Algerian Journal of Environmental Science and Technology
December edition. Vol.9. N°4. (2023)
ISSN : 2437-1114
www.aljest.org

Geographical information and geomatics tools for modelling of carcinogenic sites due to nuclear tests in Algeria

M. Naili[1]*, D. Telaidjia[1], F.Eddaoudi[2]

[1]Laboratoire d'Analyse Urbaine et Environnementale, University Of Badji Mokhtar, Department d'Aménagement, B.P.12, Annaba, 23000 Algeria
[2] Ecole Nationale de Santé Publique - Morocco

*Corresponding author: manel.naili@univ-annaba.org

ARTICLE INFO

Article History :

Received ***: 04/03/2021***
Accepted ***: 10/11/2022***

Key Words:
Geographical information;
Geomatics ;
Carcinogenic sites;
Nuclear tests;
Algeria.

ABSTRACT/RESUME

Abstract: *The impact of radioactivity on the environment and health is very overwhelming, until today these continuous radiations affect local populations by differential cancers, eye diseases, genetic malformations and other rare diseases. Fatal radiation carried by sand, water and poisoned air affects local populations directly or indirectly. The Analysis of spatial phenomena is effective by the use of techniques of geomatics, and that is when the geographical problems are quantitative and qualitative, can be easily applied in identifying and explaining phenomena. In our case how to make knowledge, despite the enormous number of cancer patients, there has been practically no geographical discussion on the aggravating factors linked to radioactive risks, we have not even spatialized radioactive territories in Algeria. The aim of this study is to identify carcinogenic sites by the spatialization of radioactivity due to nuclear tests in Algeria.*

I. Introduction

Since 1960, the radioactivity created by the 4 atmospheric nuclear tests at Reggane and the 13 underground tests at In Ekker continues to affect the health of the local population in southern Algeria [1]. Atmospheric testing has resulted in deposition of radioactive particles in the Sahara Desert, North Africa and some sub-Saharan countries [2]. Since 13 days after the first nuclear test (13 February 1960), radioactive fallout reached the Spanish coasts. Warm particles were present in precipitation and air in southwest Sweden [2, 3]. In 2010, a radiological analysis carried out by the Independent Research and Information Commission at the former nuclear test site confirmed that the dose rate measured in contact with the lava sample was 108 µSv/h. Lava samples are also heavily contaminated with cesium 137a, transuranian and americium 241 with an activity of 760,000 Bq/kg (C137) and 15,100 Bq/kg (T241) respectively [4]. On the other hand, radiation transmitted by sand, air or water has caused several forms of cancer, eye disease, genetic malformations and other rare diseases. In Saharan Algeria, the sand winds blow in all directions, which aggravates the risk of radioactive material transport. In Ekker, near a tunnel where radioactive lava ejected, significant levels of radioactive material were measured [5]. In this subject Yu Morino and others assert that during the fukushema accident precipitation was observed, because of the transient cyclone that passed over Japan and therefore radioactive materials were actually deposited on the ground by wet processes [6].The negative effects of radioactivity on health it proven. If 1 million people receive (10 millisievert), the number of radio-induced fatal cancers is estimated according to several references of 125 fatal cancers [7]. 75 to 175 fatal cancers [8]. In addition, 158 to 501 fatal cancers [9]. 6,000 fatal cancers [10], 1740 fatal cancers [11], 800 fatal cancers [12], 500 fatal cancers [13]. 1000 fatal cancers [14].The negative impact of radioactivity on the environment and health it no longer demonstrated. Depleted Uranium was reported as the cause of cancer, leukemia and other health effects on troops, local populations, who were present at locations where depleted uranium (DU) ammunition had been used during conflict [15]. Ten years after nuclear testing, there was a clear increase in the incidence of thyroid cancer in people half a mile from zero soil [16]. The International Atomic Energy Agency These observations confirmed in report published in 1999. To our knowledge, in Algeria, there is no spatial modeling of radioactive sites due to the scarcity of data. Hence the interest of this work which aims to identify radioactive sites in the south of the country. This identification is of major interest, since it will allow researchers to study the correlation between the spatial distribution of cancers and radioactive sites, on the one hand, and the planning of decontamination operations of identified sites, on the other. We used the techniques of digitization of old and new plans and maps in ArcGIS 10.8.1. Similarly, satellite image remote sensing techniques based on sentinel-2 image classification and THR images used. The GPS points (ALG-18) that represent collected points of radioactive lava and (ALG-4a) that represent black fragments of sand fused we used to validate the results found.

I.1. Location of study areas

Our study area is located in the south of Algeria located in the wilaya of Tamanrasset in the east and the wilaya of Adrar in the west. The study area consists of two sites separated by 573m.

