GEOTHERMAL HEAT FOR SOIL STERILISATION

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ABSTRACT

A study was made on using geothermal heat to sterilise soils of the Oserian flower farm located adjacent to Olkaria geothermal field in Kenya. Field experiments were conducted to evaluate different techniques of soil sterilisation. Injection of steam in to the soil proved to be the most efficient method; however it involved complex design and higher capital expenditure. A hot water spray system was adopted for its simplicity and low capital cost.

Heat from an existing geothermal well, which is not suitable for electric power production, is to be supplied to a plate heat exchanger to produce clean hot water which would be sprayed on to the soil to sterilise it.

Main issues such as soil characteristics and horticultural aspects, design aspects of the system including analysis of heat demand, availability of heat from the well, fluid transmission and distribution are discussed. Comments are made about construction and operation of the system.

1. INTRODUCTION

The Oserian Development Company grows flowers on the southern shore of Lake Naivasha, Kenya. The flowers are grown on two areas; the main farm located on the south-western shore of Lake Naivasha and the Backlands farm which is located further to the south close to the northern part of the Olkaria Geothermal field (Figure 1). Several deep exploratory geothermal wells have been drilled in close proximity to the farms.

The farms primarily produce quality flowers, mainly carnations and statice, for export. Flower crops, particularly carnations, tend to suffer from several soil borne pests and diseases which necessitates sterilising the soil layer periodically between crops to maintain the required yield. An estimated 60 hectares of land requires sterilisation each year. Soil sterilisation has been carried out over the past several years using methyl bromide gas applied to soil under a thin polyethylene plastic film over a period of approximately 5 to 6 hours. After the sterilisation the soil needs heavy watering and aeration to remove residual gas from the soil. To overcome the problems caused by soil diseases the available alternative options are; the continued use of chemicals for soil treatment, obtaining and cultivating of fresh farm land for flower production, or sterilisation of the farm soil using heat.

This report discusses some of the main tasks undertaken during the initial feasibility study and subsequent phases of the project to utilise the geothermal energy available from the wells to sterilise the Oserian farm soils.

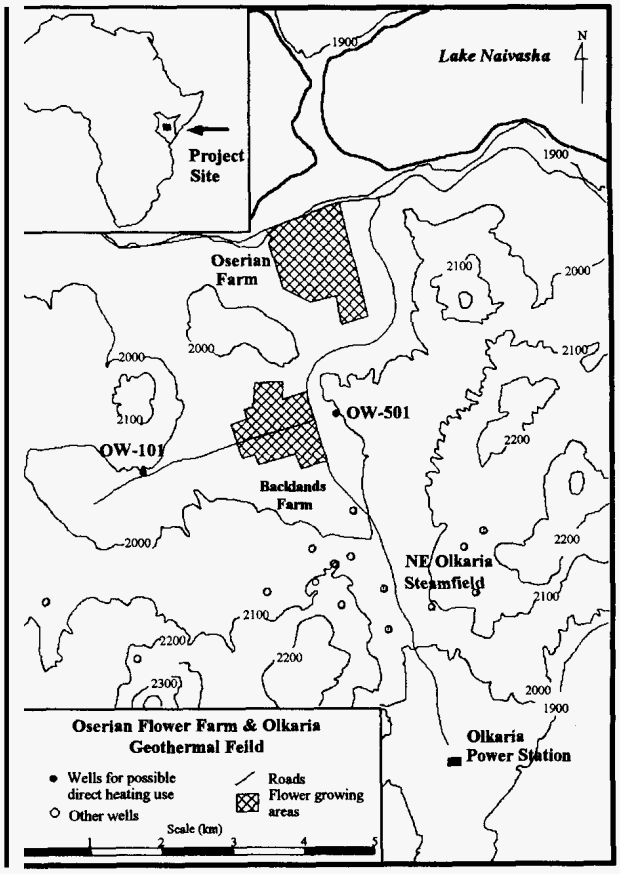

Figure 1 Location of The Oserian Farm

1.1 Background on Soil Sterilisation

Soil sterilisation is necessary to control soil pests (insects and weeds) and diseases, Among the wide range of sterilisation techniques used, soil steaming and chemical methods are the most common.

