds of drinking water alone (at least not the ones we have studied) which are responsible for the observed soil influence.

(c) *Influence of* SiO_2. DIEHL's observation (pp. 9–10) is supported by the high (more than 20 mg/l water) SiO_2 content of all "plus" soils and the values below 20 in the case of "minus" soils, except for dune sands, loess soils, and brook soils, which have very high SiO_2 values. In these latter three cases, however, the $CaCO_3$ content is very high, and it might be possible that the activating effect of SiO_2 is compensated by the counteracting effect of $CaCO_3$.

The average SiO_2 content of all "plus" soil water systems (represented by 310 municipalities) is 21·4 mg/l water, in contrast with 15·8 for all "minus" soils. (If dune sands, loess soils and brook soils are not taken into consideration, this value is only 14·8.)

The difference in cancer mortality on sea-clay soils and on river-clay soils seems correlated with the higher average SiO_2 content of the municipal water of the sea-clay soils than that of the river-clay soils. This is true for both calcareous and non-calcareous groups.

(d) *Influence of* Mg. ROBINET's assumption (see page 510) could not be confirmed by a direct comparison of the "plus" and "minus" soils. The average MgO content of water systems on "plus" soils is 13, on "minus" soils, 12·5. However, if all sandy soils (both "plus" and "minus") are eliminated, because of their, in many respects, irregular behaviour, the average MgO content of "plus" soils is 13, of "minus" soils, 15.

Sea-clay soils seem to have slightly lower MgO values than river-clay soils and loess soils. No difference was observed between calcareous and non-calcareous types.

(e) *Influence of* Mn. According to DIEHL's analysis, manganese seems to have a counteracting effect. A comparison of all "plus" and "minus" soils suggest that the municipal water from "plus" soils has, on the average, a lower Mn content (0·18 mg/l water) than that from "minus" soils (0·37).

The average Mn content of water from all sea-clay soils (0·15 mg/l water) is lower than that from river-clay soils (0·51).

It is evident that the above mentioned results should be handled with the greatest caution. Still, it is encouraging that DIEHL's observations concerning the possible influence of SiO_2 and Mn were supported while using a completely different method. The confirmation of ROBINET's assumption was limited. Even these preliminary results suggest that in view of the possible existence of both activating and counteracting factors in drinking water, it will be very difficult to solve this problem. The interaction of these different influences, particularly if an even greater number of chemical elements or compounds were taken into consideration, could create extremely irregular carcinoma death rates, which might easily leave the impression that no relationship of any kind exists.

III.–*Physico-chemical processes which may explain the possible influence of soil on cancer*

The influence of the earth crust on the living organism and its diseases could be a direct one through physical fields or an indirect one affecting the organism either chemically or biologically.

(1) *Direct or Physical effects:* Through geophysical fields.

Differences in soil could show up geophysically as follows:

(a) Differences in the *Earth-Magnetic Field*, which can be considerable in mountainous areas (negligible in Holland) particularly near the contact of sedimentary and volcanic rocks.

(b) Differences in *Electric Conductivity* of the soil which could influence:

α) Artificial and biological electro-magnetic fields (of the living organism) near the soil;

β) the electrical potential gradient of the atmosphere immediately above the soil;

[1] S. W. TROMP and J. C. DIEHL, First Report on the Geographical and Geological Distribution of Carcinoma in the Netherlands (Published by the Foundation for the Study of Psycho-Physics, Oegstgeest, Holland, February 12, 1954).

γ) the electrical conductivity and the number of ions in the air above the soil.

(c) Differences in *Radioactivity* of the soil and the air in and above the soil.

(d) Differences in *Reflected Radiation* (from a snow field ultraviolet rays are reflected four times that from water, twice that from sand, and eight times that from a field of grass).

(2) *Indirect Effects:*

(A) *Chemical effects:*

(a) Influence of tracer elements (such as Cobalt, Copper, Zinc, Molybdenum, etc.) or other chemical compounds in soil:

α) Through drinking water (surface groundwater, deep groundwater or well water, lake water, river water);

β) through food growing in the soil (vegetables, etc.);

γ) through animal products (cheese, milk, eggs, meat) produced by animals living on those soils;

δ) through soil gases and the exhalations in the atmosphere (part of the exhaled gases are fumigant vapours previously absorbed by the soil).

(b) Influence of fertilizers, weed killers and insecticides: used for promoting the cultivation of edible plants and fruits.

(c) Influence of atmosphere:

α) Through vegetation (affecting the chemical composition of the air above the soil);

β) through ground mist (frequency and intensity partly depending on type of soil; affecting human body because of increased air pollution).

