

# Radioactive Elements in Phosphorous Fertilizer —Basalt Flour-Recommended Mineral Fertilizer

**Andrzej Pawuła**

Member of the Polish Geological Society, Poznań, Pologne

Email: pawula@amu.edu.pl

**How to cite this paper:** Pawuła, A. (2022). Radioactive Elements in Phosphorous Fertilizer. *Journal of Geoscience and Environment Protection*, 10, 15-32.  
<https://doi.org/10.4236/gep.2022.104002>

**Received:** February 18, 2022

**Accepted:** April 9, 2022

**Published:** April 12, 2022

Copyright © 2022 by author(s) and Scientific Research Publishing Inc.

This work is licensed under the Creative Commons Attribution International License (CC BY 4.0).

<http://creativecommons.org/licenses/by/4.0/>



Open Access

## Abstract

The article presents the concept of using powdered basalt as a mineral fertilizer and replacing radioactive phosphate rock with it. In addition to the characteristics of phosphate rock deposits and the ecological effects of the use of phosphorus fertilizers, the issue of the genesis of phosphate deposits was discussed. Phosphate rock contains natural radioactive elements whose origin is debatable. It is generally accepted that all elements are formed in a thermonuclear fusion reaction. The natural radioactivity of the elements results only from the instability of atomic nuclei, with a large advantage of neutrons over protons. The view of the cosmic origin of elements in the primary nucleosynthesis of the Big Bang is opposed to the view of the generation of elements in the present-day core of the Earth. Depending on the adopted view, extremely different conclusions can be drawn. If it is assumed that natural radioactive elements were formed in space billions of years ago, their number decreases as they decay. Conversely, if these elements form in the Earth's core and appear as a component of basalt magma, their amount increases exponentially. Referring to publications on the theory of natural forces of nature, the article explains the phenomenon of spontaneous formation of fusion reactors. At the same time, the phenomenon of the expansion of the globe was explained, manifested by a tenfold increase in the volume of the globe over the last 200 million years. Growing basalt magma has a stabilized mineral composition and contains traces of uranium. Therefore, in the basalt rock the uranium concentration is low (<1 ppm), while in the phosphate rock uranium precipitates from concentrated igneous solutions and its concentration increases to 600 ppm.

## Keywords

Radioecology, The Origin of the Elements, Thermonuclear Synthesis  
Georeactor

## 1. The Genesis of Natural Radioactive Elements

Uranium is one of the primary radioactive elements of geological origin (**Table 1**). Uranium comes in several isotope varieties U-238, U-235, and U-234. The long-lived uranium isotope  $^{238}\text{U}$ , with a half-life of 4.568 billion years, has the dominant share.

In the official information materials concerning protection against ionizing radiation, the view about the cosmic origin of uranium is adopted. This would mean that at the beginning of the Earth's history, several billion years ago, the amount of uranium in the world was at its greatest, and it is continuing to decline due to natural decay. The initial assumption in the discussion on the genesis of elements is the role of nucleic synthesis. It is widely taught that the origin of elements is related to the process of nucleosynthesis during the "Big Bang" 13.8 billion years ago.

This view, however, contains elements of the philosophy of nature that are contrary to the principles of physics. Regarding the formation of elements, professor of physics L. Jarczyk (Jarczyk, 2007) writes: "*In principle, we can distinguish three areas (groups) of elements. The first of them includes elements up to boron ( $Z = 5$ ) inclusive. The average abundance of hydrogen and helium reaches  $10^{10}$  (in relative units). The second area covers elements ending in the vicinity of iron ( $Z = 28, A = 56$ ) their average abundance is much lower and amounts to around  $10^4$ . The third area includes elements for uranium ( $Z = 92$ ) with an average abundance of around  $10^{-1}$ ...*

*The elements are produced in the following processes:*

- *the lightest (practically hydrogen and helium) in the primary nucleosynthesis;*
- *in nuclear reactions in stars leading to the fusion of nuclei up to and including iron;*
- *in neutron capture processes, in the last stage of star development, i.e. in the so-called supernova."*

The Big Bang theory appeared at the beginning of the 20th century as an attempt to explain the phenomenon of galaxies moving away and commenting on the expansion of the universe. The author of this logical speculation, Georges Lemaître, concluded from the theorem about the expanding cosmos that if galaxies move away, they must have started their journey from some starting point. It was assumed in the discussion that it was an atom with a peculiar density of

**Table 1.** Primary natural radioactive elements.

tungsten	$^{178}\text{W}$	thorium	$^{232}\text{Th}$	samarium	$^{147}\text{Sm}$	calcium	$^{48}\text{Ca}$
uranium	$^{235}\text{U}$	lutetium	$^{176}\text{Lu}$	platinum	$^{190}\text{Pt}$	zirconium	$^{96}\text{Zr}$
potassium	$^{40}\text{K}$	rhenium	$^{187}\text{Re}$	indium	$^{115}\text{In}$	tin	$^{124}\text{Sn}$
antimony	$^{123}\text{Sb}$	rubidium	$^{87}\text{Rb}$	vanadium	$^{50}\text{V}$	bismuth	$^{209}\text{Bi}$
uranium	$^{238}\text{U}$	lantalam	$^{138}\text{La}$	neodymium	$^{150}\text{Nd}$	tellurium	$^{130}\text{Te}$

matter. In philosophical considerations, it was assumed that before the Big Bang, neither matter nor time existed, nor did the laws of nature exist. The universe was created in minutes. At that time, particles of matter began to form and physical laws were established, deciding about the processes and phenomena taking place (Hoyle, Gold, & Bondi, 1948). In the model of the creation of the universe, however, there are interpretation problems, such as the aforementioned process of nukleosynthezy. According to this theory, the collision and synthesis of nuclides occurs under conditions of compression of matter, while the Big Bang was total decompression.

It is surprising to accept a theory that is far from the exact sciences, as it is a philosophical reflection in the interpretation of the universe. The shortcomings and imperfections of the standard Big Bang model are complemented by other hypotheses such as black holes, black matter and the curvature of space-time. Given the enormity of our galaxy and the existence of millions of other galaxies, it is irrelevant to consider the issue of a zero radius universe. Apart from the scientific credibility of the given physical quantities, there is a conflict between the physical state of the singularity and the general relativistic theory and the phenomenon of gravity. According to Czerny, Einstein stated that cosmology's conclusions about the singular state are testimony to the imperfection of the theory itself, not a "success" of cosmology (Czerny, 1995).

