

RADIONUCLIDES AND WIND EROSIONMücahit KARAOĞLU¹

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ABSTRACT

Wind erosion is effective on 500 million ha of land in arid and semi-arid regions where annual precipitation is less than 500 mm such as Aralık-Iğdir, Turkey; whereas, both naturally and artificially radionuclides are almost spread over the whole earth. Humankind inevitably encountered radionuclides in July, 1945 when nuclear era started by tentatively making burst a blast in New Mexico, USA. Creep, saltation, and suspension are three different effects of wind erosion on soils. Quite small particles (<100 µm) are transported over a great distance and kept aloft for a long time. Radionuclides are also moved and carried away as soil-bonded ones and radioactive aerosols due to wind erosion caused by strong winds. This fact is evaluated as different by each science. Some radionuclide movements are an important method for exploring soil redistribution by wind due to their strongly adsorbing to soil particles. Although ¹³⁷Cs is the most commonly preferred anthropogenic radioisotope used to assess soil redistribution rates, ²³⁹⁺²⁴⁰Pu has been recently started to be used as a tracer. I want to emphasize that wind erosion area of Aralık-Iğdir, Turkey is waiting to be explored.

Key words: Radionuclides, Half-life, wind erosion, ¹³⁷Cs and ²³⁹⁺²⁴⁰Pu, wind erosion area of Aralık-Iğdir, Turkey.

RADYONÜKLİTLER VE RÜZGAR EROZYONU**ÖZET**

Rüzgar erozyonu, Iğdır-Aralık örneğinde olduğu gibi, yıllık yağışı 500 mm den düşükolan, 500 milyon hektara yayılan kurak ve yarı kurak bölgelerde etkilidir. İz elementleri ve izotopları dünyanın her bölgesine yayılmış durumdadır. İnsanlık 1945 yılında New Mexico, ABD’de gerçekleştirilen ilk nükleer deneme sonucunda nükleer çağ ile tanışmıştır. Sürüklenme, sıçrama ve havada asılı kalma rüzgar erozyonunun topraklar üzerindeki üç farklı etkisidir. 100 µm den daha küçük toprak parçacıkları ve bunlara bağlanmış iz elementleri çok uzak mesafelere taşınmaktadır. Bu olaylar farklı bilim dalları tarafından farklı bir şekilde değerlendirilir. Bazı iz elementlerinin hareketleri rüzgarla yer değiştiren toprak parçacıklarının izlenmesinde önemli bir katkı sağlamaktadır. ¹³⁷Cs, yer değiştiren toprak parçacıklarının izlenmesinde en yaygın kullanılan insan yapımı radyoizotop olmasına rağmen, ²³⁹⁺²⁴⁰Pu son zamanlarda kullanılmaya başlanan bir iz elementidir. Bu çalışmada Aralık-Iğdir-Türkiye’deki rüzgar erozyon sahasına vurgu yapılmıştır.

Key words: Radyonüklitler, yarı ömür, rüzgar erozyonu, ¹³⁷Cs ve ²³⁹⁺²⁴⁰Pu, Aralık-Iğdır, Türkiye rüzgar erozyon sahası.

INTRODUCTION

Radionuclides

A **nuclide** is a general term applicable to all atomic forms of an element. Nuclides are characterized by the number of protons and neutrons in the nucleus, as well as by the amount of energy contained within the atom. A **radionuclide** is an atom that has excess nuclear energy, making it unstable. This excess energy can either create and emit from the new radiation (gamma radiation), or a new particle (alpha particle or beta particle); or this excess energy can be transferred to one of its electrons, causing it to be ejected (conversion electron). During this process, the radionuclide is said to undergo radioactive decay (Petrucci et al., 2002). These emissions constitute ionizing radiation. The unstable nucleus is more stable following the emission, but sometimes it further decays. Radioactive decay is a random process at the level of single atoms: it is impossible to predict when one particular atom will decay (Best et al., 2013; Stabin, 2007; Loveland et al., 2006). All chemical elements have radionuclides. Even the lightest element, hydrogen has a well-known radionuclide, tritium. Elements heavier than lead, and the other elements such as, technetium and promethium, exist only as radionuclides. Radionuclides both occur naturally and are artificially made by using nuclear reactors, cyclotrons, particle accelerators or radionuclide generators.