(B) *Biological effects*:

(a) Influence of soil on development of eggs of many parasitic worms, insects, micro-organisms and viruses, either activating or hampering the development because of certain moisture conditions or presence of certain chemical compounds.

(b) Influence on type of vegetation: affecting the potential gradient and conductivity of the air, the reflected sun radiation, the humidity and chemical composition of the air above the soil, the type of food consumed in an area, the distribution of insects, the spreading of allergy-producing pollen, etc.

(c) Influence of water on development and spreading of human parasites.

Influence of Moisture. The physical, chemical, and biological fields, as a function of soil, are influenced considerably by the moisture content of the surface soil, which is determined by the mineral composition, the porosity and permeability of the surface and subsurface soil, the groundwater level (as a function of geological structure, yearly precipitation, and artificial engineering works), meteorological conditions (amount of precipitation, hours of sunshine, and strength of wind), vegetation and drainage (as a function of topography, dipping beds, subsoil fractures and impermeable subsurface layers).

Differences in the average moisture content of soil, both in the same and different areas, could have the following effects:

(1) Moisture influences the geo-chemical balance of the subsoil, which could be expressed in changes in concentration of the different salts and tracer elements (Cu, Mo, Co, Mn, etc.) dissolved in the soil, changes in the chemical and physical properties of the groundwater (and drinking water) and of the interstitial fluids in the pores of the surface layers of the soil (influencing the chemical composition of plants, grasses, vegetables, etc. growing on these soils, and thus also the living organisms feeding on them and affecting the development of human parasites in soil). In this connection we should like to refer to recent studies by BEESON and MATRONE[1]. They observed in North Carolina that the content of important biological tracer elements (such as Cu, Co, Mo, Mn, etc.) in soil depends on the drainage of the soils and the soil topography. The content of cobalt, for example, was greater in vegetation from well-drained soils, while the converse was true for iron. In marine terraces of the coastal plain the copper content of soils increased as the age and elevation of the terraces increased. Several nutritional diseases of cattle seem to be related to these geological conditions which are strongly affected by the amount of precipitation.

(2) Moisture also influences frequency, width and resistivity gradient ratios of the electric earth-conductivity zones in an area, this influence varying for different types of soil.

(3) It influences the amount of volatile radioactive substances exhaled by the soil.

(4) It affects the amount of organic compounds in soil and may create certain deficiencies, as pointed out by LEGON and others[2]. According to DAWSON and NAIR[3], soil organic matter fixes copper, for example, in a form which is non-available to plants, causing a slight copper deficiency which may affect the nervous system (see, for example, the Swayback disease[4]).

The authors are inclined to believe that either one or a combination of the factors mentioned above may prove to be responsible for the observed soil-cancer relationship. A more detailed field study is planned for the coming years.

Zusammenfassung

Statistische Studien von DIEHL und TROMP haben gezeigt, dass merkwürdige geographische und geologische Verteilungen des Krebses in Holland auftreten, die auf Grund von Altersunterschieden, Berufsunterschieden usw. nicht zu erklären sind. Sie scheinen teilweise auf Bodenunterschiede zurückzuführen sein.

[1] K. C. BEESON and G. MARTONE in *A Symposium on Copper Metabolism* (Johns Hopkins Press, Baltimore, 1950), pp. 370–398.

[2] C. D. LEGON, Brit. J. Cancer *5*, 175 (1951); Brit. Med. J. 700 (September 27, 1952).

[3] J. E. DAWSON and C. K. N. NAIR, *The Chemical Nature of the Copper Complexes in Peat soils and Plants*, Symposium on Copper Metabolism (The Johns Hopkins Press, Baltimore, 1950).

[4] A. M. G. CAMPBELL, P. DANIEL, R. J. PORTER, W. RITCHIE RUSSELL, V. HONNOR, SMITH, and J. R. M. INNIS, Brain *70*, 50 (1947).

PRAEMIA

Die Nobelpreise 1954 für Physik, Chemie und Medizin

Der Nobelpreis für Physik wurde im Jahre 1954 an Professor MAX BORN und Professor WALTHER BOTHE verliehen.

Max Born

Mit der Verleihung des Nobelpreises an den heute 72jährigen, am 11. Dezember 1882 in Breslau geborenen MAX BORN ist einem der bedeutendsten Pioniere der Quantentheorie eine im Kreise der Fachgenossen seit langem erwartete Ehrung zuteil geworden. Die Entfaltung der Quantenphysik der Atome und Elementarteilchen hat in den letzten drei Jahrzehnten so ungeahnt reiche Erkenntnisse ergeben, dass der Rückblick