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Department of the Environment

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Timber Preservation Chemicals

Volume 1b – Field Investigations

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CONSULTANTS IN ENVIRONMENTAL SCIENCES LTD

CONTENTS

1. INTRODUCTION

This report describes experiments carried out at the Princes Risborough Laboratory of the Building Research Establishment to assess the degree of preservative leaching from timber treated with different preservative solutions. This work was undertaken as part of a wider study of timber preservatives, their properties, extent of use and environmental impact.

It is widely assumed that following the treatment of timber with organic-based preservative solutions, the wood is dry and does not drip excess preservative. It is acknowledged, however, that preservatives can subsequently be leached from treated timber by rainfall. Timber treated using water-based preservatives is wet following treatment, and there is a requirement for it to be dry before usage. Ideally, such timber should be protected against rewetting during the interim period by storage under cover. The British Wood Preserving Association (BWPA) recommends that timber freshly treated with CCA preservative should be stored for a mimimum of 48 hours, or until the surface is dry whichever is the longer. However, this only encourages good practice and is not enforceable (Anon, 1986). No such recommendations exist for timber treated with organic solvent-based or creosote preservatives.

During commercial treatment of timber, the removal of excess liquid is often carried out by drawing a vacuum on the treatment vessel. In the domestic situation, liberal application of creosote is common, and this, combined with poor retention and a tendency to reapply regularly, will contribute a great deal to the loss of preservatives to the environment.

Treated timber is often stacked in the open and exposed to the weather. Leaching of the preservatives from the wood as well as the dripping of excess preservative is therefore likely to occur. There are few data available on the extent to which leaching from treated timber occurs and the experiments reported here were designed to quantify the input of preservatives to the environment

by this route. This could be a very important factor to be determined given the scale of commercial timber preservation and amateur application in the UK (see Vol.1A of this report).

The aims of the study were three fold:

1. To determine losses of preservative compounds from treated timber if exposed to controlled weathering immediately following treatment;

2. To determine the effect of storing timber under cover for a period of time and subsequently exposing it to the same weathering conditions as 1., above;

3. To quantify the losses of preservative solution from wood exposed to natural weathering conditions.

2. METHODS AND MATERIALS

Analysis of timber preservation usage in the UK (see Vol. 1A) revealed that the three main types of wood preservatives are tar oils (creosotes), organic solvent based preservatives and water based preservatives. It was decided therefore to undertake experiments using typical preservative formulations within these categories as follows:

2.1. Preservatives Utilised

2.1.1 Creosote.

This is a generic term given to blends of distillate oils derived from coal tar with a boiling range in the range 200°C to 400°C. As creosote is used on a commercial basis (for example, large scale treatment of telegraph poles and railway sleepers), and on a smaller domestic scale (creosoting of garden fences), it was decided that high pressure and temperature timber impregnation with creosote and application of creosote by brush to two separate sections of timber would be carried out and each subjected to leaching tests.

2.1.2 Organic solvent-based preservative (OSWP).

On a commercial scale the most commonly used OSWP active ingredients are the following; pentachlorophenol (PCP), gamma-hexachlorocyclohexane (HCH), metal naphthenates and bis - (tributyltin) oxide (TBTO). In the experiments reported here, PCP, HCH and zinc naphthenate were utilised and dissolved in a proproetary organic solvent (Shell sol E), routinely used at the Princes Risborough Laboratory.

2.1.3 Water-based preservative.

In the UK, these usually consist of a mixture of inorganic salts dissolved in water. The most common combination is the

copper/chrome/arsenic (CCA) wood preservative. Copper and arsenic are the principal pesticidal agents, while the dichromate fixes the copper and arsenic in the wood. The solution used in these tests consisted of a mixture of copper sulphate, sodium dichromate and arsenic pentoxide.

Two types of wood, namely European redwood and woven larchlap were used for the experiments, and treated by the same methods and solutions throughout the three phases of the study. European redwood was used for the experiments where preservative was applied by pressure and double vacuum processes. The timber was cut into sections each measuring 65mm x 65mm x 550mm. The sections used for CCA and creosote application were left unplaned while the timber to be treated with the PCP/ zinc napthenate/ HCH preservative were planed to a smooth finish. All sections were end-sealed using resistant resins to prevent disproportionate uptake of preservative through the endgrain.

Woven larchlap fencing sections were used for the brush applied creosote preservative.

2.2 Methods of Preservative Application.

2.2.1. CCA Preservative.

Sections to be treated were made free from mud, dirt, dust and bark, and also from paint polish and any other surface finishes. Timber was stacked in the treatment vessel in a manner to ensure that the preservative solution would have free access to all faces of the timber and to facilitate natural drainage.

Application of the CCA preservative was carried out at high pressure and ambient temperature according to the P2 schedule of the BWPA manual as follows.

An initial partial vacuum of -0.8 bar gauge (80kPa) was applied to the timber prior to flooding with preservative solution. This

vacuum was held for thirty minutes. Following complete immersion of the timber in preservative, the pressure was increased to between 12.4 bar (1240kPa) and 14 bar (1400kPa) to encourage impregnation. Once impregnation pressure had been reached, sixty minutes expired prior to the release of pressure and commencement of draining of preservative solution from the treatment vessel. Following chamber draining, a final vacuum of -0.8 bar (80kPa) was applied.

The water based CCA preservative solution was made up from a homogenous dry powder supplied by Hicksons Timber Products Ltd to a 3.035%(w/v) solution. The composition of the resulting preservative solution was as follows:

Copper salt($CuSO_4.5H_2O$) - 12.65g l^{-1}
Chromium salt($K_2Cr_2O_7.2H_2O$) - 12.47g l^{-1}
Arsenic salt($As_2O_5.2H_2O$) - 4.69g l^{-1}

2.2.2 Organic Solvent Based Preservative.

The planed sections to be treated were checked to be free from mud, dirt, dust and bark, and also from paint, polish and other surface finishes. Careful stacking in the treatment vessel ensured free access of preservative to all faces of the timber.

Treatment of the timber was carried out at ambient temperature through the double vacuum/low pressure V1 treatment schedule according to the BWPA manual.

An initial partial vacuum of -0.33 bar (33kPa) was applied to the timber and held for 3 minutes. This vacuum was maintained during flooding of the chamber by preservative solution. Impregnation was achieved at 0 bar(ambient atmospheric pressure) for a duration of 3 minutes prior to draining of the preservative solution from the treatment vessel. A final vacuum (-0.67 bar (67kPa)) was then applied and held for 20 minutes before releasing and returning to atmospheric pressure.

The organic solvent preservative solution was made up by dissolving 2kg of pentachlorophenol (PCP) in 40 litres of Shell Sol E solvent (an aromatic hydrocarbon solvent within a distillation range of 153 - 193°C). In addition, 5 litres of commercial 8% zinc naphthenate was also added. This created a final solution containing 1% zinc, as zinc napthenate and 5% PCP.

