The 6th International Symposium on East Asian Resources Recycling Technology
October 23 - 25, 2001, Gyeongju (慶州), Korea
ISBN: 89-952527-0-7 93530

Korea Recycling Policy for Inorganic Mineral Waste

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Along with the expansion of industrial activities, the quantity of industrial waste sludge is increasing, and the treatment/disposal of wastes is a social problem regarding the preservation of the environment. In particular, recycling the sludge as a raw material is actively required considering the situation of Korea, which is poor in natural resources and energy. Lime is a necessity for treatment of waste sludge, which often can be made recyclable by lime treatment. In this thesis, a brief description has been given of my views on the ordinary treatment of waste sludge and the effective use of inorganic industrial waste sludge focusing on lime.

1. Introduction

There has been rapid economic development all over the world since World War II, thanks to the revival of related industries such as chemical, steel, shipbuilding and electrical industry. Along with brisk industrial activities and economic growth, an increasing quantity of wastes has also been produced, doing harm to residential places.

Various kinds of waste sludge have changed through economic activities, pollution restrictions, increasing quantity of discharge and the like. Now we are facing a situation where we cannot but work out effective measures on various kinds of sludge.

Lime is used in large quantities for treatment of wastes as a resource for environmental measures. Internationally, its use was mainly aimed at disposing of harmful chemicals, but in recent years, along with the great diversification and advancement of industrial and economic development, an increasing quantity of inorganic industrial waste sludge has been produced with a lot of it containing harmful chemicals, so that the treatment and disposal of industrial sludge have become a big social problem. Countries are now dealing with it by means of various lime stabilization laws. Therefore, I would like to examine the connection between inorganic industrial waste sludge and lime industry in terms of an industrial chemical aspect. Moreover, environmental pollution is often caused by improper disposal of waste sludge, and as a result, another serious social problem is raised with respect to treatment and disposal of it together with how to make it harmless and how to reduce it.

2. Waste Sludge and Lime

In this regard, we can consider waste sludge in terms of the following three aspects.

2.1 Measures on Pre-discharge Waste Sludge

The treatments on waste sludge are originally measures against harmful chemicals. But even if it contains no harmful chemicals, discharging a large quantity of sludge itself has been connected with environmental pollution or public hazard. Therefore, the first measure on waste sludge is trying as hard as possible not to discharge waste sludge. In particular, inorganic industrial waste sludge is discharged in large quantities and often contains harmful chemicals, therefore it is necessary to make great efforts not to discharge it. It is necessary to work out measures on waste sludge in the stage prior to its production and to have a viewpoint that regards even the discharge of waste sludge as a production process, and I think it's a very important concept.

In particular, it is important to try as hard as possible not to use harmful chemicals, to employ one or more technologies capable of using chemicals efficiently and to adopt a closed system in order to help prevent discharge of harmful chemicals as effectively as possible. Moreover, it is necessary to reduce the final discharge quantity of waste sludge according to reuse and recycling of waste sludge.

2.2 Measures on Waste Sludge in the Stage of Treatment and Disposal

The treatments on waste sludge generally refer to treatment and disposal of discharged waste sludge. In general, discharged waste sludge is reduced by making it harmless, and then its final disposal is done by burying it underground or by some other means after making it harmless. But some waste sludge, which often contains harmful chemicals, is feared to flow out of the ground. Even after burying waste sludge, there is fearfully much possibility that harmful chemicals may come out of the ground near the disposal place, contaminating a stagnant lake and things like that and worsening the environment.

At last, the final purpose of the waste sludge-related laws is to prevent the effect of any second environmental pollution that may occur after disposal of it. Moreover, measures have been sought and devised in the partial position to prevent environmental pollution up to now, but from now on, it is also necessary to give consideration to the environment of the earth when considering discharged waste sludge. In order to preserve the environment of the earth, it is necessary to make as great efforts as possible not to produce harmful chemicals. To do so, it is

necessary to think of it as a basic requirement to reduce the harmfulness of waste sludge to the lowest possible level before burying it or disposing of it by some other means. In particular, artificially manufactured non-degradable materials and harmful chemicals need to be made as harmless as possible, and for this, active efforts are required to develop a technology to make such materials completely harmless. On the other hand, as for heavy metals and the like among the harmful chemicals, they should, in principle, be buried in such a way as to prevent them from spreading to the ground while controlling the largest discharge quantity by means of recovery. In such case, what is required is to make them change in such a way that the environment is least affected.

