RESEARCH ARTICLE

SUICIDAL DEATH IN UNITED STATE IN RELATION WITH SOLAR AND GEOPHYSICAL PHENOMENA (1997TO 2010)

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ABSTRACT

We have studied the relationship between death due to suicide incident in United Sate and various Solar, Interplanetary and Geomagnetic Activity parameters, such as Sunspot Numbers (SSN), Solar Flare Index (SFI), Sudden Storm Commencements (SSC), and geomagnetic activity Ap, and Kp Indices observed during the period of 1997 to 2010. The data shows that the number of deaths due to suicide and suicide rate (Death due to suicide per 100000) is well correlated with the yearly mean of Sunspot Numbers (SSN), Solar Flare Index (SFI), Sudden Storm Commencements (SSC), and geomagnetic activity parameter Ap, and Kp Indices. We have calculated a large negative correlation, with correlation coefficients of -0.749, -0.684, between yearly total number of deaths due to suicide and the geomagnetic activity parameters Kp, Ap, index . Negative correlation, with correlation coefficients of -0.814, -0.754 has been obtained between the yearly rate of deaths (Death per 100000) due to suicide and the geomagnetic activity parameters Kp, Ap, Further we have determined negative correlation, with a correlation coefficient of -0.761,-0.789, between yearly total number of deaths due to suicide and the yearly mean of the SSN and SFI , -0.762 and -0.80, between yearly rate (Death per 100000) of deaths due to suicide and the SSN, SFI .From the statistical analysis of sudden storm commencements (SSC), and death due to suicide, we have obtained a negative correlation, with correlation coefficient of -0.658 , between the yearly total number of male deaths due to suicide and Sudden Storm Commencements (SSC), as well as a negative correlation, with a correlation coefficient of -0.573 , between the yearly rate (Death per 100000) of deaths due to suicide and Sudden Storm Commencements (SSC).

INTRODUCTION

There is an increasing amount of evidence linking biological effects to solar and geomagnetic disturbances. Over the last years many studies have been carried out concerning the possible effect that solar and geomagnetic activity might have on human physiological state (Dorman *et al*., 2001; Gmitrov and Gmitrova, 2004; Dimitrova *et al*., 2004, Kay, 1994; Watanabe *et al*., 1994; Persinger and Richards, 1995; Gurfinkel *et al*., 1995; Zhadin, 2001; Cornelissen *et al*., 2002 Dorman *et al*., 2001; Ptitsyna *et al*., 1996; Villoresi *et al*., 1994, 1995; Ptitsyna *et al*., 1998, Villoresi *et al*., 1994, 1998; Dorman, 2005 Stoupel, 1999; Dimitrova, 2006, Dimitrova S,et 2009, Mavromichalaki H,2008, Mavromichalaki H,2012 , Cornelissen G,*et al* 2011, Kasatkina EA, et 2014, Nishimura T, *et al* 2014). The effects of change in geomagnetic activity on the emotional - affective sphere and personality characteristics of function- ally healthy persons were conducted using Luscher Color Test and other relevant psychological tests (Babayev & Allahverdiyeva 2007; Babayev *et al*. 2007) and revealed that geomagnetic disturbances affect mainly emotional and vegetative spheres of human beings while characteristics reacting personality

properties do not undergo significant changes in the some other investigation it is inferred that the changes in geomagnetic conditions mostly affect the activity of regulating systems, which are related to high cortical mechanisms of regulation and sub-cortical integrative apparatuses responsible for organization of routine activity of an organism, and for adaptation to changes of a physical environment (Babayev & Allahverdiyeva 2005). Verma (2012) has studied the relationship between death due to suicide in India and various Solar Activity (SA) parameters; i.e. Sunspot Numbers (SSN), Solar Flare Index (SFI), Coronal Index (CI) and Cosmic Ray Intensity (CRI) observed during the period of 1989 to 2011 and concluded that the number of Suicide Incidents of male, female, and average is well correlated with yearly averages of the SSN, SFI, and CI; as well as being positively correlated with CRI. Verma (2013) has also studied Suicide Incidents in India with geomagnetic activity parameters, such as the planetary Ap, Kp, and Dst Indices for the period of 1989-2010, and found large negative correlations between Suicide Incidents and the yearly averages of geomagnetic activity parameters: the Kp, Ap, and Dst indices. In this investigation the Suicide Incident in United State has been taken in to consideration for statistical analysis with the Solar,

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Interplanetary and Geomagnetic Activity parameters for the period of 1997-2010, in order to explore which of the Solar, Interplanetary and Geomagnetic phenomena are responsible for this event.