In deliberations on the genesis of uranium and other long-lived radionuclide, it was initially assumed that they are elements derived from pre-Earth matter. However, a comparative analysis of the global amount of alpha-emitting radio nuclides with the amount of radiogenic He-4 helium produced negates this hypothesis. According to Polański's calculations, the total amount of helium in the Earth's lithosphere and atmosphere corresponds to the production of alpha particles in a much shorter time than the age of the Earth. Calculations of the helium paradox contradict the idea that elements originated in the Big Bang.

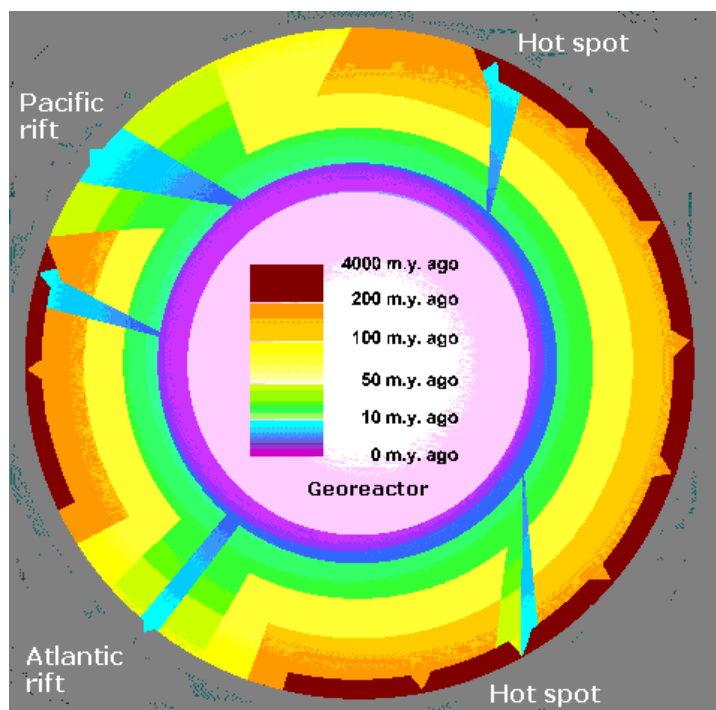
The view of the primordial origin of uranium stems from the failure to recognize that a thermonuclear reactor works in the core of the Earth. Assuming a closed cycle of matter, once produced primordial elements circulate in a closed cycle. Using the right to criticize, it can be stated that the Big Bang phenomenon, by introducing the laws of nature, does not fulfill them by itself. From the formal point of view, in accordance with the principles of scientific research, the condition for recognition of an experiment is its repeatability. In the case of the Big Bang, there is no repeatability. The reflection is that the Big Bang scenario is contrary to the laws of nature, moreover—it was not there at all.

A more convincing explanation of the origin of radionuclides is based on the theory of the natural forces of nature. At the outset, it should be stated that primary elements are formed in thermonuclear synthesis reactions. A hundred years ago this was proved by Eddington (1926) using the example of the sun. The theory of the primal forces of nature, i.e. the force of gravity, electromagnetic forces and nuclear forces proves, by analogy, the universality of the formation of spontaneous thermonuclear reactors (Pawuła, 2021a). The process of for-

mation of elemental uranium, and then the deposits of this element, is as follows. The preliminary stage is the production of hot plasma in the Earth's core (Figure 1). Activity in the Earth's core began about 4 billion years ago and remained latent until the beginning of the Paleozoic era. The expansion of the Earth, expressed by the ejection of hot plasma from the Earth's core into zone D (depth 2900 - 3000 km), began about 500 million years ago, when the first basalt rifts and traps appeared. The phenomenon of expansion and eruption of basalt magma was clearly revealed 280 millions ago, in the Lower Permian (Auntun). Since then, volcanic activity and the formation of basalt ocean plates have increased (Pawuła, 2021b, 2021c, 2021d)

Basalt magma flowing out of the rift zone is dated and geochronological studies of magma do not show the presence of older rocks. The oldest basalts in oceanic plates are dated at 180 million years. The half-life of uranium, thorium and K-40 potassium is longer than the age of the entire solar system, so the obtained results of the analyzes exclude the existence of convection cells and exclude plate subduction, suggested in the theory of plate tectonics. The results of U-Pb geochronological analyzes show zero age of ocean basalts at the place of their outflow, and thus contradict the views on the remelting of igneous rocks in the so-called convection cells. Earlier basalts from the Lower Permian period (approx. 280 million years have been preserved in the continental gangways) (Figure 1).

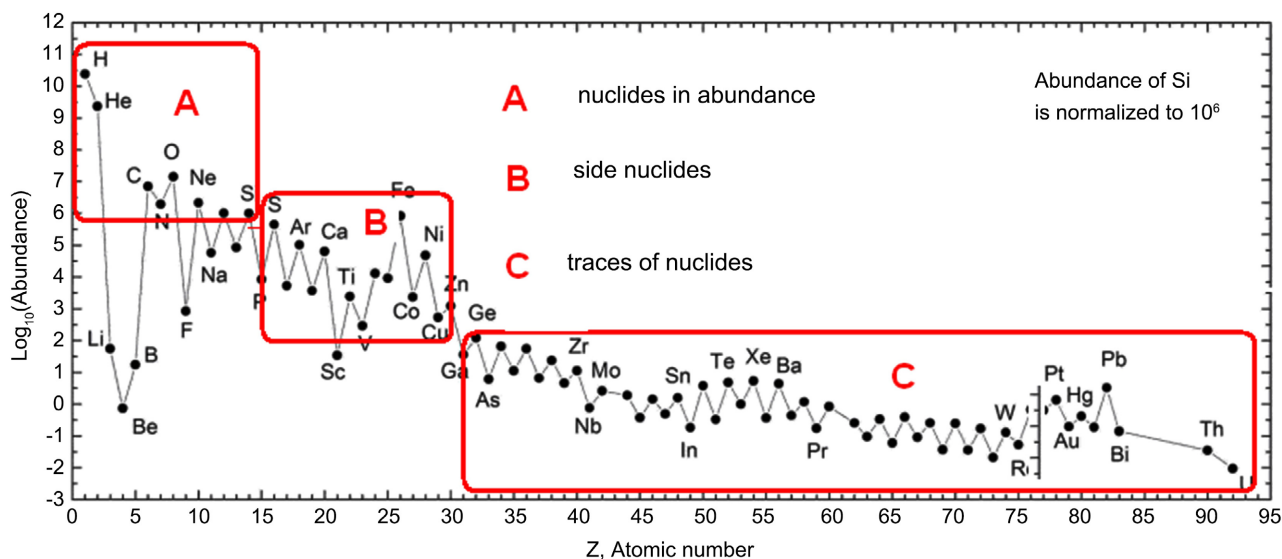
Basalt magma has an elemental composition similar to that of the plasma nuclide (Table 2, Figure 2). A characteristic phenomenon is the lack of hydrogen and oxygen elements in basalt, the nuclides of which dominate the composition



