

Estimation of Radioactivity Caused by Chemical Fertilizers on Trakya Sub-Region Soils and Its Potential Risk on Ecosystem

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ABSTRACT

Exposure to terrestrial radioactivity depends primarily on geological conditions and soil types. Phosphate, nitrogen and potassium fertilizers, which are used predominantly in order to increase crops in agriculture, provide basic nutrients to plants. Radionuclides in phosphate fertilizer belonging to ²³²Th and ²³⁸U from phosphate rocks series as well as radioisotope of potassium (⁴⁰K) are the major contributors of outdoor terrestrial natural radiation. The plants take some fractions of radioactivity and radionuclides enter the food chain in this way. Trakya sub-region, located in northwestern Turkey, constitutes one of the significant agricultural centers, 65% of this area is used for agricultural purposes. This is the region which uses the most fertilizer per unit area, with an average of 145 kg per hectare and approximately 20% of the fertilizer consumed in Turkey is used in the region. The main objective of this study is to evaluate Trakya Sub-region from the point of potential environmental effects of radionuclides which may be caused by phosphate fertilizers used in agricultural areas. For this purpose, it is aimed to determine the priority areas for the monitoring studies by analyzing the results of the use of temporal and spatial fertilizers and the studies performed in the region.

Keywords: Radioactivity, chemical fertilizers, Trakya Sub-region, soil

1. Introduction

During the four decades agricultural activities have expanded widely, resulting in an increase in the applications of the different chemical fertilizers. Fertilization increases efficiency and obtains better quality of product recovery in agricultural activities. More than 30 million tons of phosphate fertilizers are annually consumed worldwide, which increase crop production and land reclamation. Chemical fertilizers are chemical compounds that provide necessary chemical elements and nutrients to the plants and mainly contain phosphate, nitrate, ammonium and potassium salts. Phosphate rocks together with potassium ores and nitrogenous compounds are the main raw materials used for fertilizers in industrial production. Agro-chemical-based intensive agriculture has contributed substantially to the emission of the very powerful greenhouse gases CH₄ and N₂O, and the entry of pollutants (excessive nitrogen and phosphorus, pesticide, heavy metals and radioactive materials) into water bodies and soils (Jankovic, et al., 2013) (Uosif, Mostafa, Elsaman, & Moustafa, 2014) (Bayrak Yılmaz, Atik, & Sivri, 2017). These pollutants have adverse effects on environmental quality and public health.

1.1 Natural Radioactivity

Radioactivity is the emission of alpha (α) and beta (β) particles as well as gamma (γ) radiation from the unstable isotopes. Long-live radioactive elements such as uranium

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(^{238}U), thorium (^{232}Th) and potassium (^{40}K) and any of their decay products, such as radium and radon are examples of naturally occurring radioactive materials (NORM) (Gaafar, El-Shershaby, Zeidan, & ayed El-Ahll, 2016) (Hassan, Mansour, Fayez-Hassan, & Sedqy, 2016) (Zaim. & Atlas, 2016). Natural radioactivity is wide spread in the Earth's environment and it exists in various geological formations like soils, rocks, plants, sand, water, air and building materials. Hence, humans should beware of their natural environment with regard to the radiation health effects (chronic lung diseases, cancers etc.) (Mir & Rather, 2015).

Radioactivity is a normal constituent of the earth's crust. Natural radioactive nuclei are found in high concentrations in volcanic, phosphate, granite and salt rocks. The natural radionuclides which are very long half-life and have been on the earth for billions of years such as ^{238}U , ^{232}Th , ^{40}K which are involved in the soil due to the disintegration of these rocks cause the soil to be radioactive. Main primordial nuclides and mean occurrence in earth crust is shown in Table 1.