Data Sources

Solar Activity (SA) parameters, Sunspot Numbers (SSN), Solar Flare Index (SFI), and interplanetary parameters, such as Sudden Storm Commencement (SSC) are taken from STP Solar Data (http:/ /www.ngdc.noaa.gov/stp/ solardataservices). Data of geomagnetic activity parameters Kp, Ap, Indices' values have been taken from OMNI Web Data System (http://omniweb.gsfc.nasa.gov). The data of Suicide Incidents in United State has been taken from the Idaho Vital statics Suicide Report for the period of 1997-2010 (http://www.healthandwelfare.idaho.gov/Portals/0/Users/074/5 4/1354/Suicide%20Report%202013.pdf).

Data Analysis and Results

From the data analysis of Table and Figure 1, 2 it is observed that the rate of suicidal death (Death per 100000) and yearly total number of suicidal death in United State is anticorrlated with yearly total of Kp index. Around Solar Maximum, in the year 2000 the yearly mean of the sunspot numbers(SSN) are 119.6 and yearly total of Kp index is 8621 but the rate of suicidal death and total number of suicidal death have been found comparatively low 10.4 ,29350 and about solar minimum, in the years 1997 and, 2007,2008,2009, the yearly mean of sunspot numbers are 21.6 and 7.5, 2.9, 3.1 and yearly total of Kp index has been found comparatively low 5657 and 5530,5329, 3290 respectively but the rate of suicidal death and total death around these years have been found comparatively higher than solar maximum (2000), in 1997 rate of suicidal death is 11.2 and total number of suicidal

Table -Suicidal death in United State and Associated Solar, Geomagnetic and Interplanetary Parameters.

Years	US Suidal death	US Suidal death per 100000	Total Kp	Total Ap	Yearly Mean of Solar Flare Index	Yearly Average of SSN	Yearly Total SSC
1997	30,535	11.2	5657	3090	1.01	21	28
1998	30575	11.1	7364	4404	4	64.6	35
1999	29199	10.5	7983	4593	6.39	93.3	30
2000	29350	10.4	8621	5524	7.61	119.6	45
2001	30622	10.7	7649	4744	6.8	111	42
2002	31655	11	8236	4805	4.56	104	46
2003	31484	10.8	10444	7966	3.46	63.7	13
2004	32439	11	7960	4916	1.6	40.4	28
5	32637	10.9	7719	4945	1.91	29.8	26
2006	33300	11	5887	3120	0.54	15.2	20
2007	34598	11.3	5530	2751	0.47	7	14
2008	36035	11.6	5329	2566	0.03	2.9	19
2009	36909	11.8	3290	1451	0.02	3.1	21
2010	38364	12.1	4584	2196	0.39	16	15

METHODS OF ANALYSIS

In this study a statistical method correlation has been used. The correlation is one of the most common, as well as the most useful statistics. A correlation is a single number that describes the degree of relationship between two variables. The correlation coefficient, symbolized as *r*, is a numerical summary of a bivariate relationship and can range from -1.00 to +1.00. Any *r* that is positive indicates a direct or positive relationship between two measured variables. Negative r indicates indirect or inverse relationship.