**Figure 1.** Mantle-growth zones and ocean plates (<https://www.nationalgeographic.org/tickets/events/>).

**Table 2.** Chemical composition of basalt rocks.

Main elements (8)	Minor elements (16)	Elements trace (46)
O, Si, Al, Fe, Ca, Mg, Na, K	Ti, Mn, P, S, F, Ba, Rb, C, Cl, Zr, Cr, Sr, V, Ni, Cu	Li, Be, B, N, Sc, Co, Zn, Ga, Ge, Nb, Mo, Pd, Ag, Cd, In, Sn, Sb, Te, J, Cs, La, Co, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, Hf, Ta, W, Re, Pt, Au, Hg, Tl, Pb, Bi, Th, U

**Figure 2.** The abundance of nuclides in the plasma of the universe.

of hot plasma. This phenomenon can be explained by the process of degassing the magma. The above picture is complemented by the phenomenon of differentiation of cooling basalt magma in the deep water conditions (Figure 3, Figure 4).

The process of the fusion reaction in the Earth's core is developmental, in the last 280 million years there has been an increase in the radius of the Earth, from 2800 to 6373 km. Two hundred and eighty million years ago, the volume of a small globe with a radius of 2800 km was  $9.2E+10 \text{ km}^3$ , currently at a radius of 6373 km it is  $1.08E+12 \text{ km}^3$ . Thus, there was a tenfold increase in the volume of the globe by  $9.88E+11 \text{ km}^3$ . It can therefore be concluded that the annual magma increment is  $3.53E+3 \text{ km}^3$ . Taking into account the uranium concentration in ocean basalt at 1 ppm, the global increase in uranium is estimated at 2.99 trillion tons. The average annual increase in uranium is thus over 10 million tone.

Under conditions of decreasing temperature, the components of the aid solutions react with each other and precipitate selectively. The zones of primary uranium occurrence result from the tendency of individual chemical compounds in which uranium is present to precipitate.

Uranium precipitates from the assisting solution in several stages:

- in the pegmatite-pneumatolite stage, in pegmatites, pegmatite sulphides and molybdenites, in the temperature range of  $550^\circ\text{C} - 800^\circ\text{C}$ ; which corresponds to a depth of 16 - 80 km;

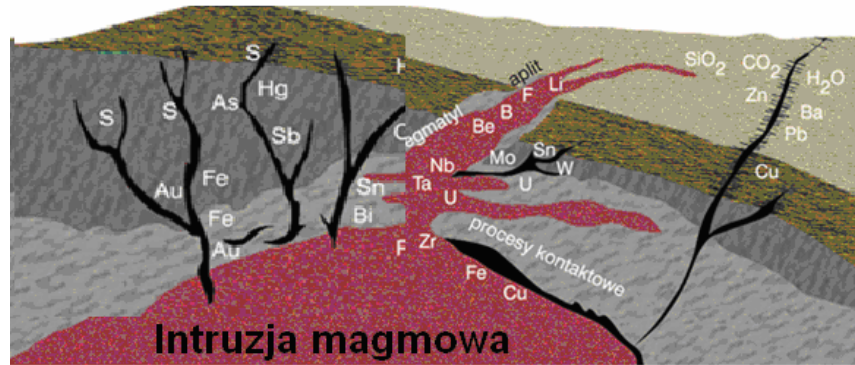


Figure 3. Igneous intrusion according to Fersman.

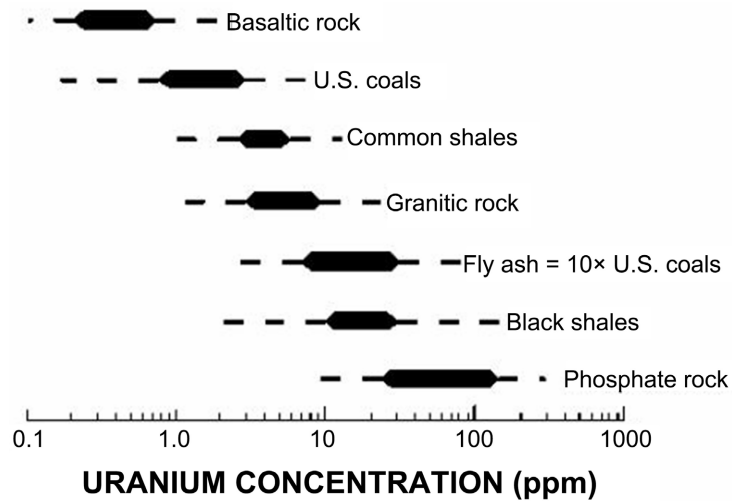


Figure 4. The phenomenon of increasing uranium concentration in rocks (source: <http://greenwood.cr.usgs.gov>).

- in the hydrothermal stage, in polymetallic and tourmaline-copper deposits, at a temperature of 200°C - 400°C; 6 - 12 km deep zone;
- in antimony-mercury deposits, at a temperature of 100°C - 150°C, which corresponds to a depth zone of 3 - 4.5 km;
- mercury preferably precipitates in the temperature range of 50°C - 100°C. At even lower temperature;
- below 50°C: phosphates, chlorides, copper, gold, as well as zinc and lead precipitate. All these elements and chemical compounds come from the basalt primordial, and that from the hot georeactor plasma.

