Disposal of Phenolic Waters From a Producer Gas Plant

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SYNOPSIS: Phenolic waters are generated in a producer gas plant in India. Since harmful environmental effects can result even with low concentrations of phenol in water, its disposal poses a problem. Four options for disposal were considered. One of these options considered involves disposal in a earthern pond situated close to a river. In order to avoid river pollution by possible seepage of phenolic waste, geotechnical aspects have to be considered. For each option, cost analysis is performed. This paper discusses as to how the final disposal technique is decided taking into account all the relevant aspects of the problem.

INTRODUCTION

Industrial development is occurring all over the world. Such activity generates certain substances that are to be disposed off in an environmentally accepted manner. Phenol is one such chemical. In this paper, a case history involving the disposal of phenolic waters and slag will be presented to illustrate as to how phenolic compounds can be safely disposed.

STATEMENT OF THE PROBLEM

Phenol is generated in several processes (Forney, 1974; Luthy, 1981; Keating, et al., 1979). In the case history cited herein, phenol is produced in a producer gas plant in India. Producer gas is manufactured by the destructive distillation of coal. Three types of phenolic waters are produced in the various units of the gas producer plant. They are:

1. First type: phenol is produced during the contact between the gas and water in scrubbers. Its concentration ranges from 20 to 30 mg/l. It has been estimated that on completion of the final stage of the project, a quantity of 14,600 m^3/day of this type of water will be generated.

2. Second type: High concentration phenolic waters (ranging from 9 to 10 g/l) are produced by the condensation of water vapors while passing through gas coolers and electrostatic filters. Upon completion of the project cited here, it is estimated that a quantity of 216 m^3/day of this type of phenolic waters will be produced.

3. Third Type: Phenolic waters with concentrations ranging from 10 mg/l to 3 g/l are also discharged from various operational units into water seals. The quantity of these waters in comparison with those of the first and the second types is small and variable. Hence this is considered to fall under the category of the second type. No further discussion of this type will be presented in this paper.

DISPOSAL OF PHENOLIC WATERS

First Type:

The first type of phenolic waters produced in the scrubbers have a concentration ranging from 20 to 30 mg/l. This concentration is less than the maximum admissible concentration of 50 mg/l of phenolic waters that can enter the central sewage treatment plant. Hence these phenolic waters do not pose any major disposal problems. This is based on the premise that the scrubbers are considered to operate with the fresh process water and that no recirculation is taken into consideration.

From the point of view of economy, reduction in the consumption of process water with consequent reduction in the capital expenditure on the treatment plant is desirable and recirculation of water is considered a necessity. As a consequence of this, the phenolic waters will have concentrations greater than 20 to 30 mg/l. In this case, if a circulation system were to be adopted, the average concentration of phenols of these waters works out to be about 85 mg/l.

The quantity of wastewater with high concentration of phenol entering the treatment plant can be regulated in the circulation system according to the requirements of the treatment plant. It may also be noted that the circulation cooling system provides for the lowering of concentration due to oxidation by atmospheric oxygen. For this reason, average phenol quantities mentioned above can be considered as maximum and the probable quantities of phenol entering the treatment plant as not exceeding the lower limit (20 mg/l).

Second Type:

These waters have concentrations from 9 to 10 g/l. They contain an average of 70% phenols and 30% substituted phenols. These waters have to be treated separately as they can not be handled by the central sewage treatment plant.

At the time of disposal, the concentration of phenol has to be reduced to that below the tolerable limits. In the following sections, a discussion on this topic will be presented.

TOLERABLE LIMITS FOR PHENOLIC WATERS

Phenol and other phenolic compounds are either toxic or lethal to fish at relative low concentration and impart objectionable tastes to drinking water. McKee and Wolfe (1963) following a review of world literature concluded that phenol in a concentration of more than 0.001 mg/l would interfere with the domestic water supplies, 0.2 mg/l would interfere with fish and aquatic life and 1000 mg/l would interfere with stock watering. Chlorinated phenols also present problems in drinking water supplies because phenol is not efficiently removed by conventional water treatment and can be chlorinated during the final water treatment process to form persistent odor-producing compounds. Hence it was decided to adopt a method of disposal that result in no pollution of river waters by the flow of phenolic waters from the slag pond.

TREATMENT OPTIONS CONSIDERED

For the treatment of the second type of phenolic waters, four different options were considered. These will be discussed in detail in the subsequent sections.