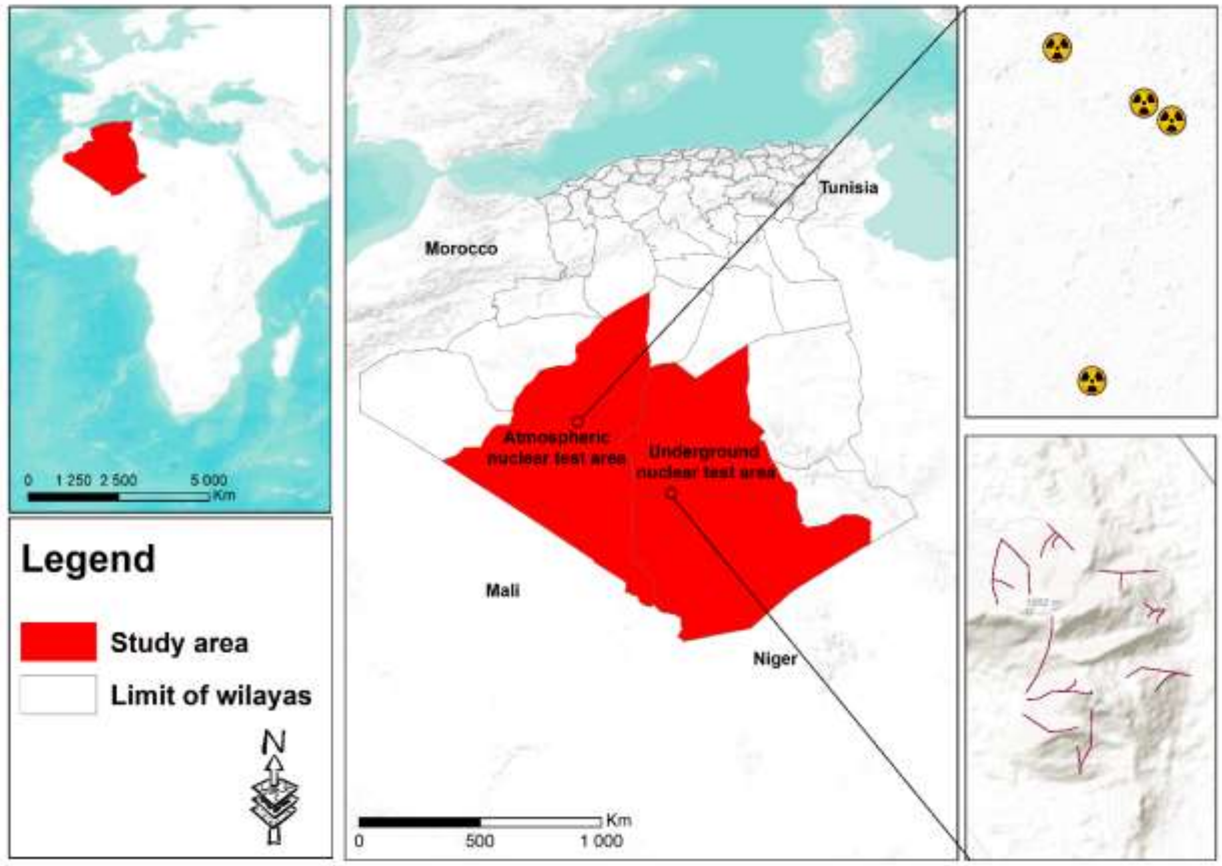

Figure 1. *Location of study Area*

I.1.1. Atmospheric Nuclear Test Area

The first is the atmospheric nuclear test area of Hammoudia, located about 65 km from the city of Reggan in the wilaya of Adrar. In This area, we have 04 atmospheric nuclear tests: Gerboise vert, Gerboise Bleu, Gerboise Rouge and Gerboise Blanc. (Table 01). Figure 2 shows the location of these nuclear test sites.

Algerian Journal of Environmental Science and Technology
December edition. Vol.9. N°4. (2023)
ISSN : 2437-1114
www.aljest.org

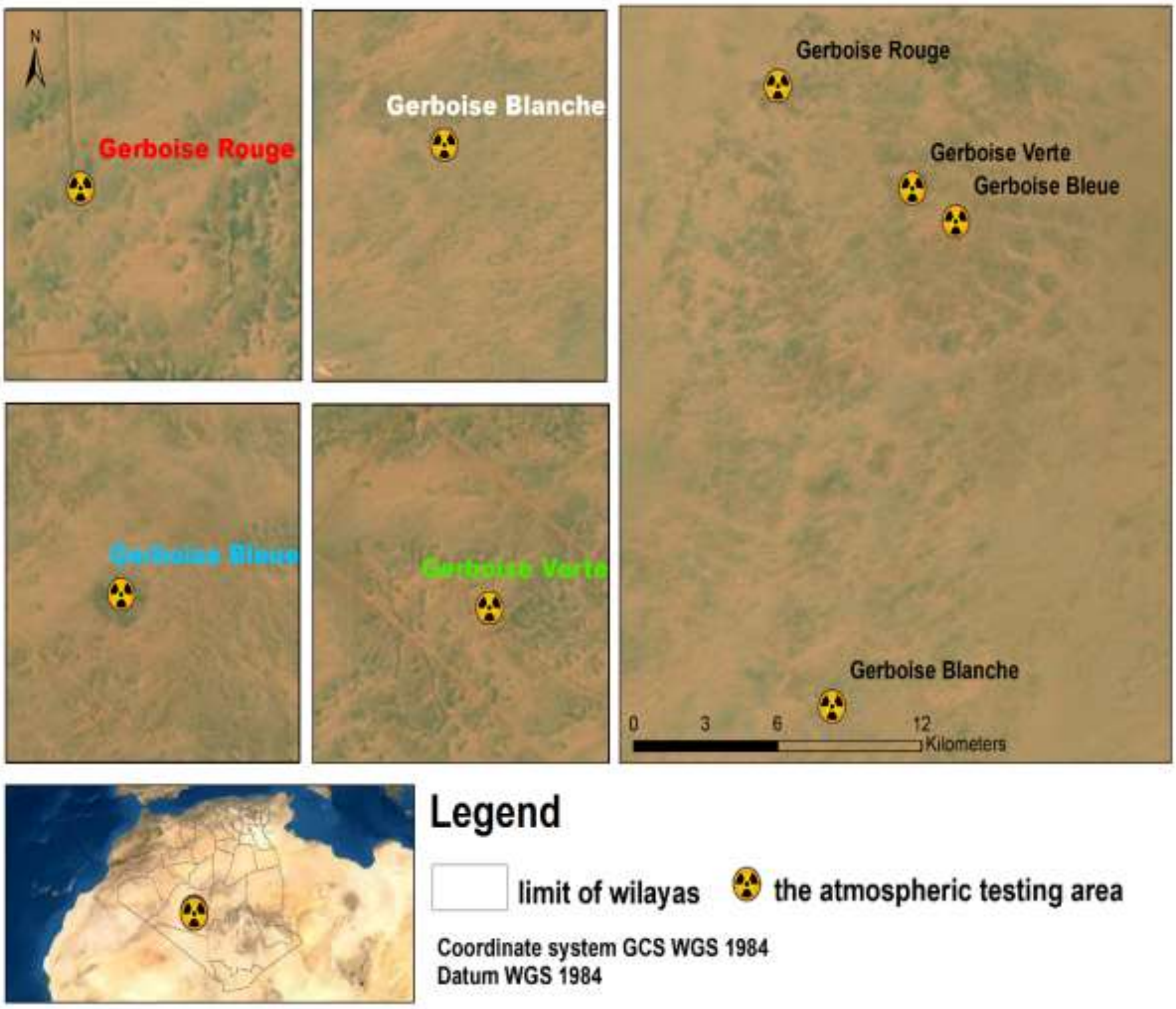

Figure 2. *Location of Atmospheric nuclear test area*

Table 1. *Atmospheric nuclear tests conducted at reggane (IAEA, 2005)*

Test name	Type	KT efficiency	Axis	Dated	Hour	Address
Blue jerboa	Tower 100m	40<w<80	East 106 °	13/02/1960	7 :04	Gerboise bleue, 1004 Reggane,RADP
Green jerboa	Tower, 50m	w<10	Westward 240 °	25/04/1961	6 :05	Gerboise verte, 1004 Reggane,RADP
Red jerboa	Tower, 50m	W<10	South 190, 210 °	27/12/1960	7 :28	Gerboise rouge, 1004 Reggane,RADP
White jerboa	Area	w<10	South 195°	01/04/1960	6 :15	Gerboise blanche, 1004 Reggane,RADP

I.1.2. Underground Nuclear Test Area

The second study area is the In Ekker area, located in the municipality of In Amguel, which is 170 km north of the city of Tamanrasset. The mountains of Tan Affela witness the underground tests dug in the 13 galleries (Table 2). Figure 3 shows the location of these nuclear test sites.