Over the past 200 million years, the volume of the globe has increased tenfold, and surprisingly, without increasing the mass of the globe. The explanation for this paradox is the process of hot plasma recombination, i.e. the transformation of ionized matter into an atomic form. Plasma recombination is based on changing the electromagnetic properties of matter by attaching an electric charge to an ion. The electron mass in this reaction is negligibly small. Globally, basalt magma grows exponentially without increasing the mass of the globe (Pawuła, 2021c,

2021d). Of course there is an increase in the mass of the globe due to gravity, and this gain increases with the mass of the globe!

An important criterion for determining the origin of basalt as well as uranium  $^{238}\text{U}$  and thorium  $^{232}\text{Th}$  is determining the age of rocks using radiometric methods. Geochronological research is the “birth certificate” of the studied rocks. The age of the basalt that make up the oceanic plates ranges from 0 to 180 million years B.P. Basalt magma flowing out of the rift zone is dated and geochronological studies of magma do not show the presence of older rocks. The oldest basalts in oceanic plates are dated at 180 million years. The half-life of uranium, thorium and K-40 potassium is longer than the age of the entire solar system, so the obtained results of the analyzes exclude the existence of convection cells and exclude plate subduction, suggested in the theory of plate tectonics. The results of U-Pb geochronological analyzes show zero age of ocean basalts at the place of their outflow, and thus contradict the views on the remelting of igneous rocks in the so-called convection cells. Earlier basalts from the Lower Permian period (approx. 280 million years have been preserved in the continental gangways).

## 2. Phosphate Rock as a Raw Material for the Production of Phosphate Fertilizers

The main rock-forming mineral of phosphates is apatite, calcium phosphate  $\text{Ca}_3(\text{PO}_4)_2$ .

The phosphoresces also contain admixtures of other minerals: calcium carbonate, compounds of fluorine, silicon, magnesium, iron and aluminum, and metals such as cadmium, lead, arsenic, vanadium and uranium. Phosphate rock contains from 12% to 40% phosphate, expressed as  $\text{P}_2\text{O}_5$ . Phosphate rock, richer in phosphorus, is used to produce phosphoric acid and super phosphate. The technological process consists in treating the sparingly water-soluble calcium phosphate with sulfuric acid, as a result of which phosphoric acid and waste phosphogypsum are obtained. The final product of the processing of phosphoric acid is primarily superphosphate, which is a mixture of monocalcium phosphate and calcium sulphate. Phosphate rock less rich in phosphorus is used as a mineral fertilizer in the form of ground rock phosphate flour.

An example of health effects caused by radioactive elements in phosphate rock is the exploitation of phosphate deposits on the island of Nauru in the western part of the Pacific (Micronesia, **Figure 5**, **Figure 6**). It is a small volcanic island with an area of  $21.3 \text{ km}^2$  and one of the largest phosphate deposits. On the island of Nauru, intensive exploitation of the phosphate deposit has continued since the beginning of the 20th century. There are no pollutants on the island other than phosphorite radionuclides. There are grounds to conclude that natural radioactive elements found in phosphate rock cause the diabetes epidemic. Statistical data from 2003 inform that in Nauru the percentage of adults with diabetes was 30.2% and was the highest in the world.

When discussing the topic of geological radionuclides, it is necessary to call



**Figure 5.** The island of Nauru in the Pacific  
(<https://www.google.com/url?sa=i&url=https%3A%2F%2Fpl.wikipedia.org%2Fwiki%2FNauru>).



**Figure 6.** Nauru. Phosphate opencast mine  
(<https://cdn.britannica.com/24/197224-050-173CDEAB/mining-phosphate-deposits-Nauru.jpg>).

for serious consideration of their threat and take protective measures. For example, instead of importing uranium and radium contaminated phosphates and processing them into phosphorus fertilizers, basalt flour should be used for fertilization.

### **3. Presence of Radionuclides in Phosphates and Their Impact on the Environment**

In the rocks of the earth's crust there are radioactive elements of geological ori-



gin (**Table 3**). This mainly applies to radionuclides of the uranium-radium series and thorium series ( $^{223}\text{Th}$ ) and radioactive potassium  $^{40}\text{K}$ . On the other hand, derivatives in the  $^{232}\text{Th}$  pathway are elements characterized also by alpha, beta and gamma radiation:  $^{228}\text{Ra}$ ,  $^{228}\text{Ac}$ ,  $^{228}\text{Th}$ ,  $^{224}\text{Ra}$ ,  $^{220}\text{Rn}$ ,  $^{216}\text{Po}$ ,  $^{212}\text{Pb}$ ,  $^{212}\text{Bi}$ ,  $^{212}\text{Po}$ ,  $^{208}\text{Th}$ . The final stage of the track series is the stable lead isotope  $^{208}\text{Pb}$ . In addition to the radionuclides from the above-mentioned uranium-radium and thorium series, phosphorites contain the radioactive potassium isotope  $^{40}\text{K}$ , which is characterized by beta radiation emission and longevity, since its half-life is 1.3 billion years.

Particularly high concentrations of these elements occur in phosphate rock and production waste, in phosphogypsum. Relatively low concentrations of uranium and thorium are found in basalt.

A sample of phosphates imported from Algeria showed the presence of radionuclides from the uranium-radium series at the level of 413 - 491 Bq/kg, from the thorium series at the level of 50 - 53 Bq/kg and potassium at the level of 19 Bq/kg (**Table 4**).

