Jose A. Martínez*

The "Moscow signal" epidemiological study, 40 years on

https://doi.org/10.1515/reveh-2018-0061
Received October 1, 2018; accepted December 13, 2018

Abstract: Between 1953 and 1979, the USSR irradiated the United States embassy in Moscow with microwaves. This episode, a classic Cold War affair, has acquired enormous importance in the discussions on the effect of non-ionizing radiation on people's health. In 2011, the International Agency for Research on Cancer (IARC) classified radiofrequency electromagnetic fields as being a possible human carcinogen (Group 2B), but the results of recent laboratory and epidemiological studies have led some researchers to conclude that radiofrequency electromagnetic fields should be reclassified as a human carcinogen instead of merely a *possible* human carcinogen. In 1978, the "Moscow signal" case was officially closed after the publication of the epidemiological study of (Lilienfeld AM, Tonascia J, Tonascia S, Libauer CA, Cauthen GM. Foreign Service health status study. Evaluation of health status of foreign service and other employees from selected Eastern European posts. Report on Foreign Service Health Status Study, U.S. Department of State 6025-619073, 1978.), showing no apparent evidence of increased mortality rates and limited evidence regarding general health status. However, several loose ends still remain with respect to this epidemiological study, as well as the affair as a whole. In this paper, we summarize the available evidence concerning this case, paying special attention to the epidemiological study of Lilienfeld et al. After reviewing the available literature (including declassified documents), and after some additional statistical analyses, we provide new insights which do not complete the puzzle, but which may help to better understand it.

Keywords: cancer; Cuban embassy; microwaves; Moscow signal; radiofrequency.

***Corresponding author: Jose A. Martínez,** Technical University of Cartagena, Calle Real 3, Cartagena 30201, Spain, Phone: +34968325776, E-mail: josean.martinez@upct.es

Introduction

Between 1953 and 1979, the USSR irradiated the US embassy in Moscow with microwaves. This episode, a classic Cold War affair, has acquired enormous importance in the discussions on the effect of non-ionizing radiation on people's health. Both those who claim that the negative biological effects of radiofrequency electromagnetic fields have been proven beyond doubt, as well as those who refuse to accept the existing scientific evidence, take this episode as proof of their arguments.

This apparent contradiction can be explained by the authentic imbroglio of reports, official publications, press articles, investigative revelations, lies and war games which have accompanied this case since it came to light in the early 1970s.

In this paper, I will summarize the available evidence concerning this episode, paying special attention to the epidemiological study of Lilienfeld et al. (1). Forty years after its publication, many questions remain unanswered.

In 2011, the International Agency for Research on Cancer (IARC) categorized radiofrequency electromagnetic fields as a possible carcinogen (Group 2B), and the debate over the safety of microwaves has raged ever since. The recent findings on animal experiments published by the National Program of Toxicology (2, 3) and the Ramazzini Institute (4) seem to indicate that a re-evaluation is needed, and that radiofrequency electromagnetic fields should be reclassified as being *probably* carcinogenic to humans (Group 2A), or even as being carcinogenic to humans (Group 1).

Moreover, the recent review of epidemiological studies published since the IARC 2011 categorization shows an increased risk of brain, vestibular nerve and salivary gland tumors associated with mobile phone use (5, 6), which has also led these authors to reach the same conclusions regarding reclassification.

In 2016, US government personnel serving in Havana, Cuba, began experiencing unusual auditory and/or sensory stimuli of varying intensity and character, along with a series of neurological symptoms (7). Several acute and persistent signs and symptoms were identified, in the absence of an associated history of blunt head trauma. As Swanson et al. (7) indicated,

patients experienced cognitive, vestibular and oculomotor dysfunction, along with auditory symptoms, sleep abnormalities and headaches. Although the etiology is still unknown, as Broad (8) explains, some scientists suspect that these symptoms were related to a microwave attack. The "Moscow signal" case therefore needs to be seriously reconsidered.

The facts

The 10-storey US embassy in Moscow was irradiated by the Soviet government from 1953 to April, 1979 (9).

The Americans were aware of this attack practically from the moment it began in 1953 (10), although other sources, such as Guthrie (11), suggest that the first evidence was obtained in 1959, when Vice President Nixon visited the building. This radiation attack soon became known as the "Moscow signal".

However, the US government decided to keep it a secret until 1972, when they began to inform some of the embassy workers (12). The other members of staff at the building were not informed of the facts until 1976 (13). Indeed, it was not until the beginning of 1976 when the event came to light, in an article published in *Time* magazine, which reported that many members of the embassy staff had returned to the US with severe health problems, that two ambassadors had died of cancer, and that a third, Walter Stoessel, was suffering from leukemia (10).

The Soviets had until then denied the use of microwaves and claimed that what the Americans had detected in the embassy was the radiation of the city produced by nearby industries (11).

After the publication of the article, both the American public and Congress (14) asked the US government to inform them of the consequences of the incident, and demanded that Moscow stop the "bombardment" immediately. It was not, however, until April 1979, when the attack finally ceased. Yet the facts of the matter remained far from clear.

Radiation levels

There is some divergence, according to the sources consulted, regarding the intensity and frequency of the radiation. The most relevant are shown in the Table 1:

As can be seen, the intensities (power densities) always lay below the Soviet maximum limit, except during the period from June 1975 to February 1976, when they were slightly higher. However, the limit for the US was 1000 times higher. This huge divergence between the limits of both countries is highly significant, due to the legal (11) and socio-economic implications that we will discuss later.

The most reliable sources of data shown in the table are probably those of Lilienfeld et al. (1) and Wikileaks (15), which are practically identical. The first is the epidemiological report prepared for the US government, and the second is a secret internal document, dated July 3, 1976, addressed to the staff of the Soviet embassy by the American government itself.

To get an idea of what these power levels would mean in modern terms, a 300 mW Wi-Fi router can have an intensity of 0.0001 mW/cm^2 at a distance of 10 cm (16). In a school with 30 laptops and a router at a distance of 0.5 m, there may be about 0.0016 mW/cm^2 (17). In addition, as Peyman et al. (18) found, 15 laptops in transmission gave a maximum exposure of 0.0087 mW/cm^2 at a distance of 0.5 m from an access point. Moreover, Hardell et al. (19) measured radiofrequency radiation in an apartment with a central location at Östermalm in Stockholm, where a group of base stations was located only 12 m from the balcony. The average exposure on a balcony outside a living room was measured at 0.00248 mW/cm^2, with a maximum of 0.0112 mW/cm^2.