Table 1. Main primordial nuclides and mean occurrence in earth crust (Scholten & Timmermans, 1996)

Nuclide	Half-life in billions of years	Mean concentration in earth crust (Bq/kg)
^{238}U	4.47	25
^{232}Th	12.4	25
^{40}K	1.28	370

The natural radioactivity in phosphate rock depends on its origin. In sedimentary rock it is much higher than in volcanic rock. Granite rocks contain thorium in significant quantities. The main producers of phosphate rock are China, Morocco, Russia and the United States. The radionuclide activity values differed among the districts, depending upon the geographic structures, rainfall amounts, and elevations of the districts. Some typical values of activity concentrations in phosphate rock is shown in Table 2. One reason for the increase in natural radiation is the chemical fertilizers used in agriculture (Scholten & Timmermans, 1996) (Alam, ve diğerleri, 1997) (Saleh, Hafez, Elanany, Motaweh, & Naim, 2007) (Ghosh, Deb, Bera, Sengupta, & Patra, 2008) (Hussain & Hussain, 2011) (Gönen, 2012) (Thabayneh & Jazzar, 2012) (Jankovic, et al., 2013) (Mir & Rather, 2015) (Durusoy & Yildirim, 2017). Variation of uranium contents in different rocks is attributed mainly to different rock types depending on its geographical and geological origin, age of the rocks, and uranium mobility (Ghosh, Deb, Bera, Sengupta, & Patra, 2008).

Table 2. Some typical values of activity concentrations (Bq/kg) in phosphate rock (Sahu, Ajmal, Bhangare, Tiwari, & Pandit, 2014)

Location	^{226}Ra	^{238}U	^{232}Th	^{40}K
Morocco	1600	1700	10	20
Togo	1100	1300	30	4
Western Sahara	900	900	7	30
Syria	300	1000	2	-
Usa	1600	1500	20	-
Tunisia	800	1000	20	30
India	1290	1340	90	10

1.2 Radioactivity in Fertilizers

In order to reach high agricultural productivity, the present practice of replacing nutrients in soils is by supplying substances and this is done by the application of chemical fertilizers. More than 100 different combinations of fertilizers are available in the market with varying concentrations of nitrogen, phosphorus, and potassium (NPK), mostly compounds commercially named MAP (Mono Ammonium Phosphate) and Urea (46% Urea Nitrogen) (Bramki, Ramdhane, & Benrachi, 2018). In NPK fertilizers, gamma activity shows a wide variation because of the difference in the factories of manufactured fertilizers and the difference in the places from which the raw minerals for manufacturing the fertilizers were taken (Hussain & Hussain, 2011).

Phosphate rocks are largely used for the production of phosphoric acid, fertilizers and gypsum (Alam, ve diğerleri, 1997) (Jankovic, et al., 2013) (Sahu, Ajmal, Bhangare, Tiwari, & Pandit, 2014). Phosphate ores typically contain about 1500 Bq/kg of uranium and radium, although some phosphates contain up to 20000 Bq/kg of U_3O_8 . In general, phosphate ores of sedimentary origin have higher concentrations of radionuclides of the uranium family. In 90% of cases, the ore is treated with sulfuric acid. The fertilizers become somewhat enriched in uranium (up to 150% relative to the ore), while 80% of the ^{226}Ra , 30% of ^{232}Th and 5% of uranium are left in phosphogypsum (Alam, ve diğerleri, 1997) (Gaafar, El-Shershaby, Zeidan, & ayed El-Ahll, 2016). Phosphoric acid is the starting material for TSP and ammonium phosphate fertilizers. Some typical values of activity concentrations in fertilizers is shown in Table 3.

Table 3. Some typical values of activity concentrations (Bq/kg) in fertilizers in the World

Location	Reference	^{226}Ra	^{238}U	^{232}Th	^{40}K
Bangladesh	(Alam, ve diğerleri, 1997)	5-329		3-22	8-12628
Iraq	(Hussain & Hussain, 2011)		13-89	1-27	12-2276
Saudi Arabia	(Alharbi, 2013)	64		17	2453
India	(Shahul Hameed, Sankaran Pillai, & Mathiyarasu, 2014)		2-396	5-39	33-93
Egypt	(Uosif, Mostafa, Elsaman, & Moustafa, 2014)	12-244		3-99	109-670
Serbia	(Jankovic, et al., 2013)	87	220		4860
Croatia	(Barišić, Lulić, & Miletić, 1992)	75	120		
Egypt		301		24	3
Egypt	(Ghosh, Deb, Bera, Sengupta, & Patra, 2008)			125-239	446-882
Egypt		366		67	4