**Table 3.** Radionuclide concentrations in rocks.

	Uranus nature. ppm	Rad Bq $^{226}\text{Ra}$ /kg	Thor Bq $^{228}\text{Th}$ /kg	Potassium Bq $^{40}\text{K}$ /kg
Basalt	0.4 - 4.4 (1)	11 (1)	25 (1)	-
Sand	0.45 (1)	2 - 17 (2)	1 - 76 (2)	34 - 466 (2)
Clay	1.8 (1)	22 - 161 (2)	25 - 127 (2)	161 - 939 (2)
Phosphogypsum	-	19 - 620 (2)	4 - 48 (2)	1 - 680 (2)
Phosphate rock	100 - 650 (1)	490 (3)	53 (3)	19 (3)

(1) Polański (1961): Geochemistry of isotopes. Geological Publishers, Warsaw, 1961; (2) Statistical Yearbook of the Central Statistical Office, Environmental Protection, Warsaw, 1994; (3) Depart. of Radiological Protection and Radiobiology, National Institute of Hygiene, Warsaw, 1997 (**Table 3**); (note: natural uranium composition: 99.28%  $^{238}\text{U}$ ; 0.715%  $^{235}\text{U}$ ; 0.0058%  $^{234}\text{U}$ ).

**Table 4.** Radiological analysis of Algerian phosphates\*.

Radionuclide	Measurement of activity [Bq/kg]
Radium $^{226}\text{Ra}$	491.31 +/- 5.0%
Lead $^{214}\text{Pb}$	413.68 +/- 2.9%
Bismuth $^{214}\text{Bi}$	413.76 +/- 5.0%
Thorium $^{232}\text{Th}$	52.36 +/- 3.6%
Actinium $^{228}\text{Ac}$	52.36 +/- 3.6%
Lead $^{212}\text{Pb}$	53.02 +/- 5.1%
Thallium $^{208}\text{Tl}$	50.20 +/- 5.4%
Potassium $^{40}\text{K}$	19.04 +/- 10.9%

\*Departement of Radiological Protection and Radiobiology, National Institute of Hygiene, Warsaw.

In phosphate rock, the radionuclides of these series are in radioactive equilibrium. The quantitative decrease in the uranium-radium series, of the order of 80 Bq/kg, results from the release of the gaseous radon  $^{222}\text{Rn}$  from the rock, which has a half-life of 3.8 days. In the case of the track series, a decrease in radion concentration below the gaseous radon  $^{220}\text{Rn}$  is observed, only in the order of 2 Bq/kg, because the half-life of this radon isotope is only 54.5 s (**Table 4**).

According to the observations of the Central Laboratory for Radiological Protection, the concentration of radioactive isotopes of geological origin in soils is quite varied. The concentration of  $^{226}\text{Ra}$  in most of the country's area is lower than 20 Bq/kg of soil. The lowest concentration of radium is 4.2 Bq/kg, and the highest - 124 Bq/kg. The concentration of lead  $^{210}\text{Pb}$  in the soil ranges from 7.9 to 91.2 Bq/kg, while the concentration of  $^{228}\text{Th}$  thorium ranges from 3.7 to 86 Bq/kg. The average post-Chernobyl contamination with cesium  $^{137}\text{Cs}$  in the soil, determined in 1990 in a 0 - 10 cm layer, was on average 4.72 kBq/m<sup>2</sup> and ranged from 0.76 to 54.5 kBq/m<sup>2</sup>, in 1996 the average soil contamination with this the radionuclide was lower (3.65 kBq/m<sup>2</sup>); the decrease in contamination was caused by radioactive decay of  $^{137}\text{Cs}$  and to some extent by its migration to deeper layers. The average contamination of  $^{134}\text{Cs}$  in soil in 1990 was 0.51 kBq/m<sup>2</sup>, with the range from 0.02 to 6.82 kBq/m<sup>2</sup> (Pietrzak-Flis, 1999).

It should be realized that the annual addition of mineral fertilizers to the soil causes a constant increase in the concentration of geological radionuclides. The phenomenon of accumulation of these elements in the soil results from their migration properties in the environment and their longevity. The half-life of primary radionuclides is:

Uranium  $^{238}\text{U}$ —4.51 billion years

Thorium  $^{232}\text{Th}$ —13.9 billion years

Potassium  $^{40}\text{K}$ —1.3 billion years

Research conducted in Germany (Rothamsted) showed that, as a result of the constant use of phosphorus fertilizers from 1843, in the annual dose of 75 kg  $\text{P}_2\text{O}_5$  per hectare, uranium accumulation in the soil up to the level of 1300 g  $^{238}\text{U}$  per hectare (Gassner & Grzebisz, 2003). Some of the radionuclides are washed out of the soil and transported to rivers, which was observed at the municipal water supply filter station in Poznań (**Table 5**) (Pawuła & Chudy, 2001). The other part of these elements remains in the soil, from where it is absorbed by the

**Table 5.** Radionuclides on water supply filters in Poznań (Bq/kg)\*.

Place of sampling	Service life of the deposit	Global beta activity	$^{40}\text{K}$	$^{137}\text{Cs}$	$^{226}\text{Ra}$	$^{228}\text{Th}$ ( $^{228}\text{Ac}$ )
filter 7	15 years	4492	2807	285	290	628
filter 9	15 years	5419	3540	359	274	803
filter 1	24 years	4992	3684	374	343	911
Reserve sand	0	192	109.3	7	61	32

\*Radiological protection division.

plant root system and goes to food products (Pietrzak-Flis, 1999).

Water supply filters show a particularly high concentration of radioactive potassium  $^{40}\text{K}$ , emitting beta radiation, as well as elements from the thorium and uranium-radium series. In addition, significant amounts of  $^{137}\text{Cs}$  cesium were found from the radioactive fallout after the Chernobyl disaster (1986).

An expert in the field of radiochemistry Z.P. Zagórski from the Institute of Nuclear Chemistry and Technology describes the phenomenon of the formation of “radon clouds” as an effect of sowing phosphorus fertilizers on farmland (Zagórski, 1997): “Particular attention is paid to the physicochemistry of radon release from the matrix, in the case of main and waste products of the large chemical industry. It is superphosphate, which contains the entire inventory of uranium, radium and radon, derived from apatites, which generally contain more uranium than the average content in the earth’s crust. Another object of interest is phosphogypsum, which may contain even more natural radionuclides. Some figures are important here. And so, the radon itself at the moment of its creation has a recoil energy of 86 eV (only because of its large mass). This energy is sufficient for a shift of only 30 nm in the plaster. No wonder that the emission of radon from such materials may constitute only 10% of its total content. The emission depends largely on the porosity, fineness and moisture of the joyful materials. Superphosphate is sown in the fields ‘with the benefit of the livestock’. It is no wonder then that with the onset of plant germination, which loosen the soil, radon ‘clouds’ begin to rise above the fields, which was found already in the times when radon was not considered a threat.” (Zagórski, 1997).