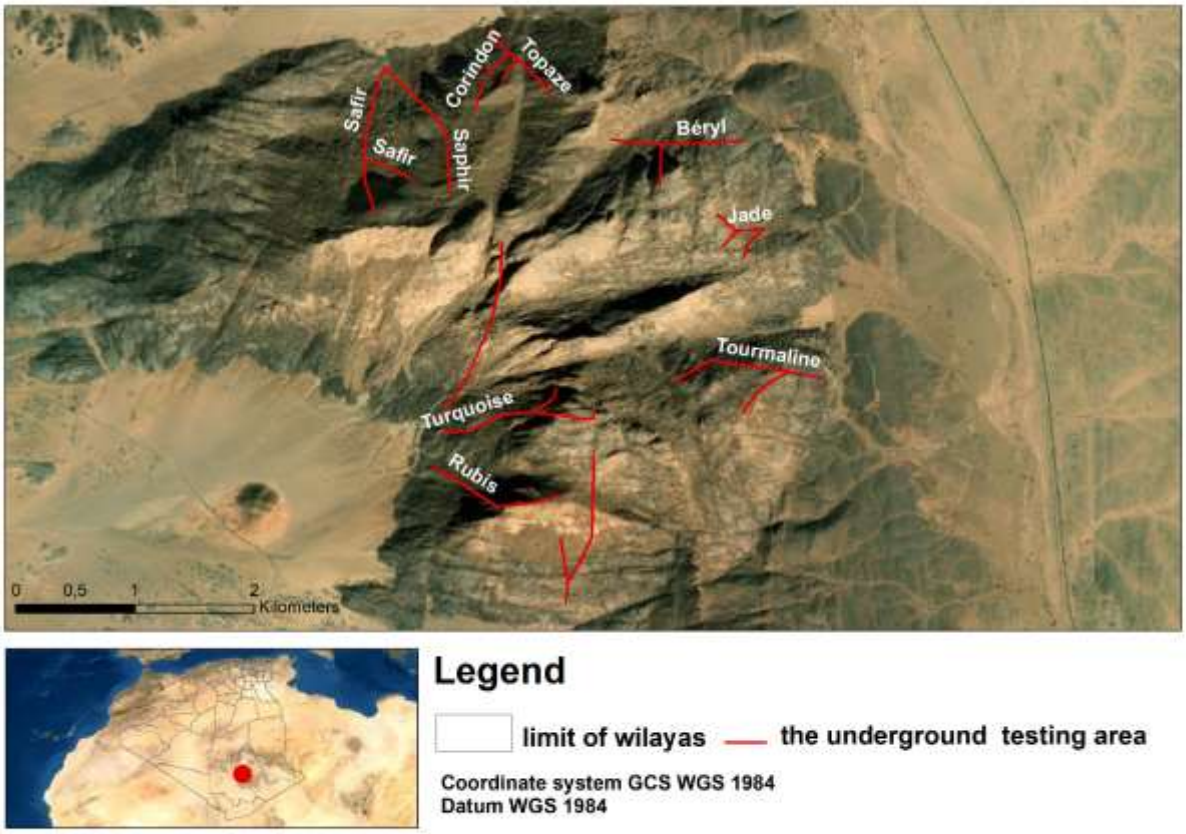

Figure 3. *Location of underground nuclear test area*

Table 2. *Underground nuclear tests performed in the taourirt tan afella Massif (IAEA, 2005)*

Test name	Gallery	KT efficiency	Dated	Hour	Address
Topaze	E 6-1	1	06/15/1964	13	Taourirt Tan Affela
Corindon	E 6-2	4	10/01/1965	10	Taourirt Tan Affela
Saphir	E 7	115	02/27/1965	11 :30	Taourirt Tan Affela
Béryl	E2	30	05/01/1965	10	Taourirt Tan Affela
Agathe	E1 Nord	5	11/07/1961	11 :30	Taourirt Tan Affela
Jade	E1-3	0.6	05/30/1965	11	Taourirt Tan Affela
Opale	E1 Sud	4	02/14/1964	11	Taourirt Tan Affela
Améthyste	E3 bis	0.7	03/03/1963	10	Taourirt Tan Affela
Emeraude	E3 Sud	15	03/18/1963	10	Taourirt Tan Affela
Tourmaline	E3 Nord	10	12/01/1965	10 :30	Taourirt Tan Affela
Grenat	E4-2 Nord	15	02/16/1966	11	Taourirt Tan Affela
Turquoise	E4	05	11/28/1964	10 :30	Taourirt Tan Affela
Rubis	E5	60	10/20/1963	13	Taourirt Tan Affela

II.Method

The analysis of territories has undergone a significant evolution thanks to geographical information systems. GIS is an innovative technology that has made it possible to map and monitor rapidly changing phenomena on the Earth's surface [17]. Several studies have used GIS to analyze and map radioactivity. Several researchers to configure the general circulation model (EMAC) have used GIS [18]. Other researchers used the spline technique to estimate the spatial distribution of the air dose rate at Fukushima [19]. In this work, GIS used to model radioactivity to identify areas of high radioactive contamination in Adrar and Tamanraset wilayas.

We began by acquiring the geographic coordinates of each nuclear test in order to locate them. Another step is the collection of dose rate and radioactivity data that were obtained from the SENATE report, published by [20], from the IAEA survey published in 2005 that cover one. In addition, by Radiological analyses of materials taken from the former nuclear test site of In Ekker (Algeria) of the Independent Research and Information Commission on Radioactivity published in 2010. Historical data are very important for radioactivity analysis. For this, we have collected archives on nuclear tests in Algeria. For geographic data, we used Google earth satellite imageries collected by SAS Planet and Sentinel-2 images acquired by USGS. In order to analyze the data we used different tools of the ArcGIS 10.8.1 software (Buffer Analysis, Spline Interpolation, Maximum likelihood classification, Unassisted Iso cluster classification) for spatial identification of radioactive sites respectively for (Fireball, Iso doses, radioactive lava, black checked sands) Figure 4 outlines the approach:

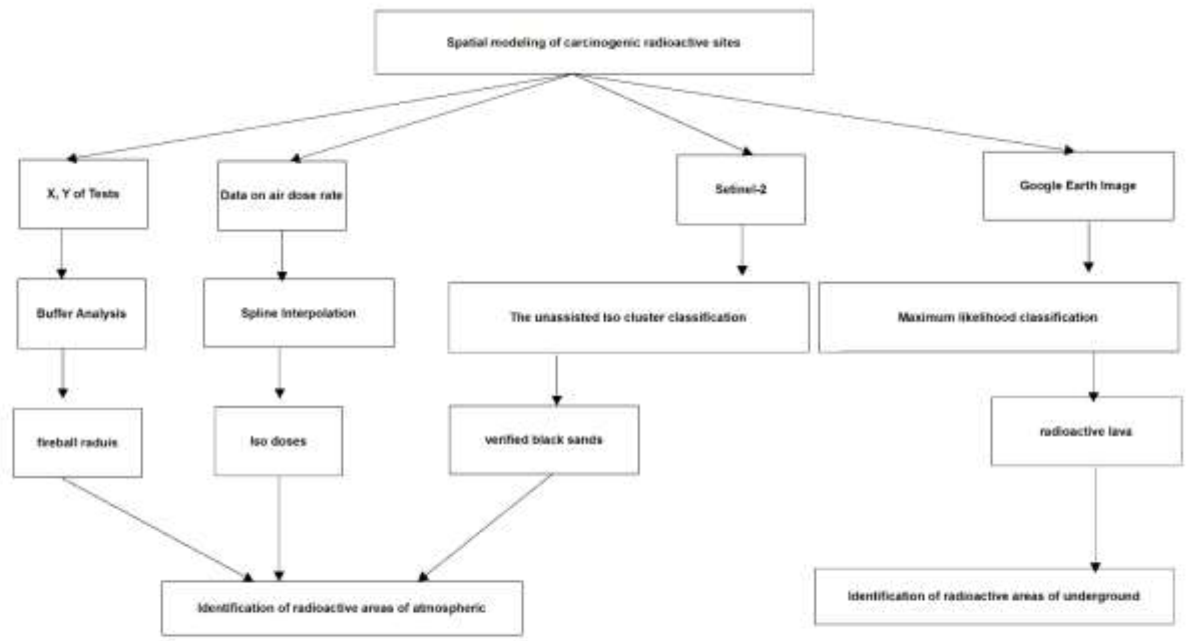

Figure 4.*An outline of our research steps*

III.Results

III.1. Identification of radioactive sites due to Atmospheric nuclear tests

III.1.1. Fireball radius

The power of nuclear explosions is very difficult to evaluate, even under very controlled experimental conditions, several researchers try to estimate the calculation of the explosion rays. In our case, we choose the method of «Geoffrey Ingram Taylor», based on a simple dimensional analysis, According to Taylor, the maximum size of the nuclear fireball and the damage to the ground depends on the height of the detonation. When the fire hits the ground, the amount of radioactive fallout increases considerably. Everything inside the fireball it effectively vaporized [21].

$$R = c \left(\frac{E \times t^2}{\rho}\right)^{1/5}$$

In which
R the radius of the explosion.
E the energy of the explosion.
t the time after the detonation.
ρ air density.
c speed of light in vacuum.

According to Taylor for 22 kilotons of TNT the radius is calculated at 140 meters, by applying the rule of three, It is estimated that at time t = 0.025 s. Taking ρ to 1 kg/ m3 and solving E. This very simple calculation is in agreement with the official efficiency value of the bomb to within 35% (70 kilotons of TNT, or 2.9288 10 + 14 J). The blast radius was 445.46 meters. According to Alex Wellerstein simulation method based on the formulas of Samuel Glasstone and Philip J. Dolan (1977), the radius is 430 meters. After the calculation of the indicators, we used a spatial analysis tool (Buffer spatial analysis) to map the results. The neighborhood radius R, which is the buffer distance (width), is the primary indicator of the run buffer and can be a constant or variable [22].

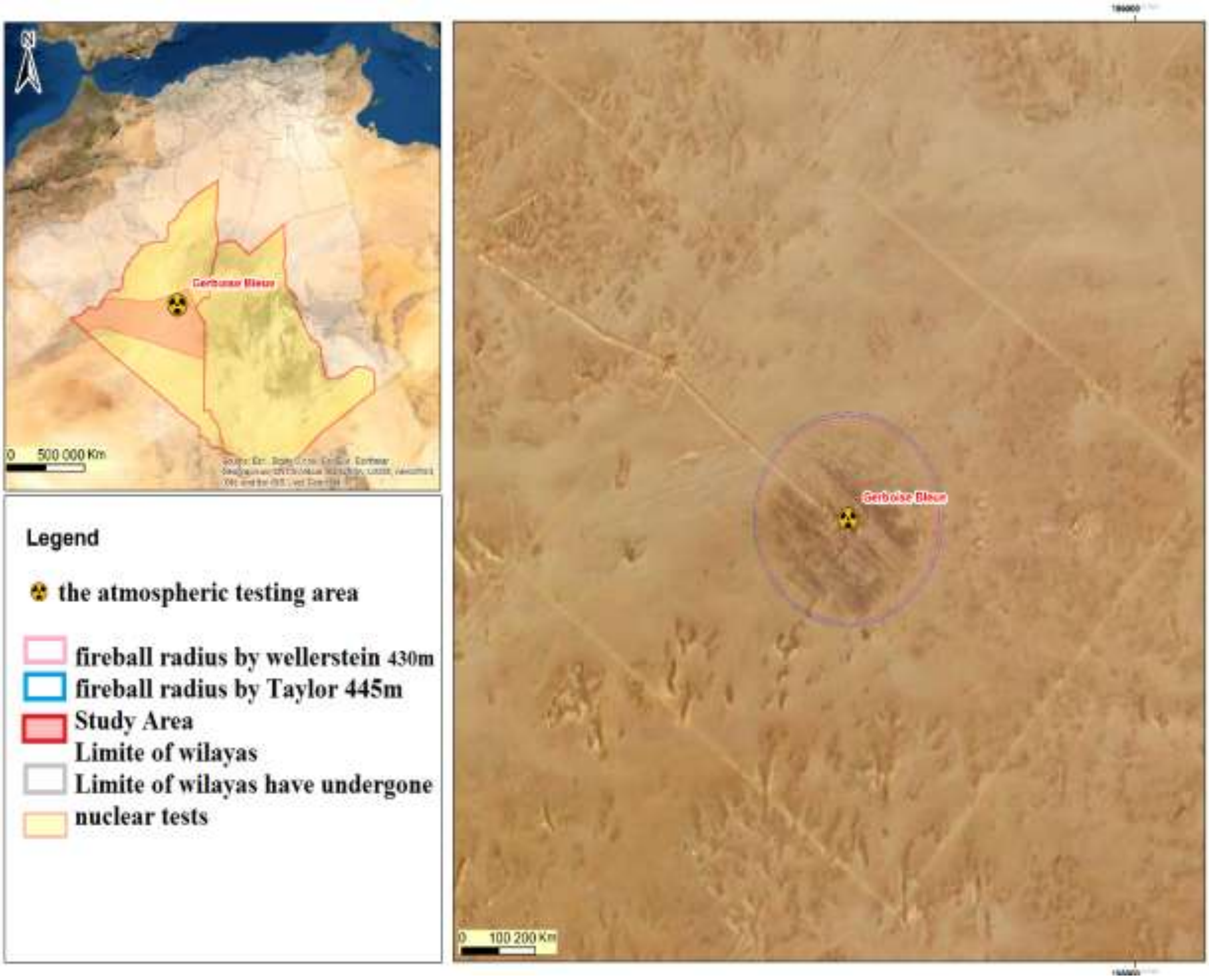

Figure 5. *Fireball radius of blue jerboa*

III.1.2. Black fragments of vitrified sand in Hammoudia

According to the International Atomic Energy Agency report, all the Reggane sites are contaminated. Most of the contamination lies in the black fragments of vitrified sand it is the result of fusion now of the explosion (Figure 06).

Algerian Journal of Environmental Science and Technology
December edition. Vol.9. Nº4. (2023)
ISSN : 2437-1114
www.aljest.org

Figure 6. *Photo of black fragments of vitrified sand in Hammoudia (IAEA, 2005)*

On the other hand, from the first visualization of satellite imagery a clear difference appeared between the Hammoudia area and the other areas. Between yellow and black sand spots, a “leopard skin” effect has been created [2]. We used 10 classes for the classification of non-assisted ISO clusters on Sentinel-2 ; subsequently the technique of photo interpretation of satellite imagery to delineated and calculated the area of black fragments of vitrified sand in the Hamoudia area. After the validation of the classification by the points collected by IAEA we found and 421,679 entities of fragments with an area that equals 4814.58 km^2.