The formula for the correlation is:

$$r = \frac{N\sum XY - \left(\sum X\right)\left(\sum Y\right)}{\sqrt{\left[N\sum X^2 - \left(\sum X\right)^2\right]\left[N\sum Y^2 - \left(\sum Y\right)^2\right]}},$$

Where:

N= number of pairs of scores, $\sum XY$ = sum of the products of paired scores, $\sum X$ = sum of x scores, $\sum Y$ = sum of y scores, $\sum X^2$ = sum of squared scores, $\sum Y^2$ = sum of squared score

The scale of correlation coefficient is

.8 to 1.0 or -.8 to -1.0 (very large relationship)
.6 to .8 or -.6 to-.8 (large relationship)
.4 to .6 or -.4 to -.6 (good medium relationship)
.2 to .4 or .2 to -.4(weak relationship)
.0 to .2or .0to -.2 (weak or no relationship)

death is 30535 , in the year 2007 rate of suicidal death is 11.3 and total number of suicidal death is 34598 in the year 2008, rate of suicidal death is 11.6, and total number of suicidal death is 36035 and in the year 2009, rate of suicidal death is 11.8 and total number of suicidal death is 36909 but at solar maximum in year 2000 the rate of suicidal death is 10.4 and total death is 29350 which are comparatively low in comparison to the years around solar minimum (1997,2007,2008,2009) .
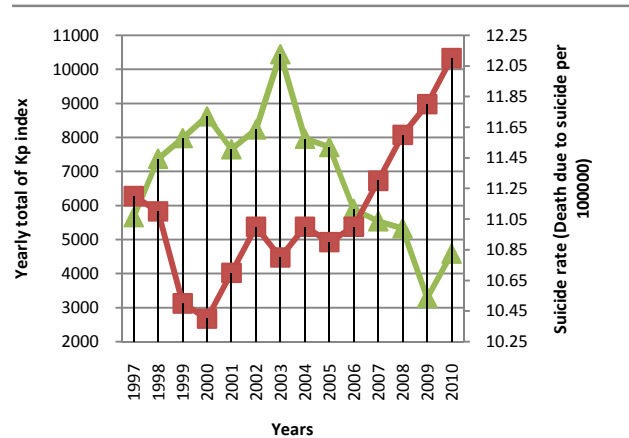

Figure 1-Shows line graph of yearly rate of suicide in United State and total of Kp index for the period of 1997-2010.

To know the statistical behavior of yearly total suicidal death with yearly total of Kp index a scatter plot has been plotted between these two events and the scatter plot so obtained is shown in Figure 2. The trend line of the scatter plot shows

very large negative correlation between yearly total suicidal death and yearly total of Kp index. Statistically calculated correlation coefficient has been determined -0.7499 between these two events. Negative correlation with correlation coefficient -0.81 has also been found between yearly total of Kp index and rate of suicidal death (Death per 100000) by statistical method.
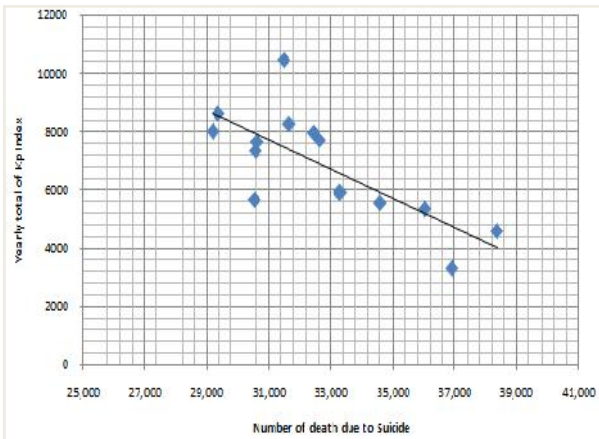

Figure 2 Shows scatter plot between yearly total death due in United State and yearly total of Kp index for the period of 1997-2010 showing large negative correlation with correlation coefficient -0.7499.

From the data analysis of Table and Figure 3, 4 it is observed that the rate of suicidal death (Death per 100000) and yearly total number of suicidal death in united state is anticorrlated with yearly total of Ap index.
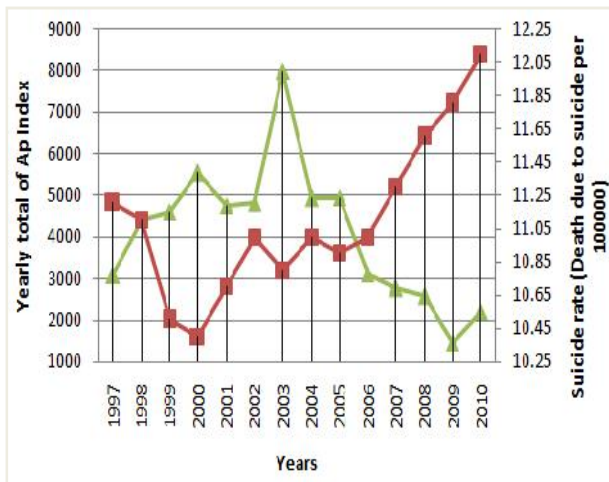

Figure 3 Shows line graph of yearly rate of suicidal death in United State and total of Ap index for the period of 1997-2010.