The release of uranium as a result of burning coals is estimated worldwide at 140 tons per year, the amount of uranium released into the environment through the use of phosphorus fertilizers is much higher. The process of coal combustion as well as the phosphorus and cement industries are among the main reasons for the increase in radium concentration in the natural environment. According to the research, as a result of global coal consumption, about 150 Ci of radium  $^{226}\text{Ra}$  are released into the air annually, while the phosphorus industry introduces 400 Ci of radium into the environment (Kabat-Pentias & Pentias, 1979).

(Explanation: activity units 1Ci =  $3.7 \times 10^{10}$  Bq; 1 Bq—1 radius decay/s).

#### 4. The Problem of Phosphogypsum

According to the data of the Central Statistical Office, the average concentration of indicator elements in phosphogypsum is: 109 Bq  $^{40}\text{K}$ /kg, 358 Bq  $^{226}\text{Ra}$ /kg and 15 Bq  $^{228}\text{Th}$ /kg (Statistical Yearbook, Environmental Protection, 1994). The resulting radioecological indexes f1 and f2 exceed the permissible limits for building materials. The maximum concentrations of these indicator radionuclides are, respectively: 680 Bq  $^{40}\text{K}$ /kg, 620 Bq  $^{226}\text{Ra}$ /kg and 48 Bq  $^{228}\text{Th}$ /kg. In relation to the tested sample of Algerian phosphates (Table 3), there is a similar concentration of radionuclides from the thorium series, a slightly higher concentration of radium and a very strong increase in the concentration of ra-

radioactive potassium.

The issue of environmental threats posed by heaps of phosphogypsum and various forms of their management is signaled in the quarterly “Polski Gips”; phosphogypsum is the result of the complex process of producing phosphoric acid from phosphate rock. There are trace amounts of radionuclides in the phosphate rock mined in opencast mines. The radiation emitted by these nuclides can be dangerous to human health and the environment. Chemical processes separate the radionuclides in such a way that the uranium remains in the phosphoric acid produced and the radium is transferred to the phosphogypsum. Radium and other elements remain out of balance. The use of products containing radium and derivative elements, which may cause contamination to groundwater, dispersal in the air, and accumulate in food products, is of particular concern to governmental agencies dealing with environmental protection. For every ton of phosphoric acid produced in this way, there is about 5 tons of phosphogypsum. The industrial use of the waste product—phosphogypsum, obtained in the process of obtaining pure phosphoric acid, is legally limited by government environmental protection agencies, mainly due to the presence of such impurities in the waste as radionuclides (radium 226 and radium 228). For this reason, phosphogypsum is stored in landfills in plants processing phosphate rock, and those commonly called “gypsum heaps” are only monitored for fear of contamination of groundwater and air. Any use of phosphogypsum must be reported to the national government agencies that issue the appropriate permits. This applies to both the use of phosphogypsum in agriculture and in other areas of the economy. After the review and revision of the limit value of the radiation index, the scope of application of phosphogypsum has been significantly expanded (*Industrial Use of Phosphogypsum, 2004*).

Examples of products in which phosphogypsum admixtures are already used are:

- agents for improving the properties of arable land;
- glass and ceramic products (e.g. roof tiles);
- road base materials;
- building materials (plasterboards);
- oyster growing medium.

It should be noted that there is a fundamental contradiction in the assessment of phosphogypsum. On the one hand, it is stated that there is a legal ban on the industrial use of phosphogypsum, and on the other hand, examples of the use of this phosphogypsum are given. A derogation from the original rule is “after a review and revision of the limit value of the radiation index”. This dichotomy emerged from the interpretation of the atomic law, which relativizes the environmental impact of elements of geological origin. Therefore, referring to the applicable law, an attempt is made not to count the radiation dose of radioactive elements of geological origin in the limit dose, even though they are introduced into the environment as a result of human economic activity. This delicate interpretive boundary consists in blurring the difference between the concepts—radiation

from radionuclides of natural origin and natural radiation.

## 5. The Problem of Ionizing Radiation Dose from Radionuclides Occurring in Phosphates and Phosphogypsum

Formally, the dose limit for the general population, expressed as the effective (equivalent) dose, is 1 mSv/year. The limiting dose is here defined as the maximum equivalent dose, above the natural background, at which the radiation exposure is considered to be safely low. With such a definition, there is a pretext to exclude from the calculation of the limit dose the influence of radioactive elements of geological origin. The criterion for taking into account or ignoring the dose of radiation from natural sources when calculating the dose limit lies in determining the role of humans.

In the act was introduced with the following wording:

- 1) The dose limits are the sum of doses from external and internal exposure.
- 2) Limit doses do not cover exposure to natural radiation, if the exposure has not been increased as a result of human activity, in particular, do not cover exposure to radon in residential buildings, from natural radionuclides contained in the human body, from cosmic rays at ground level, as well as above-ground exposure to radionuclides found in the intact earth's crust.

As there is an interaction of various sources of radiation, independent of human activity, such as cosmic radiation, radiation of ground rocks and X-ray diagnostics, the International Commission for Radiological Protection ICPR defined the so-called genetic dose at the level of 50 mSv/30 years, i.e. on average 1.67 mSv/year. The rationale for establishing the genetic dose is to reduce the mutational risk of the population in the reproductive period. This level of the received dose of ionizing radiation was determined in the 1950s, before the period of radioactive contamination in the atmosphere. In the 1990s, after the Chernobyl disaster, the average annual dose of ionizing radiation in Poland was estimated at 3.6 mSv. Part of the dose, about 0.9 mSv/year, is attributed to artificial radiation sources, and the rest (2.7 mSv/year) is attributed to natural radiation sources. Of course, among natural radioactive isotopes, radionuclides of geological origin are of great importance, but they are largely introduced into the environment as a result of the use of mineral fertilizers in agriculture. Therefore, this part of the radiation dose should not be treated as coming from natural sources.