For the second and third Phases of the experiment, gamma hexachlorocyclohexane (lindane) was added to the above solution at a concentration of 0.5%m/m. Lindane was not available in the first Phase for addition to the preservative solution.

2.2.3 Pressure Applied Creosote.

Exposure of timber to creosote preservative was carried out as part of normal commercial operations by Burt Boulton Timber Ltd., Belvedere, Kent. The timber to be used was treated together with a batch of telegraph poles. The wood sections treated here were of the same type and size as those used in section 2.2.1 and 2.2.2 above. Timber was treated by the following method. The treatment vessel and timber was put under a pressure of 340kPa for thirty minutes. The chamber was then flooded with creosote at 87°C while remaining at 340kPa. Pressure was increased to 1205kPa and once reached, held for 1.5 hours prior to releasing and draining of creosote. After draining was completed, a vacuum was applied (approximately 87kPa) and left over night. Withdrawal of treated timber the following morning reveals that the wood surface is essentially dry to the touch.

2.2.4 Brush Applied Creosote.

For this test a panel of woven larch lap fencing (surface area 1.67m^2) was purchased and one coat of nut brown creosote (HSE approval number 1166, marketed by Langlow Products Ltd. and purchased from a retail outlet) was applied liberally to one side using a new 100mm wide brush.

2.3 Conditions of Exposure to Weathering.

Two different methods of exposure to weathering were used for the three phases of the experiment;

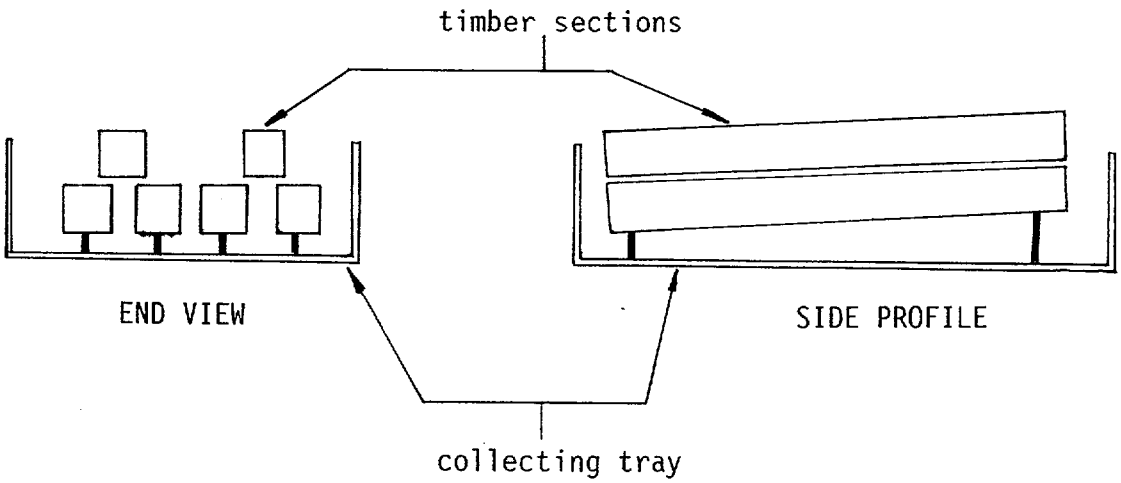
1. for the first and third phases, all wood remained undercover and was subjected to controled irrigation by manual spraying with measured volumes of deionised water; and,

2. in the second phase all wood was located in the open and therefore exposed to natural rainfall conditions.

For all phases of the experiment wood was stacked in the same manner. The brush applied creosoted fence was placed upright in a drip tray for collection of runoff. Aluminium blocks were placed underneath the fence so as to prevent the bottom of the fence from coming into contact with any accumulated runoff; the endsealed redwood sections were stacked on top of each other in collecting trays with one end slightly elevated to allow water to drain off the wood. Glass rods were used to prevent touching of the sections. The stacking arrangement is shown in Figure 1.

FIGURE 1

Illustration of the Stacking Arrangement of Timbers.



2.4 Irrigation Rate.

During the first and third Phases of the experiment wood was exposed to water sprayed at a controlled rate calculated as follows:

Monthly average peak rainfall in the UK is approximately 75mm (2.5 litres/m^2/2 days). The surface area of the stacks was calculated to be 0.16m^2 and therefore an irrigation rate of 800ml every 2 days was used(applied over a period of one hour). The first application of water during Phase 1 was some 30 minutes after the timber had been removed from the treatment vessel. In Phase 3 however, a 7 day gap separated treatment and the first application of water.

This irrigation rate was used for all timbers following treatment with the exception of the fencing section. The irrigation rate for the fences was calculated thus:

The surface area of the fence section was measured at 1.67m^2. At the above rate the timber section would require irrigation of 4.2 litres per day. However, a vertical fence would not receive the full effect of rainfall falling vertically so an arbitary attenuation factor of 0.15 was assumed producing a daily irrigation rate of 0.63 litres (4.2 x 0.15).

Tables 1 and 3 illustrate the irrigation schedule for Phases 1 and 3 of the experiment.

During the second phase of the experiment, timber was located in the open so exposure to precipitation was beyond experimental control and thus irregular in time of event and amount recorded. Table 2 illustrates the daily rainfall recorded during the period of exposure.

TABLE 1

Schedule of Controlled Irrigation (Phase 1)

	Volume Applied (litres)			
DAY	CCA	ORGANIC SOLVENT WOOD PRESERVATIVE	PRESSURE APPLIED CREOSOTE	CREOSOTED FENCE
1	0.4	0.4	0.8	0.63
2	0.4	0.4		0.63
4			0.8	
5	0.8	0.8		1.26
6			0.8	
7	0.8	0.8		1.26
8			0.8	
9	0.8	0.8		1.26
12			0.8	
13	0.8	0.8		1.26
14			0.8	
15	0.8	0.8		1.26
18			1.2	
19	1.2	1.2		1.89
21			0.4	
22	0.4	0.4		0.63

TABLE 2

Precipitation Recorded During Phase 2

DAY 1 - 2	2.3mm
2 - 3	0.4mm
3 - 4	0.5mm
4 - 7	11.4mm
7 - 8	1.0mm
8 - 9	2.9mm
9 - 10	0.3mm
10 - 11	5.0mm
11 - 14	1.4mm

TABLE 3

Schedule of Water Application (Phase 3)

	Volume Applied (litres)		
DAY	CCA	ORGANIC SOLVENT WOOD PRESERVATIVE	PRESSURE APPLIED CREOSOTE
7	0.4	0.4	0.4
8	0.4	0.4	0.4
9	0.8	0.8	0.8
12	0.8	0.8	0.8
14	0.8	0.8	0.8
16	0.8	0.8	0.8
20	0.8	0.8	0.8
23	0.8	0.8	0.8

Note: Timber kept dry for days 1 - 6 inclusive.