Around Solar Maximum, in the year 2000 the yearly mean of the sunspot numbers are 119.6 and yearly total of Ap index is 5524 but the rate of suicidal death and total number of suicidal death have been found comparatively low 10.4 ,29350 and about solar minimum, in the years 1997 and, 2007,2008,2009 the yearly mean of sunspot numbers are 21.6 and 7.5, 2.9, 3.1 and total of Ap index has been found comparatively low 3090, 2751,2566 , 1451 but the rate of suicidal death and total death around these years have been found comparatively higher than solar maximum (2000), in 1997 rate of suicidal death is 11.2 and total number of suicidal death is 30535 , in the year 2007 rate of suicidal death is 11.3 and total number of suicidal death is 34598 in the year 2008, rate of suicidal death is 11.6, and total number of suicidal death is 36035 and in the year 2009, rate of suicidal death is 11.8 and total number of suicidal death is 36909 but at solar

maximum in year 2000 the rate of suicidal death is 10.4 and total death is 29350 which are comparatively low in comparison to the years around solar minimum (1997,2007,2008,2009) .To know the statistical behavior of yearly total of suicidal death with yearly total of Ap index a scatter plot has been plotted between these two events and the scatter plot so obtained is shown in Figure 4. The trend line of the scatter plot shows very large negative correlation between yearly total of suicidal death and yearly total of Ap index. Statistically calculated correlation coefficient has been determined-0.684 between these two events. Negative correlation with correlation coefficient-0.754 has been found between yearly total of Ap index and rate of suicidal death by statistical method.
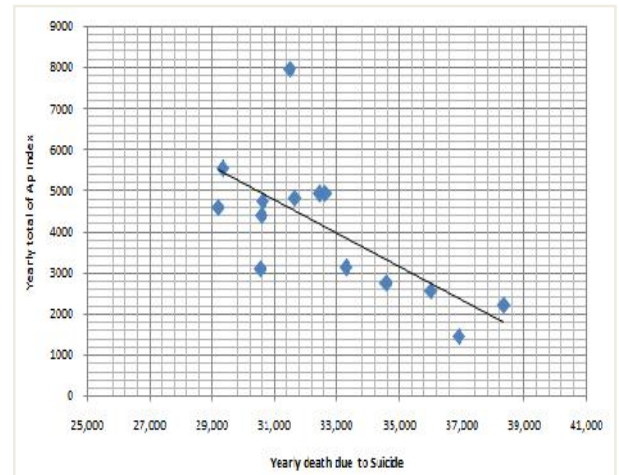

Figure 4 -Shows scatter plot between yearly total death due to suicide in united state and yearly total of Ap index for the period of 1997-2010. Showing large negative correlation with correlation -0.684.

From the data analysis rate of suicidal death, yearly total of suicidal death and yearly total of sudden storm commencements (SSC), it is observed that the rate of suicidal death , yearly total suicidal death is negatively correlated with yearly total of sudden storm commencement .We have calculated large negative correlation with a correlation coefficient of -0.658, between yearly total number of Sudden Storm Commencements (SSC) and the yearly total number of deaths due to suicide and medium good negative correlation with correlation coefficient of -0.573, between yearly total number of Sudden Storm Commencements (SSC) and the yearly rate (Death per 100000) of deaths due to suicide.
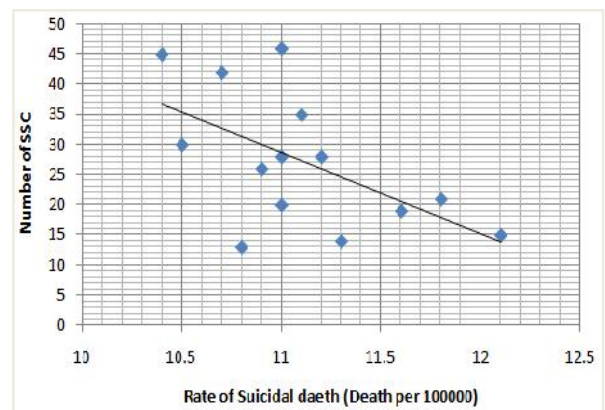