The research carried out at the Central Laboratory for Radiological Protection showed that, in addition to  $^{40}\text{K}$  potassium, radionuclides from the uranium-radium and thorium series enter the human body with food, with the largest amounts related to the toxic derivatives of radium: lead  $^{210}\text{Pb}$  and polonium  $^{210}\text{Po}$  (**Table 6**).

The connection with soil fertilization is also related to the so-called supply of  $^{40}\text{K}$  natural potassium with food, which is estimated at about 50 kBq/year and which, as a consequence, causes the adoption of an average annual radiation dose of 0.25 mSv. On the other hand, the annual effective dose of radioisotopes from the uranium-radium and thorium series is additionally 0.09 mSv (**Table 7**).

Moreover, the dose of gaseous radon  $^{222}\text{Rn}$  and its derivatives, determined at 1.8 mSv/year (about 50% of the dose from all radiation sources), should be added to the radiation dose from the uranium-radium and thorium series radionuclides. The total average dose of radionuclides of geological origin is therefore over 2 mSv/year, i.e. exceeds the genetic dose and twice the limit dose!

## 6. Basalt Flour—An Alternative Mineral Fertilizer

High concentrations of radionuclides in phosphorites and in phosphorus fertilizers produced from them encourage the search for other, safer, mineral resources. An alternative to phosphate rock flour can be basalt flour, a waste material in basalt quarries [4].

Basalts, as already shown, contain relatively small amounts of radioactive elements and contain numerous mineral microelements that are beneficial for the metabolic processes of organisms. Obviously, the proportion of phosphates in the mineral composition of phosphates is high. The content of phosphates, calculated as  $\text{P}_2\text{O}_5$ , exceeds even 30% (Table 8). In basalt, the share of phosphates is much lower and in the tested samples it ranges from 0.8% to 1.31% (Table 9, Table 10), however, other beneficial minerals are present.

Among the trace elements found in basalt (Table 9), beneficial for the development of organisms, include trace elements, e.g. strontium, vanadium, chromium,

**Table 6.** Average annual uptake with food of natural radioactive isotopes (Bq) [5].

Izotope	$^{238}\text{U}$	$^{234}\text{U}$	$^{232}\text{Th}$	$^{230}\text{Th}$	$^{228}\text{Th}$	$^{226}\text{Ra}$	$^{210}\text{Pb}$	$^{210}\text{Po}$
Annual absorption	6.12	8.37	1.09	1.74	4.92	18.6	43.4	44.0

**Table 7.** Average annual effective doses from natural radioactive isotopes taken with food by adult inhabitants of Poland (microSv) [5].

Izotope	$^{238}\text{U}$	$^{234}\text{U}$	$^{232}\text{Th}$	$^{230}\text{Th}$	$^{228}\text{Th}$	$^{226}\text{Ra}$	$^{210}\text{Pb}$	$^{210}\text{Po}$	Suma
Effective dose	0.28	0.42	0.25	0.37	0.35	5.20	30.4	52.8	90.0

**Table 8.** Chemical composition of phosphate rock (%).

Ingredients	Kaurigha (Morocco)	Ain Dibba (Algeria)
$\text{Al}_2\text{O}_3$	0.09	
$\text{Fe}_2\text{O}_3$	0.30	1.95
CaO	52.60	50.17
MgO	0.58	
$\text{P}_2\text{O}_5$	34.80	32.22
$\text{CO}_2$	3.57	6.15
$\text{SO}_3$	1.65	1.54
F	2.92	2.80

Bolewski A., Turnau-Morawska M.: Petrografia, Wyd. Geologiczne, Warszawa, 1963.

**Table 9.** Mineral macronutrients of basalt (% by weight) (Dziedzic, 1993).

Basalt quarry	Granowskie Wzgórze	Sulików	Bogatynia	Bukowa Góra	Księginki
SiO <sub>2</sub>	49.90	40.77	40.51	41.22	42.41
TiO <sub>2</sub>	3.37	3.18	3.24	2.87	2.95
Al <sub>2</sub> O	12.42	13.91	11.51	12.17	11.87
Fe <sub>2</sub> O	1.66	1.65	1.58	1.58	1.55
FeO	10.97	10.93	10.51	10.48	10.33
MnO	0.17	0.22	0.23	0.17	0.17
MgO	11.59	8.52	12.67	13.34	11.58
CaO	13.25	14.10	14.32	12.95	12.41
Na <sub>2</sub> O	3.87	4.42	3.20	3.52	3.40
K <sub>2</sub> O	0.78	1.01	1.16	0.81	0.37
P <sub>2</sub> O <sub>5</sub>	1.03	1.31	1.07	0.88	0.80

**Table 10.** Mineral micronutrients of basalt (ppm) (Dziedzic, 1993).

Basalt quarry		Granowskie-wzgórze	Sulików	Bogatynia	Bukowa Góra	Księginki
Rubid	Rb	81	-	39	-	40
Bar	Ba	500	800	972	800	700
Niobium	Nb	82	-	-	-	62
Lantan	La	73	102	97	75	59
Cer	Ce	110	90	166	120	120
Stront	Sr	931	-	1206	-	721
Neodymium	Nd	70	80	72	60	50
Zircon	Zr	299	-	-	-	268
Itr	Y	32	-	-	-	17
Iterb	Yb	2	-	1.87	-	3
Skand	Sc	26	18	-	20	14
Vanadium	V	310	340	298	290	230
Chrom	Cr	300	200	446	500	400
Cobalt	Co	65	51	-	50	48
Nickel	Ni	220	90	262	500	340

cobalt and nickel [2]. On the other hand, in the basalt, no significant amounts of the harmful elements found in the phosphates—cadmium, lead and arsenic—were found. The beneficial properties of soils formed on weathered basalt are known from volcanic areas where human settlement persists despite the threat. Generally, volcanic soils are fertile and have a high humus content.

Basalt flour is not a complete substitute in mineral fertilizers. phosphorus The

content of phosphorus, expressed in  $P_2O_5$ , in phosphates is over 30%, while in basalt it is about 1% (**Table 8** and **Table 9**). However, basalt meal has many advantages that ultimately increase soil fertility and additionally reduce the radioactivity of the environment and agricultural products. The addition of basalt flour to sterilized soils causes remineralization of the soil substrate. It is enriched with trace elements, the presence of which in food is desirable, that is: Mn, Zn, Cu, Mo, B, Fe and Se. Their most important advantage is their non-toxicity, also for aquatic animals. The use of agents of this type regulates the mineral balance of the soil, increases the resistance of plants, positively influencing the development of the root network, allows to limit the amount of used fungicides, facilitates the continuous, even growth of plants, increasing the yield (Zagożdżon, 2008).