METHOD 1 Hydraulic Transport of Slag with High Concentration Phenols as the Carrying Medium

Daily, 14,600 m^3 of the first type of phenolic waters with a concentration of 85 mg/l will be mixed with 216 m^3 of the second type of phenol with a concentration of 10 g/l. This will result in a total quantity of phenolic water of 14,816 m^3/day with a concentration of 230 mg/l. Slag produced by the burning of coal in the producer gas plant along with the phenolic water will be transported hydraulically to an open air slag pond. This pond is proposed to be constructed outside the plant area.

The treatment proposed in this option consists of the following:

1. Adsorption of the highly concentrated phenolic waters by slag.

2. Effect of atmospheric oxygen on slag saturated with phenolic waters in the proposed slag pond.

In this chemical process, some of the phenols gradually change to harmless humus substances and the rest remain combined with water in the slag, which according to the preliminary tests conducted show a high degree of saturation. To achieve maximum contact between phenolic waters and slag particles from producer gas plant and boiler house, the slag will be hydraulically conveyed utilizing the high concentration phenols as the medium to a proposed slag dump pond outside the plant area.

Details of the Slag Dump Pond

The slag dump pond will be situated southwest of the plant adjacent to the left bank of a river. For the construction of the bottom and the sides of the pond, it is proposed to utilize the locally available soils. The banks must be above the level of the surrounding area in order to check monsoon storm water coming into the area. It is also necessary to provide an intercepting trench around the pond to prevent flooding of the pond by torrential rain water from outside and to prevent the leakage of phenolic water from the inside of the pond into the river so as not to cause river pollution. The pumping station for return water is built near the pond. This water is to be pumped back into the gas producer plant wherein it will be mixed with highly concentrated phenolic waters and slag and from there it will be led again to the pond.

Figure 1 shows the layout of the pond with respect to the plant. An existing railway embankment forms on one side of the pond. The other enclosures will be provided by a curvilinear embankment as shown. An intercepting trench all around the embankment is provided on the outer side. The purpose of this trench is two fold: (1) to to collect water seeping out of the pond and (2) to monitor the quality of water seeping out in order to take suitable mitigating measures in time.

Soil Conditions at Site

Preliminary borings and test pits were performed for investigating the in-situ conditions. The soil conditions comprise of a layer of top soil about 0.5 meters thick on top of a 10 meter thick layer of silty clay. This is underlain by a layer of clayey silt, 6 meters thick. Soil Samples were obtained for testing. Relevant standards of the American Society for Testing and Materials referred to as A.S.T.M. were utilized for testing procedures.

Geotechnical Properties of In-situ Soils

Index tests were conducted to classify the soils. The liquid limits for the silty clay and the clayey silt were determined to be respectively 65 and 38. Corresponding plastic limits were 32 and 22 respectively. Modified proctor compaction tests were conducted on these materials with a view to utilizing these materials for embankment. Optimum moisture contents for the above two materials were 15 % and 12%, respectively. Maximum dry densities corresponding to these optimum moisture contents were 123 lbs/cubic foot and 110 lbs/cubic foot respectively. From a compaction point of view, the locally available material did not pose any problems.

Permeability Tests

In order to prevent any seepage of water from inside the pond to the river, the foundation material has to be sufficiently impervious. Otherwise, suitable liner systems or slurry walls have to be provided with imported