Figure -5 Shows scatter plot between rate of suicidal death due to suicide in united state and yearly total of SSC for the period of 1997-2010. Showing large negative correlation with correlation -0.658.
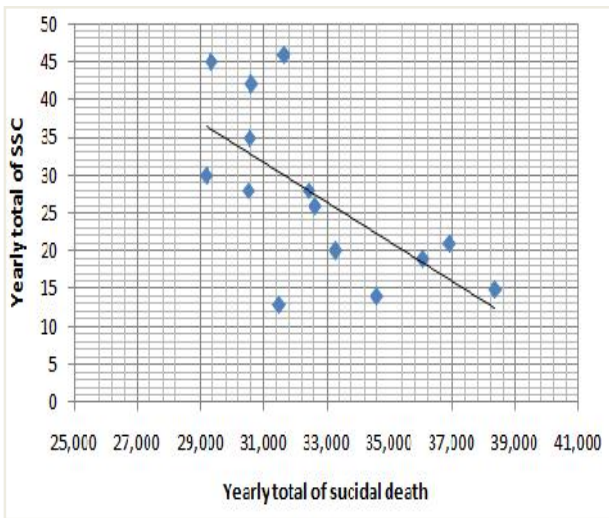
Figure 6 Shows scatter plot between yearly total death due to suicide in united state and yearly total of SSC for the period of 1997-2010. Showing medium good negative correlation with correlation -0.573
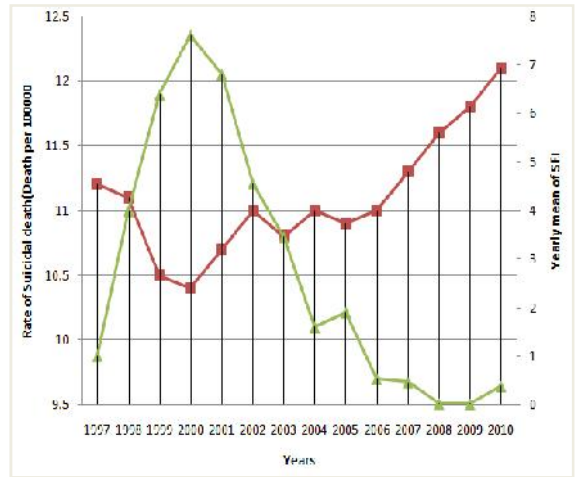
From the data analysis of Table 1 and Figures 7, 8, it is inferred that the death due to suicide in United Sate closely related to the yearly mean of sunspot numbers (SSN) and solar flare index (SFI). Around Solar Maximum in the year 2000, where the yearly mean of Sunspot Numbers (SSN) and Solar Flare Index (SFI) are at a maximum (sunspot number 119.6 and solar flare index 7.61) the suicide death rate and total death due to suicide have been found comparatively low (suicide rate in year 2000 is 10.4, and total death due to suicide in this year is 29350) in comparison to corresponding Solar Minimum where the Sunspot Number (SSN) and Solar Flare Index (SFI) are at minimum in number. About solar minimum where the yearly mean of Sunspot Number (SSN) and Solar Flare Index (SFI) are minimum in 1997 the sunspot numbers and solar flare index are 21,1.01 and in years 2007,2008,2009 the sunspot numbers and solar flare index are 7.0, 0.47; 2.9 ,.03 ;3.1,0.2 the suicide death rate and total death due to suicide has been found comparatively higher than corresponding solar maximum. In 1997 suicide death rate is 11.2 and total death due to suicide is 30535 ,in year 2007 suicide death rate 11.3 total death due to suicide is 34598 , in the year 2008,suicide death rate 11.6 and total death due to suicide is 36035 in the year 2009 , suicide death rate is 11.8 and total death due to suicide is 36909.
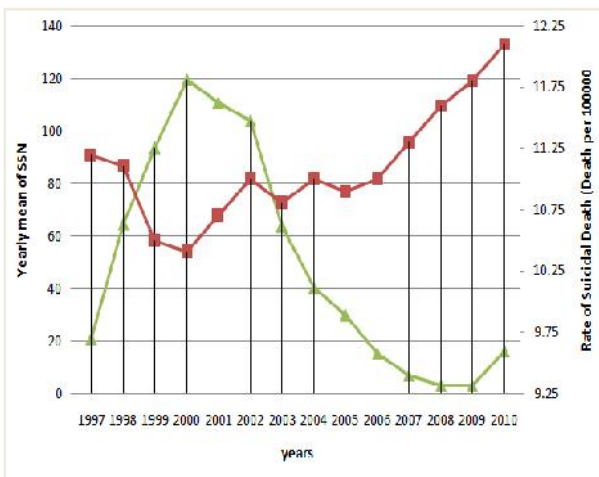