Phosphogypsum is a waste by-product from the processing of phosphate rock by the “wet acid method” of fertilizer production, which currently accounts for over 90% of phosphoric acid production. The wet process is economic but generates a large amount of phosphogypsum (5 tons of phosphogypsum per ton of phosphoric acid produced). World phosphogypsum production is variously estimated to be around 100-280 mega tonnes per year. The nature and characteristics of the resulting phosphogypsum are strongly influenced by the phosphate ore composition and quality. Wet processing causes the selective separation and concentration of naturally occurring radium, uranium and thorium: about 80-90% of ^{226}Ra is concentrated in phosphogypsum while nearly 86% of U and 70% of Th end up in the phosphoric acid. The discharge of phosphogypsum on earth surface deposits is a potential source of enhanced natural radiation and heavy

metals, and the resulting environmental impact should be considered carefully to ensure safety and compliance with environmental regulations. The radionuclide ^{226}Ra produces radon gas (^{222}Rn), which has a short half-life of 3.8 days, an intense radiation capacity, and causes significant damage to internal organs. For this reason the United States Environmental Protection Agency (USEPA) has classified phosphogypsum and rock phosphate as “Technologically Enhanced Naturally Occurring Radioactive Materials” (TENORM) and phosphogypsum exceeding 370 Bq/kg of radioactivity has been banned from all uses by the EPA since 1992. Depending on the quality of the rock source, phosphogypsum can contain as much as 60 times the levels normally found prior to processing (Alam, ve diğerleri, 1997) (Sahu, Ajmal, Bhangare, Tiwari, & Pandit, 2014). It is estimated that approximately 9–22 million tons of uranium could be recovered from the total phosphate rock deposits which may control substantially the price of the uranium in the market. However, conventional technology is not economical to recover uranium from the phosphate rock sources (Gupta, Chatterjee, Datta, Veer, & Walther, 2014).

As a nonrenewable resource, phosphorus is the second most important macronutrient for plant growth and nutrition. Demand of phosphorus application in the agricultural production is increasing fast throughout the globe. The bioavailability of phosphorus is distinctively low due to its slow diffusion and high fixation in soils which make phosphorus a key limiting factor for crop production. Applications of phosphorus-based fertilizers improve the soil fertility and agriculture yield but at the same time concerns over a number of factors that lead to environmental damage need to be addressed properly (Gupta, Chatterjee, Datta, Veer, & Walther, 2014). Phosphate fertilizer also contains various stable elements. ~~These stable elements~~ that are macronutrients (N, P, K, Ca, Mg, and S), micronutrients (B, Cl, Co, Cu, Fe, Mn, Mo, Ni, Se, Si and Zn), and fluorine and toxic elements (As, Al, Cd, Pb, and Hg) (Ghosh, Deb, Bera, Sengupta, & Patra, 2008).

Reallocation of naturally occurring radionuclides takes place through the use of fertilizers at trace levels throughout the environment and becomes a source of radioactivity, which may lead to radiological hazards due to the exposure during resident time in the soil and intake of foodstuff grown on such fertilizer amended soils. Moreover, during handling, packing and transportation of fertilizers, an additional external exposure is also evident. Since phosphate contains some natural radionuclides like ^{238}U , ^{232}Th and ^{40}K , fertilizers become the major contributor for outdoor terrestrial natural radiations. Among the constituents of agricultural phosphate fertilizers are potassium ores (potassium sulphate, potassium chloride) (Hussain & Hussain, 2011) (Uosif, Mostafa, Elsaman, & Moustafa, 2014). Potassium is of concern rather in K-fertilizers, however the long lived primordial radionuclide ^{40}K with half-life of 1.28-109 years and an isotopic abundance of 0.0118%, can contribute to the external radiation exposure of workers (Alharbi, 2013) (Gupta, Chatterjee, Datta, Veer, & Walther, 2014).

