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Chapter 3

Bioremediation of Agricultural Land Damaged by Tsunami

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Additional information is available at the end of the chapter

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1. Introduction

Bioremediation is the process of using naturally occurring microbes to digest and convert unwanted material into harmless substances. In this chapter, an innovative study has been carried out by using compost and specific bacteria (Halo Bacteria) to restore the high saline soil damaged by Tsunami occurred on 11th March, 2011 at the Tohoku Area in Japan.

A disaster is the tragedy of a natural or human-made hazard (a hazard is a situation which poses a level of threat to life, health, property, or environment) that negatively affects society or environment. A natural disaster is a consequence when a natural hazard (e.g., volcanic eruption or earthquake) affects humans. Tsunamis and earthquakes are two of the most dangerous and yet most common hazards to affect population centers and economic infrastructures worldwide. Generally, tsunami flooding results from a train of long-period waves that can rapidly travel long distances from where they were generated by deep-ocean earthquakes, submarine landslides, volcanic eruptions, or asteroid impacts [1, 2, 3]. Due to tsunami the sea water carry sediments along with salt itself. There have been many studies on recent and ancient tsunami deposits. These include descriptions of tsunami deposits in coastal lake, estuary, lagoon, bay floor and shelf environments and even the farmland [4,5]. The mega earthquake and consequent tsunami had caused a great damage to not only human life and infrastructure but also the agricultural land and the crops in Tohoku region, Japan. The after math of the tsunami has created many problems to environment and geo-environment of these affected areas. Soil pollution and high salinity which caused the farmland unusable for cultivation is one of the major geo-environmental problems. The objective of this study is to get an idea about the extent of soil chemical properties change due to tsunami and to apply bioremediation approach to salinity control of the agricultural land.

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The sea water inundated the large areas of agricultural land causing the excessive saline in the soil.

2. Salinity of soil

Salinity of soils is the condition of soils that have a high salt content. The predominant salt is normally sodium chloride (NaCl). As a result, saline soils are therefore also *sodic soils* but there may be sodic soils those are not saline, but alkaline. Salty soils are a common feature and an environmental problem in irrigated lands in arid and semi-arid regions all over the world. They have poor or little crop production. The problems are often associated with high water tables, caused by a lack of natural subsurface drainage to the underground. Poor subsurface drainage may be caused by insufficient transport capacity of the aquifer or because water cannot exit the aquifer. Worldwide, the major factor in the development of saline soils is a lack of precipitation. Most naturally saline soils are found in (semi)arid regions and climates of the globe.

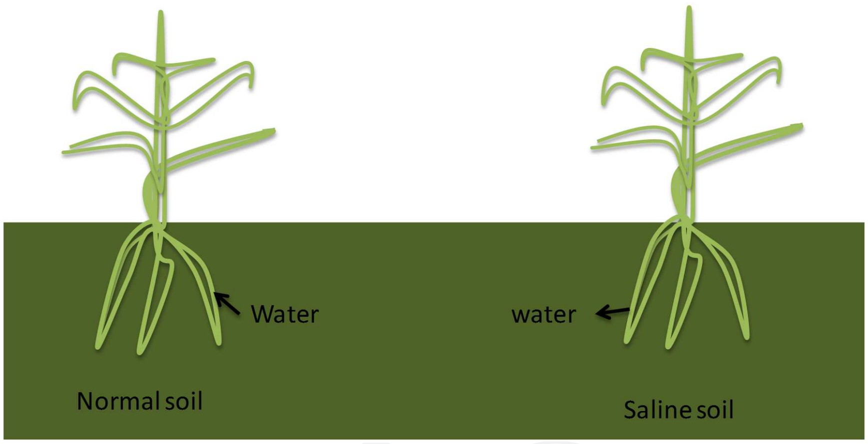

Figure 1. Mechanism of salinity affected soil and plant interaction

Figure 1 shows the mechanisms of salinity affected soil and plant interaction. Salinity becomes a problem when enough salts accumulate in the root zone to negatively affect plant growth. Excess salts in the root zone hinder plant roots from withdrawing water from surrounding soil. This lowers the amount of water available to the plant, regardless of the amount of water actually in the root zone. For example, when plant growth is compared in two identical soils with the same moisture levels, one soil receiving salty water and the other receiving salt-free water, plants are able to use more water from the soil receiving salt-free water. Although the water is not held tighter to the soil in saline environments, the presence of salt in the water causes plants to exert more energy extracting water from the soil. The main point is that excess salinity in soil water can decrease plant available water and cause plant stress. So, high salinity of soil is very dangerous for the plant as most of the plants can not survive in that soil condition.