Soil steaming was widely used until the 1970's when cost of fuel became prohibitive and chemical methods became more economic. However, increased environmental concerns in recent years have led to a renewed interest in the use of soil steaming. Steaming methods are based on heating the soil by direct contact either by applying the steam through steam pipes dug into the soil or by applying steam on the surface of the soil under a plastic sheet. Much of the research information on soil steaming dates from the work carried out before the 1970's.

Methyl bromide is the most widely used and effective method of chemical for sterilising soil. These gaseous chemicals are usually applied under polythene sheet and are difficult and dangerous to handle. High levels of chemical residues such as methyl bromide can result due to continued use of these chemicals on the soil.

Other soil sterilisation techniques include sprinkling of hot water under a cover sheet and soil solarisation where the soil is covered with polythene sheeting and heated to milder temperatures which can result in the death of some weed seeds and other soil pests. Some irradiation techniques have also been shown to be very effective. Steam sterilisation, however, is the major alternative to using chemical treatment.

For this study, the alternative options to chemical fumigation were either steaming or spraying of hot water, both produced from the geothermal heat. Table 1 compares the simplest and most common steaming method (sheet steaming) with hot water spray method.

Table 1: Comparison of Steaming Versus Hot Water Spray for Soil Sterilisation

Method	Application time (hour)	Requirement (kg/m^2)
Sheet steaming	4.5 - 8	50 - 80
Hot water spray	36 - 48	1080 - 1440

2. METHODS AND PROCEDURES

To conduct the initial feasibility study a number of specific tasks were carried out, namely:

- Investigation of horticultural and agricultural engineering aspects,
- Analysis of the resource, methods for generation and transmission of steam,
- Engineering design and construction aspects

2.1 Horticultural and Agricultural Engineering

The best method for sterilisation of soil depends on the texture and composition of the soil. Soil which has had minimum cultivation and a coarse tilth will allow easiest permeation of steam because of the large spaces between the soil clumps, while a good permeability of the soil and subsurface drainage is necessary for sterilisation with hot water spraying. Hot water has the added advantage of washing the soil. The time of sterilisation depends on the soil characteristics. Steaming generally takes approximately 10 hours to treat the soil to a depth of 30 - 40 cm while for the time of application using hot water will largely depend on the permeability of the soil and may vary between 5 to 48 hours.

The application of steam or hot water to the soil can change the various chemical components of the soil to levels which may be toxic to the crop. High temperature, moisture and reduced oxygen content are the main factors leading to these chemical changes. Steaming has been shown to often result in toxicity problems from aluminium, manganese, ammonia and nitrite. These toxicities can be controlled to a large extent by adjustment of soil pH between 6.5 to 7.0. Use of very long steaming periods and excessive temperature will tend to enhance reduction reactions which result in soil toxicities.

2.2 The Geothermal Resource

Two deep geothermal exploration wells are located at a distance of 1 to 2 km from the Oserian farm (see Figure 1). These wells were drilled by the Kenya Power Company as part of an on-going exploration programme to determine the extent of the Olkaria geothermal resource beyond the presently developed borefield.

These wells, OW-101 and OW-501, have proven to be of relatively low productivity and are located far from the existing power station and therefore will not be used for power generation in the near future. The unsatisfactory results fiom these wells indicated that they lie in the outer margins of the resource and consequently there has been limited interest in hrther drilling in these areas. Neither of these wells are currently being considered for use as either production or reinjection wells for the Olkaria geothermal projects.

ow-101

Well OW-101 lies approximately 2 km west of the centre of the farm area (see Figure 1). This well has proven to be a small but reliable producer of steam and apart from its distance, is very suited to the proposed use.

Testing indicated a maximum output of about 51 t/hr at a wellhead pressure of 5 bar (abs) and an enthalpy of 1100 kJ/kg. This indicates a steam production of about 12 t/hr at that pressure.

