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# RECOVERY OF PADDY FIELD DAMAGED BY TSUNAMI AND EARTHQUAKE USING STEELMAKING SLAG

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## Abstract

*Paddy filed in Sendai area has suffered a huge damage after the Tsunami, caused by the great earthquake on 11th March 2011. Thick sludge covered the paddy field after brine receded, and some parts of this field still remain uncultivable even now. To restore cultivation, firstly the soil must be desalted, and then many lost nutrient elements should be resupplied. In such circumstances, the steelmaking slag, which is suitable for the above two purposes, has been proposed with full expectation as a solution for recovery. In this study, the laboratory scale experiments, has been carried out to evaluate the role of steelmaking slag on paddy field.*

## Destruction of paddy field

The entire world has been astonished by the great earthquake happened in Japan on 11th March 2011. Unimaginable damages occurred, not just only by the earthquake itself but the horrible Tsunami it brought. Sendai area, which is quite close to the epicentre, could not escape from the claws of Tsumani, although it is such smooth ground rather than canyon coastal. Figure 1 accounts the horrible damage. Almost 150 $km^2$ of farmland in the entire Miyagi area (including Sendai area) has been immersed, of which nearly 90% is paddy field. That means, a fertile granary, as we so remembered, was gone.

Before Tsunami Right after Tsunami Now remains uncultivable

**Figure 1**: Damage to paddy filed in Sendai area

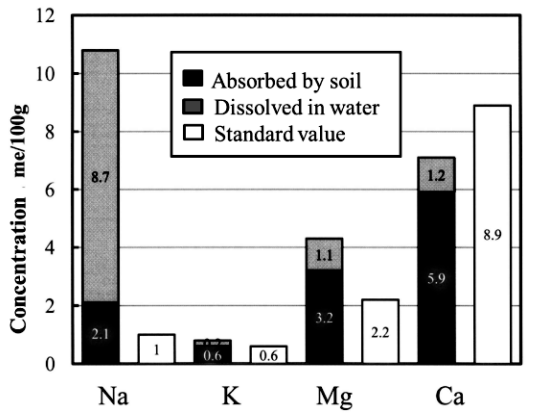


**Figure 2**: Concentrations of base elements in paddy soil after Tsunami

To restore cultivation, firstly the balance among base elements must be regained. Figure 2 shows the current status of paddy field environment[1], the sodium concentration is too high while calcium concentration stays low. This leads to many problems, such as high electrical conductivity of paddy field water, which makes it hard for plant root to absorb moisture and nutrition.

Moreover, the drainage property and breathability of soil has also been damaged, due to the destruction on the aggregate structure. During the reconstruction, it has been found that the sodium absorbed by soil could not be simply removed by fresh water irrigation or rainfall. Instead, the supplement of calcium ion holds the key. As shown in Figure 3[1], after supplying the paddy soil with calcium ion, the sodium ion could be exchanged and finally washed away by rainfall.

## Recovery of paddy filed using steelmaking slag

Based on above description, the primary step is to seek out proper source for feeding calcium. Because steelmaking slag could dissolve out certain amount of calcium ion and also many other elements[2], it can be considered as an economic solution for the recovery of paddy field, without leading to the acidification of soil compared with gypsum. In long term, it could continuously provide many nutrient elements, which are exceedingly necessary for soil as it would become barren after the desalting process. On the other hand, by the elution of ferric ion, the anxiety on the generation of hydrogen