2.5 Sample Collection.

2.5.1 Controlled Irrigation.

Runoff collection from the first Phase initially took place immediately prior to the following application (48 hours later) of water to allow runoff time to be maximised. However, due to evaporation of collected runoff from the pressure-creosoted timber during an extended period without irrigation, the sampling strategy was changed so that the collection of runoff from timber during the first and third Phases took place approximately 1 hour after application.

2.5.2 Natural Exposure.

Runoff was collected from timber in the second Phase at 09.30 each morning if precipitation had been recorded during the previous 24 hours. Below a certain level of precipitation (0.4mm) (Table 2) no runoff was recorded and therefore no sample taken.

Sample collection was in glass sampling bottles for creosoted and organic solvent treated timbers and plastic sampling bottles for CCA treated timber.

2.6. Analytical Methods.

Leachate samples from timbers were analysed for the following parameters:

Leachate from timbers treated with CCA preservative were analysed for copper, chromium and arsenic. Leachate from timbers treated with organic solvent preservative were analysed for pentachlorophenol, zinc and gamma-hexachlorocyclohexane (HCH) (Phases 2 & 3 only). Leachate from timbers treated with creosote(pressure and brush applied) were analysed for total phenols and PAH(naphthalene, acenaphthene, fluorene, phenanthrene and anthracene, and fluoranthene).

Copper, chromium, arsenic, zinc, gamma HCH and pentachlorophenol were determined using methods routinely in use at the Princes Risborough Laboratory of the BRE. Total phenols were determined by the Standard Method for Waters and Wastewaters (DoE, 1981). Individual PAH were determined on a toluene extract of runoff samples using gas chromatography with flame ionisation detection. Calibration was achieved by PAH standard compounds dissolved in toluene and PAH identification was made on the basis of matched retention times.

3. RESULTS

The amount of preservative taken up by the timber during treatment varied with preservative type and between the Phases. The volume of runoff (and therefore the volume sampled) also varied. These results are given in Appendices 1 - 10. Figures were not available for uptake of creosote in all Phases or for runoff from CCA and organic solvent treated timber in Phase 1 due to recording difficulties.

During Phase I, only the volume of water used for irrigation was determined accurately, the runoff samples being made upto a convenient volume prior to analysis. However, when it became apparent that evaporation might have a significant effect, the runoff volumes during Phases 2 and 3 were also recorded accurately.

An accurate assessment of creosote uptake by the redwood sections could not be made because the appropriate facilities were not available at the treatment plant. However, an accurate estimate was made on the basis of subsequent weighings and this is included in Appendix 7.

Chemical analyses were carried out on eighty nine water samples collected during the experimental period. The results of the analyses of leachate are presented in Appendices 11 to 32.

It should be noted that no sample was collected on day 4 from the pressure creosoted timber during phase 1 of the experiments. This was due to the unavoidable evaporation of runoff that had not been absorbed by the timber. To prevent this reoccurring, the sampling strategy was altered as previously described in Section 2.4 above.

3.1 Discussion of Results

3.1.1 Uptake and Runoff Rates.

Runoff in Phase 1 from pressure creosoted timber represented about 50% of the volume of water applied. In Phase 3 this figure had

increased to 72%. By contrast, run-off from the brush-creosoted fence in Phase 1 ammounted to only 20% of the volume of water applied.

The total recorded runoff from treated timbers during Phase 2 was highly variable depending on precipitation. However, the runoff from CCA treated timber (11.6 litres) was almost double that from the OSWP treated timber and pressure applied creosoted timber (5.8 litres and 5.6 litres respectively). As the CCA treated timbers were located in two collecting trays, it was expected that the amount collected would be double that collected from either of the other trays. Runoff from the fence section during Phase 2 was considerably higher than for all other timber types (15.2 litres).

Uptake of CCA and OSWP preservative solutions during the 3 separate treatments were very similar. Total metal uptake by timbers treated with CCA in the 3 Phases only differed by about 7% (of 90 - 100g absorbed)(Appendices 4 - 6). PCP and zinc retention during the 3 treatments only varied by 9g and 1.8g respectively (of 24 and 5g retained) (Appendices 7 - 9). Given the differences in the starting weights of the timber used, this variation in uptake rate is not significant. As pressure applied creosoted timber was treated off site it was impossible to guage accurate uptake rates of creosote.

3.1.2 Leaching During Phase 1 (controlled irrigation).

The mass of phenol leached during Phase 1 from timber treated with creosote under pressure fell steadily from day 1 and quickly after day 18, as is illustrated in Fig 2. The mass of PAH in the leachate did not follow the same trend; alternating peaks and troughs can be identified in Fig 3 as differing amounts of PAH were leached.

Fig 4 illustrates that the concentration of phenols leached from the creosoted fence section in Phase 1 decreases very rapidly from the first day onwards. The concentration of phenol in leachate