Table 1: Power density levels and radiation frequency.

	Guthrie (11)	Lilienfeld et al. (1)	Wikileaks (15)	Krishnan (10)	Limit in the URSS	Limit in the US
From 1953 to May 1975	Up to 0.4 mW/cm^2	0.005 mW/cm^2 9 h per day	0.005 mW/cm^2 9 h per day	Never above 4 mW/cm^2	0.010 mW/cm^2	10 mW/cm^2
From June, 1975 to February, 1976	0.018 mW/cm^2	0.015 mW/cm^2 18 h per day	0.013 mW/cm^2 18–20 h per day	Never above 4 mW/cm^2	0.010 mW/cm^2	10 mW/cm^2
After February, 1976	–	Fractions of μW/cm^2 18 h per day	Less than 0.002 mW/cm^2	Never above 4 mW/cm^2	0.010 mW/cm^2	10 mW/cm^2
Frequency range	–	0.5–10 GHz	0.5–9 GHz	2–7 GHz	GHz	GHz

When the embassy was shielded at the beginning of 1976, levels inside the building dropped to less than 0.001 mW/cm^2.

The Soviet experience and the American experiments

It is essential to understand the historical context in which this episode occurred. On the one hand, the Soviets had considerable experience in researching the biological effects of radiofrequency electromagnetic fields, while the Americans had experimented with microwaves as a weapon of mind control. It is hardly surprising, therefore, that with this background, the matter was considered to be so significant.

That the USSR had extensively investigated the effects of this type of radiation on humans was backed up by a declassified report by Adams and Williams (20), written for the US Navy.

As indicated by the Associated Press (21), referring to this report, Soviet scientists were absolutely convinced of the biological effects of microwaves at low intensities, that radiation could be used as a weapon to disorient and affect the behavior of military and diplomatic personnel, and that it could also be used in interrogations. The report also indicated that radiation could cause heart attacks and affect the blood-brain barrier. As a result, a person could develop severe neuropathological symptoms and even die from the resulting neurological disorders. In addition, Adams and Williams pointed out that reports had emerged from communist countries claiming that women who worked in industrial environments may have suffered miscarriages due to exposure to microwaves.

The Soviet Union extensively investigated the effects of microwaves on people, and found that those exposed frequently developed headaches, loss of appetite, tiredness, difficulty in concentration, poor memory, emotional instability and labile cardiovascular function. These effects were found at lower intensities than those that caused problems due to tissue heating (22).

The American public was so disturbed by the results published in the Soviet literature that the president of the American Foreign Service Association, John Hemenway, said in May 1976 that the objective of the Soviet microwave bombardment was not to interfere with communications but to harm the health of the Americans present there. Hemenway asserted that it was well-known that such waves could cause cataracts, damage to the nervous system, circulatory problems, fatigue and headaches (23).

Congressman Edward I. Koch appeared before Congress on August 2, 1976, in connection with this question, and again alluded to the fact that the literature had shown that microwaves had harmful side effects, and that measures therefore had to be taken in order to preserve the health of the American staff (14).

It was certainly suspicious that the Soviets had a maximum exposure level 1000 times lower than that of the Americans. What did the USSR know about the effects of microwaves that the US did not know? As pointed out by Guthrie (11), the standards in the US were approved in 1953 and were based on theoretical considerations, under the assumption that microwave radiation produced only thermal effects on biological systems, and that these effects could not be cumulative as microwaves are non-ionizing. Guthrie (11) recognized that, by 1977, several medical studies had already cast serious doubt on previous assumptions. For example, Dr. Milton Zaret, Associate Professor of Ophthalmology at the New York University-Bellevue Medical Center, who had conducted several microwave investigations for the US government, said, *"The American National Standard Institute's standard is not a safe standard. Instead, it is a statement defining the highest possible degree of occupational risk. It was based solely on whole body thermal burden calculations. It ignored the question of organ sensitivity and delayed effects following chronic low-level exposure"* (11).

Professor Herman Schwan of the University of Pennsylvania, one of the proponents of the 10 mW/cm^2 standard, stated *"No one knows whether safe exposure standards, which may be appropriate for adults, are so for children"* (11).

However, as Guthrie (11) explained, the Soviet bloc also had other safety standards. At the Symposium on the Biological Effects and Health Implications of Microwave Radiation, held in 1970, Karel Marha of Czechoslovakia explained that they had proposed a standard of 0.01 mW/cm^2, as it was recognized that there was evidence of biological effects up to levels of 0.1 mW/cm^2, so a safety factor of 10 had been proposed until finally deciding on the standard of 0.01 mW/cm^2. These maximum levels were introduced to prevent not only damage to the organism but also any unpleasant subjective feelings. In addition, the standard in Czechoslovakia was lowered to 0.001 mW/cm^2 when it was assumed that exposure did not occur during a working day, but over a 24-h period.

The Soviets were, however, not the only ones deeply interested in this issue; the Americans had, since the 1950s, been investigating the possible use of microwaves as a weapon of mind control.

As Krishnan (10) explains, in the 1950s the CIA had looked into the use of electromagnetic fields for mind control purposes as part of its MK ULTRA project. MK ULTRA was a top secret program first set up in the late 1940s to investigate behavioral modification and the control of individual minds in the service of American geopolitical and ideological interests (24).

Subproject 62 of MK ULTRA was run by the neurosurgeon Maitland Baldwin, and aimed to analyze the effect of electromagnetic waves on monkeys. This was one of 149 subprojects designed by the CIA, and was entitled "Effects of radio-frequency energy on primate cerebral activity" (25). In one of these experiments, monkeys were exposed to high-powered (100 V) frequencies of 388 MHz, resulting in several changes in the electroencephalogram, as well as arousal and drowsiness. In addition, he observed lethal effects after just a few minutes of exposure (10).

Ewen Cameron, a psychiatrist who actively participated in the MK ULTRA project, carried out experiments using personnel from the purpose-built Radio Telemetry Laboratory, probably with the intention of finding out more about the effects of the microwave bombardment of the American embassy. In 1965, the Defense Advanced Research Project Agency (DARPA) commissioned the Walter Reed Army Medical Center Research Institute and the Johns Hopkins University to study the possible biological effects of microwave exposure on humans, in what was dubbed the Pandora Project (10).