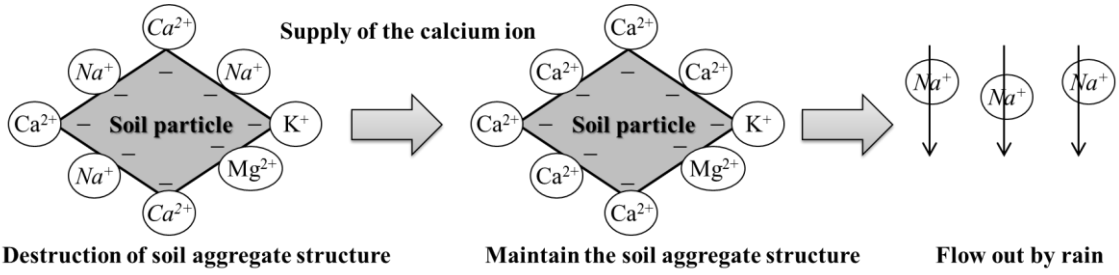


**Figure 3**: Reconstruction of soil aggregate by supplying calcium ion

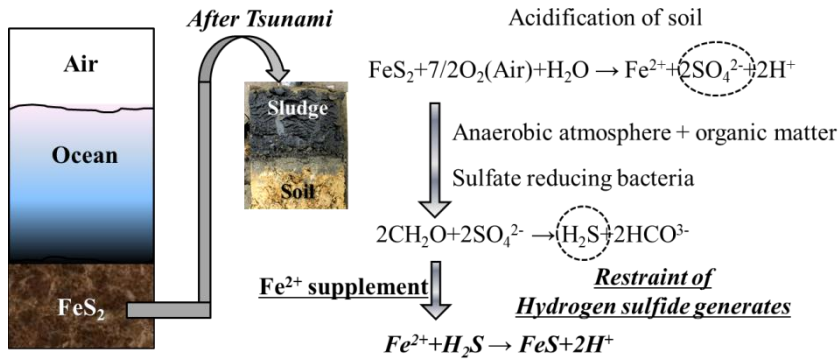


**Figure 4**: Restraint on the generation of hydrogen sulphide

sulphide, due to the sludge accumulation, can be put aside. This principle is described in Figure 4[1].

Though it is well known, some kinds of steelmaking slags have already been applied as fertiliser or pesticide, in both several European countries and Japan. However, the utilisation of steelmaking slag is still confronting many limitations, and the modification on the injured paddy filed by steelmaking slag has not even been considered before. Therefore, it can be said that the employment of steelmaking slag on the recovery of paddy filed, should be a worthwhile attempt and also an innovative method for dealing with abundant steelmaking slag. The expectation on the effect of fertiliser made by steelmaking slag is summarised in Table 1. Certainly, people have to be very cautious before actual utilisation, since many unconfirmed matters still remain.

**Table 1:** Characteristic of fertiliser made by steelmaking slag

| Main functional components | Content (mass%) | Effect |
|---|---|---|
| CaO | 50% | Enhancement of exchanging eluviations of Na and adjustment of concentration balance in basic elements. |
| | | Adjustment of pH by the supplement of basic element. |
| Iron oxides | 20% | Restraint on formation of $H_2S$ by the supplement of easily reducible iron oxides. |
| $SiO_2$ | 15% | Improvement of rice growth by the alleviation of excess Na damage through the supplement of silicate. |
| $P_2O_5$ | 1% | Normal nutrient elements |
| MgO | 4% | Normal nutrient elements |
| MnO | 3% | Normal nutrient elements |


**Figure** 5: Attempt on paddy cropping in salted soil with steelmaking slag spread

## Experimental evaluation on the utilisation of steelmaking slag

As shown in Figure 5, some trials have been made by current authors. Paddy has been planted in salted soil with steelmaking slag spread as fertiliser. The existence of steelmaking slag promotes the paddy growth during sprouting and maturity season. Also within those periods, the paddy grows even better than in the normal cropping condition.

Although the positive effect of steelmaking slag on desalting has been found, there are still many unclear issues, as mentioned, that need to be solved before practical application. To be specific, primarily, the dissolution behaviour of element in the paddy field environment remains ambiguous, as well as the variation of pH and soil properties. On the other hand, it is believed that the highly complex mineral structures of steelmaking slag influence the element dissolution a lot, but this has not been clarified yet. For instance, the dissolution mechanism of calcium from dicalcium silicate should be different from that of gehlenite. Similarly, the dissolution of ferrous from magnesio-wustite should be different from that of dicalcium ferrite, and so on. In the future, hopefully after studying on the above issues, the proper slag composition and proper method for mineral structure controlling as fertiliser shall be proposed.

## Conclusions

In order to restore the paddy field damaged from the great earthquake and Tsunami, the steelmaking slag has been proved as an effective base elements balance factor and fertiliser. Further investigation is undergoing.

## References

1. Shinya Kitamura, Toyoaki Ito, Nobuhiro Maruoka, Hiroyuki Shibata, “Recovery of Rice Field Using Steelmaking slag”, Kinzoku, **82** (11) 1011-1015.
2. Takuya Teratoko, Nobuhiro Maruoka, Hiroyuki Shibata and Shinya Kitamura, “Dissolution Behaviour of Dicalcium Silicate and Tricalcium Phosphate Solid Solution and other Phases of Steelmaking Slag in an Aqueous Solution”, *High Temp. Mater. Proc.*, **31** 329-338.