Figure 2. Salt accumulated on the surface of the tsunami sediment in Tohoku area, Japan

Figure 2 shows the salt accumulation on the surface of the soil after the tsunami in Tohuku area in Japan. For the case of tsunami, a vast area of the land area goes under sea water. And the accumulation of salt after the tsunami water caused a serious damage to the geo-environment. Soil water salinity can affect soil physical properties by causing fine particles to bind together into aggregates. This process is known as flocculation and is beneficial in terms of soil aeration, root penetration, and root growth. Although increasing soil solution salinity has a positive effect on soil aggregation and stabilization, at high levels salinity can have negative and potentially lethal effects on plants. As a result, salinity cannot be increased to maintain soil structure without considering potential impacts on plant health.

3. Tohoku region Pacific Coast earthquake in 2011

The great east Japan Earthquake (Higashi Nihon Daishinsai in Japanese) was a magnitude 9.0 undersea mega thrust earthquake off the coast of Japan that occurred at 14:46:23 JST on Friday, 11 March 2011.The location of the epicenter (38.322^0 N, 142.369^0 E) of this earthquake is about 70 kilometers east of the Oshika Peninsula of Tohoku and the hypocenter at an underwater depth of approximately 32 km. It was the most powerful known earthquake to have hit Japan, and one of the five most powerful earthquakes in the world overall since modern record-keeping began in 1900. The earthquake triggered extremely destructive tsunami waves of around 40 m in Miyako, Iwate prefecture and in some cases travelling up to 10 km inland. In addition to loss of life and destruction of infrastructure, the tsunami caused a number of nuclear accidents in the power plant in Fukushima which caused evacuation zones affecting hundreds of thousands of residents. The sea water inundated the large areas of agricultural land causing the excessive saline in the soil.

4. Soil investigation

The field test of soil for its chemical analysis was conducted in Rikuzentakata city of Iwate prefecture, Japan. Fig. 3 shows the damaged area in Rikuzentakata city [9]. This city was one the major affected areas by the tsunami on 11th March, 2011. Fig. 4 shows the place of investigation on 5th May, 2011. Fig. 5 shows the place of soil investigation on 30th June, 2011.

The pH and EC (Electric Conductivity) of the damaged agricultural land were measured by the digital pH meter (Horiba, D-54SE). The electrical conductivity of the soil was also measured by using digital EC meter (Oakton, PCSTEST35). The salinity of the soil can be calculated by the value of electrical conductivity.