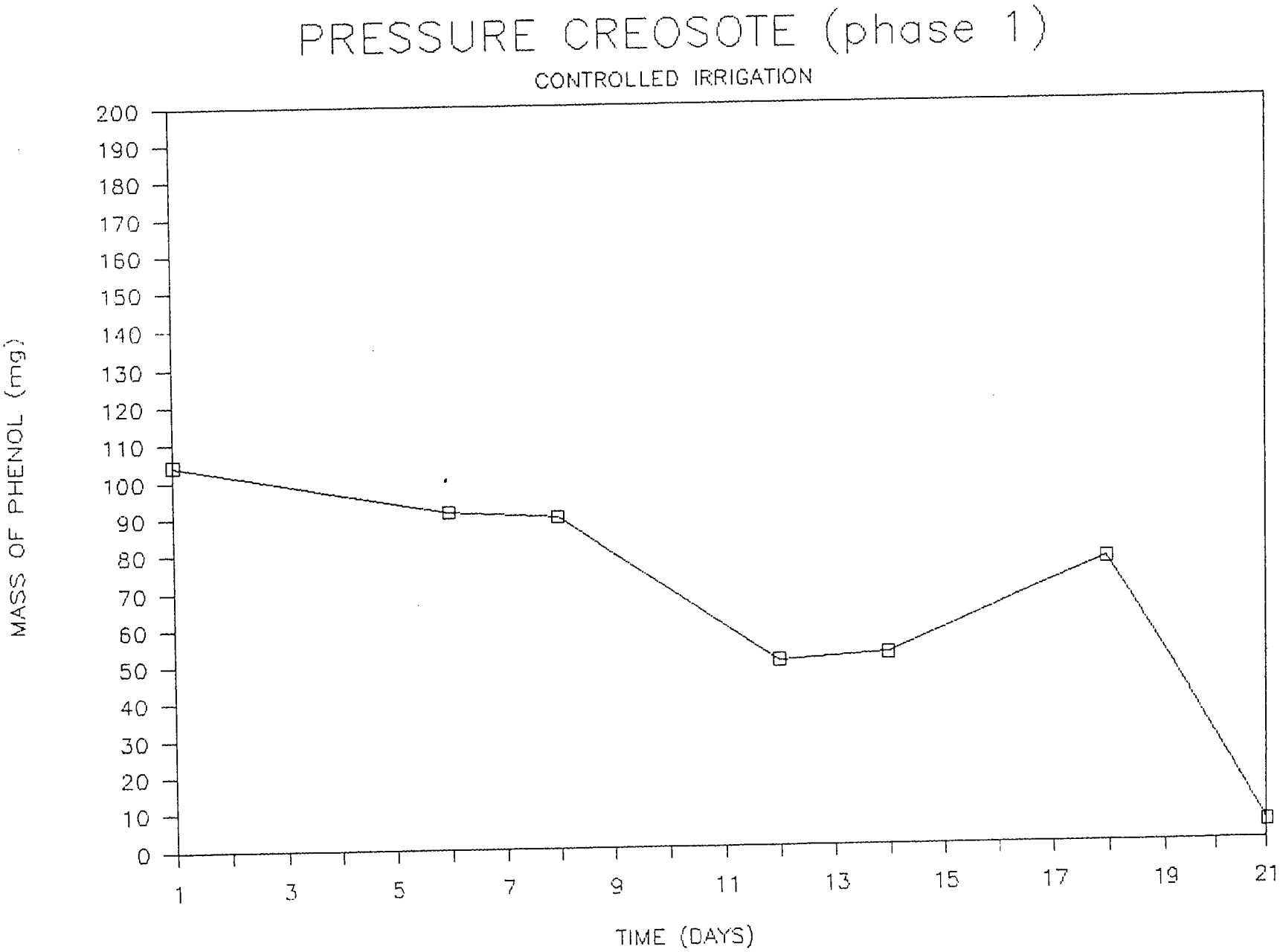

PRESSURE CREOSOTE (phase 1)
CONTROLLED IRRIGATION
MASS OF PHENOL (mg)
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
1
3
5
7
9
11
13
15
17
19
21
TIME (DAYS)

Fig 2

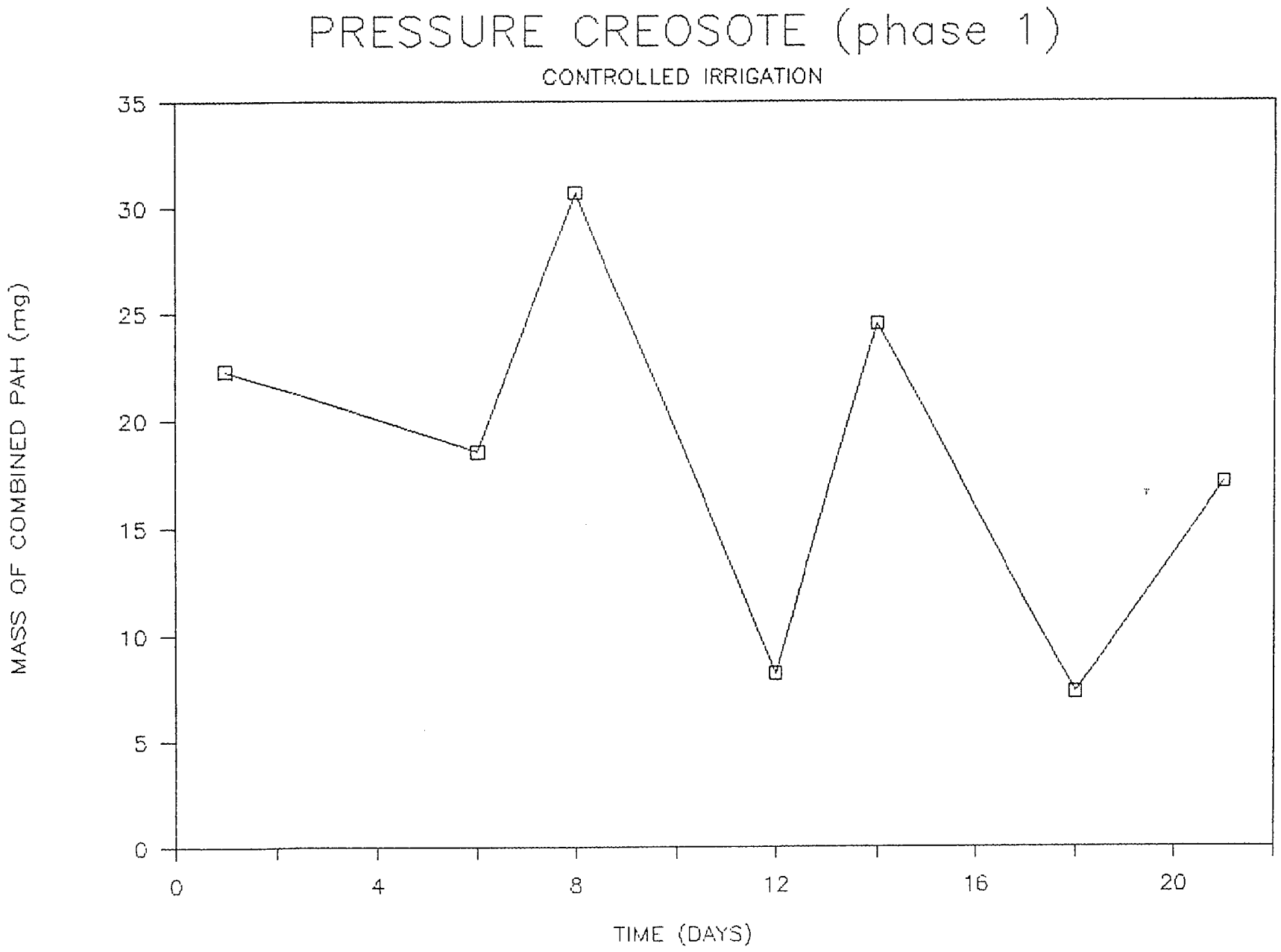

PRESSURE CREOSOTE (phase 1)
CONTROLLED IRRIGATION
MASS OF COMBINED PAH (mg)
35
30
25
20
15
10
5
0
0
4
8
12
16
20
TIME (DAYS)