2.3 Management after Final Disposal

Even if waste sludge has been insolubilized, it cannot be said that harmful chemicals will never flow out of the ground permanently. Even though final disposal of these harmful chemicals has been carried out, careful management of the final disposal place is required in order to prevent any of them from leaking and spreading in the event of an accident, together with an awareness that they are kept there. Besides, although little attention has been paid to water pollution around the disposal place so far, comprehensive consideration needs to be given to it.

3. Characteristics of Waste Sludge and How To Treat It

The characteristics of inorganic industrial waste sludge and my views on the treatment of it are described briefly as follows: When treating and disposing of waste sludge or making effective use of it, it is necessary to understand the characteristics of waste sludge such as its discharge condition, its discharge quantity, its chemical composition, its physical properties and the like.

The greatest characteristic of various kinds of inorganic industrial waste sludge such as minerals, metals and dusts is a great quantity of discharge. When it is difficult to secure a disposal place just like these days, a great quantity of discharge is a big defect. Waste sludge is used effectively in chemical industry. Effective use of a great discharge quantity of waste sludge is important not only for saving resources and energy but also for securing a disposal place. Therefore, these wastes should be used in large quantities in principle. Using only a small quantity of the wastes is not a good idea even if it's possible to apply an advanced method, because the remnants have to be discarded. The second characteristic is that while it is possible to use organic sludge as heat energy and it becomes water and carbon dioxide when it is heat-treated, inorganic waste sludge leaves a solid body whatever kind of treatment is applied to it. The third characteristic is that a lot of inorganic industrial waste sludge contains harmful chemicals and that it is necessary to treat and make it harmless before discarding it. Also, the quantity of waste sludge often increases when treating and making it harmless. In case of discarding and disposing of inorganic industrial waste sludge by taking these characteristics into consideration, it is necessary to secure a disposal place, investigate whether it is harmful or not by making it flow out or by some other means, and treat and make it harmless. Therefore, it is ideal and desirable to reuse inorganic industrial waste sludge as a resource rather than discard and dispose of it.

4. Lime as A Substance for Anti-Pollution Measures

A lot of inorganic waste sludge contains harmful chemicals, but lime cannot be ignored regarding environmental measures and removal of such harmful chemicals. A lot of lime is used as a neutralizer or a pH adjusting agent. Ca belongs to Group Two, and although calcium hydroxide ($Ca(OH)_2$) less alkaline than hydroxide of Group One, hydroxide and salt of Group Two are much less soluble than those of Group One. For example, the solubility of NaOH is 42g/100ml; that of $Ca(OH)_2$ is 0.2g/100ml; that of Na_2SO_4 is 19.4 g/200 ml; and that of $CaSO_4 \cdot 2H_2O$ is 0.2g/100ml. As it shows, the solubility of Group Two is lower than that of Group One. And this low solubility is the greatest reason why lime is used for anti-pollution measures.

5. Inorganic Industrial Waste Sludge as Construction Materials

Particularly much inorganic waste sludge is used as construction materials. Magnesia slag is used as a material for cement. Phospho gypsum is used as a congelation adjusting agent for cement or for a plasterboard. There are some reasons why lots of inorganic waste sludge is used as construction materials. In other words, inorganic waste sludge is easy to use as construction materials, which have the following three properties:

(1) Essentially, construction materials have the quality of a composite material, and the purity of their quality does not matter a lot.

(2) Construction materials are widely used, and every construction material ranging from the ones of high-purity quality to the ones of low-purity quality.

(3) Construction materials are used in large quantities.

The qualities of (1) and (2) give waste sludge a big merit when it is used as a construction material. For example, in case consideration is given to SiO2 and Al2O3 contained in fly ash that is produced in large quantities at thermal power plants, there is no need to classify waste sludge in the pure form and it is better to use the impurities contained in fly ash as well because the value of a construction material is determined by its physical properties its strength, hardness and relative importance. Byproducts or waste sludge competition contains impurities by all means and it is economically difficult to remove impurities from inorganic waste sludge, therefore it is proper and effective to use inorganic waste sludge as

construction materials when it comes to using a material containing impurities for construction. And it is not only the things of regular material properties that are used as construction materials, but depending on their material properties, construction materials are used for various purposes. Therefore, although the composition of waste sludge is not regular, it is easy to use as a construction material. Moreover, inorganic industrial waste sludge is produced in large quantities, which can be one of its strong points because construction materials are also used in large quantities.

6. Importance of Lime for Inorganic Industrial Waste Sludge

6.1 Use of Lime and Its Quantity Used

Limestone is used as a raw material for cement or iron manufacture, and also as a main material for various inorganic chemical industry. Therefore, waste sludge produced from these industries contains a considerable amount of lime. Also, a large amount of lime is used for treatment of waste sludge that is produced from the inorganic chemical industry. After all, a large quantity of lime is also used for treatment of lime waste sludge.