Figure 7 Shows line graph of yearly rate of suicidal death in United State and yearly mean of SSN for the period of 1997-2010.

Figure 8 shows line graph of yearly rate of suicide in united state and yearly mean of SFI for the period of 1997-2010.

From the data analysis of yearly mean of sunspot numbers (SSN) and rate of suicidal death and yearly total death, it is inferred that rate of suicidal death and total yearly death is aniticorrelated with yearly mean of sunspot numbers (SSN) (Figure 7). Large negative correlation, with a correlation coefficient of -0.762, has been found between the yearly mean of the Sunspot Numbers (SSN) and the yearly rate (Death per 100000) of deaths due to suicide and large negative correlation, with a correlation coefficient of -0.761, has been found between the yearly mean of Sunspot Numbers (SSN) and the yearly total number of deaths due to suicide by the statistical methods. From the data analysis of solar flare index and rate of suicidal death and total death due to suicide, , it is inferred that rate of suicidal death and total yearly death is aniticorrelated with yearly mean of solar flare index (Figure 8) .Large negative correlation, with a correlation coefficient of -0.80, has been found between the yearly mean of the Solar Flare Index (SFI) and the yearly rate (Death per 100000) of deaths due to suicide and large negative correlation, with correlation coefficient of -0.789 has been found between the yearly mean of the Solar Flare Index (SFI) and the yearly total deaths due to suicide by the statistical methods .

MAIN RESULTS

a) Large negative correlation, with a correlation coefficient of -0.814, has been found between the yearly total of Kp index and the yearly rate (Death per 100000) of deaths due to suicide.

b) Large negative correlation, with a correlation coefficient of -0.749, has been found between the yearly total of Kp index and the yearly total number of deaths due to suicide.

c) Large negative correlation, with a correlation coefficient of -0.754, has been found between the yearly total of Ap index and the yearly rate (Death per 100000) of deaths due to suicide.

d) Large negative correlation, with a correlation coefficient of -0.684, has been found between the yearly total of Ap index and the yearly total number of deaths due to suicide.

e) Large negative correlation, with a correlation coefficient of -0.762, has been found between the yearly average of the Sunspot Numbers (SSN) and the yearly rate (Death per 100000) of deaths due to suicide.

f) Large negative correlation, with a correlation coefficient of -0.761, has been found between the yearly average of Sunspot Numbers (SSN) and the yearly total number of deaths due to suicide.

g) Large negative correlation, with a correlation coefficient of -0.80, has been found between the yearly mean of the Solar Flare Index (SFI) and the yearly rate (Death per 100000) of deaths due to suicide.

h) Large negative correlation, with correlation coefficient of -0.789 has been found between the yearly mean of the Solar Flare Index (SFI) and the yearly total deaths due to suicide.

i) Negative correlation, with correlation a coefficient of -0.573, has been found between yearly total number of Sudden Storm Commencements (SSC) and the yearly rate (Death per 100000) of deaths due to suicide.

j) Large negative correlation, with a correlation coefficient of -0.658, has been found between yearly total number of Sudden Storm Commencements (SSC) and the yearly total number of deaths due to suicide.