Fig 3

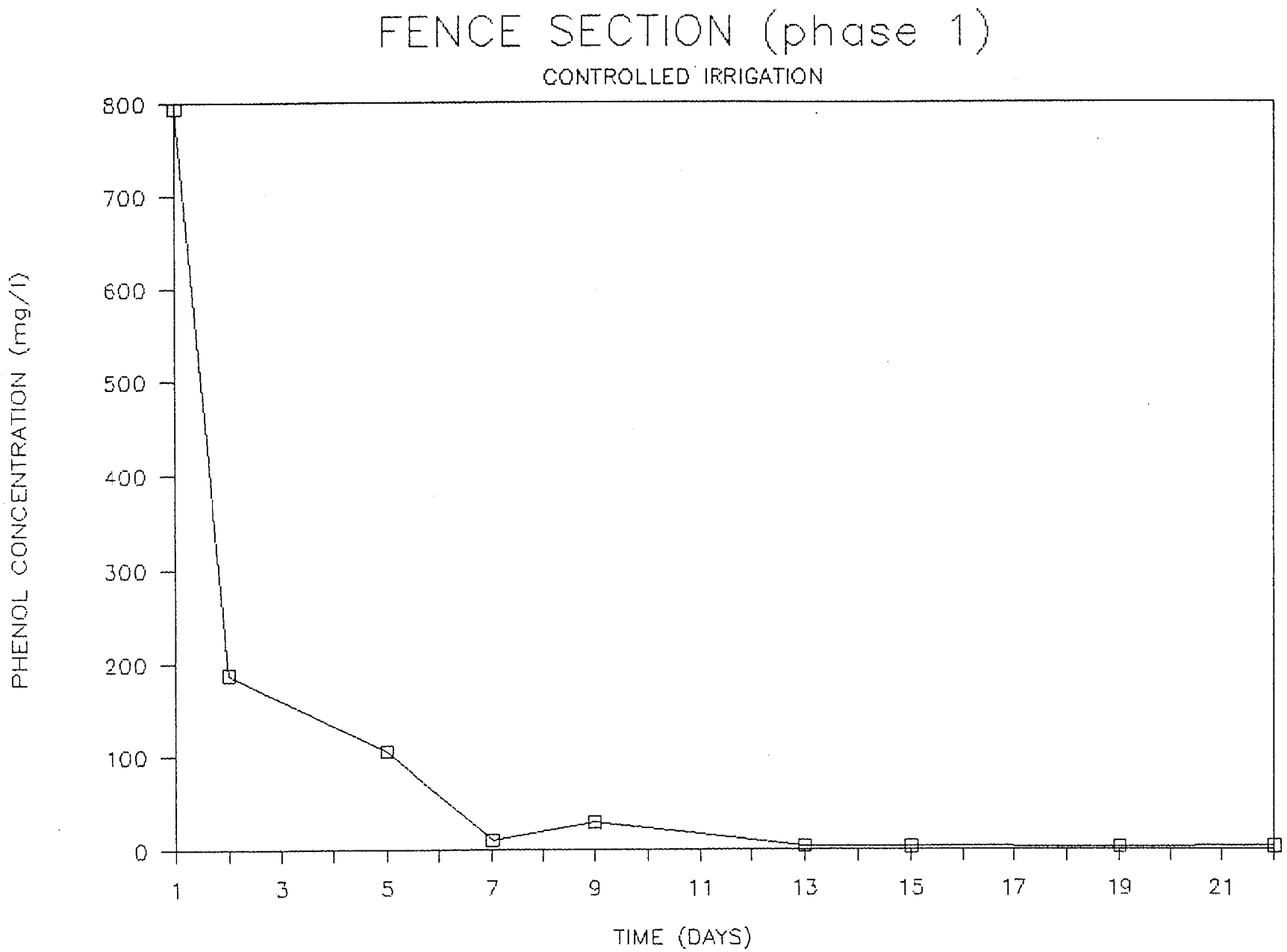

FENCE SECTION (phase 1)
CONTROLLED IRRIGATION
PHENOL CONCENTRATION (mg/l)
800
700
600
500
400
300
200
100
0
1
3
5
7
9
11
13
15
17
19
21
TIME (DAYS)

Fig 4

settled down to around 2 mgl^{-1} for the last 9 days of the trial. The concentration of PAH leached from the same timber follows a similar path with high concentrations initially, decreasing thereafter. During the last three days however, a slight increase is recorded. Figure 5 illustrates this rise in mass of PAH leached from the fence towards the end of Phase 1. Of the total PAH leached from the fence section in Phase 1, over 55% is naphthalene, with the smallest amount being attributable to fluoranthrene.

Large masses of all metals (copper, chromium and arsenic) were leached from timber in Phase 1 following the initial irrigation. Of the total mass of copper washed out during Phase 1, 75% was leached from the timber on day 1; the figures for chromium and arsenic are 47% and 85% respectively (Fig 6). Of the 93.7g of metals taken up by the timber during treatment for Phase 1, a total of 1.13g is leached out.

The results of analyses of leachate from timber treated with organic solvent, PCP, and zinc naphthenate in Phase 1 show some unusual trends. The mass of PCP averaged around 8 mgl^{-1} for the first 19 days and then rose to a peak of 27 mgl^{-1} before falling to 13 mgl^{-1} on the last day of sampling (Fig 7). This peak accounts for over 65% of the total mass of PCP leached from the timber during Phase 1.

The mass of zinc drops slowly from 4.4 mgl^{-1} on day 1 to zero on day 9 before producing a small peak towards the end of the sampling period (Fig 8).

3.1.3 Leaching During Phase 3 (controlled irrigation).

The mass of PAH leached from pressure applied creosoted timber during Phase 3 (following the 7 day drying period) remained low for the whole of the experimental period, but there was a general increase over the first five days of exposure to water (with a peak of 26.145mg) was recorded. PAH levels subsequently decreased (Fig 9). A trend similar to that for mass of PAH is also recorded for

