Simulation Modeling for Planning a Soil Remediation Process

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1. Introduction

This paper describes the development of a simulation model that can be used for logistics planning for soil remediation at the Kori 1 reactor site. A FlexSim discrete event simulation model of the site soil remediation and waste management process was developed to support optimization of performance, resources, and time and to minimize nuclear waste.

Operation of a nuclear power plant may result in the release of radioactive materials to the soil and groundwater at the site. Small radioactive releases may not be discovered until the NPP undergoes decommissioning [1].

Nuclear power plant site remediation is performed after site structures have been removed and is the last step in decommissioning. Remediation may be required to remove contamination from the site soil to allow the reuse of the site subject to the regulatory requirements for site release.

2. Development of the Simulation Model

In this study we modeled the soil washing process shown as Module 2 Contaminated Soil Treatment (Fig. 1).

The soil washing process recommended by the US EPA for removal of radionuclides was chosen as the basis for the soil washing process model (Fig. 2) [2]. A simulation model of the soil washing process was developed using Flexsim, a discrete-event simulation modeling application that is widely used in industries such as material handling, manufacturing, logistics, transportation, and mining [3]. The model was operated as a batch process rather than a continuous process because it may be necessary to meet radioactive waste management requirements that prohibit mixing of wastes with different classifications.

Soil particle size distribution data collected by KAERI at the Kori site was used as input data [4]. The simulation model has several simplifying assumptions as follows: Fifteen tons of soil can be treated per a batch. The system has 240 tons/day processing capacity under 8-hour operation a day. The system has enough capacity to operate without bottlenecks and there are no unplanned shutdowns due to equipment failure or maintenance.

Fig. 1. Soil Washing Process Model [1].

Fig. 2. Detailed Soil Washing Process Model [2].

Fig. 3 shows the soil washing FlexSim model. The excavated soil from the contaminated site is fed to the feed hopper on the left side of the Fig. 3, and the soil that has been cleaned through dry separation is sent to each queue according to the grain size i.e. rubble, gravel, sand, silt and sludge/clay.
In this study, the simulation model was verified by checking the output of the simulation. In the simulation, we can observe the soil washing process and the waste throughput. Once the simulation starts, 30 tons of soil per hour are supplied to the feed hopper and the soil washing system operates at 36 tons per hour. Due to the difference between the soil excavation rate and process rate, this system can be maintained as a 1-hour batch process.

![Fig. 3. Logistical Simulation of Soil Washing Process.](image1)

Table 1 shows the process results after 2 hours of operation. The results show that the process output is approximately equal to the input meaning the simulation is operating correctly according to the intended logic. The model generates detailed processing data as a numerical table or graphical chart as shown in Table 1 and Fig. 4.

![Fig. 4. Graphical Report for Soil Washing (at 2 hours).](image2)

### Table 1. Simulation Results at 2 Hours of Operation

| Queue    | Rubble | Gravel | Sand  | Silt  | Sludge | Total |
|----------|--------|--------|-------|-------|--------|-------|
| Processed Soil (ton) | 0.588  | 3.111  | 50.031| 2.354 | 3.916  | 60.000|
| Ratio (%) | 0.98%  | 5.19%  | 83.39%| 3.92% | 6.53%  | 100.00%|
| Input Data (%) | 1.0%   | 5.3%   | 83.4% | 3.9%  | 6.4%   | 100.00%|
| Error (%) | -2.00% | -2.08% | -0.01%| 0.51% | 2.03%  | -     |

The system is shown to be operating in a batch process as seen in Fig. 4 which shows that the soil in the feed hopper accumulates and is emptied repeatedly. The State Pie diagram in Fig. 4 shows utilization of the system equipment elements.

### 3. Conclusions

In this study, we investigated the applicability of discrete event simulation for a soil washing process for planning site remediation. It was shown that a batch process such as soil washing can be effectively modeled as a discrete event process. Efficient allocation of resources and efficient waste management including volume reduction can be achieved by use of the model for planning the soil remediation process. Furthermore, we suggest extending the scope of the simulation model to include excavation and waste management as shown in Fig. 1 (Module 1 and 3).

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