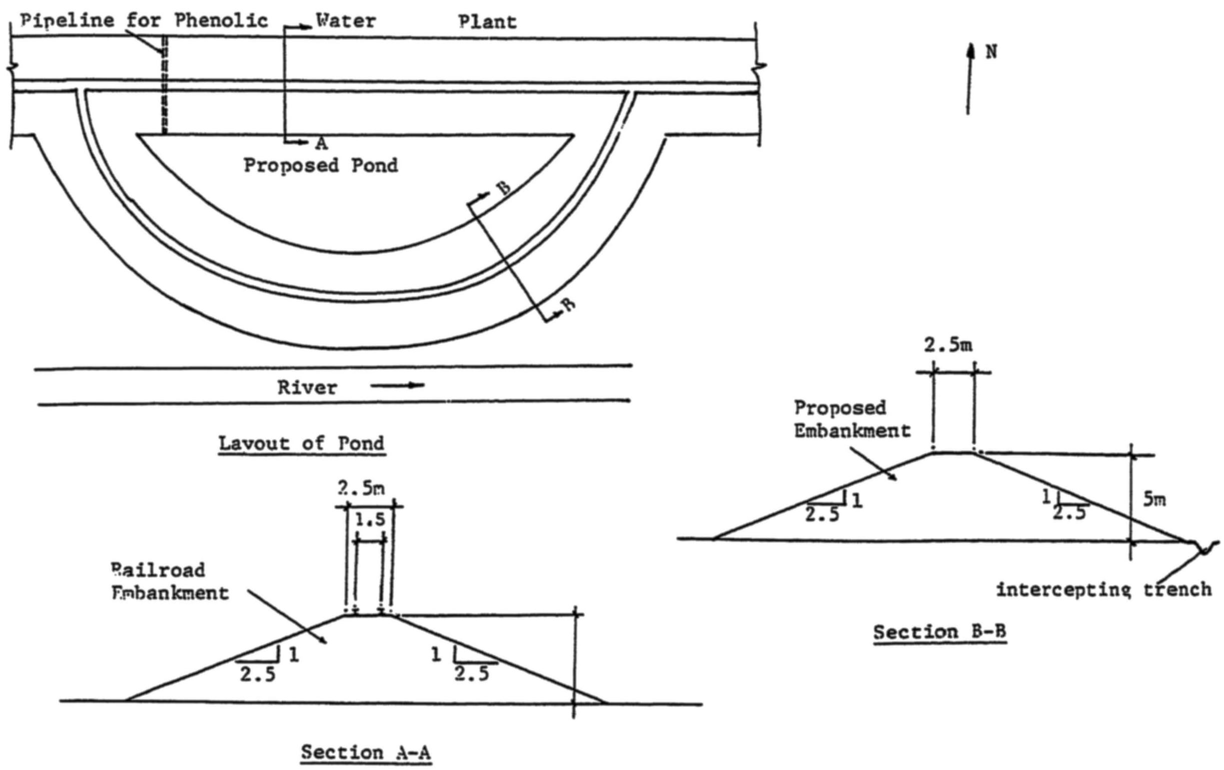

FIGURE 1

oils and geotextiles. So permeability tests ere conducted for this purpose on the in-situ aterials. Several types of tests are available o determine the permeability of soils. A eview of available literature indicates that he conductivity is affected by the type of test Daniel, et al., 1985). Mitchell and Madsen 1987) feel that the consolidometer permeability est is potentially the most useful one due to he versatility of the equipment. Hence, the use f consolidation tests for determining the ermeability of silty clays in this paper can be ustified.

For imperviousness, compaction on the wet ide of the optimum is required (Daniel 1984). ence, consolidation tests to determine ermeabilities of local soils were conducted at ry densities corresponding to 95 percent aximum proctor dry densities on the wet side of ptimum. These tests indicate that the silty lay and the clayey silt have average oefficients of permeability respectively 7.3 x .0^{-7} cm/sec and 1.1 x 10^{-6} cm/sec. onsolidation tests conducted on in-situ ndisturbed silty clay foundation materials ndicated that the average coefficient of ermeability was of the order of 10^{-7} cm/sec.

ffect of Phenolic Waters on the Hydraulic onductivity

The permeability determinations referred to bove were made with water as conducting fluid. t is well known that hydraulic conductivity is susceptible to changes with time or exposure to chemicals. Mitchell and Madsen (1987) recommend that the permeant used for testing to be of the same composition as to that to which the foundation material will be subjected in the field. Since, in this project, phenolic waters will be seeping through the foundation material of the dam, the possibility of conducting permeability tests on silty clay with phenolic waters as permeant was considered. As stated earlier, the concentration of phenolic waters will be 230 mg/l. But, due to oxidation in pond, only 32% of phenols will remain, thus reducing the concentration of phenolic waters reaching the bottom of pond to 76 mg/l.

A review of literature regarding the effect of phenols on the hydraulic conductivity was made. For this project, it can be stated that the hydraulic conductivity of silty clays will not be affected by phenols of the concentration produced in this plant, based on the following:

1. It appears that concentrations of organic solutions at or below the solubility limit have no effect of hydraulic conductivity of clay soils irrespective of the test methods (Mitchell and Madsen, 1987). The solubility of phenol in water is 86 g/l (Mitchell Et. all, 1987), whereas the concentration of phenol in the case history cited in this paper is 74 mg/l.

2. Acar et al. (1985), observed from flexible wall tests that in a compacted soil with 0.1 % concentration phenol the hydraulic

conductivity did not change appreciably. The concentration of phenolic waters from the producer gas plant is 74 mg/l and thus it is less than 0.1%.

Hence, it was decided not to perform hydraulic conductivity tests on native clay with phenol as permeant.

Based on the foregoing discussions, it can be assumed that a coefficient of permeability value of the order of 10^{-7} cm/sec would be admissible. Thus, it can be inferred that the native foundation soil has sufficient imperviousness to retain the phenol without polluting the river, eliminating the need for cutoff walls or special lining systems.