As Krishnan (10) also pointed out, Dr. Milton Zaret acknowledged that effects on the nervous system due to microwave exposure were possible, and Robert O. Becker, twice nominated for the Nobel Prize in Medicine for his work on the effects of electromagnetic fields on living tissues, indicated in an interview to the BBC in 1984 that he thought it was unquestionable that exposure could produce disturbances in the central nervous system. Becker did not believe that, with the technology available at the time, someone could be made to instantly fall asleep, but that exposure to microwaves could possibly interfere in an individual's decision-making ability. This could produce a situation of chronic stress resulting in the embassy staff operating less efficiently than usual, to the obvious advantage of the Soviets.

Weinberger (26) tells how the Americans themselves deceived the embassy staff when, in 1965, doctors began performing blood tests. The staff were told that the doctors were looking for a new virus but, in reality, they wanted to integrate the information obtained into the Pandora Project. In October 1965, Richard Cesaro took over the DARPA Program Plan 562, the technical name of the Pandora Project. Cesaro had been responsible for translating dozens of Soviet investigations into this subject, and realized that the neurological effects of microwaves fascinated the enemy.

As Weinberger (26) continues, the Pandora project involved experiments on monkeys carried out in government laboratories rather than universities, due to the top-secret nature of the project. The monkeys were exposed to the same signal levels that the embassy received in Moscow. The results were not subject to peer review but, in December of 1966, Cesaro reported that the first monkey involved in the tests had shown erratic and repetitive behavior, which led him to assert that it was unquestionable that the signal had penetrated the central nervous system and caused changes in the assigned work functions. He was so convinced by the results that he recommended that the Pentagon immediately begin to investigate potential military applications, and requested that the project be extended to include experiments on humans, something that certain sections within the CIA viewed with suspicion, as it was too reminiscent of the questionable practices of the MK ULTRA project. It was May of 1969 and the scientific committee of Pandora was considering extending the study to include eight humans, but in the end this did not occur as the results of experiments carried out on primates were still being reviewed and there were doubts over whether this behavioral change was in fact produced by the microwave signals. In 1968, Dr. James McIlwain took over the Pandora Project and, after reviewing the results thus far obtained, concluded that the microwave signals did not result in the ability to control the minds of the monkeys.

As Weinberger (26) concludes, in 1969 DARPA ended its support for Pandora, and Cesaro was fired. At the end of the decade, the American intelligence services claimed that the Soviets had used these waves not to control the minds of diplomats, but to activate listening devices on the walls of the building.

The Soviet objective

To activate listening devices on the walls? This may well have been, as we have just indicated, one of the explanations given by the Americans, but serious doubts had, by this time, been cast on American institutional credibility. After all, the State Department had, for more than 15 years, hidden from its own employees the fact that that they were being irradiated, had lied to them about the purpose of the blood tests, and had categorically denied

that some of the results were of concern to their health. For example, the State Department had reported that Ambassador Walter Stoessel was in good health and that blood tests showing high levels of white blood cells were unrelated to leukemia (13). Nevertheless, Stoessel died of leukemia on December 9, 1986, aged 66 (27).

The mind control hypothesis was also considered by the American government (28). The Americans themselves had been experimenting on mind control as part of the MK ULTRA project, and suspected that the Soviets might be doing the same.

The former CIA agent Victor Marchetti claimed that the microwave bombardment had nothing to do with a threat to health, but with a strategy of confusion in order to waste the time of the American government while it studied and analyzed what it believed might be taking place (13). Whether this is true or not, the reality is that the American government had indeed devoted huge resources and efforts to analyzing what had happened, especially with the epidemiological study of Lilienfeld et al. (1).

The Soviets, on the other hand, finally admitted at the beginning of 1976 to the use of microwaves, after denying it for 15 years. The official version until then had been that the radiation detected by the Americans at the embassy was caused by the industrial activity of a large city such as Moscow. When they finally came clean, they indicated that the purpose of the bombardment had not been to damage the health of the American personnel, but to interfere in the communications of the embassy (11).

In the end, both official versions concurred, which, given the history of lies and deceit by the two sides involved, may be equally suspect.

The epidemiological study of Lilienfeld et al. (1)

On June 21, 1976, Dr. Lilienfeld and his team signed a contract with the Government of the US to carry out what would become the most ambitious epidemiological study conducted to date on the effect of microwaves on human health (1).

The report compared the embassy workers and their relatives with their counterparts in other European embassies (Belgrade, Bucharest, Budapest, Leningrad, Prague, Sofia, Warsaw and Zagreb). A retrospective cohort study included all those people who had worked in these places between January 1, 1953 and June 30, 1976.

After 2 years of work and the release of a 400-page report, the conclusions were not as alarming as some may have expected. O'Toole (29) summarized them as follows: there was an increase in the number of white blood cells, as well as complaints of headaches, memory loss and sleep disorders among the workers, which the researchers explained as being due to the high incidence of bacterial infections in the USSR and the publicity given to the topic of microwaves since 1976. There were no differences in terms of mortality (including different types of cancer). Moreover, mortality from all causes among Soviet workers and those of the eight other embassies was smaller compared to that of the population as a whole. This is known as the "healthy worker effect", something logical among employees who are selected precisely for tasks involving a high degree of responsibility and who generally have an above-average level of health. Table 2 summarizes the main results of the report, regarding mortality rates among employees.

Table 2: Mortality in employees (from table 5.6 of (1)).

	Moscow				Other embassies			
	Obs	Exp	SMR	95% CI	Obs	Exp	SMR	95% CI
All causes	49	105.3	0.47	(0.4; 0.6)	132	223.7	0.59	(0.5; 0.7)
All malignant neoplasms	17	19.0	0.89	(0.5; 1.4)	47	41.1	1.1	(0.8; 1.5)
Arteriosclerotic heart disease	16	32.6	0.49	(0.3; 0.8)	28	73.2	0.38	(0.2; 0.6)
Selected malignant neoplasms								
Digestive organs	3	4.6	0.65	(0.1; 1.9)	11	10.8	1.0	(0.5; 1.8)
Brain tumors	0	0.9	0.0		5	1.5	3.3	(1.1; 7.7)
Pancreas	1	1.0	1.0	(0.0; 5.6)	1	2.2	0.45	(0.0; 2.5)
Lung	5	5.8	0.86	(0.3; 2.0)	11	12.2	0.90	(0.4; 1.6)
Leukemia	2	0.8	2.5	(0.3; 9.0)	3	1.7	1.8	(0.4; 5.3)
Breast	2	0.5	4.0	(0.5; 14.4)	3	1.2	2.4	(0.5; 0.7)
Uterus	1	0.2	5.0	(0.1; 27.9)	0	0.1	0.0	
Cervix	1	0.1	10.0	(0.3; 55.7)	0	0.0	0.0	

Obs, observed; exp, expected based on US mortality data; SMR, standardized mortality ratio; CI, confidence interval.