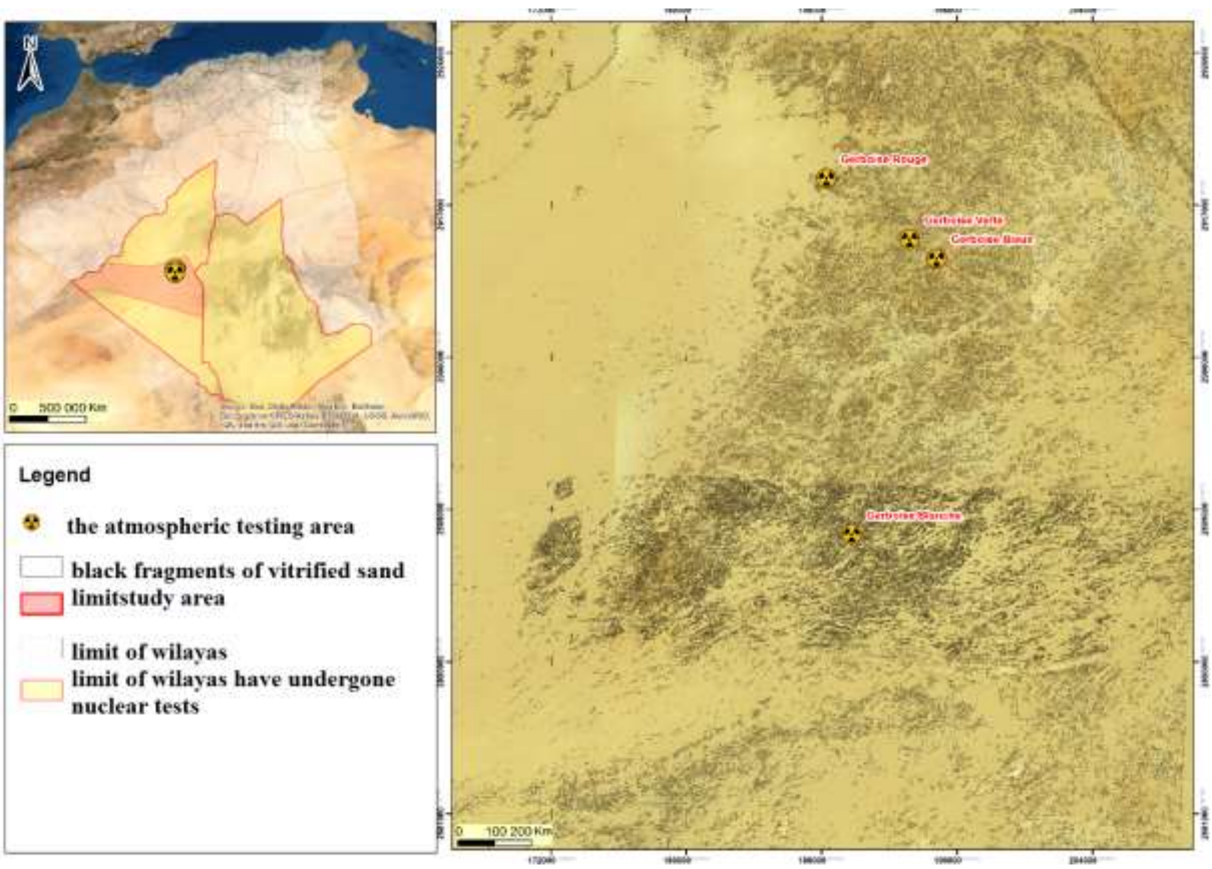

Figure 7. *Black fragments of vitrified sand in Hammoudia*

III.1.3. Simulation mapping of estimated fallout Curves at total dose for a surface gust of 70 kilotons with a wind of 15 mph

We used the simulation of Alexe Welerstrine (NucMap) to map the contour of the fallout for 1, 10, 100, 1000 rads per hour respectively an Approximate Area affected by (3,730 km², 1,770 km², 539 km², and 27.3 km²) with a maximum width of (22.8 km, 14.7 km, 6.64 km, and 2.03 km). For this performance, the radiation contour of cloud fallout with mapped according to the different wind directions.