CONCLUSION

From the results of the analysis it is observed that total death due to suicide and rate of suicide deaths (Death due to suicide per 100000) are closely related to solar activity parameter sunspot numbers (SSN), solar flare index (SFI) , geomagnetic activity parameters Kp, Ap index and interplanetary parameters sudden storms commencements (SSC) . The yearly mean of sunspot numbers, solar flare index yearly total of Kp, Ap index are anti correlated with yearly total of death due to suicide and rate of death due to suicide. Large negative correlation, with a correlation coefficient of -0.814 between the yearly total of Kp index and the yearly rate (Death per 100000) of deaths due to suicide.-0.749, between the yearly total of Kp index and the yearly total number of deaths due to suicide.-0.754, between the yearly total of Ap index and the yearly rate (Death per 100000) of deaths due to suicide.-0.684, between the yearly total of Ap index and the yearly total number of deaths due to suicide.-0.762, between the yearly mean of the Sunspot Numbers (SSN) and the yearly rate (Death per 100000) of deaths due to suicide.-0.761 between the yearly mean of Sunspot Numbers (SSN) and the yearly total number of deaths due to suicide.-0.80, between the yearly mean of the Solar Flare Index (SFI) and the yearly rate (Death per 100000) of deaths due to suicide.-0.789 between the yearly mean of the Solar Flare Index (SFI) and the yearly total deaths due to suicide.-0.573, between yearly total number of Sudden Storm Commencements (SSC) and the yearly rate (Death per 100000) of deaths due to suicide.-0.658 between yearly total number of Sudden Storm Commencements (SSC) and the yearly total number of deaths due to suicide shows that death due to suicide is relatively low in solar maximum when the sun is most active period and the occurrences of all the energetic solar phenomena becomes very higher and death due to suicide are relatively high in solar minimum when the sun becomes in quit period and the occurrences of all the energetic solar phenomena are relatively very low . Solar, Interplanetary, and Geomagnetic Activity parameters lead to the conclusion that variations in Solar, Interplanetary and Geomagnetic Field can directly or indirectly affect the human organism, Although there is currently no known geophysical mechanism to explain this phenomena, it is expected that particular changes in the ambient electromagnetic and acoustical signals caused by Heliogeophysical factors could promote the exacerbation of the mental state and even act as a trigger of the suicidal behavior. However, the clarification of the mechanisms behind the impact of Solar, Interplanetary and Geophysical factors on humans requires more detailed studies.

References

1. Babayev E.S., Allahverdiyeva A.A, Effects of geomagnetic activity variations on the physiological and psychological state of functionally healthy humans: Some results of Azerbaijani studies Advances in Space Research, 40(12), 1941, 2007.

2. Babayev, E.S., & Allahverdiyeva, A.A., 2005. 'Revista CENIC: Ciencias Biologicas.' Numero Especial in CD, La Habana, Cuba, 36, 7, 2005.

3. Cornelissen G, Dimitrov BD, Carandente F, Halberg F : Space and earth weather mirrored in patterns of suicide incidence. World Heart Journal 3: 31, 2011.

4. Cornelissen G, Halberg F, Breus T, Syytkina E, Baevsky R, Weydahl A, Watanabe Y, Otsuka K, Siegelova J, Fiser B, Bakken E ,Non-photic solar associations of heart rate variability and myocardial infraction. JASTP 64:707–720 Relationship between human physiological parameters and geomagnetic variations of solar origin. Adv Space Res 37:1251, 2002.

5. Dimitrova S. Geo-Effective Heliophysical Variations and Human Physiological State . Sun and Geosphere, 4(2), 79, 2009.

6. Dimitrova, S. Stoilova, I., Cholakov, I. Influence of local geomagnetic storms on arterial blood pressure. Bioelectromagnetics 25, 408, 2004.

7. Dorman LI, Iucci N, Ptitsyna NG and Villoresi G: Cosmic ray as indicator of space weather influence on frequency of infract myocardial, brain strokes, car and train accidents. In: Proceedings in 27th ICRC (Hamburg), 3511, 2001.