Regarding morbidity, a large number of statistical tests were conducted to search for significant differences between the Moscow group and the comparison group, for both males and females.

A disease history involving some 70 diseases or medical conditions was abstracted from the medical records of all employees. Only three of the 140 comparisons were 95% significant: appendicitis (males), sleepwalking (males) and venereal disease (males). In addition, higher occurrences of appendicitis and sleepwalking were reported for the control group.

Clinical evaluations were also obtained in 19 organ systems for males and females. No difference was found after performing 38 comparisons.

Lilienfeld et al. (1) also analyzed the occurrence rates for 44 additionally selected medical conditions reported as part of routine or special medical examinations. Only four of the 87 comparisons were significant: protozoal intestinal disease (males), benign neoplasms (males), diseases of the nerves and peripheral ganglia (males), and complications during pregnancy, childbirth and puerperium (females).

The medical history questionnaire provided another source of information for obtaining comparisons. Researchers examined 20 symptoms for males and females, obtaining six significant results out of 40: depression (males), irritability (males), difficulty in concentration (males and females), memory loss (males) and other symptoms (females). In addition, they examined 28 medical conditions, obtaining six significant results out of 56: eye problems (males and females), psoriasis (males), skin conditions (males), anemia (females) and ulcers (females).

Although it is true that the results on cancer mortality were not significant, the differences found in some morbidity variables have led several authors (22, 30) to conclude that these symptoms are in line with those expected after prolonged exposure to low intensity microwaves. They are precisely those symptoms linked to electrohypersensitivity (31).

Goldsmith's response

The researcher J. R. Goldsmith harshly criticized the results of the study of Lilienfeld et al. (1), claiming that the findings had been massaged by the US Department of State, and that the results had been toned down (32).

Goldsmith criticized the methodology of comparing the staff of the Soviet embassy with that of the other embassies. Why use the other embassies as a control group? How could they be sure that these other embassies had not also been irradiated?

As indicated by Carpenter (22), Goldsmith reinterpreted the data from the original study by grouping the cases of deaths among all the embassies and comparing them with the reference population.

By presenting the data in this way, the results change ostensibly. Goldsmith linked the cases of workers' deaths to those of their relatives ("dependents"), which resulted in mortality due to leukemia becoming significant in Moscow. He then added these results to those of the other embassies ("both groups") and found a statistically higher-than-expected number of cases of leukemia, brain tumors and breast cancer.

Goldsmith did not cease in his determination to show that the conclusions derived from the study by Lilienfeld et al. (1) were unconvincing. According to EMFacts (33), an initial study carried out in Moscow in 1967 on a group of 43 workers (37 exposed and seven unexposed), found abnormalities in the chromosomes of 20 of the 37 who had been exposed to microwaves, compared to two of the seven who had not. Subsequently, in 1976, another hematological study found significant differences between the embassy workers in Moscow and other employees of the foreign affairs service. Larger numbers of white blood cells were reported among the Moscow staff, but these results were never published. However, Goldsmith obtained them thanks to the Freedom of Information Act, which allows American citizens to access official government information.

According to Goldsmith, the conclusions of the study by Lilienfeld et al. (1) were intentionally toned down by the State Department. In addition, he assured that several cases of cancer had been eliminated from the final analysis, which had distorted the statistical analysis performed. Finally, Goldsmith agreed with Lilienfeld et al. (1) in that additional follow-up of the cohort of participants was necessary, since certain cancers may not have manifested at the time of study closure.

Loose ends

Why did the study carried out by Lilienfeld et al. (1) not include a detailed report on cancer incidence instead of just cancer mortality? This is very important for the final interpretation of the results. In fact, Congressman Edward I. Koch (14) had specified in his speech before Congress that five women from the embassy had been subjected

to mastectomies. This would indicate that the number of cases of breast cancer would be higher than the two deaths reported as a main result in the study by Lilienfeld et al. (1).

Another particularly disturbing fact is related to the causes of death of several US ambassadors in Moscow, who held this position during the period of analysis. Charles Bohlen was ambassador from April 20, 1953 to April 18, 1957 and died of cancer on January 1, 1974, aged 69 (34). Llewellyn Thompson was ambassador from July 16, 1957 to July 27, 1962, and later again from January 23, 1967 to January 14, 1969, and died of cancer on March 6, 1972, at 67 years of age (35). Finally, Walter J. Stoessel, who was ambassador from 1974 to 1976, died of leukemia on December 9, 1986, at 66 years of age (27). Three cancer deaths among the ambassadors, whose offices were precisely those that received the greatest intensity of radiation, as well as the Stoessel leukemia case, which was not included in the analysis by Lilienfeld et al. (1).

In 1976, Dr. R.M. Tartell (36), of the Walter Reed Army Medical Center, in a letter to the editor of the *Washington Post*, indicated that "*one need not be a physician to appreciate the significance of the disproportionate incidence of leukemia and other forms of cancer among past members of the Moscow embassy staff*". What data did Tartell use in order to claim a "disproportionate" incidence of leukemia if the official epidemiological report published 2 years later only mentioned two cases of death from this disease? In a recent interview with Dr. Tartell (Tartell, personal communication, 2018, June 7), he indicated that he had made the comment based on the material he had been reading at the time.

In 1977, in an article published in the *Los Angeles Times* (37), it was reported that an "authority" had told President Carter that the first residents of the embassy had the highest incidence of cancer of any group of people in the world. The US public had, in fact, already begun to question if living near antennas was safe, and several collectives and lawyers were starting to take action. According to the article, the army knew that microwave weapons could cause sudden death, estimating that the US population at risk could number between 15 and 20 million people.

Also, in 1977, Stevens (38) published that a third of the diplomats and their families had shown abnormally high levels of lymphocyte counts in recent months. Although at first this was linked to microwaves, the medical authorities soon abandoned this theory, claiming that it was temporary and not a cause for alarm, and that this was not indicative of the development of leukemia. These levels of lymphocytes returned to normal 2 weeks after the individuals left Moscow. The cause of this abnormal level of lymphocytes was blamed on a possible parasite in the drinking water, or on a respiratory infection. However, as Stevens indicated in his article, there was no evidence that the Soviet citizens of Moscow had such high anomalies in the incidence rate as those that existed in the embassy. Stoessel's death from leukemia a few years later cast doubt on the official American version.