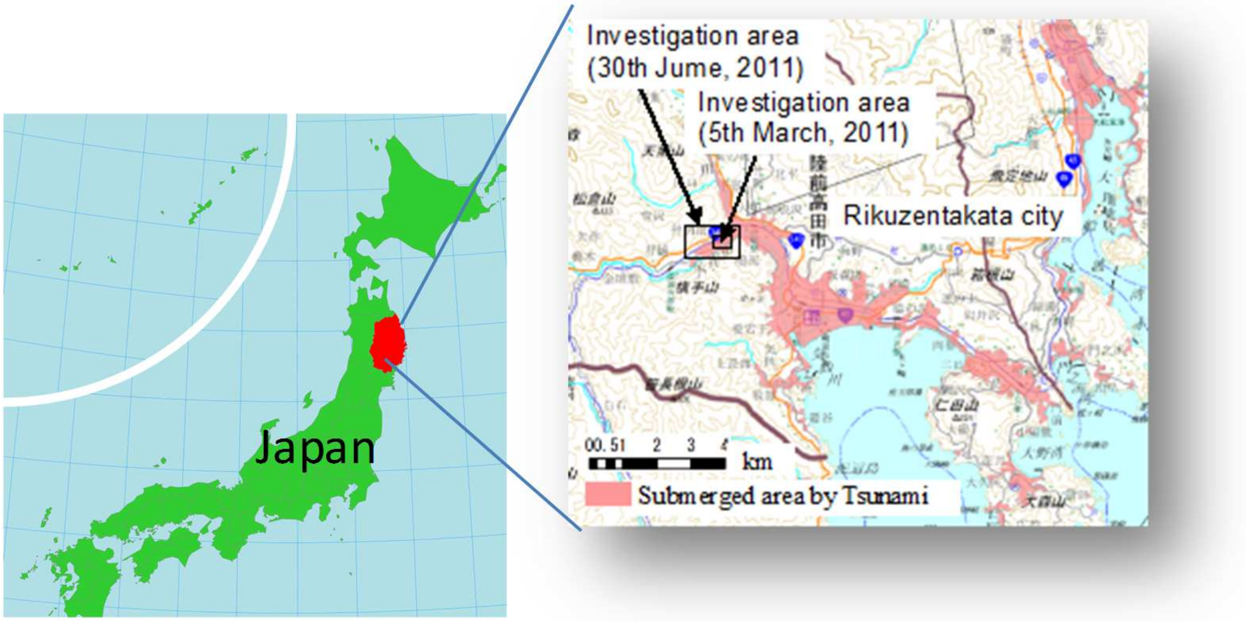

Figure 3. Map of Japan indicating the study area and soil investigation area

5. Soil properties of Rikuzentaka area after tsunami

The soil of the Rikuzentakata was very fertile. The farmers used to cultivate different types of crops including the corn and vegetables. The average moisture content of the soil was around 25 %. However, due to the tsunami water inundated the large areas of the Rikuzentakata, a huge amount of submarine sediments come along with the sea water and settled on the agricultural land along with different types of tsunami debris. The sediment of the tsunami also brought some kinds of toxic materials which were settled under the sea over a long period of time. The sediment is mainly a clay but some sandy particles were also found in different parts of the area.

Figure 4. The place of soil investigation on 5 May 2011 in Rikuzentakata area

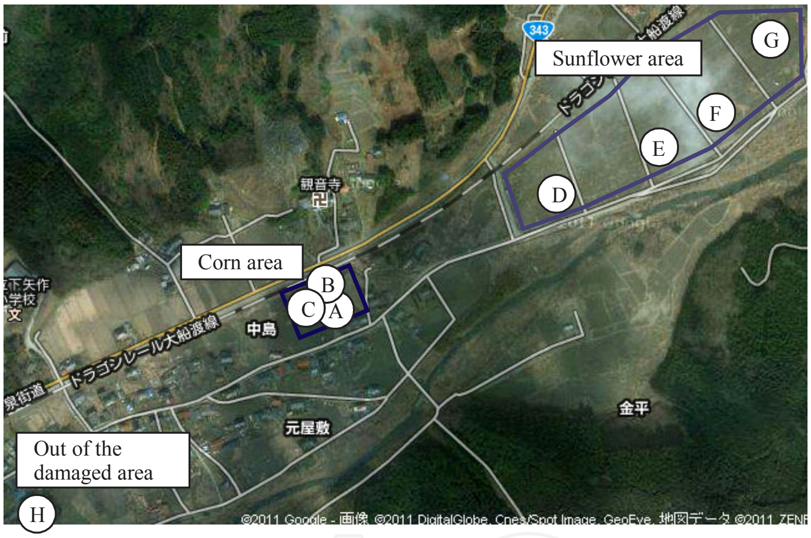

Figure 5. The place of soil investigation on 30th June 2011 in Rikuzentakata area

6. Bioremediation for restoration of saline soil

The aim of soil salinity control is to prevent soil degradation by salinization and reclaim already salty (saline) soils.

Various attempts are now carrying out to control the salinity of the agricultural land. The primary method of controlling soil salinity is to permit 10-20% of the irrigation water to leach the soil, be drained and discharged through an appropriate drainage system.

The salt concentration of the drainage water is normally 5 to 10 times higher than that of the irrigation water, thus salt export matches salt import and it will not accumulate. However, it

Figure 6. Tsunami Sediment deposited on the vast area in tohoku, Japan

will take a long time and efforts for such kind of design of the salinity removal from the saline soil [7,8].

In this study, an innovative idea has been taken for reducing the salt concentration from the soil of the agricultural areas by bioremediation. By using the halo bacteria with the compost the bioremediation was carried out.

