

Site Remediation Technique for Hexavalent Chromium Contamination Soils

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Abstract

Contaminated soil by heavy metals, arsenic, and other toxic metals are formed by geo-pollution processes associated with exploitations of metallic resources or various industrial activities. In this paper we report a new on-site technique for remediation of chromium-contaminated pollution soils where the concentration of Cr⁶⁺ ranges around 0-0.5ppm. Prior to remediation treatment, detailed characterization of mineralogy and chemistry of contaminated soil shall be made. In the first step of the remediation treatment, the contaminated soil is mixed with appropriate quantity of natural ion-exchange material, natural zeolites. In addition to the natural zeolites, clay minerals (halloysite, smectite, etc.) may be mixed with the contaminated soils. Then the same weight percent of unslaked lime is also admixed. The effect of the remediation treatment mentioned above was verified by an adsorption experiment of the mixture with 1.000 ppm chromium solution in laboratory. Two hours adsorption reaction of the mixture (zeolite+clay+lime) provokes a drastic decrease of the concentration of soluble chromium in the solution up to 0.033 ppm. Chromium was eventually fixed in newly formed mineral crystals as a minor element after the complete adsorption within the soil, which is geochemically stable. Thus pollution soils contaminated by toxic heavy metals and/or arsenic can be successfully remediated with this mixing treatment.

Keywords: environmental pollution, cleanup, heavy metals, zeolite, clay minerals

1. Introduction

Site remediation of hazardous waste sites, such as hexavalent chromium contamination, has been an issue of major environmental concern (Nirei and Satoh, 1998). If hazardous waste are introduced in any area due to a spill or other mismanagement, there may be both short- and long-term effects on human health and the ecological system. Currently available site remediation technique is to classify the technologies according to the way they treat contaminants (Soesilo and Wilson, 1997). In this classification remediation technologies may fall into three major categories, physical, chemical, and biological technologies. The physical technologies adopt various physical treatments such as heating, destruction, removal, or isolation by shielding or fixing materials. The chemical technologies normally reduce the solubility or leachability of toxic metals by using chemical treatment. This technology requires the addition of stabilizing agents that chemically stabilized given toxic metals. Biological technologies generally apply activities of microorganism such as bacteria for the treatment.

However, in the case of remediation program of heavy metal contamination sites, these techniques previously developed have more or less weakness. For instance, one of the most popular treatment, removal of contaminated materials or physical isolation by shield involves a risk of spread of pollution. Chemical treatment is also very popular technique but it often causes secondary pollution with artificial chemicals. Biological technologies are still unmatured for general uses.

To answer the questions above, we propose new environment-friendly remediation technique, the Sealingsoil™ system, which applies only natural mineral materials in the treatment (PAT. Japan H8-197376; Minato *et al.*,1996; Okano *et al.*,1996; Minato *et al.*,1997; Minato *et al.*,1998).

In this paper, we report a case study of Sealingsoil™ treatment for the site remediation of Cr⁶⁺ contamination soils in an industry compound, Japan.

2. General Procedure

In general, the procedure of Sealingsoil™ treatment for site remediation can be outlined by four steps (Figure 1). The first step is the characterization of contamination site. Proper site characterization is critical for appropriate site remediation planning. It is essential to describe the type of contaminants that lie in the subsurface, the characteristics of the subsurface geology and groundwater, and the movement of the contaminants in the subsurface. Its geology, mineralogy, chemical composition, groundwater, pollutants, and pollution process should be described in detail. The second step is the design of Sealingsoil™ for given contamination site, which is the determination of most suitable combination of natural ion-exchange minerals such as zeolite, natural clay, clay minerals, and calcium carbonate. The third step is in-door experiment for verification of the designed composition of Sealingsoil™. Some adsorption tests are normally made with a standard solution of heavy metals. After the completion of these three steps, actual site remediation action can be performed (Figure 1).