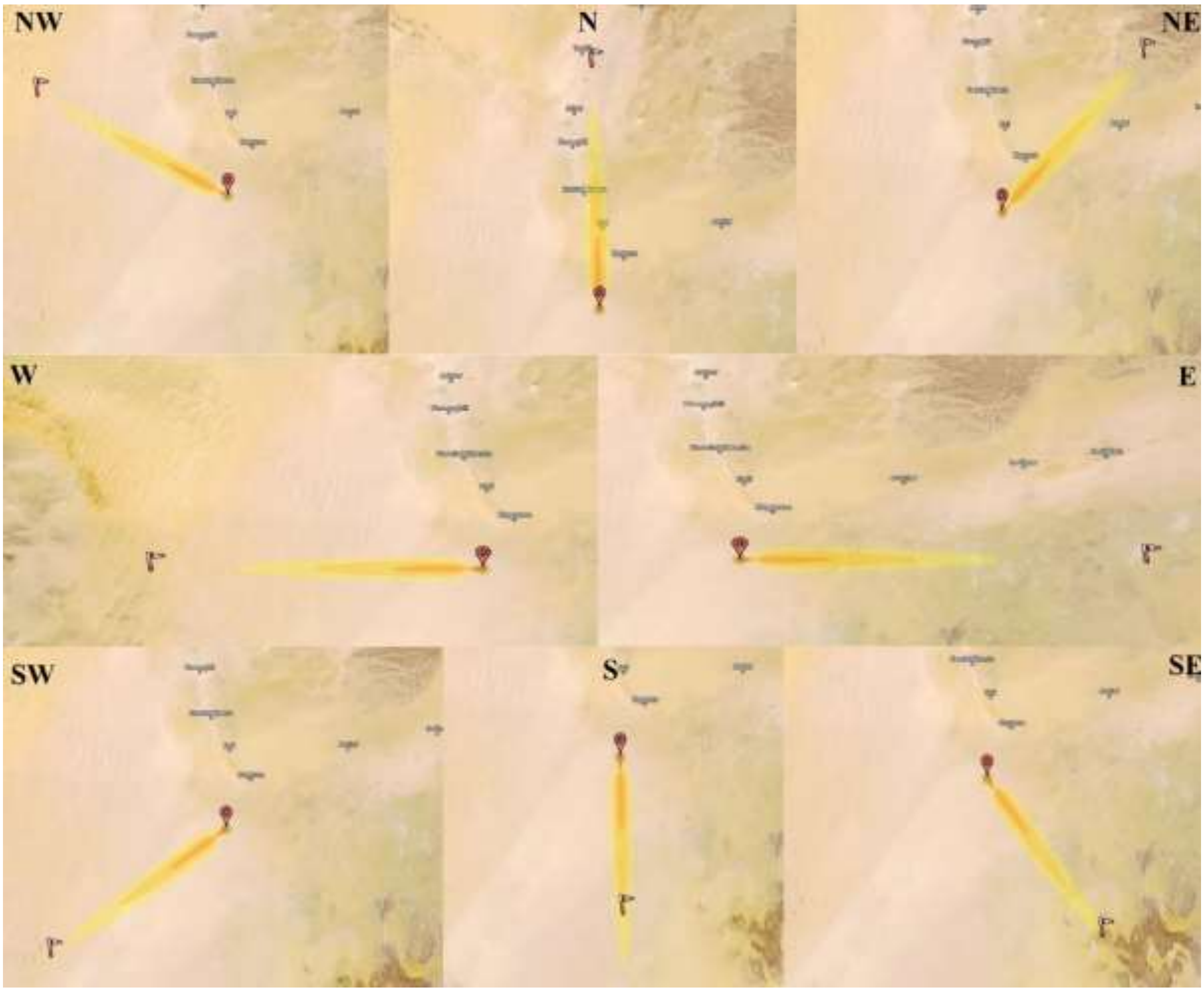

Figure 8. *fallout estimated at the total dose for a surface gust of 70 kilotons of TNT*

III.2 Identification of radioactive sites due to underground nuclear tests

III.2.1. Delimitation of radioactive lava

The sampling of the points by Global Positioning System and a method used for the validation of a classification, in our case we started with the location of the validation points collected by the IAEA in the lavas of In Ekker, then we start with the photo-identification of lava to create the spectral signature. To make a classification of maximum likelihood. The total area of radioactive lava is 5.655958 km^2.

Algerian Journal of Environmental Science and Technology
December edition. Vol.9. N°4. (2023)
ISSN : 2437-1114
www.aljest.org

Figure 9. *Photo of radioactive lava (CRIIRAD, 2010)*

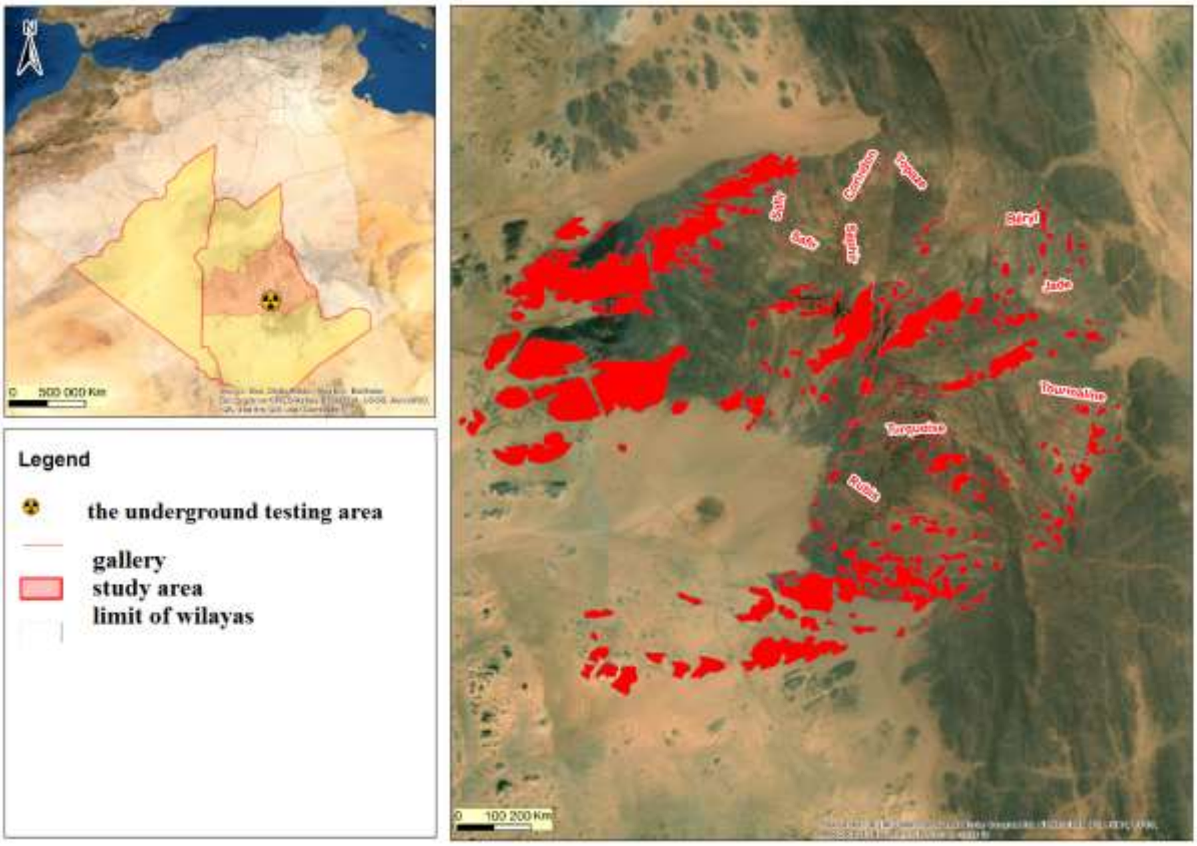

Figure 10. *radioactive lav*

IV- Discussions

IV.1. Mapping for 238U and 232Th flows of geoneutrinos from natural and artificial decay

The radioelements include the parent nuclides of the three radioactive families 235U, 238U and 232T exist in the earth's crust [23]. The results of the World Geoneutrino Flux Map of the 238U and 232Th natural decays in the Earth's crust and mantle as well as the geoneutrinos emitted by artificial power reactors worldwide. Shows that Algeria it classified in the second rank of radioactivity (108.7 and 10 8.6 νe/cm/s) the color just dark towards the south of Algeria is yet we do not have the nuclear reactors, which means another explanation that assures our study.

Using the Arc GIS 10.8 geo-referencing tools, we scanned the AGM2015 image. We then digitized the classes according to the 04 levels of gluers. For the analysis of the spatial distribution of Uranuim 238 and Thorium 232 we used the method of discretization into equal amplitudes classes is very simple. First, we have to measure the range of the series, then we have to determine the number of classes we want in our case, we used four classes. For this, we used a single data source for the mapping presentation. Four classes, which vary between 108.7 and 108.6, represented by a color degradation map. Alternatively, the darkest color represents the first class with a higher U 238. The first class with an area of 761, 1201.4611 Km^2 with a percentage of 32.95%, while the second class occupies 729,340.6921 km^2 with 31.57%. Class three with a 721512, 149km^2 with 31.23% and the last with 97732, 12161 km^2 with 4.23%. According to the Independent Research and Information Commission on Radioactivity, samples taken at the level of the area contaminated by Beryl fire in areas with a clear gamma radiation flux in contact, with the ground higher than the natural level.