1.3 Potential Environmental Effects of Radioactivity of Fertilizers

Radioactivity of phosphate rocks leading to health problems from radiation at the level of the industrial processes which involves mining and transportation of phosphate ores and production of fertilizers. Relatively large concentrations of natural

radionuclides present in phosphate fertilizers contaminate the environment and agricultural lands during cultivation. At the usage level, when fertilizers dispersed into the geo and biospheres, have a potential to transfer to living beings. Leaching of the minerals and wastes is another potential source of radioactivity dissemination which may contribute to enhanced exposure of workers, public and the environment to these radionuclides (Jankovic, et al., 2013) (Sahu, Ajmal, Bhangare, Tiwari, & Pandit, 2014). The uptake and distribution of radionuclides in soil depends on several factors such as soil pH, type and amount of clay, exchangeable Ca and K and organic matter contents, physicochemical properties of the radionuclide, type of crop (crop species and variety, and cultural practices), fertilizer application, irrigation, plowing, liming and climate conditions (Bramki, Ramdhane, & Benrachi, 2018).

The environmental impact of chemical fertilizer production depends on the raw materials, production processes and the status of the pollution control equipment (Hussain & Hussain, 2011). Proper management of phosphorus along with its fertilizers is required that may help the maximum utilization by plants and minimum run-off and wastage. Phosphorus solubilizing bacteria along with the root rhizosphere of plant integrated with root morphological and physiological adaptive strategies need to be explored further for utilization of this extremely valuable nonrenewable resource judiciously (Gupta, Chatterjee, Datta, Veer, & Walther, 2014).

A possible negative effect of chemical fertilizers is contaminating the cultivated lands by trace metals and some naturally occurring radioactive materials. The large concentration of natural radionuclides in the fertilizers contaminates the environment and agricultural field. Direct inhalation of dust of phosphate fertilizers could affect the farmers on agricultural land. From the viewpoint of biological effect of radiation, the urea fertilizers did not cause any effect on human health. The main reason for the high radioactivity in the leafy fertilizers was ^{40}K . Chemical fertilizers caused increase in annual exposure dose by no more than 0.15% which should be taken into account at the continuing use of chemical fertilizers (Hussain & Hussain, 2011). The fertilizers which are all water soluble substances dissolve instantly in water. These dissolved radionuclides, taken up by aquatic foods and fishes, enter into the human body through vegetables, food grains, fruits, aquatic food and fishes, and through the meat and milk of pastured animals (Alam, ve diğerleri, 1997) (Uosif, Mostafa, Elsaman, & Moustafa, 2014).

The transfer of natural radionuclides to vegetation is low. Therefore the risk to the public from consumption of crops with enhanced natural activity derived from the use of fertilizer is negligible. Extended use of phosphate fertilizer raises the dose rate in air above the ground by about 0.8 nGy/h. This may give rise to an additional exposure of man at continuous residence on such previously contaminated farm land of 0.007 mSv/y. If phosphogypsum is used as a soil amendment, the doses may be no longer insignificant, mainly due to the exhalation of radon (Scholten & Timmermans, 1996).

Soil not only acts as a source of continuous radiation exposure to humans but also as a medium of migration for transfer of radionuclides to biological systems, which can cause harmful biological effects such as DNA damage and cancer. Despite a well-known effect of cancer, scientists have long known that ionizing radiations with high doses may also cause mental retardations in the children of mothers exposed to radiations during the pregnancy period. All types of food including wheat and apples contain a detectable

amount of radioactivity which successively relocates into the human body via the ingestion pathway. The activity of food is strictly linked to the activity of the soil where the food was grown. Knowledge of the concentration and the distribution of the radionuclides in these materials is very important because they provide useful information for the monitoring of environmental contamination by natural radioactivity (Bramki, Ramdhane, & Benrachi, 2018). Radionuclides enter the human body in ways of direct inhalation of airborne particulates, ingestion through the mouth, and entry through the skin. The ultimate state of the radionuclides depends upon their chemical and physical form. After uniform distribution, some radionuclides irradiate the entire body at the same rate (Ghosh, Deb, Bera, Sengupta, & Patra, 2008).

2. Materials and Methods

2.1 Study Area

Trakya Sub-region remains between Northern Marmara Basin, Meriç Basin and Greek and Bulgarian border; North Egean Sea, Marmara Sea and Black Sea (northwestern Turkey, 40°45', 42°10' North latitude and 26°15', 28°15' East longitude) are shown in Figure 1.