Controversial details of the epidemiological study

After a detailed review of the study by Lilienfeld et al. (1), several questions arise:

1. It is unclear why workers and relatives were chosen as study subjects when some of these relatives, including wives and children, obviously received much less exposure to the microwave bombardment.
2. The authors admit that some medical records were never found, as the investigation was stopped prematurely due to the urgent need to publish the results. Recall that the investigators involved were under pressure to finish the report by a given deadline, and this led to relevant information not being included.
3. When responding to questions, many of the participants did not remember the exact location of their workplace within the embassy, and were therefore categorized as being of questionable exposure.
4. Only the population that could be followed in its entirety was studied, i.e. all those for whom a medical history was available. The identified population included 1827 people from the Moscow embassy and 2561 from the other embassies, but it was not possible to obtain information from all of these individuals. In the end, they entered cohorts of 1719 and 2460, respectively. Despite this being a high percentage of the population initially identified, given the low number of cancer cases reported, then, if some cases were not identified, this could lead to the results changing from being statistically insignificant to statistically significant.
5. Of the 4179 employees who could finally be followed, 194 died during the period under consideration. However, 13 of these deaths (seven from Moscow and six from the other embassies) were excluded from mortality analysis for different reasons, so only 181 were finally counted instead of 194. Two of the seven deaths excluded from the Moscow group were from cancer (lung and kidney), and other two were unknown.

6. The authors themselves complained in the report about the low response rate to the questionnaires, even though the employees they were sent to were supposed to have a high level of education.
7. Thirty-six percent of the causes of death were not obtained from death certificates, but from other sources. Thus, the authors indicate that the results must be interpreted with caution, because more than a third of the deaths were subject to coding errors.
8. There exists an apparent contradiction in that the overall mortality rate is lower (healthy worker effect) and that the same population reported higher-than-expected incidences of certain health problems, such as those already mentioned for morbidity.
9. In addition, due to the healthy worker effect, there was another apparent contradiction between the standardized mortality rate (SMR) of all causes of mortality (0.47) and the SMR of cancer mortality (0.89).
10. No control variable was used for the analyses. It is only indicated that there was an equal number of smokers among the Moscow staff and that of the other embassies.

These limitations of the epidemiological study must be taken into account when interpreting the results.

Simulations

Based on these limitations and some of the "loose ends" discussed, simulations can be made with the data from the original study by Lilienfeld et al. (1).

For example, what number of breast cancer cases would have been necessary in order to consider that there was, in fact, a significant effect? In 1977, the age-adjusted Surveillance Epidemiology and End Results (SEER) incidence of breast cancer in the US was 100.8 cases per 100,000 women (103.32 cases per 100,000 women for the White females). This is known as the incidence density (Ir), and is defined as the number of new cases per unit of person-time at risk. Therefore, Ir = 0.001.

The report by Lilienfeld et al. (1) does not provide detailed information on the follow-up times of each participant, but overall, for women, the exposure was 3131 person-years. Since there was a total of 410 women with 23 years of follow-up, the average exposure was 7.64 years. In any case, this last detail is not very informative. However, if we take these 3131 person-years as the denominator in the computation of incidence density, then it would have been necessary to detect nine cases of breast cancer for the incidence density to have been statistically and significantly higher than that of the base population. We would also assume the limitation of not knowing the times of each individual person and the age distribution of the Moscow embassy staff. With nine cases of breast cancer, the Ir (study) would be 0.0028, but taking into account the computation of the 95% error with the assumption of normality, then the results would border statistical significance.

Were there nine cases of breast cancer in the Moscow embassy? The press mentioned five mastectomies, and we know that two women died from breast cancer, but we do not know if these two women were among the five that the press included. Lilienfeld et al. (1) indicated among the 17 malignant neoplasms reported in women, there were three breast cancers and three other with site unspecified. As in 1977 the percentage of breast cancer from all cancers was 26% in females (39), it is probable that some of the unspecified cancer were also breast cancer. However, even if those three unspecified cancers were breast cancer, the mentioned threshold of nine cases would not be reached.

We can perform even more simulations, e.g. with the "SMR" given in the list of causes of mortality. Lilienfeld et al. (1) only considered two deaths from leukemia but we know that there were at least three deaths, as Walter Stoessel died of this disease a few years later and the American government tried to cover this up during the study period (40). We could attempt to simulate a follow-up of 10 more years (up to 1986, when Stoessel died). To achieve this simulation, we have computed the person-year mean for the period 1953–1976 (18,106/24 = 754.4), and then multiplied the result by 10 years, to obtain 7544.16 additional person-years. Therefore, the total person-years for the period 1953–1986 would be 25,650.17. Lilienfeld et al. (1) reported 4.41 expected deaths per 100,000 persons. Considering that this only referred to White people, and acknowledging that trends of mortality from leukemia have been stabilized since the 1950s (41, 42), then the expected deaths would be 1.13 (4.41*25,650.17/100,000).

We can now compute the 95% confidence interval (CI) using disparate methods (see (43)) and the OpenEpi software (www.openepi.com). The results are shown in Table 3.

Under this simulation, with three cases of leukemia, 95% CI does contain one and is therefore not significant. However, with four cases, the interpretation of the results would be different. Was there any other case of leukemia (apart from Stoessel) that was not included in the original study? Well, we simply do not know.

Table 3: Simulation of SMR 95% confidence intervals for the expanded period 1953–1986.

Method	Leukemia cases = 3	Leukemia cases = 4
	SMR = 2.66	SMR = 3.54
Mid-P exact test	(0.68; 7.23)	(1.13; 8.56)
Fisher's exact test	(0.55; 7.76)	(0.96; 9.06)
Byar approximation	(0.53; 7.76)	(0.95; 9.06)
Rothman Greenland method	(0.86; 8.23)	(1.33; 9.43)
Ury and Wiggins method	(0.54; 7.52)	(0.96; 8.87)
Vandenbroucke method	(0.50; 6.51)	(0.92; 7.86)

In any case, numbers must always be looked at with statistics, but also beyond statistics; after all, the determination of type I error size is arbitrary. If we look at the previous simulations with this broader perspective, we find that, with five cases of breast cancer, the incidence density in Moscow would have been 159.7 cases per 100,000 person-years, whereas in the US the figure was 103.32 cases per 100,000 person-years. If we now look at the incidence of mortality from leukemia, the number of confirmed cases would be three, when to the expected figure would be (approximately) 1.13. If we then join these two data (incidence of breast cancer and mortality from leukemia), we see a trend, which could form a pattern. In fact, Lilienfeld (44) indicated that because of the sample size limitations, the Moscow study was not able to significantly detect increased risks unless they were unusually large.