The well showed little decline in output at a higher test pressure (7 bara). Good discharge may be possible at wellhead pressures higher than 7 bara which would give a greater output temperature (7 bara ≡ 165 °C saturation temperature).

OW-501

OW-501 is the well closest to the flower growing areas, being 900m from the centre of the farm (see Figure 1). It has a slightly smaller output than OW-101. It requires special techniques to initiate discharge and can not discharge at high wellhead pressures.

The proximity of this well to the farm areas makes the well an attractive option if it can be easily discharged and if it can operate at higher wellhead pressure than indicated by existing test results.

Fluid Chemistry

The following tables present summarised analyses from wells OW-101 and OW-501. Table 2 presents the chemistry of separated water from the weir box.

Table 2: Water chemistry of OW-101 and OW-501 discharges.

	ow-101 ppm (wt)	ow-501 ppm (wt)
pH	8.5 - 9.5	9.5
Ca	0.4	0.4
Cl	310	320
Na	700	500
K	100	70
Mg	0.1	0.1
Li	3	1.5
Fl	25	50
B	10	2.5
SiO_2	610	350
CO_2	1100	500
H_2S	4	15
NH_3	1.0	0.5

There is limited gas analysis data available for the discharge from the wells. Table 3 presents gas analysis data for well OW-101.

Table 3: Discharge gas chemistry OW-101.

Gas concentration (mole %)	OW-101
CO_2	99.6
H_2S	0.2
CH_4	0.1
H_2	0.1
CO_2 (weight % of steam)	3.5
H_2S (weight % of steam)	0.007

The suitability of the discharged steam for direct use in a soil steaming process is difficult to assess because of very limited experience with geothermal steam for this type of application. Ammonia and H_2S are the components of the steam most likely to directly cause toxicity problems to plants. The steam could also contain mercury for which analysis data is not available.

The high C02 and H_2S content could significantly reduce pH during the steaming process which would tend to result in reduction reactions leading to manganese and aluminium toxicities. This may be overcome by suitable application of lime before steaming.

CO_2 is the major gas component in the steam *(3.5%* by weight measured in OW-101) and at steam application rates of about 100 kg/m^3 amounts to 3.5 kg/m^3 of soil. The H_2S component at about 0.01% by weight of steam amounts to approximately 0.01 kg/m^3 of soil or about 10 ppm.

If geothermal steam was to be used directly for the soil steaming, the steam would be separated from the water component of the discharge before use, but this separation process will always have some small "carry over" of water from the separation process. Therefore some of the components of the water phase of the discharge may be carried with the steam. None of the components of the separated water have extreme concentrations and, except possibly for boron, the small amounts likely to be carried over would not be expected to cause major problems.

CO_2, H_2S and mercury are likely to be the main contaminants of the geothermal steam that could cause problems if used directly. The levels of these contaminants may be sufficiently low that the steam may prove suitable for direct use in the soil sterilisation, but this cannot be recommended without further trials using geothermal steam. The obvious simplicity of being able to use the raw geothermal steam may prove to be outweighed by the difficulties and high costs in transporting this steam over long distances when compared to using hot water. It is primarily due to this fact that a simpler and less costly option of using hot water was recommended for the soil sterilisation.

3. PROPOSED SYSTEM

The proposed system for sterilisation of soil utilises hot water applied to the soil by means of a spray nozzle reticulation system arranged under insulated polyethylene cover Fresh water from the lake will be supplied from an existing elevated reservoir, currently used for irrigation, by gravity to the site ofwell OW-101

A plate heat exchanger located at the wellhead will be used to heat the lake water To minimise the problems of deposition and corrosion in the piping, caused by geothermal fluid, a two loop system which isolates the geothermal fluid from the hot water piping and equipment has been proposed The outlet temperature of the geothermal fluid was designed so that deposition of silica in the plates of the heat exchanger on the geothermal side will not occur.

Due to the risks of stress corrosion cracking with stainless steel plates, in the presence of chloride and stress at higher temperatures, careful consideration has been given in selecting the appropriate material of the plate heat exchanger.