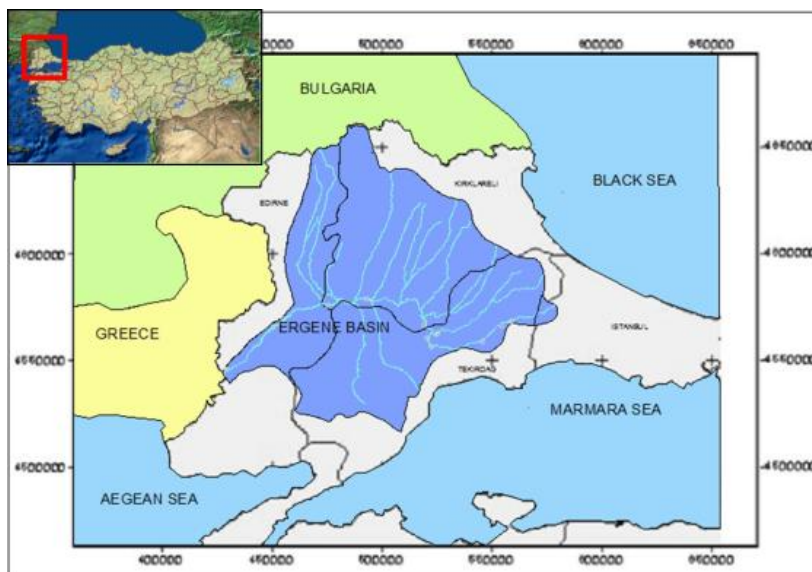


Figure 1. Geographical Location of Trakya Sub-region

Trakya Sub-region and Ergene Basin constitute one of the most important agricultural centers of our country. Sub-region has a total land area of 2376400 hectares, of which about 65% are cultivated. Excluding the parts of Istanbul and Canakkale which are located in sub-region, Tekirdağ, Edirne and Kırklareli have total agricultural land of 1239102 ha constitutes 73.8% of the total area I, II. and III. in the Land Use Capability Class, fertile and well-qualified agricultural land, which should be carefully protected. Despite the fact that the surface area of the three provinces forming the sub-region

constitutes approximately 2.32% of the total surface area of Turkey, the absolute protected agricultural land located in the sub-region constitutes 8.23% of the total agricultural land protected by Republic of Turkey. The agricultural land in sub-region is seen to be between 10% and 70% more than the productivity capacities of many cultivated plants grown compared to the agricultural land in the country. If it is thought that the land on different marine, terrestrial and alluvial sediments in the high plain system forming an integral part in the sub-region is deep and rich in plant nutrients; it appears that the region is an agricultural sanctuary. 109512 ha of meadow-pasture; 512380 ha in the forest; the remaining 43425 ha are other land and water surfaces used for non-agricultural purposes (TU, 2007).

This is the region which uses the most fertilizer per unit area, with an average of 145 kg per hectare (TU, 2007). The fertilizer is used intensively in the region and the chemical fertilizers used are mostly nitrogen content. The most widely used fertilizer types are 20-20 (NP), 15-15-15 (NPK), Ammonium Nitrate and Urea varieties. In the wheat cultivation, 20-20 (NP) and 15-15-15 (NPK) are used as base fertilizer. Urea and Ammonium nitrate are used as upper end fertilizer. In the sunflower, the same base fertilizer is used, but top fertilizer application is not very common. In the rice cultivation, 20-20 (NP) and 15-15-15 (NPK) are used as lower fertilizer, and the nitrate and urea are used besides fertilizers containing sulfate as upper fertilizer. Sulphate-containing fertilizers are mostly used in Edirne province and they are mostly used in paddy farming. In Tekirdag province, the unit area is the fertilizer which uses the most fertilizer (Inan, 2012).

Three geological rock groups in Trakya Sub-region are observed in different sizes. Trakya is located on the Alpine Himalaya belt. Pontian located north of Turkey is located at the northwest end of the tectonic units. Rhodoplas that are surfacing on the Greek borders to the west, Rhodope intermediate masses to the north and silent strandja tectonic units of the Balkan fold system. In the north of Trakya, there is the Istranca massif consisting of Palaeozoic and Mesozoic aged magmatic and metamorphic rocks. The Ergene basin, located in the middle of the lower section, is a growth zone between the Istranca Massif and the Biga Massif in the south and constitutes one of the existing 13 sedimentary basin. In the basin, volcanic rocks belonging to young volcanism are available. The Miocene and Oligocene series are overlain by Pliocene aged series composed of basalt gravel. In the eastern part of the basin there are lakeshops with a thickness of 30 m. The thickness of the Pliocene series in the basin center is 600 m. In the central and southern parts of the basin there are young volcanic outcrops of augite-olivine basalt in the Pliocene series (TU, 2007).