As previously mentioned, there was another apparent contradiction between the SMR of all causes of mortality (0.47) and the SMR of cancer mortality (0.89). If we review the data provided by the Center for Disease Control and Prevention regarding the leading causes of death, the average ratio between malignant neoplasm deaths and total deaths (all causes) was 16.60% in the period 1953–1976. However, in the study of Lilienfeld et al. (1) this ratio was 34.69% (17 of 49 deaths). Therefore, the Poison exact 95% CI for this ratio was (20.21%; 55.55%), which does not contain 16.60%. Consequently, the cancer mortality rate was higher for the individuals working in the embassy than for the general population.

Finally, we can aggregate the responses to the health questionnaire regarding medical conditions and symptoms (Table 4). After applying several Fisher exact tests, the results clearly show a significantly worse health status for the Moscow group, for both males and females, as well as for the overall sample.

Legal and social consequences

According to Guthrie (11), the Soviets committed a violation of International Law (Vienna Convention on Diplomatic Relations – Article 29 on the inviolability of diplomatic personnel), and therefore should have been held accountable. Although the maximum exposure standards for the US were not exceeded, those of the Soviets were, which therefore constituted a crime.

The author indicated that there were reasonable doubts concerning the safety of humans exposed to such high levels of microwave intensity, with scientific evidence supporting the possibility of bodily harm. In addition, given that there was a willingness to irradiate, on the one hand, as well as a non-explicit consent, on the other hand, then this also constituted an affront to the dignity of the affected individuals.

Table 4: Aggregated analysis for medical conditions and symptoms (data from (1)).

		Moscow group	Control group	p-Value
General medical conditions (28 conditions examined)				
Males	Observed	Person-years = 7029 785	Person-years = 8249 803	0.004
Females	Observed	Person-years = 2189 327	Person-years = 4222 491	<0.001
Males + females	Observed	Person-years = 9218 1112	Person-years = 12,471 1294	<0.001
Symptoms (20 examined)				
Males	Observed	Person-years = 7029 519	Person-years = 8249 373	<0.001
Females	Observed	Person-years = 2189 230	Person-years = 4222 285	<0.001
Males + females	Observed	Person-years = 9218 749	Person-years = 12,471 658	<0.001

It also highlighted the neglect of the US Department of State towards its embassy staff, because it was fully aware of what was happening and yet did not communicate the facts until many years later. And, more importantly, protesting about this would have meant accepting that the limits of American security were fraudulent, which would have cost hundreds of billions of dollars in military and defense facilities that exceeded Soviet limits.

This legal and economic element is fundamental for understanding the results and the evaluation of this episode. What would the legal and economic consequences have been if the conclusions had admitted carcinogenic effects? In fact, the standards for radiofrequency electromagnetic fields in the US have remained virtually unchanged over the last 70 years. In 1992, a slight modification was published as a function of frequency, where for the general population the maximum values of exposure were delimited as f/1500, f being the frequency measured in MHz. Thus, for 3000 MHz, i.e. 3 GHz, the limit value would be 2 mW/cm^2, but for 10 GHz it would be 5 mW/cm^2; in other words, several orders of magnitude above the intensity measured at the embassy in Moscow.

Further research

Four decades on, the "Moscow signal" case has transmuted into "the Thing" or "the Havana syndrome" (45). From December, 2016, to August, 2017, some State Department personnel and other CIA employees began to suffer a series of neurological symptoms, including headaches, dizziness and sleep abnormalities, while working at the Cuban embassy, or staying at other places in Havana, such as the Capri and Nacional hotels.

Because of the political nature of this affair, many details remain undisclosed, such as the names of the CIA employees affected, who exactly was responsible for the attack (the Cuban government continues to deny all knowledge), or the specific "weapon" employed (some scientists suspect a microwave attack). However, the preliminary results of the study of Swanson et al. (7) on 21 individuals identified by the US Department of State as having possibly been exposed, showed persistent cognitive, vestibular, and oculomotor dysfunction, as well as sleep impairment and headaches, along with reports of directional audible and/or sensory phenomena of unclear origin. As Swanson et al. (7) concluded, these individuals appeared to have sustained injury to widespread brain networks without an associated history of head trauma.

Therefore, there exist clear similitudes with the Moscow embassy case; a (hypothesized) directional weapon that produces several identifiable neurocognitive symptoms and that leaves no detectable traces, contextualized in a framework of secrecy and political tension. The main difference is that, in the Cuban case, there is still no confirmation of the use of microwaves.

In addition, another difference with respect to the Moscow case is the advanced analyses conducted on the participants in the investigation of Swanson et al. (7), including magnetic resonance imaging (MRI). Nevertheless, most of the participants showed normal imaging findings, and only three had abnormalities which could not be attributed to the specific exposure experienced. Advanced structural and functional neuroimaging studies remain unpublished, but could maybe shed light on some of the concerns that other researchers have expressed regarding possible alternative explanations (see (46, 47)), such as mass psychogenic illness or functional neurological disorders, which Hampton et al. (48) preliminarily discarded, preferring to wait for confirmation in subsequent analyses.

Consequently, future research should be addressed specifically toward the need for functional brain scans [positron emission tomography (PET), Single-photon emission computed tomography (SPECT) and functional MRI]. Further investigations should also include neuropsychological as well as ear, nose and throat (ENT) evaluations. The "Havana syndrome" presents, therefore, an opportunity to carry out a thorough study of the exposed participants in order to identify structural brain changes that, as Hampton et al. (48) stated, may underlie the neurological manifestations – something which was not done with the workers at the Moscow embassy in the 1970s.

Conclusion

This event was just one of many that took place during the Cold War, and must therefore be assessed in the context of manipulation, political interests and classified information typical of the time. With the data in hand, with what we have been able to gather and what we have shown in this article, we can approach the truth, possibly even guess it, but not reveal it in its total dimension. And we will probably never be able to do so.

Those who, in the published results we have mentioned, use this event to deny the harmful effects of microwave radiation do not have enough evidence to support their position. There are too many loose ends, unanalyzed information, methodological flaws, and debatable interpretations.