It was possible to increase a volume of the compost by mixing rice bran, oil cakes, grinds of fish bones and water in a specific ratio. Total 30 kg compost was made. Further, it had increased up to 300 kg. After mixing each material, temperature of the compost increased at 48 ˚C for 2 days and turned over for aeration (Figs. 7 and 8).

Figure 7. Preparing compost by mixing rice bran, oil cakes, grinds of fish bones and water

Figure 8. Compost by mixing rice bran, oil cakes, grinds of fish bones and water after 3 days

Then, the compost containing the halo bacteria had been applied in the large areas of Rikuzentakata of Iwate Prefecture which was affected by sea water inundation due to tsunami. Due to bacterial activities, the salinity of the agricultural areas would have been reduced as well as compost would supply some nutrients and organics to the soil.

(a) EC (mS/cm)										
Depth	1	2	3	4	5	6	7	8	9	10
5cm	1.51	0.36	0.39	1.49	1.26	0.47	1.20	1.77	1.01	0.25
10cm	3.04	2.00	1.94	2.93	3.16	1.32	2.77	3.43	1.83	1.15
15cm	2.23	2.43	2.81	4.03	2.21	1.84	0.97	3.46	2.4	2.25
(b) pH										
Depth	1	2	3	4	5	6	7	8	9	10
5cm	7.21	8.47	8.06	7.55	7.22	8.39	7.71	7.62	7.19	8.27
10cm	5.75	5.68	6.5	5.78	5.71	6.57	5.98	5.6	6.74	6.52
15cm	6.22	5.48	5.69	5.2	6.13	5.84	7.12	5.64	5.77	5.82

Table 1. EC and pH of soil in different depths on 5^{th} May 2011

(a) EC (mS/cm)

Depth	A	B	C	D	E	F	G	H
Surface	0.56	0.11	0.13	0.083	0.09	0.064	0.13	-
5 cm	-	-	-	-	-	-	-	0.032
10 cm	0.97	1.19	0.62	-	0.093	0.15	-	-
15 cm	-	-	-	-	-	-	0.21	-
20 cm	1.83	1.58	1.64	0.21	0.096	0.46		0.026
25 cm	2.15	-	-	-	-	-	-	-
30 cm	-	-	1.65	-	-	-	-	-

(b) pH

Depth	A	B	C	D	E	F	G	H
Surface	7.2	8.1	7.4	8.3	9.0	8.4	8.0	-
5 cm	-	-	-	-	-	-	-	6.9
10 cm	6.6	5.9	6.7	-	9.1	8.4	-	-
15 cm	-	-	-	-	-	-	6.7	-
20 cm	6.1	5.6	5.9	7.0	8.0	7.1	-	6.9
25 cm	6.4	-	-	-	-	-	-	-
30 cm	-	-	5.7	-	-	-	-	-

Table 2. EC and pH of soil in different depths on 30th June, 2011

7. Laboratory test of Bioremediation with the compost

In order to confirm the effect of the compost, an artificial saline soil was made by mixing natural salt. The original EC of the soil is 2.85 mS/cm. The compost with Halo bacteria of 1g and rice bran of 15 g were mixed into the soil of 500 cm^3. The rice bran is a material for accelerate growth of the bacteria. After the incubation, a value of EC is measured. Fig. 9 shows the result of EC for the soil mixed with the compost. It is clear that EC of the soil with salt is decreased by mixing the compost with Halo bacteria. It is estimated that 25% of salt can be reduced by mixing the compost for 7 days in this bioremediation.

The bioremediation of the saline soil is possible by using the home made compost. The way of making the compost is easy and less costly. So, this method of remediation can be used in many developing countries in the world. The benefit of this bioremediation is that the cost during the process of bioremediation is very low compare to other method of salinity management of agricultural soil currently used.