After the Chernobyl accident in Turkey in ~~Thrace~~ Trakya region, the activity concentration of ^{137}Cs in the soil was determined as 324 Bq/kg in Edirne and 45 Bq/kg in Saray town of Tekirdağ province. ^{137}Cs is a product of fission, it is not found naturally in nature, nuclear tests or reactor accidents are the result. ^{137}Cs half-life is 30.2 years (Gönen, 2012).

2.2 Experimental Procedure

The fertilizer usage data of Edirne, Kırklareli and Tekirdağ provinces which constitute the Trakya sub-region were obtained from the Provincial Directorates of

Environment and Urbanism according to years. ^{226}Ra , ^{238}U , ^{232}Th and ^{40}K activity concentrations in phosphate rocks, fertilizers and soil were set from various studies conducted in our country and in the world, compared with limit values of UNSCEAR (2000).

3. Results and Discussion

Trakya sub-region is an important agricultural region where the fertilization is 2-fold that of fertilizer consumption in Turkey. Agricultural activities have decreased in the basin. However, agriculture sector is still among the most important factors that shape socio-economic structure of the basin.

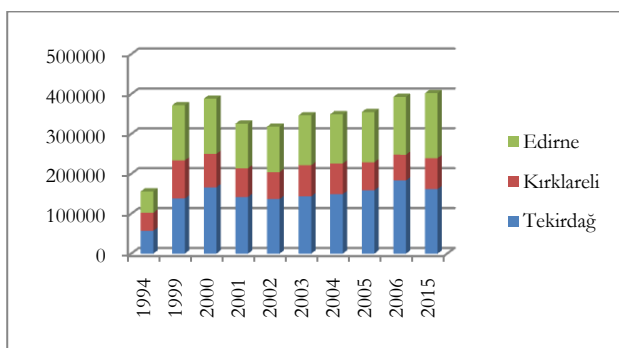


Figure 2. Chemical fertilizer consumption in Trakya Sub-region by years (tons)

When we look at the fertilizer usage according to the provinces that constitute the region (Figure 2); fertilizer consumption has increased in the last 15 years, mostly in Tekirdağ and Edirne provinces and fertilizer consumption in Kırklareli province is considerably lower than the others. Furthermore, it is estimated that fertilizer usage will continue at significant rates. When we consider the fact that the global climate change affects the hydrological cycle and nutrient transport, it seems that the fertilizer usage control is vital for agricultural production.

The fertilizer is used intensively in the region and the chemical fertilizers used are mostly nitrogen content. The most widely used fertilizer types are 20-20 (NP), 15-15-15 (NPK), Ammonium Nitrate and Urea varieties. Sulphate-containing fertilizers are mostly used in Edirne province and they are mostly used in paddy farming (Inan, 2012). Demand of phosphorus application in the agricultural production is increasing fast throughout the globe. The bioavailability of phosphorus is distinctively low due to its slow diffusion and high fixation in soils which make phosphorus a key limiting factor for crop production. Applications of phosphorus-based fertilizers improve the soil fertility and agriculture yield but at the same time concerns over a number of factors that lead to environmental damage need to be addressed properly (Gupta, Chatterjee, Datta, Veer, & Walther, 2014). Phosphate fertilizer also contains various stable elements. These stable elements are macronutrients (N, P, K, Ca, Mg, and S), micronutrients (B, Cl, Co, Cu, Fe, Mn, Mo, Ni, Se, Si and Zn), and fluorine and toxic elements (As, Al, Cd, Pb, and Hg) (Ghosh, Deb, Bera, Sengupta, & Patra, 2008). The amount of phosphorus is also considerable as we can see in Figure 3.