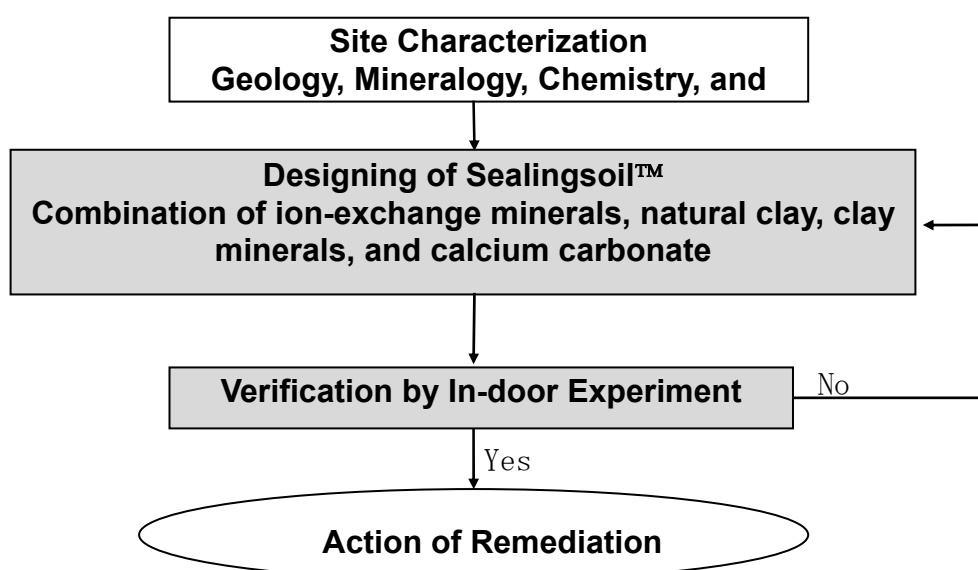


Figure 1: Flowchart of Sealingsoil™ remediation program.

3. Chromium Contamination Soils

An actual condition of chromium contamination soil in the area was surveyed by borehole drilling tests and the distribution was measured by chemical field screening technique with an on-site test kit (“Pack Test”). Exact concentration of soluble Cr^{6+} was determined by a wet chemical analysis, where the regulatory level of maximum concentration of Cr^{6+} for the toxicity is defined as 0.05 mg/l. The concentration in the survey area is around a several mg/l level. Then mineral property of the soil was determined by means of X-ray diffractometry.

To make a stable condition to chromium in the pollution soils, the composition of Sealingsoil™ for present site is designed as following combination: 5 weight percent of natural ion-exchange minerals and 5 weight percent of calcium carbonate. Clay minerals are sufficiently contained in the pollution soils, so that it is not necessary to add another natural clay. Within this mixture, a very small quantity of chromium in the contaminated soil is expected to be adsorbed and fixed.