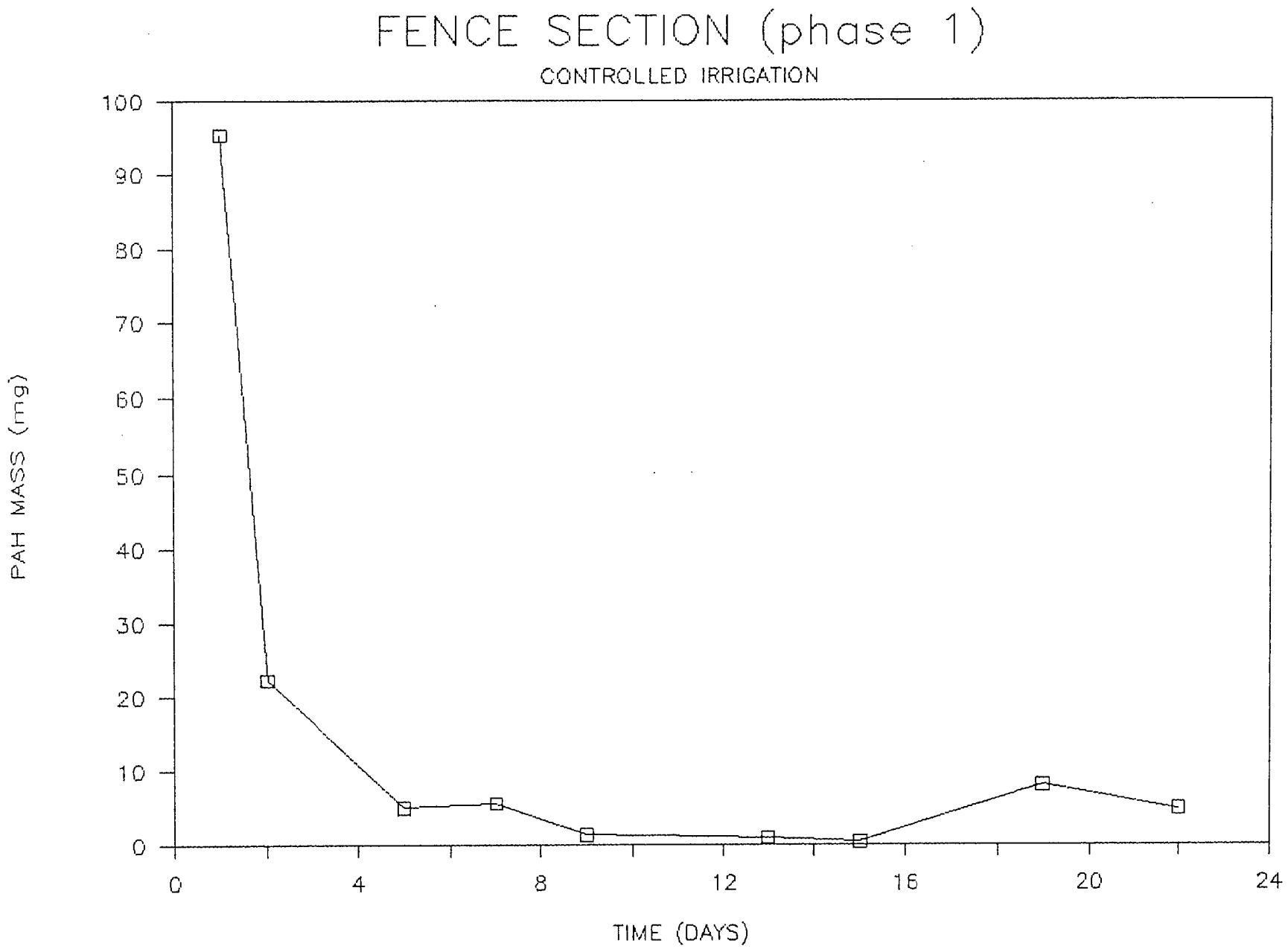

FENCE SECTION (phase 1)
CONTROLLED IRRIGATION
PAH MASS (mg)
100
90
80
70
60
50
40
30
20
10
0
0
4
8
12
16
20
24
TIME (DAYS)

Fig 5

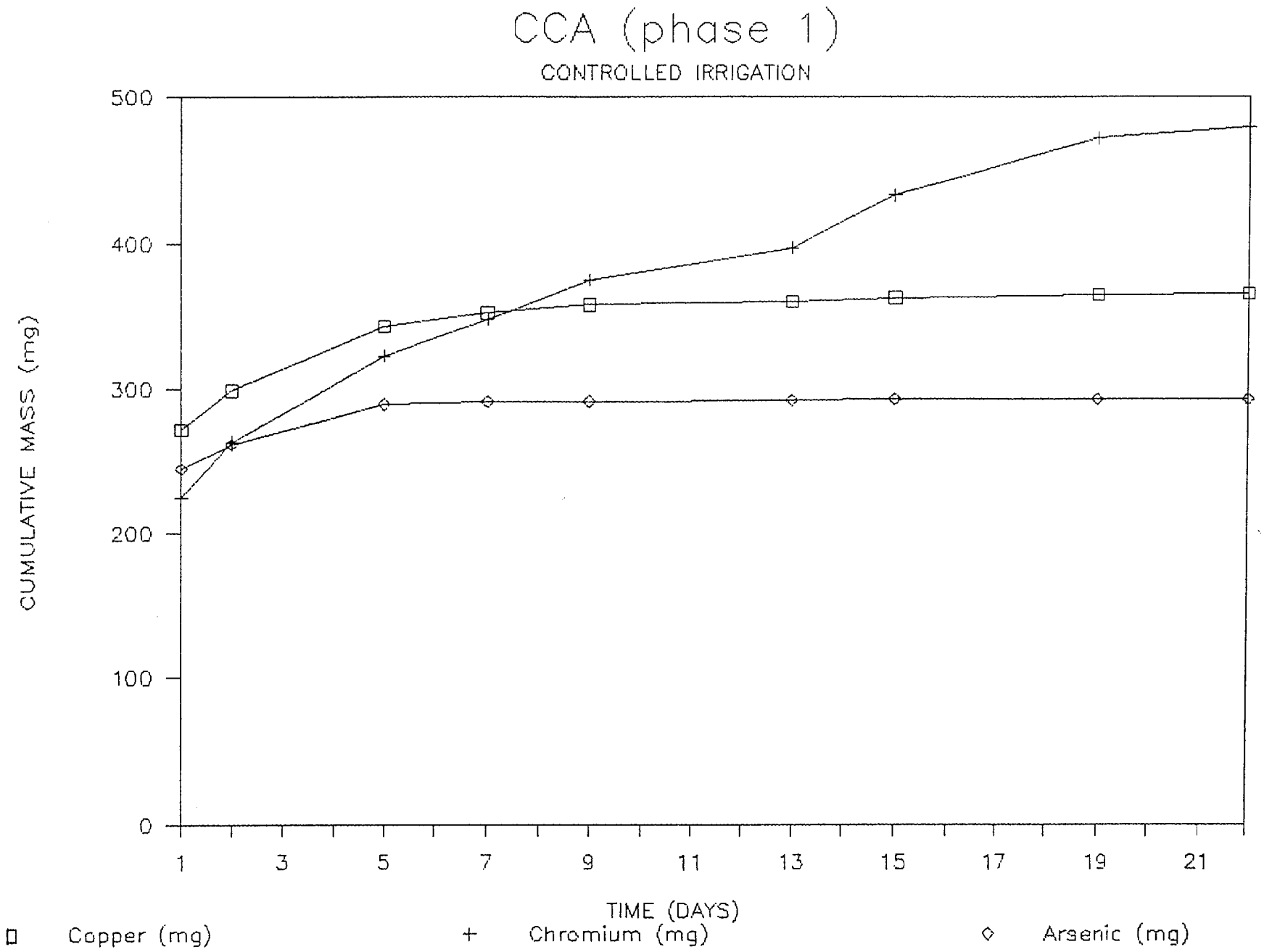

CCA (phase 1)
CONTROLLED IRRIGATION
CUMULATIVE MASS (mg)
500
400
300
200
100
0
1
3
5
7
9
11
13
15
17
19
21
TIME (DAYS)
Copper (mg)
Chromium (mg)
Arsenic (mg)