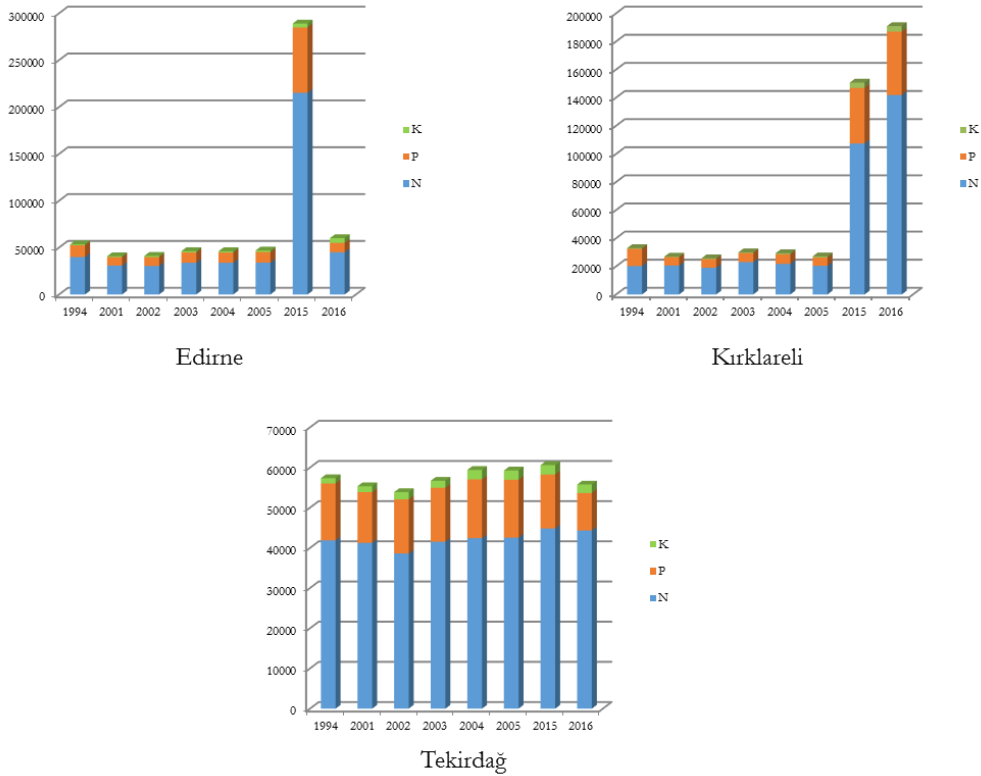


Figure 3. Chemical fertilizer consumption based on plant nutrient in provinces in the sub-region by years (tons)

Heavy metals such as Co, Cu, Fe, Mn, Mo, Ni, Zn, As, Al, Cd, Pb, and Hg which can be caused by phosphorous and potassium fertilizers used in the sub-region may cause contamination of soil and water resources and accumulation in the food chain. Nucleid contents and environmental effects of different chemical fertilizers (as shown in Table 3) and soil (as shown in Table 4) can be different from those of different phosphate rocks with different production technologies. The use of fertilizers produced in our country or imported, in sub-region with high agricultural value, can cause radioactive contamination in soil and water resources and in produced vegetables.

When we examine Table 4, in studies conducted by Edirne (Gönen, 2012) (Zaim. & Atlas, 2016), it is seen that the average activity concentrations of ^{226}Ra , ^{232}Th and ^{40}K are generally above the UNSCEAR limit values. According to Zaim and Atlas (2016), while the average activity concentrations for ^{226}Ra in the soil samples of the study area excluding Havsa and İpsala are between 1.04 and 1.47 times higher than the worldwide figures, average value of Edirne province is 1.14 times higher than the same figures. All activities of ^{232}Th in the studied regions are higher than the world average and average value of Edirne province is 1.86 times of the world average. The highest amount of ^{232}Th was found at Lalapaşa, is about two times of the world average value. The result may be due to the geological structure. The activity concentrations of ^{232}Th in Edirne soil

samples were higher than the activity concentrations of ^{226}Ra . Among the ^{40}K concentrations, while values are lower than the world average except Lalapaşa, Süloğlu, Edirne (center) and Enez, average value of Edirne is similar to the world average. The ^{137}Cs was also determined in the soil samples in six districts of Edirne (Lalapaşa, Edirne-center, Meriç, İpsala, Enez and Keşan). ^{137}Cs does not exist in soil naturally, this result may be due to Chernobyl nuclear power accident in 1986 or nuclear weapon testes. The concentrations of ^{137}Cs are consistent with the world average (Zaim. & Atlas, 2016). A similar work has not been reached for Kırklareli and Tekirdağ.