Figure 2 is a schematic drawing of the proposed sterilisation system

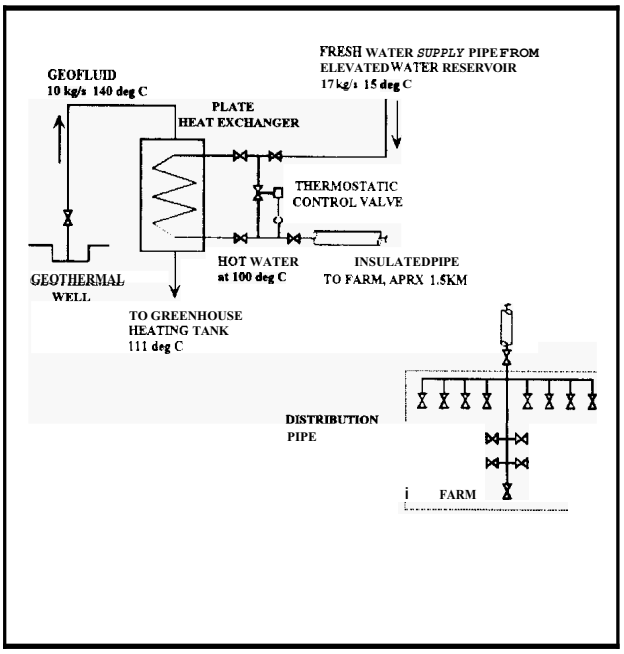

Figure 2 Simplified Schematic Diagram of The Proposed System

3.1 Heat Demand

The heat demand was estimated with the assumption that the soil sterilisation is conducted in stages covering an area of land 20m wide and 100m long (2000 m²). The heat consumption rate and some of the following design parameters were determined from field tests conducted by the Oserian Development Company.

Area of Application (A) 2000 m²
Rate of Application (R) 0.5 l/m²/ min
Duration of Application 36 - 48 hr
Hot Water Requirement *60* m³/ hr
Temperature of lake water (T_1) 15 °C
Hot Water Temperature (T_2) 93 °C
Pressure Required at nozzles 1 bar g

Thus the total flow of the hot water required (M) is calculated as indicated in equation (1) below:

$$M = \frac{AR}{60} \quad (kg/s) \qquad (1)$$

The heat exchanger duty (Q) was estimated using equation (2) below:

$$Q = 4.2M(T_2 - T_1) \quad (kW) \qquad (2)$$

Allowing for sufficient temperature drop between the heat exchanger at the wellhead and the application site at the flower farm, about *6300* kW of heat is required to sterilise the required area using hot water.

3.2 Heat Transmission

One of the main technical problems involved in the study is the transmission of heat from the geothermal well site to the flower farm. The hot water spray system seemed more attractive than the steam system due to smaller size piping and its simpler construction.

The hot water produced using the plate heat exchanger at the wellhead is transported to the farm area over a distance **of 1** to 2 kilometres. The pressure drop and temperature loss in the pipeline are designed to yield a pressure of 1 bar g and a temperature of 93°C at the farthest point of the farm at all times. The main transmission piping will be insulated with fibreglass insulation and covered with cladding. Overland piping is proposed from the wellhead to the edge of the farm, followed by buried piping within the farm to allow vehicle access. The buried piping will have take-off hydrants coming to the surface for connecting the hot water spray reticulation system when treatment of the soil in that vicinity is needed

4. CONCLUSIONS

The use of geothermal heat for soil sterilisation is expected to be an economical and environmentally sound alternative when compared to chemical methods. Exploration wells which are not suitable for power generation could be suitable for such applications.

While the application of steam seems more effective, the use of hot water is favoured due to its low cost and simpler construction. The direct use of geothermal steam on the soil is an alternative option, but the effect of geothermal contaminants on the soil need further investigation.

Implementation of the proposed system may not proceed in the near future, mainly due to the fact that developing of fresh farm land close to the current flower growing areas appear to be a simpler option.

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