Fig 6

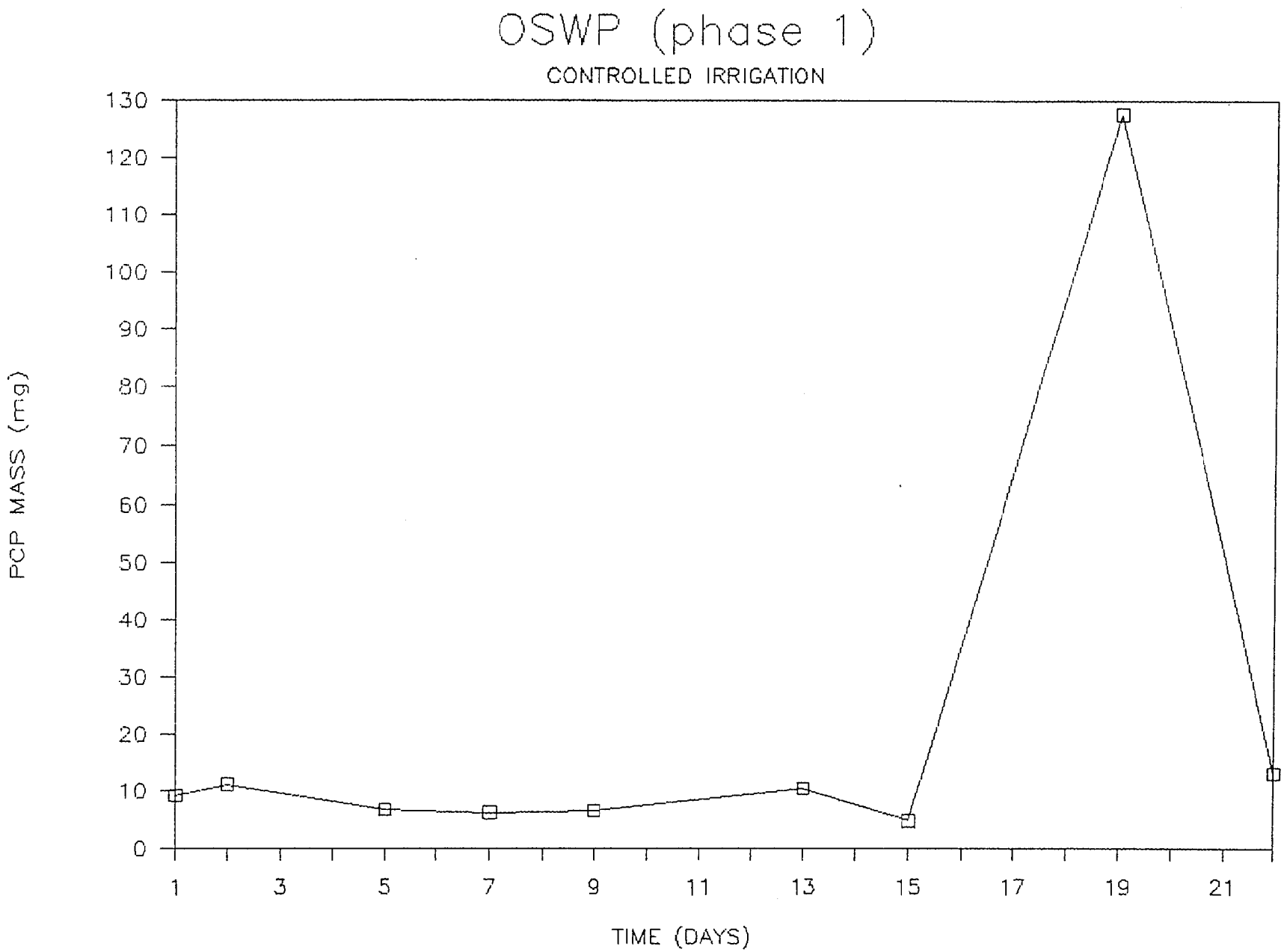

OSWP (phase 1)
CONTROLLED IRRIGATION
PCP MASS (mg)
130
120
110
100
90
80
70
60
50
40
30
20
10
0
1
3
5
7
9
11
13
15
17
19
21
TIME (DAYS)

Fig 7

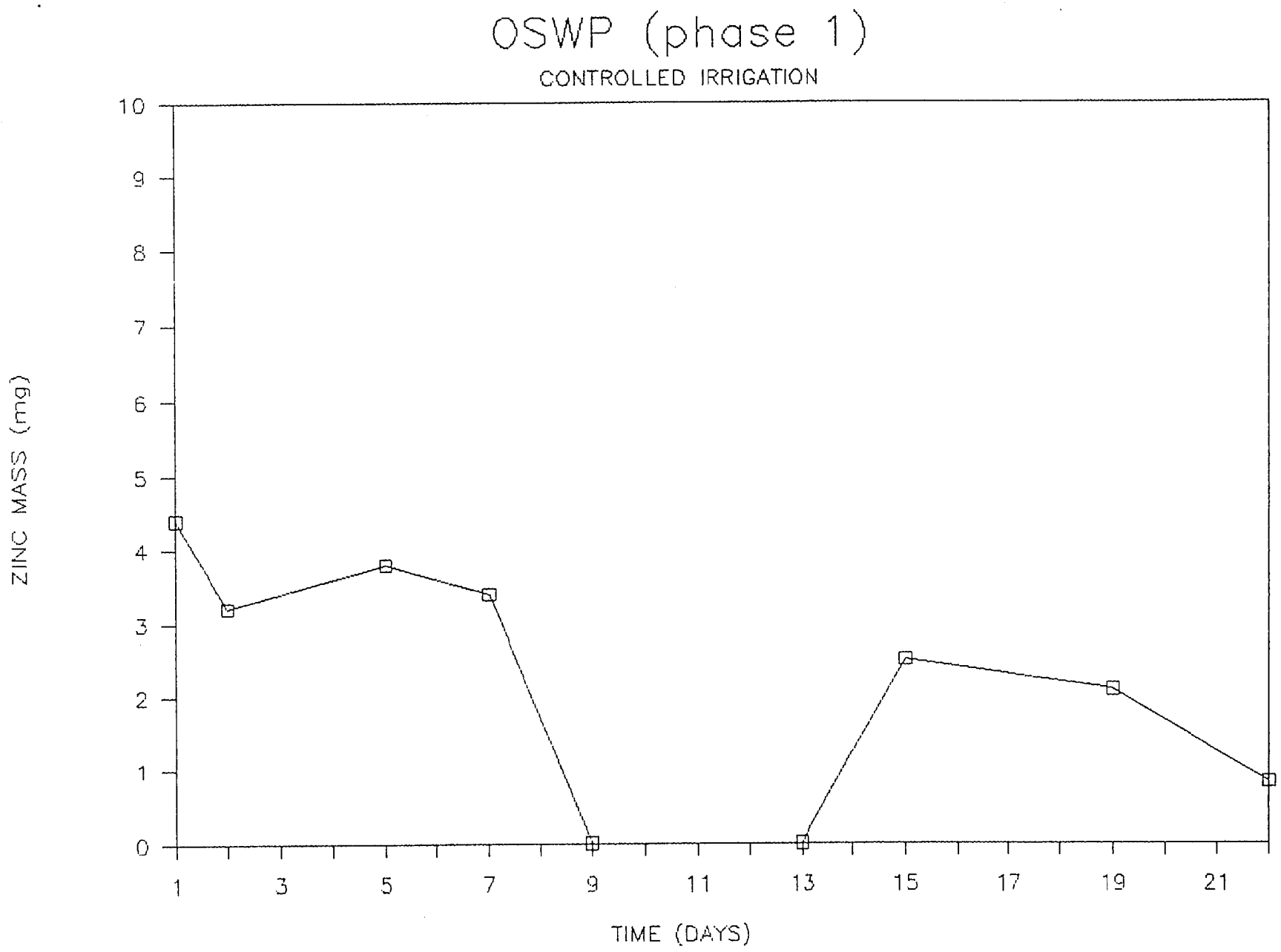

OSWP (phase 1)
CONTROLLED IRRIGATION
ZINC MASS (mg)
0
1
2
3
4
5
6
7
8
9
10
1
3
5
7
9
11
13
15
17
19
21
TIME (DAYS)