However, on the opposite side of the debate, those who take this case as incontestable evidence of the

harmful effects of microwaves on humans at low intensities, must also admit that there is a lack of statistical consistency in the results. There is still too much imprecision.

A global vision of the whole event, including the nuances and details that we have explained in this article, show the latter to be closer to the truth than the former, even more so when we consider non-carcinogenic effects linked to what is now associated with electrohypersensitivity. However, it must be recognized that the methodology used by Lilienfeld et al. (1) also casts doubt on this claim, as the health status symptom questionnaires were filled in after the case was made public (nocebo effect). In addition, the results of our simulations are also partially dependent of the quality of data of Lilienfeld et al. (1), which were not complete, having a different degree of potential bias regarding mortality, cancer incidence and health status. Further research on the personnel of the Havana embassy who were recently subjected to a similar attack, could indirectly help to better understand what happened in Moscow more than 40 years ago.

Power densities measured at the Moscow embassy were higher than the average levels typically found nowadays in homes, schools and urban areas, and were of the same order of magnitude as the more extreme case of living just a few meters from a base station (see (19)) This means that exposure at the embassy could have been high in terms of today's typical levels of exposure. Nevertheless, the exposure was several orders of magnitude lower than those suggested by the ICNRIP guidelines, adopted by many countries as legal limits. As Hardell et al. (19) indicated, the BioInitiative Report (49) with updated references defined the scientific benchmark for possible health risks as 0.000003–0.000006 mW/cm^2. Consequently, the exposure at the Moscow embassy was from 3 to 4 orders of magnitude higher than this safety benchmark, but 3 orders of magnitude lower than the legal limits of many countries.

In any case, and as Frentzle-Beyme (50) stated, "*The level of proof required to justify action for health protection should be less than that required to constitute causality as a scientific principle*". The "Moscow signal" remains a "signal"; let us not reject it, but listen to it instead.

Acknowledgements: The author would like to thank Martí Casals and Klaus Langohr for their comments in the development of this manuscript. The author would also like to thank editor and the three anonymous reviewers for their helpful suggestions.

Research funding: Fundación Séneca (Funder id: 10.13039/100007801, 19884/GERM/15); MINECO/FEDER (ECO2015-65637-P).

Conflict of interest: Authors state no conflict of interest.
Informed consent: Not applicable.
Ethical approval: Not applicable.

References

1. Lilienfeld AM, Tonascia J, Tonascia S, Libauer CA, Cauthen GM. Foreign Service health status study. Evaluation of health status of foreign service and other employees from selected Eastern European posts". Report on Foreign Service Health Status Study, US Dept of State 6025-619073, 1978.
2. NTP. NTP Technical Report on Toxicology and carcinogenesis studies in Hsd:Sprague Dawley SD rats exposed to whole-body radio frequency radiation at a frequency (900 Mhz) and modulations (GSM and CDMA) used by cell phones. National Toxicology Program, 2018a. Available from: https://ntp.niehs.nih.gov/ntp/about_ntp/trpanel/2018/march/tr595peerdraft.pdf.
3. NTP. NTP Technical Report on Toxicology and carcinogenesis studies in B&C3F1/N mice exposed to whole-body radio frequency radiation at a frequency (1900 Mhz) and modulations (GSM and CDMA) used by cell phones. National Toxicology Program, 2018a. Available from: https://ntp.niehs.nih.gov/ntp/about_ntp/trpanel/2018/march/tr596peerdraft.pdf.
4. Falcioni L, Bua L, Tibaldi E, Lauriola M, De Angelis L, Gnudi F, et al. Report of final results regarding brain and heart tumors in Sprague-Dawley rats exposed from prenatal life until natural death to mobile phone radiofrequency field representative of a 1.8 GHz GSM base station environmental emission. Environ Res 2018;165:496–503.
5. Belpomme D, Hardell L, Belyaev I, Burgio E, Carpenter DO. Thermal and non-thermal health effects of low intensity non-ionizing radiation: an international perspective. Environ Pollut 2018;242:643–58.
6. Miller AB, Morgan LL, Udasin I, Davis D. Cancer epidemiology update, following the 2011 IARC evaluation of radiofrequency electromagnetic fields (Monograph 102). Environ Res 2018;167:673–83.
7. Swanson RL, Hampton S, Green-McKenzie J, Diaz-Arrastia R, Grady MS, Verma R, et al. Neurological manifestations among US government personnel reporting directional audible and sensory phenomena in Havana, Cuba. J Am Med Assoc 2018;319:1125–33.
8. Broad WJ. Microwave weapons are prime suspect in ills of U.S. Embassy workers, 2018, September 1. Taken from: https://www.nytimes.com/2018/09/01/science/sonic-attack-cuba-microwave.html.
9. NYT. Soviet halts microwaves aimed at U.S Embassy, 1979, mayo 30. Retrieved from: https://www.nytimes.com/1979/05/30/archives/soviet-halts-microwaves-aimed-at-us-embassy.html.
10. Krishnan A. Military neuroscience and the coming age of neurowarfare. Routledge, 2017.
11. Guthrie LB. Legal implications of the Soviet microwave bombardment of the US Embassy. Boston College Int Comp Law Rev 1977;1:Article, 6.
12. Association for Diplomatic Studies. War of the waves: combating espionage in Embassy Moscow, 2013. Taken from: https://adst.org/2013/09/microwaving-embassy-moscow/.