Limestone is used for various purposes. It is most used as a raw material for cement, which is a construction material. The second largest use of limestone is for roads and as broken stones for concrete for civil engineering and construction. Its third largest use is for steel industry, where about 20 million tons of limestone are used. The limestone supplied to the lime business circles is calcinated into quicklime, which is then used for steel manufacture.

Since slag that is produced by steel industry is also used as a material for construction and engineering works, about 90% of the limestone production is used for civil engineering and construction industry.

Moreover, slag that is produced by steel industry as well as lime is used for civil engineering and construction industry. Therefore, the combined quantity of limestone used for both cement and civil engineering and construction industry is 177 million tons (74% of the total), which means more than 80% of the limestone dug out is used in relation to construction and civil engineering works.

Since it is used in large quantities, wastes including lime are also produced in large quantities. Recently waste materials produced from the construction business area have increased, posing a social problem regarding how to dispose of them.

Approximately 3 million tons of lime is used in the form of quicklime and slaked lime for chemical industry such as carbide, bleaching agents and seawater magnesia. Lime is often used as part of a product component. The quantity of lime used for construction is decreasing, but the quantity of lime used for ALC or soil stabilization is increasing.

Moreover, lime is a necessity for immobilizing acidic components. It is used to immobilize acidic components for mining or prevention of pollution. The lime used for mining is decreasing, but the lime used for prevention of pollution is increasing in response to increasing anti-pollution restrictions including the ones on water drainage. And it is expected to increase in proportion to the increase of restrictions on water drainage.

The quantity of lime supplied for prevention of pollution and water supply and drainage was 273,000 tons and 520,000 tons respectively in 1984, and it is increasing each year. It is expected to increase in proportion to the increase of restrictions on water drainage and rearrangement of public sewage systems.

6.2 Making Waste Sludge Harmless by Lime and Gypsum

In general, a lot of inorganic industrial waste sludge contains harmful chemicals, and it is lime-treated by using a detoxicating or immobilizing agent before being discarded. The waste sludge is often made harmless so that it may be discarded or recycled. Gypsum is produced in the process of immobilizing sulfuric acid, and it is closely connected with acid, alkali and fertilizer industry.

As this shows, lime is indispensable for immobilizing acidic components and plays an important role as a material for environmental measures with regard to application of flue gas desulfurization.

Moreover, as a material for environmental measures, lime is used to treat exhaust gas or drainage water that contains fluorine. It precipitates as calcium fluoride and is removed. And since fluorine often originates from phosphate ore, fluorine and phosphoric acid often coexist in the factory drainage water, in which case the fluoroaperlight is produced as a precipitate by lime-treatment. While phosphoric acid contained in the water which is drained not only from factories but also from homes is a social problem against lakewater and seawater, addition of lime into drainage water for its third treatment is very effective for removing phosphoric acid.

Gypsum is good as a raw material for construction when its crystal size is large with few impurities and little hygroscopic water. Since making its crystal size large is related with a decrease of impurities and hygroscopic water.

The things that underwent drainage water treatment and contain phosphoric acid are discarded and disposed of as sludge. In general, this kind of sludge has high moisture and needs to be dehydrated, dried or incinerated before disposal. In case of adding lime as a precipitating agent for the sludge, it is often used as a cohesive agent without being directly included in the process of making insoluble calcium salt. The typical lime is used together with such agglutinating agents as alum and ferric salt to get rid of unclean substances in the streams and dams for water supply by agglutinating them. Besides, this agglutination and precipitation method is used to remove floating substances which are difficult to precipitate in some sewage systems. Moreover, factories using large amounts of industrial water are now recycling drainage water and using lime and agglutinating agents to remove suspension in drainage water before recycling it. In such case, lime shows high agglutinating efficiency and helps keep proper

pH but the electric charge 2+ of Ca ion seems to also contribute to agglutination.