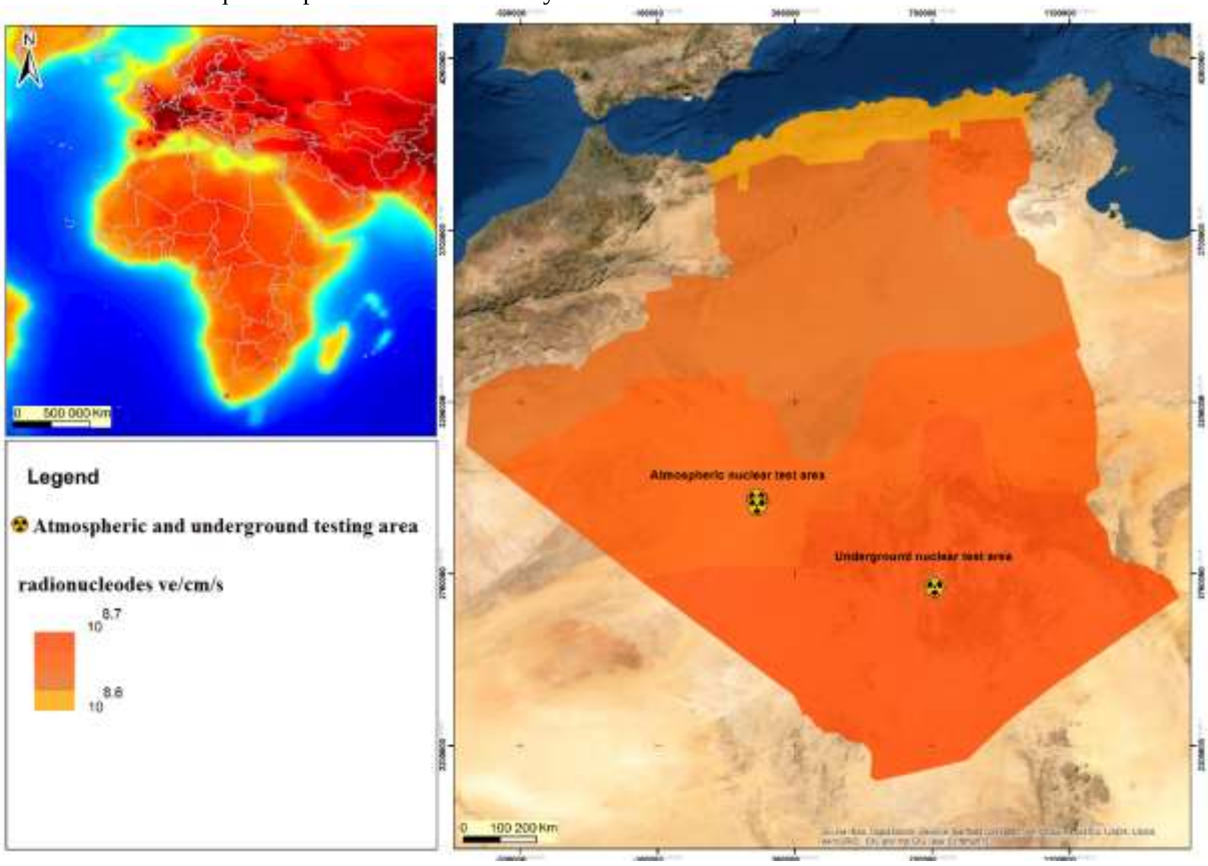

Figure 11. *radioactive lava*

IV.2. Fallout dose estimation

Studies of the most contaminated regions in the most affected countries indicate a relationship between thyroid cancer and radioactive fallout [24]. For the mapping of nuclear dosimetry in mSv we collected dosimetric sampling information from the International Atomic Energy Agency and other sources, then we located point by point to make a spline interpolation. On the other hand, the analysis of key components used to analyze the structure of statistical data through correlations between variables and the identification of factor axes [25].

Algerian Journal of Environmental Science and Technology
December edition. Vol.9. Nº4. (2023)
ISSN : 2437-1114
www.aljest.org

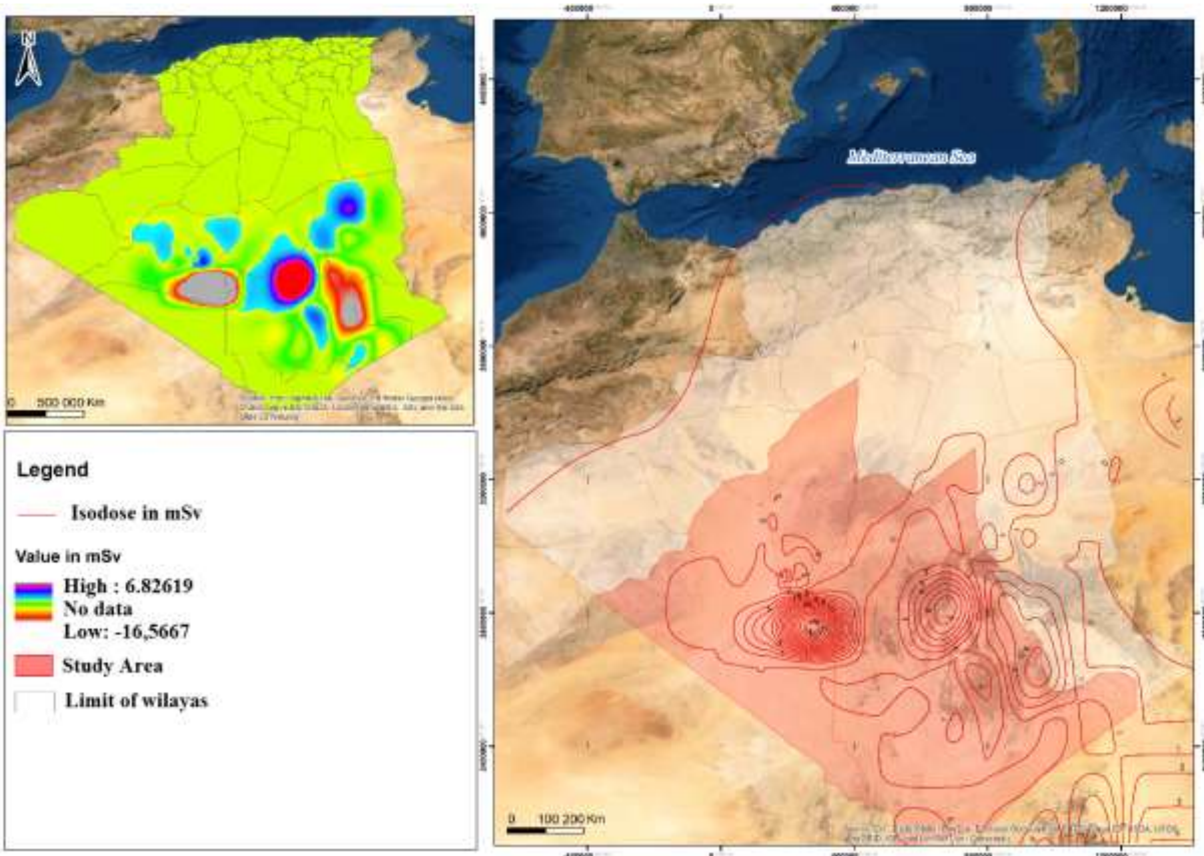

Figure 12. *Fallout dose estimation*

V. Conclusion

This article carried out to identify radioactive sites that are carcinogenic for the local population of southern Algeria by using geomatics tools to analyze geographic information. According to the interpretation of the latest satellite images collected in 2020, the lava and vitrified sands are still in situ; the total area calculated at high risk of radioactivity equals 4840.44 km^2. However, according to Alex Welerstrine's model, the nuclear fallout covers an area of 3,730 km2 and we found in the same area a coverage of 4,814.58 km^2 with a tolerance of 29.07%. For the radius of the fireball, we found a radius of 445 m according to the Taylor method and 430 by the Welerstrine's model and therefore a tolerance of 3.3%. Our result facilitates national and international decision-makers rapid intervention for the decontamination of carcinogenic sites at the earliest.