13. Love T. Radiation at U.S. Embassy long known, ex agents' say, 1976, febrero 21. Retrieved from: https://www.cia.gov/library/readingroom/docs/CIA-RDP88B01125R000300120092-0.pdf.
14. Congresional Record. 1976, August 2. Retrieved from: https://www.cia.gov/library/readingroom/docs/CIA-RDP88B01125R000300120110-9.pdf.
15. Wikileaks. 1976STATE166451_b, 2006. Retrieved from: https://wikileaks.org/plusd/cables/1976STATE166451_b.html.
16. Liptai P, Dolník B, Gumanová V. Effect of Wi-Fi radiation on seed germination and plant growth – experiment. Annals of Faculty Engineering Hunedoara, Fascicule 1, 2017;XV:109–12.
17. Hedendahl LK, Carlberg M, Koppel T, Hardell L. Measurement of radiofrequency radiation with a body-borne exposimeter in Swedish schools with Wi-Fi. Front Public Health 2017;5:279.
18. Peyman A, Khalid M, Calderon C, Addison D, Mee T, Maslanyj M, et al. Assessment of exposure to electromagnetic fields from wireless computer networks (Wi-Fi) in schools; results of laboratory measurements. Health Phys 2011;100:594–612.
19. Hardell L, Carlberg M, Hedendahl L. Radiofrequency radiation from nearby base stations gives high levels in an apartment in Stockholm, Sweden: a case report. Oncol Lett 2018;15:7871–83.
20. Adams RL, Williams RA. Biological effects of electromagnetic radiation (radio waves and microwaves) Eurasian communist countries. U. S. Army Medical Intelligence and Information Agency Office of the Surgeon General, 1976. Retrieved from: https://electroplague.files.wordpress.com/2014/09/dia-report-1976.pdf.
21. Associated Press. Soviets study microwaves weapon, 1976, November 22. Retrieved from: https://www.cia.gov/library/readingroom/docs/CIA-RDP88B01125R000300120041-6.pdf.
22. Carpenter DO. The microwave syndrome or electro-hypersensitivity: historical background. *Rev Environ Health* 2015;30:217–22.
23. CIA. Document number: RDP88B01125R000300120045-2, 2012a, October 5. Retrieved from: https://www.cia.gov/library/readingroom/docs/CIA-RDP88B01125R000300120045-2.pdf.
24. Lemov R. Brainwashing's avatar: the curious career of Dr. Ewen Cameron. Grey Room 2011;45:60–87.
25. Ross CA. The CIA Doctors: human rights violations by American psychiatrists. Richardson, TX: Manitou Communications, 2006.
26. Weinberger S. The secret history of diplomats and invisible weapons, 2017, August 25. Retrieved from: http://foreignpolicy.com/2017/08/25/the-secret-history-of-diplomats-and-invisible-weapons-russia-cuba/.
27. Barnes B. Walter J. Stoessel dies, 1986, December 11. Retrieved from: https://www.washingtonpost.com/archive/local/1986/12/11/walter-j-stoessel-dies/155b904e-79ea-40dd-b223-1cf42474fc7e/?utm_term=.fe58d5d1455d.
28. Le Miere J. Did Russia attack U.S. officials in Cuba? U.S.S.R. used microwaves against American diplomats during cold war, 2017, October 8. Retrieved from: http://www.newsweek.com/russia-us-attack-cuba-officials-649546.
29. O'Toole T. Moscow mircowaves: no harm seen, 1978, November 21. Retrieved from: https://www.washingtonpost.com/archive/politics/1978/11/21/moscow-microwaves-no-harm-seen/7a4b045f-e2ff-401e-a1f5-34e748d4cf13/?utm_term=.a520a3a1b9c6.
30. Liakouris AG. Radiofrequency (RF) sickness in the Lilienfeld study: an effect of modulated microwaves? Arch Environ Health 1998;53:236–8.
31. Redmayne M. Past, present and future hyperelectrosensitivity. *15th World Congress on Public Health*, Melbourne (Australia), 2017.
32. Goldsmith JR. Where the trail leads: ethical problems arising when the trail of professional work leads to evidence of cover-up of serious risk and misrepresentation of scientific judgement concerning human exposure to radar. Eubios J Asian Int Bioeth 1995a;5:92–5.
33. EMFacts. John Goldsmith on scientific misconduct and the Lilienfeld study (An oldie but still relevant today), 2012. Retrieved from: https://www.emfacts.com/2012/06/john-goldsmith-on-scientific-misconduct-and-the-lilienfeld-study-an-oldie-but-still-relevant-today/.
34. Phelps RH. Charles Bohlen, diplomat, 69, dies, 1974, January 2. Retrieved from: https://www.nytimes.com/1974/01/02/archives/charles-bohlen-diplomat-69-dies-exenvoy-to-moscow-and-paris-was-top.html.
35. Associated Press. Llewellyn Thompson dead at age of 67; ExEnvoy to soviet, 1972, February 7. Retrieved from: https://www.nytimes.com/1972/02/07/archives/llewellyn-thompson-dead-at-age-of-67-exenvoy-to-soviet-llewellyn.html.
36. Tartell RM. Microwave radiation at the Embassy in Moscow, 1976. Retrieved from: https://www.cia.gov/library/readingroom/docs/CIA-RDP88B01125R000300120046-1.pdf.
37. United Press International. Authorities question microwave safety, 1977, December 25. Retrieved from: https://www.cia.gov/library/readingroom/docs/CIA-RDP88B01125R000300120018-2.pdf.
38. Stevens E. Blood-test request embassy, 1977, January 6. Retrieved from: https://www.cia.gov/library/readingroom/docs/CIA-RDP88B01125R000300120037-1.pdf.
39. Silverberg E. Cancer statistics, 1977. CA Cancer J Clin 1977;27:26–41.
40. CIA. Document number: RDP88B01125R000300120097-5, 2012b, October 5. Retrieved from: https://www.cia.gov/library/readingroom/docs/CIA-RDP88B01125R000300120097-5.pdf.
41. Guilliam AG, Walter WA. Trends in mortality from leukemia in the United States, 1921–55. Public Health Rep 1958;73:773–84.
42. National Cancer Institute. Cancer stats facts: Leukemia, 2018. Retrieved from: https://seer.cancer.gov/statfacts/html/leuks.html.
43. Soe MM, Sullivan KM. Standardized mortality ratio and confidence interval, 2005. Retrieved from: http://www.openepi.com/PDFDocs/SMRDoc.pdf.
44. Lilienfeld AM. Practical limitations of epidemiologic methods. Environ Health Perspect 1983;52:3–8.
45. Entous A, Anderson JL. The mystery of the Havana syndrome, 2018, November 19. Retrieved from: https://www.newyorker.com/magazine/2018/11/19/the-mystery-of-the-havana-syndrome.
46. Bartholomew RE. Neurological symptoms in US government personnel in Cuba. J Am Med Assoc 2018;320:602.
47. Stone J, Popkirov S, Carson AJ. Neurological symptoms in US government personnel in Cuba. J Am Med Assoc 2018;320:602–3.
48. Hampton S, Swanson II RL, Smith DH. Neurological symptoms in US government personnel in Cuba – reply. J Am Med Assoc 2018;320:604–5.
49. BioInitiative Working Group. BioInitiative report 2012: a rationale for biologically-based public exposure standards for electromagnetic radiation, 2012.
50. Frentzle-Beyme R. John R. Goldsmith on the usefulness of epidemiological data to identify links between point sources of radiation and disease. Public Health Rev 1994; 22:305–20.