6.3 Movement of Inorganic Components in Inorganic Industrial Waste Sludge

As mentioned before, organic waste becomes water and carbon dioxide when it is burned but inorganic waste doesnt disappear itself but leaves a solid body by all means whatever kind of treatment is applied to it. Therefore, it is necessary to consider treatment and disposal of inorganic waste sludge from the perspective of recycling based on each element. The furnace for steel manufacturing is usually a vertical-type furnace called a blast furnace. A mixture of iron ore, coke and limestone is loaded into it from the top and high-temperature air is blown into it from the bottom by using the heat blower to melt them. The lime, the silicic acid in the iron ore and the alumina powder react and become calcium silicate and alumino calcium silicate, thus forming slag. The slag that is melted by the difference in specific gravity floats and the extract from it is a blast furnace slag. As for chemical composition of blast furnace slag, electric furnace slag and cement, among the elements in the iron ore as a material for steel manufacturing, coke and limestone, iron moves toward the cast iron while all the other elements except carbon and oxygen move toward slag. In other words, the main elements of slag are CaO, Al_2O_3 and SiO_2, which all come from materials for steel manufacturing, and whatever kind of treatment is applied to slag, components move but nothing disappears as gas. Therefore, as we can see from this example, it is necessary to make effective use of these inorganic components contained in inorganic waste sludge when treating and disposing of it. Although lime is used in large quantities to treat inorganic waste sludge, if the waste sludge is made reusable by lime-treatment of it there will be no problem, but if there is no other choice but to discard and dispose of it, since the quantity of lime added for the treatment increases the quantity of sludge even if it is made immaterial, therefore it cannot be said to be an effective treatment method. In particular, since it is difficult to secure a disposal place now, countries are doing active researches on the positive opening of waste recycling technologies that make it possible to finish without discarding it.

7. Entropic Views on Recycling on Industrial Waste Sludge

Along with the growing interest in international environmental problems such as global warming, acid rain and destruction of ozone layers by freon gas, brisk discussions are under way at international organizations and conferences to find ways to solve them, and as a result, they have got the limitedness of resources in the earth and energy widely recognized and aroused a strong interest in the limitedness of the earth including the fact that the essence of the environmental problems of the earth is the purification capacity. At this point, the problem of industrial waste sludge is no exception.

On the other hand, the quality of waste sludge has been diversified and it has obviously increased along with the recent economic growth and improvement of living standards. Also, the cost of treatment and disposal of it continues to show a tendency to increase rapidly. Therefore, it is feared that if this situation continues, the living environment will get worse and there will be much inconvenience with our daily life and industrial activities. Considering this social environment condition, reduction of wastes all over industrial areas and establishment of a recycling society was strongly required as a fundamental measure and advanced countries have legislated recycling laws and amended waste disposal laws.

7.1 Significance of Recycling and Phenomena

The system of the existing industrial society has had the form of a one-way passage line of natural resources -> materials -> processing and production -> consumption. Resource recycling is the restoration process where a product returns to the status of a raw material from consumption or the middle road to consumption. It is an attempt to form a cycle system by adding it to the existing system.

Now I would like to survey the phenomena of the recycling system by using the concept of entropy. Introduced by Clausius, entropy is understood as representing the progress of irreversibility while Boltzmann describes it as representing the degree of disorder in his statistical consideration. The process of irreversibility increases entropy and also along with the transition to the great condition of probability, entropy increases.

The resource recycling system is shown in figure 1. Here the process of Resources -> Consumption is rearranged and appears as a Production Source. In Plant means making the waste that is produced in this process return to the previous process by a short circuit according to its quality.

The cycle point of the process of Natural Resources -> Consumption in the Production Source in these recycling systems gets as close to Natural Resources as the outer circuit. The processes of In Plant, Recycling and Final Disposal include a lot of treatment processes, which are irreversible processes, and in general, they increase to get orderly raw recycling materials, resulting in a system

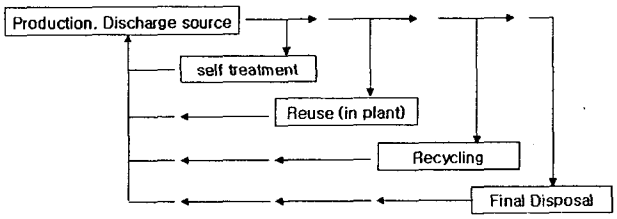

Fig. 1 Waste recycling system

where entropy increases as much as the outer circuit, which causes the increase of energy consumed to make it return to its original state.

And looking at the other side of it, if the disorder of the recovered thing increases just like the outer circuit at the

restoration point in the restoration process of Production Source, the result will be high entropy. After all, it is important to process by a short circuit in resource recycling, try to make entropy low at each unit process plant and analyze the cost etc. of the distribution routes of the restoration process.

7.2 Production Design for Recycling and Final Products

The comprehensive attributes of each kind of waste sludge need to be evaluated by examining and analyzing its chemical and biological properties (whether or not it contains harmful chemicals, environmental pollution, causative materials etc.), its physical properties (weight, volume, compression, crushing etc.), the universality of disposal facilities, and the safety and hygiene levels for working (whether disposal facilities have been damaged, whether workers' safety and health may be affected, etc.).