## 7. Conclusion

Natural radioactive elements, from the uranium-radium series and the thorium series, as well as K-40 radiopotass, occurring in phosphate rock, pose an ecological threat. The threat is all the more serious as it is cumulative and irreversible. Regarding the origin of these elements, it is legitimate to think about their formation in thermonuclear fusion reactions in the Earth's core. So it is wrong to think that uranium, thorium, and the radioactive potassium isotope come from primary lysis synthesis because they are formed by the recombination process of the hot georeactor plasma. The product of the recombination process is basalt magma, containing all nuclides, with the number from 1 to 92. A significant feature of basalt magma is the domination of protons and alpha particles and the trace presence of thorium and uranium nuclides. The consequence of plasma recombination is a change in the structure of matter, creating, in place of small atomic nuclei, huge atoms, elements that make up the basalt magma. Compared to plasma, the volume of magma increases billions of times, which causes a sharp increase in pressure and the uplift of overlying layers. Plasma discharges are variable, local and random within continental blocks, and global and regular in the ocean rift zone.

In the case of open fractures, basalt magma flows to the surface, where it degasses and forms basalt rock. The uranium content in basalt rock is the same as in magma, i.e. below 1 ppm. On the other hand, in the case of a closed fissure, there is an igneous intrusion, differentiation of magma and igneous solutions, as well as pegmatite crystallization and selective precipitation of salts and mineral compounds. For example, at temperatures below  $100^\circ\text{C}$ , uranium oxides  $UO_2$  precipitate together with the phosphorus compounds  $P_2O_5$ . Therefore, uranium occurs together with phosphates and the concentration of uranium in the phosphate deposit exceeds 200 ppm.

Heavy radionuclides from the uranium and thorium families as well as radioactive potassium get into the human environment through fossil raw materials, primarily in the chimney smoke and phosphorus fertilizers. The coal com-



bustion process and the phosphorus and cement industries are the main sources of radium in the natural environment. According to the research, as a result of the global consumption of coal, about 150 Ci of radium Ra-226 are released into the air annually. The phosphorus industry, which introduces 400 Ci of radium ( $1.48E+13$  Bq) into the environment, is an even greater threat.

The concept of purifying phosphates from radioactive elements is theoretically possible, but practically not feasible due to economic reasons and difficulties in removing uranium concentrates. As the use of phosphorus fertilizers may lead to the progressive degradation of soil and an increase in the radioactivity of the environment, their use as a mineral fertilizer should be abandoned. On the other hand, basalt flour, despite its low phosphorus content, should be treated as a valuable mineral fertilizer.

### Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

### References

- Czerny, J. (1995). The Issue of Self-Creation of Matter in the Light of Recentivistic Theory. *Folia Philosophica*, 13, 171-179.
- Dziedzic, K. (1993). Genesis and Differentiation of Neogene Basaltoid Magmas in the Sudetes. SW Poland Evidence from Trace Element Modeling. *Neues Jahrbuch für Geologie und Paläontologie—Monatshefte*, 1993, 1-15. <https://doi.org/10.1127/njgpm/1993/1993/1>
- Eddington, A. S. (1926). *The Internal Constitution of Stars*.
- Gassner, A., & Grzebisz, W. (2003). Phosphorus Fertilizers. *Journal of Elementology*, 8, 61-76.
- Hoyle, F., Gold, Th., & Bondi, H. (1948). *The Theory of the Stationary State Referring to the Copernican View of the Eternal and Infinite Universe*.
- Industrial Use of Phosphogypsum (2004) *Quarterly of the Polish Gypsum Association-Polish Gypsum*, March 2004.
- Jarczyk, L. (2007). *The Formation of Elements in the Universe* (pp. 16-27). Foton 98, Institute of Physics of the Jagiellonian University.
- Kabat-Pentias, A., & Pentias, H. (1979). *Trace Elements in the Biological Environment*. Geological Publishing House.
- Pawuła, A. (2021a). The Phenomenon of a Natural Thermonuclear Reactor. *Journal of Geoscience and Environment Protection*, 9, 92-109. <https://doi.org/10.4236/gep.2021.92006>
- Pawuła, A. (2021b). The Problem of Natural Radioactive Elements. *Journal of Geoscience and Environment Protection*, 9, 176-194. <https://doi.org/10.4236/gep.2021.94011>
- Pawuła, A. (2021c). Volcanism and Earthquakes—Polemical Notes on Mantle Plumes. *Journal of Geoscience and Environment Protection*, 9, 96-110. <https://doi.org/10.4236/gep.2021.98006>
- Pawuła, A. (2021d). *Georadiation*. Lambert Academic Publishing. <https://www.lap-publishing.com/catalog/details//store/gb/book/978-620-3-85657-6/geo>

[radiation](#)

- Pawuła, A., & Chudy, R. (2001). *Radionuclides of Geological Origin on the Infiltration Intake in Poznań* (pp. 10-22). Polish Geological Society-Institute of Geology, UAM University, Papers.
- Pietrzak-Flis, Z. (1999). *Radioactive Contamination of the Environment and Man in Poland*. Department of Radiation Hygiene CLOR, Materials: Congress of Polish Physicists.
- Polański, A. (1961). *Geochemistry of Isotopes*. Geological Publishers.
- Statistical Yearbook, Environmental Protection (1994). Central Statistical Office, Warsaw.
- Zagórski, Z. P. (1997). Radon—A Glance at the Whole Issue. In *Conference Materials "Radon-Occurrence and Consequences"* (pp. 82-103). XVII Autumn School of the Polish Society for Radiation Research Maria Skłodowska-Curie.
- Zagożdżon, P. P. (2008). *Basalt Meals in Agricultural and Related Applications*. Scientific Works of the Mining Institute of the Wrocław University of Technology, No. 123, Studies and Materials No. 34.