Half-life ($t_{1/2}$) is the amount of time required for the amount of something to fall to half its initial value. The term is very commonly used in nuclear physics to describe how quickly unstable atoms undergo radioactive decay, but it is also used more generally for discussing any type of exponential decay. The original term, dating back to Ernest Rutherford's discovery of the principle in 1907, was "half-life period", which was shortened to "half-life" in the early 1950s (Ayto, 1989). There are about 650 radionuclides with half-lives longer than 60 minute. More than 2400 radionuclides have half-lives less than 60 minutes. Most of these are only produced artificially, and have very short half-lives. Table 1 illustrates some of long-lived radionuclides, and their half-lives and radiation types.

Table 1. Some long-lived radionuclides and their characteristics.

Isotope	Half-life	Radiation types
⁹⁰ Strontium	28.9 years	Beta
¹³⁷ Caesium	30.1 years	Gamma & beta
²⁴¹ Americium	432.2 years	Gamma & alpha
²³⁸ Uranium	4.468 x 10 ⁹ years	Alpha
²³⁸ Pulitonium	87.7 years	Alpha
²³⁹ Pulitonium	24110 years	Alpha
²⁴⁰ Pulitonium	6563 years	Alpha
²²⁶ Radyum	1600 years	Alpha
¹²⁹ Iodine	1.6x10 ⁷ years	Gamma & beta
¹⁴ Carbon	5730 years	Beta

The fallout of anthropogenic nuclides

The fallout of anthropogenic radioisotopes dates back to July, 1945 (Van Pelt, 2013). In that date, a blast was made burst in a desert in the New Mexico, USA. Shortly after this explosion, the other two atomic bombs were thrown to Japan. The other nations, including the USSR, Great

Britain, and France, had developed nuclear weapons in the 1950s. The fallout of anthropogenic radioisotopes deposited and peaked from 1963 to 1964.

As nations competed to improve nuclear weapons, their testing and atmospheric fallout of radioactive fuel and daughter products increased (Robbins, 1985). Except for a few explosions in the Southern Hemisphere by France and Great Britain, almost all atmospheric testings were performed between 10° and 80° North latitude. As the weapons' technology was perfected, the nations exploded most of the bombs at altitude to decrease local fallout contamination, resulting in stratospheric pollutants that turned the globe a few times allowing for the short-lived very radioactive species' decay before fallout took place (Simon et al., 2004).

The chain reaction of atomic nuclei fission caused bomb power and in addition to unused nuclear fuel, many other fission daughter products were generated which are distributed with the prevailing wind until they settle to the earth (Hala and Navratil, 2003). A few anthropogenic radioisotopes were longer lived and settled back to earth near and downwind of the blast sites, especially for low altitude explosions (Saito-Kokubu et al., 2007; Simon et al., 2004). The ^{137}Cs and $^{239+240}\text{Pu}$ were met in layers of arctic ice deposited in 1945 (Kudo et al., 1998).

Little amounts of ^{239}Pu happen in nature as a result of neutron capture processes prevalent in aged uranium ores (Wilcken et al., 2008). Pu is created artificially from ^{238}U in high neutron flux environments such as breeder reactors or nuclear explosions (Hala and Navratil, 2003) and these technologies were present only in the 1940s (Van Pelt and Ketterer, 2013). The fissionable material in newer-design weapons is primarily ^{239}Pu with a $^{240}\text{Pu}/^{239}\text{Pu}$ of ~0.06 (Parekh et al., 2006). During the nuclear era, some of Pu was released into the atmosphere. In H-bomb tests, using Pu-containing fission devices to initiate a fusion bomb, some of the ^{239}Pu and ^{240}Pu were converted into heavier isotopes (Kelley et al., 1999).

Table 2. Fission processes and principal radionuclides.
(After Hala and Navratil, 2003)

Elapsed time	Principal radionuclides
Fission	
Immediately after	^{131}I and ^{140}Ba (short-lived)
A few months later	^{141}Ce , ^{95}Zr , ^{95}Nd , and ^{89}Sr
2-3 years later	^{144}Ce , ^{144}Pr , ^{106}Ru , ^{106}Rh , and ^{147}Pr
A few years later	^{238}U , $^{239+240}\text{Pu}$, ^{90}Sr , ^{129}I , and ^{137}Cs

*I: iodine; Ba: barium; Ce: cerium; Zr: zirconium;
Nd: neodymium; Sr: strontium; Pr: praseodymium;
Ru: rubidium; Rh: rhodium; U: uranium; Pu: plutonium;
Cs: cesium.*

RADIONUCLIDES AND ENVIRONMENT

Anthropogenic radionuclides have been radiated globally due to nuclear guns testing, nuclear accidents, nuclear guns fabrication, and nuclear fuel reprocessing (Alewell et al., 2014). Depending on differences in half-lives of radionuclides, their environmental fate differs from each other. Table 2 illustrates activities of radionuclides after a fission event.