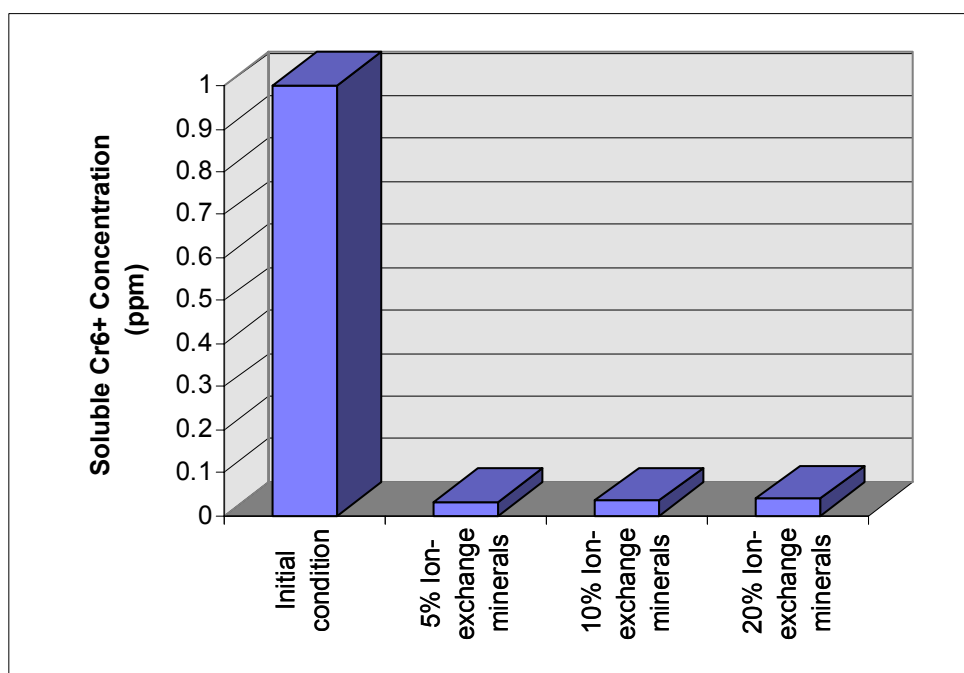


Figure 2: Adsorption test for different admixture in Sealingsoil™.

A preliminary adsorption experiment was made for given Sealingsoil™, of which results confirm the potency of remediation (Figure 2). It has been widely accepted that an admixture of ferrous sulfate (FeSO_4) is capable to the remediation of Cr^{6+} contaminated soils because of its reducing reaction ($\text{Cr}^{6+} \rightarrow \text{Cr}^{3+}$). For comparing the capability of remediation between ferrous sulfate and Sealingsoil™ treatment, we undertook adsorption test with different admixture (Figure 3). Based on the result, the ferrous sulfate mixture is not very sufficient for adsorption of Cr^{6+} .

Another example of in-door experiment, similar adsorption effects on As and heavy metals (Zn, Cd, Cu, Cr, Pb, Ni) by Sealingsoil™, is also shown in Figure 4.