If this option were to be implemented, besides the storage pond, approach roads, pipe bridges, pumping stations for pumping water from peripheral trenches are to be constructed. Basalt coated pipes are needed for the hydraulic transport of phenol to prevent abrasion due to the slag. These pipes have to be imported from abroad, costing valuable foreign exchange.

The major disadvantage of this method is that very strict quality control measures for compaction have to be adopted to make the dam impermeable to prevent river pollution.

METHOD 2 Treatment of Phenol in an Independent Treatment Plant

In this option, the slag is transported hydraulically by the phenolic waters of low concentration obtained by the treatment of high concentration phenols by a special process. As part of this technique, high concentration phenol waters are diluted with 5 times low concentration waste to give an effluent of 1,296 m^3/day of concentration 1,525 mg/l. Depending on the condition of the diluted effluent, it may be necessary to adjust pH value between 7 to 10 prior to treatment. Nutrients are added to obtain a concentration in the diluted effluent of 75 mg/l nitrogen and 15 mg/l of phosphorus.

An aeration tank is provided for the biological treatment of wastewater. This tank is fitted with mechanical aerators to supply oxygen nd with an anti-foam dosing device which will perate automatically in the event of a build-up f foam occurring. A settling tank is also rovided to separate the sludge from clarified ffluent. This 16 ft diameter concrete settling tank is fitted with mechanical sludge scraper. The settled biological sludge will be recycled y means of pump to the aeration tanks to aintain a constant concentration of icroorganisms in the aeration tank and the larified treated effluent will overflow from the settling tanks to the drain. The treated effluent has a concentration of only 10 mg/l. This can be handled by the central sewage treatment plant.

The advantages of this method are:

1. Construction of earthern dam is avoided.

2. Load on central sewage treatment plant will be reduced.

3. Neither change nor alteration in the mechanical equipment for which orders are already being placed.

Method 3 Biological Treatment of Phenol an storage of sludge only in the pond

In this method, uncrushed slag delivered b conveyor belt falls in the truck and transporte to a storage pond. For access to the pond, a underbridge below the railway line will b built. High concentration phenol water will b treated separately by the special proces explained in the above option. The effluent wil be allowed to enter the sanitary sewer leadin to the central sewage treatment plant.

Advantages claimed are:

1. River pollution is totally avoided.

2. Trucks manufactured in India can be utilized avoiding costly foreign exchange.

3. Crushers, pumps, basalt-coated pipes and pipe bridge are unnecessary and hence savings in foreign exchange can be realized.

4. Disposal of slag into a particular place is not necessary. The whole area can be used. capital and operating costs are less.

METHOD 4

This option differs from the Method 3 i that the mode of transportation of uncrushe slag is by aerial ropeway. Spreading of slag i accomplished by human labor.

Advantages are the same as those fo method 3. Disadvantage is the aerial ropewa that would impede with height clearances and ai rights.

COST ANALYSES

For each option, capital costs, operation costs and working costs were estimated an presented in the form of tables. Costs wer worked out for a period of operation of 2 years. In arriving at working costs, annua maintenance, operation and depreciation for suc items whose life is shorter than 25 years an are to be replaced by new ones are considered In order to aid in the process of comparison the costs are shown in units and not in an currency.

A comparison of the four different method discussed above can be made from the figures i Table I:

TABLE I

COST COMPARISON

Item	Method 1	Method 2	Method 3	Method 4
Capital cost	17,091,380	7,826,170	2,150,880	12,537,380
Working cost per year	1,848,006	2,372,482	735,560	1,272,140
Working cost for 25 years	46,200,150	59,312,050	18,390,000	31,803,500
Total Cost (Add A and C)	63,291,530	67,138,220	20,540,880	44,340,880

Basis For Selection Of Disposal Technique

From the above table, it appears that the methods 2 and 3 have respectively the highest and the lowest working costs for 25 years. The capital costs for option 1 are the highest of all. Method 2 was rejected on the basis of high costs. It was decided to adopt method 3 since it costs the least. But due to the existing problems regarding the import of equipments, it was anticipated that there will be a 2-year delay in obtaining the required equipment. Hence it was decided to adopt option 1 in the interim (for a period of two years).

Phenolic waters will be pumped into the pond through a pipeline and the slag will be transported by trucks. In the meanwhile orders will be placed for basalt-coated cast iron pipes from abroad. These pipes will be used for the hydraulic transport of phenolic waters and slag.

CONCLUSIONS

As the avoidance of river pollution is the main technical concern, the scheme that satisfies this requirement in addition to being the cheapest in respect of the total cost was the one chosen. Thus it can be shown as to how geotechnical aspects such as pollution control and other environmental aspects control the final solution to the problem.

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