Owing to its ability to substitute for calcium in biological systems and its potential incorporation into bone tissue, ^{90}Sr was the radioisotope of interest in many of the early nuclear waste distribution studies (Ballantyne, 1961). ^{90}Sr is a biological counterpart for Ca, is picked up by plants through the roots, and takes part in the food chain (Haghiri, 1964; Mouat, 1960; Vose and Koontz, 1960). Contrarily, ^{137}Cs is not easily received by plant roots and only joins in the food chain when rain splash or wind erosion causes soil particles to become bonded to the edible plant (Muminov et al., 2010).

Isotopes of Pu are bound to soil particles (Beasley et al., 1998; Litaor and Ibrahim, 1996) and carried mainly by physical processes such as erosion (Ketterer et al., 2011; Everett et al., 2008; Ketterer et al., 2004). Global fallout $^{240}\text{Pu}/^{239}\text{Pu}$ ratio is 0.18. The plutonium isotopic ratio data provides possibility to assume if plutonium found in environmental samples has originated from atomic energy plants or global fallout (Matsunami et al., 1988).

^{90}Sr and ^{137}Cs are also bonded firmly to soil particles (Bihari and Dezso, 2008; Bossew et al., 2007; Quang et al., 2004) and soil organic matter. There is a very strong correlation between ^{137}Cs and soil organic matter used to trace soil organic matter on the landscape (Ritchie et al., 2007; McCarty and Ritchie, 2002).

Long-lived radionuclides like ^{137}Cs are lustily sucked to the soil particles met near the surface of the soil profile. The activities of radionuclides reduce logarithmically with depth (Osaki et al., 2007; Al-Masri, 2006; Whicker and Ibrahim, 2006; Sigurgeisson et al., 2005).

WIND EROSION

Wind erosion often accelerated by human activities such as overgrazing (Muminov et al., 2010; Neff et al., 2005), tith (Sharratt et al., 2010), building (Keating, 2003), and recreation (Goossens and Buck, 2009) is a soil degrading process. Wind erosion transports the finer, more chemically active, and nutrient rich portion of the soil (Van Pelt and Zobeck, 2007; Zobeck and Fryrear, 1986) and may unfavorably influence soil water dynamics (Lyles and Tatarko, 1986). Wind erosion does harm crops through sandblast injury (Baker, 2007) and dust deposition (Farmer, 1983). Wind erosion causes fugitive dust spreading that unfavorably affects air quality (Sharratt and Lauer, 2006).

Wind erosion is the drift and current of individual soil particles or small aggregates by strong wind that is approximately parallel to the soil surface (Bagnold, 1941). Wind erosion does not act with gravity in a presumable direction like water and tillage erosion and sediments may actually go back to their point of origin on the landscape because the wind might blow from any direction. Mostly, coarse-grained to medium sediments collect in nearby aerodynamically rough areas in leeward of the source field (Hagen et al., 2007) and the fine fugitive dust, which is the most common indication of wind erosion, disappears from the source soil and is transported to long distances before going back to earth (Pye, 1987).

Direct measurements of wind erosion take a long time because of its large temporal and spatial variability (Chappell, 1999). Wind speeds and directions surge on scales of seconds for separate incidents and the number of erosive events changes between months and years (Van Pelt, 2013). And furthermore, unlike measurements of water erosion, sediment cannot be gathered at a single point because the wind may blow from different directions, particles driven by the wind

happen at many heights above the ground, and the area of particle origin cannot be described (Stroosnijder, 2005). This requires the gathering of a large number of spatially distributed samples on a frequent basis (Chappell et al., 2003).

USING OF RADIONUCLIDES IN WIND EROSION STUDIES

Radionuclides such as constantly replenished cosmogenic ones that are created in the atmosphere by ionizing solar radiation and settled to the surface as dust or in downfall, or anthropogenic radionuclides are utilized to calculate erosion rates. Beryllium-7 (^7Be) and excess lead-210 (^{210}Pb) are the most commonly used cosmogenic radionuclides, and their timescales are weeks (event based) for ^7Be and approximately 100 years for excess ^{210}Pb (Muminov et al., 2010).