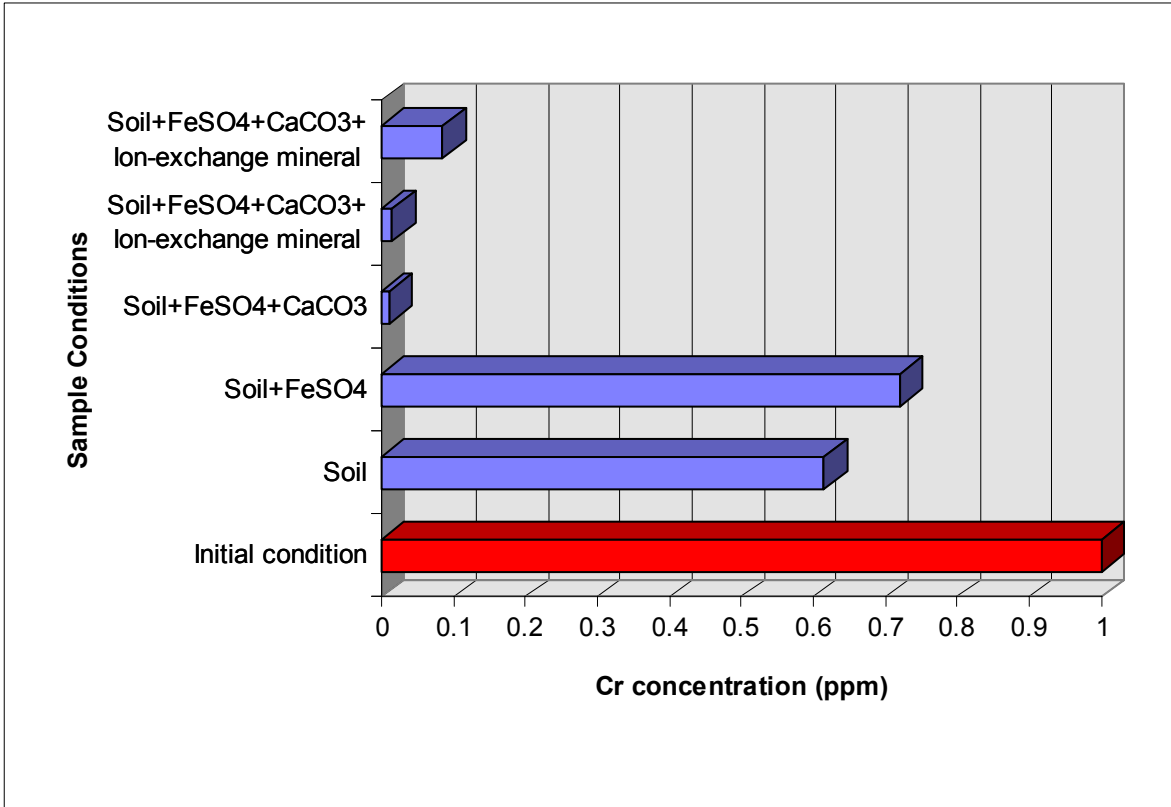


Figure 3: Comparison of the capability of adsorption effect in ferrous sulfate admixture.

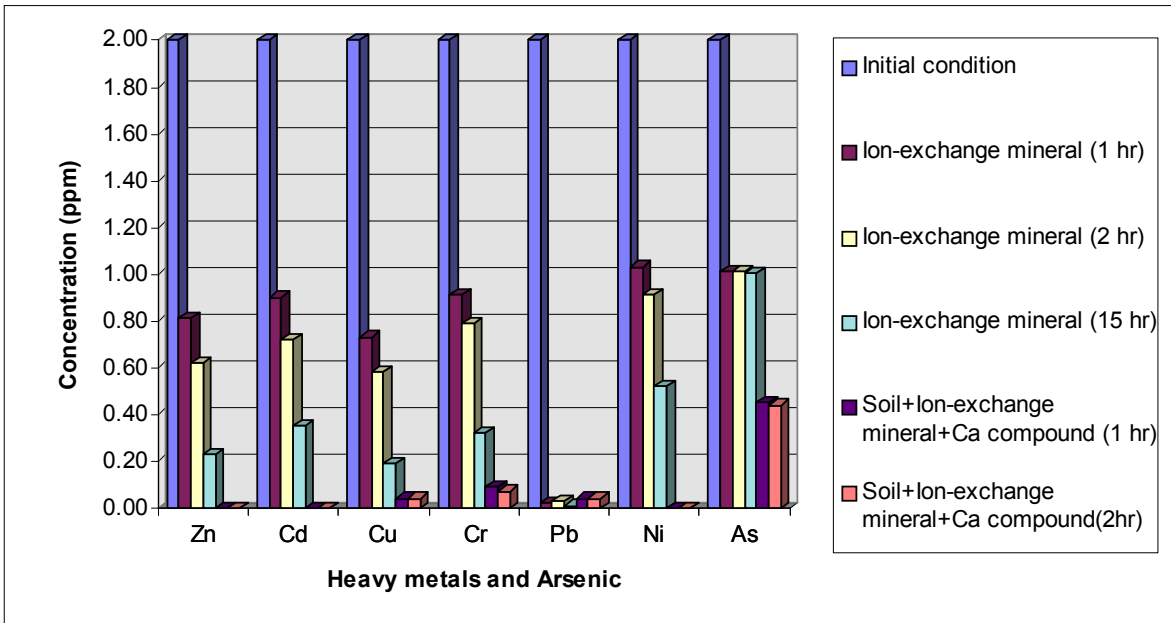


Figure 4: Adsorption test among different heavy metals. The number of hour (hr) indicates the duration of adsorption treatment, and each bar indicates the concentration of given element after the adsorption.

4. Concluding Remarks

The characteristics of the Sealingsoil™ technique are as follows: (1) perfectly on-site remediation technique and possible to re-use the remediated soils, (2) only natural mineral materials are employed in the treatment, (3) based on adsorption, ion-exchange, and crystallization of artificial minerals, (4) applicable for arsenic and heavy metals.

Similar technique has been successfully applied for shielding wall materials at solid-waste disposal sites (Minato et al., 1998).

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