In case of industrial waste sludge, which is classified into the category of inorganic, organic or metal waste sludge, the basic concept for making final recyclable products is broad and very vague for definition. It is very difficult to make comprehensive units of the processes ranging from understanding the necessity and validity of making final products by seeking the recycling of a certain kind of industrial waste sludge to manufacturing and selling them.

Here we can think of classification of general industrial waste sludge into the time axis and the space axis as follows:

<Angles based on the time axis>
- Initial design (preliminary design, concept design)
- Detailed design (basic design)
- Production design (Minute design)

Needless to say, the whole stages have an area for thinking of ideas regarding the necessity of recycling products, the setting of a goal, investigations and the like. Although it may not be reasonable about this, I think the designs connected along another axis called the space axis need to overlap here. The concept of the space axis design can be said to be what is recognized and examined in various design concepts.

<Angles based on the time axis>
1. Material design: processing design, productivity design, physical property design, separation and treatment design
2. Function design: system design, process design, security design, safety design, equipment design, element design (heat, electricity, circuit etc.)
3. Form design: human space design, ray out design, general organization design

Various designs based on these two axes are restricted in the frames of economy and the environment (influence when placed in the environment regarding the structure of cultural, social, political and religious society). We need to be aware that treatment and recycling when waste sludge is produced are decisively important as they are high factors whose relative importance is great in the aspect of the environment.

If a final product that is produced out of waste sludge has high entropy, recycling of the waste needs to be reexamined. Once it is determined to be unworthy of recycling by examining the energy and cost required for making entropy low, a problem may be raised regarding the validity of recycling such as "Is it ideal only when designing is based on low entropy recycling products?" In other words, what is important for designing low entropy products is that suggesting the validity of recycling through reduction of irreversibility process and improvement of disorder can be regarded as the best result (Fig. 2).

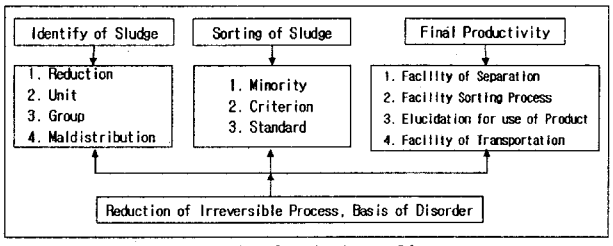

Fig. 2 Main point for design of low entropy recycling product.

The process of identifying waste sludge may include reducing its quantity, using the same kind of sludge for the same purpose, selecting and localizing waste sludge, and mixing the pieces of waste sludge that are recyclable even if they are mixed together. In the process of sorting the waste sludge, it is necessary to choose and apply as easy a sorting method as possible by making the quantity of waste sludge small and standardizing it for the sake of easy reuse and recycling.

In the process of making recycling products, it is necessary to sort waste sludge according to processing, transportation and characteristics for each part that can be reused and recycled as to the whole units of sorted waste sludge and to make sure there is no pollution for the second time as well as developing ways of making good use of it for various purposes together with application methods.

In the United States, a consideration for separating and sorting waste sludge for a final design of recycling products has recently been presented by way of the "design for disassembly" or the "disassembly oriented design," which is drawing attentions. Needless to say, the progress of the recycling technology involves the conservation of energy in the irreversible treatment and processing and the promotion of low entropy, which increases the purity of recycling substances, and it is necessary to consider how advanced this technology is when deciding how suitable low-entropy products should be for designing them. After all, each independent technology such as the recyclability evaluation technology through the treatment and progressing needs to be developed and established for each plant with regard to the indicators of energy consumption and the degree of difficulty of treatment and processing. The recyclability is regarded as a characteristic corresponding to each treatment technology, but a big

technological renovation or progress is absolutely required for the recycling treatment technology which is less advanced than the production processing. I think it is a big task for us to establish a generally favorable system for each plant including social expenses for recycling.

8. Conclusions

After all, it is best not to produce waste sludge, but it is necessary to develop a process that can minimize the quantity of waste sludge and try to recycle the produced waste sludge by actively developing sludge uses as well as making efforts for reduction and improvement. Also, it is absolutely necessary to understand the process of improvement and recycling as an extension of the production process.

The importance of research on recycling of all kinds of waste sludge is expected to increase under the concept that the resources and energy in and on the earth are limited. In particular, considering the risk of the increasing quantity of inorganic waste sludge, I think each unit research on the identification process for each industry and sludge needs to be carried out in advance as there is an urgent need of efforts for decision making and development of sludge uses for recycling.

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