Soil investigation at the site was performed on March 2012. Table 3 shows comparison of electric conductivity of the soils before and after the restoration by the compost. Due to the rail fall and vegetation of sunflower, the salt concentration decreased gradually and the highest EC at the site was 0.25 mS/cm on September 2011. The value of EC decreased furthermore on

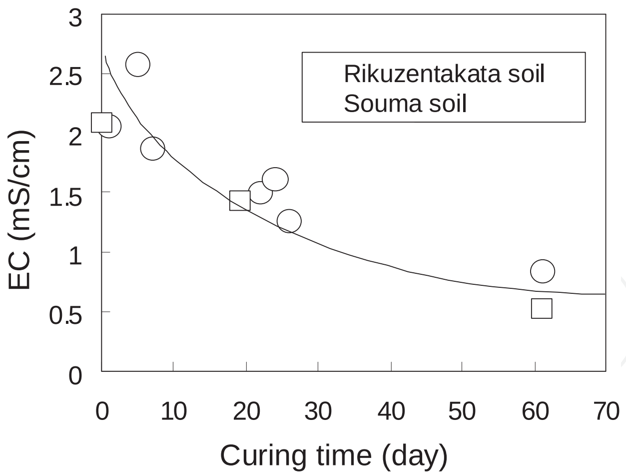

Figure 9. Relationship between electric conductivity and curing period on soil with salt

March 2012.The effect of bioremediation is understood in the field, however, the exact amount of the bioremediation is difficult to measure in the field as the natural environmental effects have the influence on the soil properties in the wide areas of the Rikuzentakata.

	EC (mS/cm)						
Date	A	B	C	D	E	F	G
30/9/2011	0.174	0.213	0.211	0.249	0.186	0.203	0.226
12/3/2012	0.016	0.017	0.018	0.143	0.017	0.016	0.017

Table 3. Comparison of electric conductivity of the soils before and after bioremediation

Some substances known to have toxic properties have been introduced into the environment through man-made activities. These substances range in degree of toxicity and danger to human health. Many of these substances either immediately or ultimately come in contact with or are sequestered by soil. Conventional methods to remove, reduce, or mitigate toxic substances introduced into soil or ground water via anthropogenic activities and processes include pump and treat systems, soil vapor extraction, incineration, and containment. Utility of each of these conventional methods of treatment of contaminated soil and/or water suffers from recognizable drawbacks and may involve some level of risk.

8. Mechanisms of bioremediation of salinity affected soil

The mechanism of bioremediation of the salt affected agricultural land is illustrated in the Figure 10. It is seen that the bacteria mixing with compost help to release the salt element from the soil surface due to the microbial activities. When the effects of bioremediation were taken place then the salt removed easily from the surface with the help of rain water or snow melting.

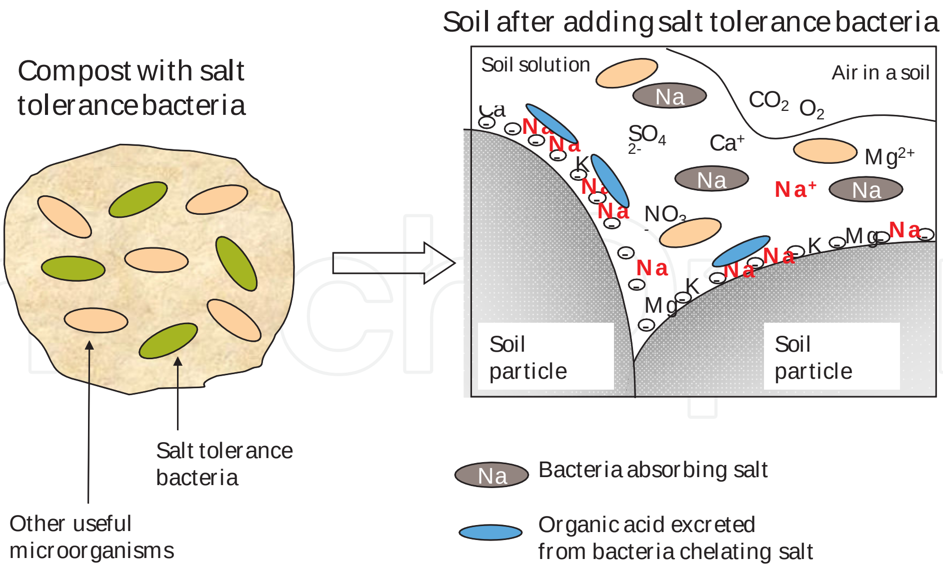

Figure 10. Mechanism of salt removal from tsunami affected soil by bioremediation

The salt in the soil particle can be easily removed by this bioremediation. So this mechanism to remove the salt from the saline soil can be used not only for the tsunami affected areas but also in the coastal areas in different countries in where the sea level rise caused by global warming is a real threatening matter for the local population.