VI. Recommendations

This study wishes to recommend strengthening the scientific media on the issue of nuclear explosions in order to clean up contaminated areas of radiation and spread nuclear awareness and culture for the peoples.

VII. Reference

1. International Atomic Energy Agency. Radiological Conditions at the Former French Nuclear Test Sites in Algeria: Preliminary Assessment and Recommendations. *Radiological assessment reports series.* (2005)1-71.
2. Collin, J.M. ; Bouveret, P. Les déchets des essais nucléaires français en Algérie Sous le sable, la radioactivité ! Analyse au regard du Traité sur l’interdiction des armes nucléaires. *La Fondation Heinrich Böll* (2020)1-55.
3. Lindblom, G. Advection over Sweden of Radioactive Dust from the First French nuclear Test Explosion. *Tellus* 13(1960) 106-112.
4. Commission de Recherche et d’Information Indépendantes sur la Radioactivité (CRIIRAD). Analyses radiologiques de matériaux prélevés sur l’ancien site d’essais nucléaires d’In Ekker (Algérie). Note CRIIRAD N°09-113. (2010)1-15.
5. Danesi, P.R.; Moreno, J.; Makarewicz, M.; Louvat, D. Residual radionuclide concentrations and estimated radiation doses at the former French nuclear weapons test sites in Algeria, *Applied Radiation and Isotopes* 66(2008) 1671-1674.
6. Morino, Y.; Ohara,T.; Nishizawa, M. Atmospheric behavior, deposition, and budget of radioactive materials from the Fukushima Daiichi nuclear power plant in March 2011, *geophysical research letters* 38(2011) 1-7.
7. International commission on radiological protection (I.C.R.P.). Recommendations, I.C.R.P. Publication 26, Oxford, *Pergamon press* (1977)1-87.

8. United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). UNSCEAR, report to the General Assembly, *United Nations publication*, (1977) 1-727.
9. National Research Council. Effects on Populations of Exposure to Low Levels of Ionizing Radiation, 1980 BEIR III. Washington, DC. *The National Academies Press*. (1980) 1-542.
10. Kneale, G.W. Mancuso TF and Stewart AM. Job Related Mortality Risks of Hanford Workers and Their Relation to Cancer Effects of Measured doses of External Radiation, *British Journal of Industrial Medicine* 41(1984) 9-14.
11. RERF. Reassessment of Atomic Bomb Radiation Dosimetry in Hiroshima and Nagasaki, Final Report, Vols. 1-2, edited by W.C.Roesch (Hiroshima: RERF Printing Office). (1987) 66-142.
12. National Research Council. Health Risks of Radon and Other Internally Deposited Alpha-Emitters: BEIR IV. Washington, DC: The National Academies Press. (1988) 1-623.
13. International commission on radiological protection (I.C.R.P.).Recommendation of the international commission on radiological protection. Publication 60, Oxford, *Pergamon press* 21(1990), 1-211.
14. National Radiological Protection Board. National protocol for patient dose measurements in diagnostic radiology, majornuclear reactor accidents. European Geosciences Union 12(2012), 4245–4258.
15. National Radiological Protection Board (1992) 1-46.
16. Bleise, A.; Danesi, P.R.; Burkart, W. Properties, use and health effects of depleted uranium (DU): a general overview, *Journal of Environmental Radioactivity* 64(2003) 93-112.
17. Glasstone,S.; Dolan, P.J.; The Effects of Nuclear Weapons , Biologicals EFFECTS ,United States department of Defense and the United states department of energy, USA (1977)1-660.
18. Alseroury F. Use of GIS to study the effect of air pollutants on the vegetation cover, *International Journal of Biosciences* 11(2017) 1-8.
19. Lelieveld, J.; Kunkel, D.; Lawrence, M.G.; Global risk of radioactive fallout after
20. Yasutaka, T.; Iwasaki, Y.; Hashimoto, S.; Naito, W.; Ono, K.; Kishimoto, A.; Yoshida, K.; Murakami, M.; Kawaguchi, I.; Oka, T.; Nakanishi, J.; 2013. GIS-based evaluation of the effect of decontamination on effective doses due to long-term external exposures in Fukushima. Chemosphere 93(6), 1222–1229.
21. Bataille, C. ; Revol, H. ; Les incidences environnementales et sanitaires Des essais nucléaires efféctues par la France Entre 1960 et 1996 Et éléments de comparaison avec les essais Des autres puissances nucléaires. Office parlementaire d'évaluation Des choix scientifiques et technologiques. (2002) 1-49.
22. Taylor, G.I. The formation of a blast wave by a very intense explosion I. Theoretical discussion, The Royal Society 201(1950), 195-174.
23. Wan, A.J.; Liu, Y.X.; Xie, X.J.; Tu, R.Q.; Qi, X.L.; Chen, H.L. Study on the influence of water systems and roads based on arcgis on the layout and morphology of the forest plates in western Sichuan. EPPCT 474 (2020) 1-8.
24. Usman, S.M.; Jocher, G.R.; Dye, S.T.; Mc Donough, W.F.; Learned, J.G. AGM2015: Antineutrino Global Map 2015. Scientific Reports 5(2015)1-11.
25. Cardiset, E.; Krewski, D.; Boniol, M.; Drozdovitch, V.; Darby, S.C.; Gilbert, E.S.; Akiba, S.; Benichou, J.; Ferlay, J.; Gandini, S.; Hill, C.; Howe, G .; Kesminiene, A.; Moser, M.; Sanchez, M.; Storm, H.; Peter Boyle, L.V.; . Estimates of the cancer burden in Europe from radioactive fallout from the Chernobyl accident, International Journal of Cancer 119(2006) 1224–1235.
26. Bio-Bangana, S.; Ossè, R.A.; Vodounou, A.; Orou-Bata, I.; Houssou, C.; Boko, M.; Akogbéto, M.; . Application of GIS and remote sensing in the identification of environmental determinants of the spatial distribution of Anopheles gambiae sl and Anopheles funestus in the health district Ouidah-Kpomassè-Tori Bossito, International Journal of Biosciences 15(2019) 109-120.

Please cite this Article as:
Naili M., Telaidjia D., Eddaoudi F. Geographical information and geomatics tools for modelling of carcinogenic sites due to nuclear tests in Algeria, ***Algerian J. Env. Sc. Technology***, **9:4 (2023) 3364-3375**