Many of radionuclides are strongly adsorbed to soil particles and their behavior on the landscape is a powerful method for investigating soil redistribution by wind, water, and tillage. ^{137}Cs is the most commonly used radionuclide to detect soil redistribution rates (Van Pelt, 2013). Unfortunately, the release of ^{137}Cs from local/regional sources such as the 1986 Chernobyl accident makes the practice of ^{137}Cs difficult in soil erosion studies in many locations around the world. In addition, on account of the 30.2 year half-life of ^{137}Cs , the reserves may be below useful detection limits in a very short time. If this technique is useful in erosion and deposition research, another similar radionuclide must be identified (Van Pelt and Ketterer, 2013).

Due to ^{239}Pu and ^{240}Pu having half-lives of 24110 and 6563 years respectively (Hala and Navratil, 2003), they might be ideal alternate to future studies for investigating soil redistribution by all erosive forces in nature and modern agricultural production (Van Pelt and Ketterer, 2013). ^{239}Pu and ^{240}Pu are mostly evaluated as a sum of activities and written as $^{239+240}\text{Pu}$ since these isotopes are unresolved in conventional alpha spectrometry (Vajda and Kim, 2010).

QUANTIFYING METHODS OF SOIL-BOUND RADIONUCLIDES

To exemplify with split-spoon coring devices that get undisturbed fillings, the filling may be divided at chosen depths and the separate depth samples from multiple fillings composite for gamma spectrometry (de Jong et al., 1982). So as to quantify the redistribution of radionuclides, the soil profiles must be illustrated at various locations on the landscape (Walling, 1998; Ritchie and McHenry, 1990).

In the laboratory, a 100–1000 g dry soil sample is placed in a Marinelli beaker, and the activity measured most commonly in a gamma spectrometer with Germanium detector coupled with a multi-channel analyzer. Generally, ^{137}Cs activity is estimated using 662 keV terminal (Alewell et al., 2014; Van Pelt and Ketterer, 2013; Muminov et al., 2010; Schuller et al., 2007; Wallbrink and Murray, 1996; Ritchie and McHenry, 1990; Murray et al., 1987).

The circulation of the radionuclide with depth is important data for undisturbed soils. In some cases, large holes have been dug and samples are taken from separate depths along the pit wall (Ritchie et al., 2003). In situ measurements of ^{137}Cs activity have been made by using a field portable gamma detector (Funk et al., 2011). A few different mass spectrometric techniques, especially AMS (accelerator mass spectrometry) and ICPMS (inductively coupled plasma mass spectrometry), present important advantages vs. alpha spectrometry in the definition of Pu isotopes. These methods, especially ICPMS, are convenient for usage in erosion/deposition studies and give some advantages (Van Pelt and Ketterer, 2013).

ARALIK-IGDIR, TURKEY WIND EROSION AREA

The second largest wind erosion area of Aralik-Igdir is located in eastern part of Turkey, and has boundaries with Armenia, Nakhichevan and Iran. It has a considerably high erosion potential,

in which the percentage of aggregates, whose diameter is larger than 0.84 mm, is 0.48-30.47% by using vibratory sieve shaker, and estimated soil loss is between 0-48.18 t ha⁻¹y⁻¹ by using wind erosion equation (Karaoglu et al., 2017).

According to Thorntwaite method, there was no excess water in the wind erosion area. The water deficit and potential evapotranspiration values were found as 553.7 and 718.6 mm, respectively. The water deficit was present from June to October and the most powerful winds happened from June to September (Karaoglu, 2012).

One Russian VVER-440 nuclear power plant operates at Metsamor, 36 km from the capital Yerevan, 16 km from border of Turkey, 26 km from Iğdir city, and 48 km from wind erosion area. It lies near earthquake-prone terrain. It was closed due to the 1988 earthquake in Armenia and reopened in 1993. There have been occurring more than one hundred accidents there up to now.

CONCLUSIONS

In wind erosion studies, it is an important redistribution indicator that some radio isotopes strongly adsorb to soil particles and move together. The foremost radionuclide is ¹³⁷Cs about this subject, and has been researched for years. Some recent studies put forth that radio isotopes ²³⁹Pu and ²⁴⁰Pu can be successfully used. Since they have longer lived than ¹³⁷Cs, it is thought that results belonging to Pu isotopes will be consistent. Direct measurements of wind erosion are unachievable up to now and determining of radionuclides in wind erosion area of Aralık-Iğdir will be useful.

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