8. Dorman, L.I., Space weather and dangerous phenomena on the Earth: principles of great geomagnetic storms forcasting by online cosmic ray dataAnn. Geophys., 23, 2997,2005.

9. Dzvonik, O., Stetiarova, J., Kudela, K., and Daxner, P.: A monitoring of space weather effects on some parameters of mental performance and health in aviation personnel, Studia Psychological, 48, 273, 2006.

10. Gmitrov, J., Gmitrova, A. Geomagnetic field effect on cardiovascular regulation. Bioelectromagnetics 25, 92, 2004.

11. Gurfinkel, Iu.I., Liubimov, V.V., Oraevskii, V.N., *et al.* 1995, Biofizika (Russian J. Biophysics), 40(4), 793 , 1995.

12. Kasatkina EA, Shumilov O I, Novikova TB, Chramov AV (2014) Peculiaririties of Dynamics and Cyclicity of death from suicides and heliophysical and anthropological factors in norther region Kola (in Russian), Human Ecology 2: 45,2014.

13. Kay, R.W. Geomagnetic storms: association with incidence of depression as measured by hospital admission. Br. J. Psychiatry 164 (3), 403, 1994.

14. Mavromichalaki H, Papailiou M, Dimitrova S, Babayev ES, Loucas P (2012) Space weather hazard and their impact on human cardio-health state parameters on Earth. Natural Hazards 64:1447, 2012.

15. Mavromichalaki H, Papailiou M, Dimitrova S, Babayev ES, Mustafa FR Geomagnetic disturbances and cosmic ray variations in relation to human cardio-health state: a

wide collaboration. In: Proceedings in 21st ECRS (Kosice), 351, 2008.

16. Nishimura T, Tada H, Nakatani E, Matsuda K, Teramukai S,:Stronger geomagnetic field may be a risk factor for male suicides. Psychiatry and Clinical Neurosciences 68: 404, 2014.

17. Persinger, M.A., Richards, P.M. Vestibular experiences of humans during brief periods of partial sensory deprivation are enhanced when daily geomagnetic activity exceeds 15–20 nT. Neurosci. Lett. 194 (1–2), 69, 1995.

18. Ptitsyna N.G., G. Villoresi, L.I. Dorman, N. Iucci, M.I. Tyasto :'Natural and Man-made Low-frequency Magnetic Fieldsas a Potential Health Hazard.' UFN (Uspekhi PhysicheskikhNauk), 168(7), 76, 1998.

19. Ptitsyna, N.G., Villoresi, G., Kopytenko, Y.A., Tyasto, Eugene A.Kopytenko, Nunzio Iucci, Pavel M. Voronov Y and Z componentset., Bioelectromagnetics 17, 436, 1996.

20. Verma, P.L. Suicide incidents in India in relation with solar activity parameters and cosmic ray intensity (1989

21. Verma, P.L., 'Suicide Incident in India in Relation with Geomagnetic Activity Parameters During the Period of 1989-2010.' IJAR, 3(6) 464, 2013.

22. Villoresi G., Breus T.K., Dorman L.I., Iucci N., RapoportS.I., Physica Medica, 10, 79,1994.

23. Villoresi G., Dorman L.I., Ptitsyna N.G., Iucci N., TiastoM.I.,, Proc. 24th Intern. Cosmic Ray Conf., Rome, 4, 1106, 1995.

24. Villoresi G., Ptitsyna N.G., Tiasto M.I., Iucci N, Myocardial infarct and geomagnetic disturbances: analysis of data on morbidity and mortality Biofizika, 43,.623,1998.

25. Watanabe, Y., Hillman, D.C., Otsuka, K., *et al.* Cross-spectral coherence between geomagnetic disturbance and human cardiovascular variables at non-societal frequencies. Chronobiologia 21 (3–4), 265, 1994.

26. Zhadin, M.N., 'Review of russian literature on biological action of DC and low-frequency AC magnetic fields Bioelectromagnetics.' 22(1), 27, 2001.

to 2011). : International Journal of Physical Sciences, 7(49), 6240, 2012.

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