9. Salinity, plant growth and bioremediation in tsunami affected area

Salinity is an important land degradation problem. Soil salinity can be reduced by leaching soluble salts out of soil with excess irrigation water. Soil salinity control involves watertable control and flushing in combination with tile drainage or another form of subsurface drainage however, if the vast area is affected by salinity then it is really difficult to treat that soil as the fresh waster needed to wash the soil will need a huge amount of money. So bioremediation of saline soil is a better option as the compost can supply some nutrients as well to the soil. High levels of soil salinity can be tolerated if salt-tolerant plants are grown. Sensitive crops lose their vigor already in slightly saline soils, most crops are negatively affected by (moderately) saline soils, and only salinity resistant crops can stay alive in severely saline soils.

A high salt level interferes with the germination of new seeds. Salinity acts like drought on plants, preventing roots from performing their osmotic activity where water and nutrients move from an area of low concentration into an area of high concentration. Therefore, because of the salt levels in the soil, water and nutrients cannot move into the plant roots.

As soil salinity levels increase, the stress on germinating seedlings also increases. Perennial plants seem to handle salinity better than annual plants. In some cases, salinity also has a toxic effect on plants because of the high concentration of certain salts in the soil. Salinity prevents the plants from uptaking the proper balance of nutrients they require for healthy growth. So, in our bioremediation of saline soil, we can easily provide the sufficient nutrients as well as to restore the salinity affected soil for a vast area generally affected by tsunami in a reasonable cost.

10. Conclusions

The mega earthquake and consequent huge tsunami has done a great damage to the entire areas of the pacific regions in Tohoku, Japan. The sea water which covered the agricultural lands in these areas has created a critical situation for the farmers. The farmers have lost not only the crops they were cultivating but also the soil of the agricultural field had been seriously damaged by the sea water, salinity and other pollutants. The pH value and EC value of the soil in these areas are considered as the higher value in terms of safer limit for the regular crops. To reclaim this saline soil, compost containing the Halo bacteria had been applied as an approach of bioremediation. The Halo bacteria used the excessive salts from the soil and consequently can reduce the salinity problem which was proved in the laboratory test. This compost can also provide necessary nutrients to the soil and plant. So, bioremediation by compost to restore the tsunami damaged saline soil proved to be an efficient and can be applicable in other parts of the world especially developing countries which are suffering by the sea level rise problems.

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References

[1] Morton, R.A., G. Gelfenbaum and B.E. Jaffe (2007) Physical criteria for distinguishing sandy tsunami and storm deposits using modern examples. *Sedimentary Geology*, vol. 200,,pp.184-207.

[2] Katsudanso Kenkyu (Active Fault Res. Jpn.)12, pp 1-23 (in Japanese with English abstract).

[3] Minoura K.,Gusiakov, V.G.,Kurbatov,A., Takeuti,S.,Svendsen, J.I., Bondevik, S.,Od, T.(1996). Tsunami sedimentation associated with the 1923 kamchatka earthquake. *Sedimentary Geology,* Vol.106, pp.145-154.

[4] Bourgeois J., T.A. Hansen, P.L. Kauffman,E.G. (1988). A tsunami deposit at the Cretaceous-Tertiary boundary in Texas. Science, Vol. 241, pp. 567-570.

[5] Dawson A.G., Long, D., Smith, D.E., (1988). The steregga slides; evidence from eastern Scotland for possible tsunamis. Marine Geology. Vol.99,pp.265-287.

[6] Yamazaki T., Yamaoka,M.Shiki,T.(1989). Miocene offshore tractive current-worked conlomerates-Tsubutegaura, Chiba Peninsula, Central Japan. In: Taira,A.,Masuda,F(Eds). Sedimentary Facies in the Active Plate Margin, TERRAPUB, Tokyo, pp. 483-494.

[7] Shiki T and Yamazaki,T.,(1996). Tsunami-induced conglomerates in Miocene upper bathyal deposits, Chiba Peninsula, Central Japan. *Sedimentary Geology*. Vol 104, pp. 175-188.

[8] Wright C.,Mella, A. (1963). Modifications to the soil pattern of south-central Chile resulting from seismic and associated phenomena during the period May to August 1960. Bull.Seismol.Soc.Am.Vol 53,pp. 1367-1402.

[9] The Geospatial Information Authority of Japan.