Table 4. Some typical values of activity concentrations (Bq/kg) in soils in the World

Location	Reference	Soil			
		^{226}Ra	^{238}U	^{232}Th	^{40}K
World Wide	(UNSCEAR, 2000)	35	35	30	400
Edirne, Turkey	(Gönen, 2012)	11-38		18-56	294-822
Edirne, Turkey		40		56	407
İstanbul, Turkey		28		33	388
Zonguldak, Turkey	(Zaim. & Atlas, 2016)	23		20	245
Kayseri, Turkey		36		37	430
Rize, Turkey		50		42	643
Rize, Turkey	(Durusoy & Yildirim, 2017)		7-80	10-171	36-924
Bangladesh	(Alam, ve diğerleri, 1997)		36	46	351
Palestine	(Thabayneh & Jazzar, 2012)		34.5	23.8	120
Iran	(Asgharizadeh, ve diğerleri, 2013)	31-45		27-57	328-769
India	(Shahul Hameed, Sankaran Pillai, & Mathiyarasu, 2014)		8	98	436
India	(Sahu, Ajmal, Bhangare, Tiwari, & Pandit, 2014)	22-683	21-674	11-44	51-295
Bosnia and Herzegovina		32	41	32	331
Albania			34	18.3	348
Bulgaria		45	40	30	400
Montenegro		29		23.7	246
Czech		44		41	613
Greece		29	45	28	383
Croatia		43	53	37	423
Hungary		33	29	28	370
Macedonia		23	37	25	456
Poland	(Kasumović, Adrović, Kasić, & Hankić, 2015)	25	25	25	410
Romania		32	32	38	490
Slovenia		41		35	374
India		24		55	549
Iran		39		43	555
Mexico		203		22	252
Nigeria		55		91	287
Italy		72		48	617
Spain		46		49	650
India	(Bangotra, Mehra, Kaur, & Jakhu, 2016)	18-98		46-248	53-756
Algeria		24-66		26-27	221-261
Algeria		53.2		50	311
Egypt		14		12	1233
India				49	1147
Jordan	(Bramki, Ramdhane, & Benrachi, 2018)	58		18	138
Nigeria		41		30	413
Spain		39		41	578
Iran		19		18	338
Saudi Arabia		5		3	71

Conclusions

In order to decrease environmental effects from natural and chemical fertilizers in agricultural areas and water sources, farmers should be informed; good agriculture practices and organic agriculture should become widespread, incentives for the recycling of organic manure should be improved; fertilizer management system should be used to prevent excessive fertilizing for plants and tighten the regulations and national standards on organic waste disposal and pesticides use. Sustainable agriculture covers all these applications. The key principles for sustainability are to integrate biological and ecological processes such as nutrient cycling, nitrogen fixation, soil regeneration, allelopathy, competition, predation and parasitism into food production processes; minimize the use of those non-renewable inputs that cause harm to the environment or to the health of farmers and consumers; make productive use of the knowledge and skills of farmers, thus improving their self-reliance and substituting human capital for costly external inputs (Pretty, 2008). Also it will minimize specific soil threats such as soil erosion by wind, water, and tillage, and soil compaction and physical deterioration and the loss of biodiversity from the soil.

To protect the soil and water sources in the sub-region, long-term monitoring is essential; which should include baseline, extreme, and representative sites. A well-distributed network of monitoring stations across all land uses, topographic conditions, and sub-catchments of the larger catchment would assist in model evaluation and verification when estimating at smaller scales. Legislation to ensure the continuity of long-term monitoring, cross-media monitoring (water, soil, air) at different scales such as field, farm catchment, sub-basin and basin and detailed information on soil and farm management are needed for all provinces in the sub-region. Studies should also be done to determine the radioactivity caused by fertilizers in Kırklareli and Edirne province soils.

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