Fig 8

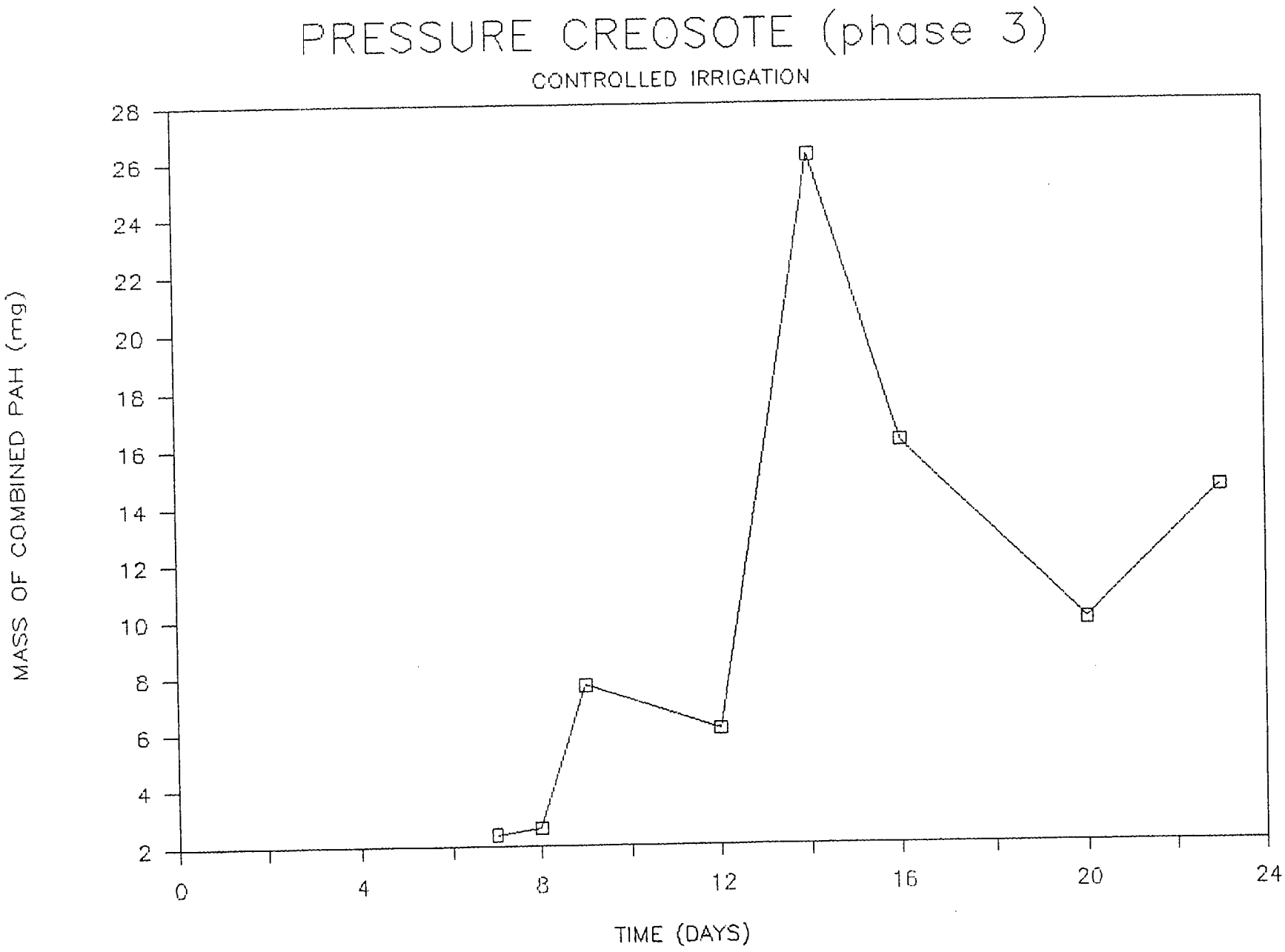

PRESSURE CREOSOTE (phase 3)
CONTROLLED IRRIGATION
MASS OF COMBINED PAH (mg)
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
4
8
12
16
20
24
TIME (DAYS)

Fig 9

the leaching of phenols from timber during Phase 3; the mass leached increases up to the 14th day after treatment and subsides (Fig 10).

The total amount of PAH washed off timber treated in Phase 1 was some 43mg greater than that from Phase 3. Both Phases show results with alternate peaks and troughs as PAH is leached out from the timber (Fig 11). The make up of the total PAH however is slightly different; while in both Phases naphthalene and phenanthrene/anthracene dominate as the most common PAHs, in Phase 3 more acenaphthene and fluoranthrene was present (as a percentage of the total PAH present).

The mass of phenol leached from timber applied with creosote under pressure decreased from 104mg to 4.5mg in Phase 1, while in Phase 3 the leached mass of phenol rose from 25mg to 86mg before decreasing over the next nine days to under 40mg. The cumulative amount of phenol leached from timber in Phase 1 was over 48mg more than from timber in Phase 3 (Fig 12).

The mass of Cu, Cr and As leached from timber in Phase 3 followed a similar trend as for those from Phase 1 but at a much reduced level (Figs 13 and 14). The concentration of Cu in leachate never exceeded 1.4 mgl^{-1}, while Cr concentration only exceeds 5 mgl^{-1} on one occasion, and the highest As concentration is recorded at 0.089 mgl^{-1}. The combined total of metals leached represents 0.078% of the total initially taken up by the timber.

The amounts of metals leached from timber treated with CCA preservative solution in Phase 3 was considerably less than from Phase 1 - over 460 times as much arsenic is leached from Phase 1 timber on day 1 than for the <u>whole</u> of Phase 3. The comparable figures for chromium and copper are 3 and 24 times respectively.

The concentration of PCP in leachate during Phase 3 exceeded 1 mgl^{-1} on just one occasion (following the third washing on day 9). For the remainder of the period, the trend is steadily

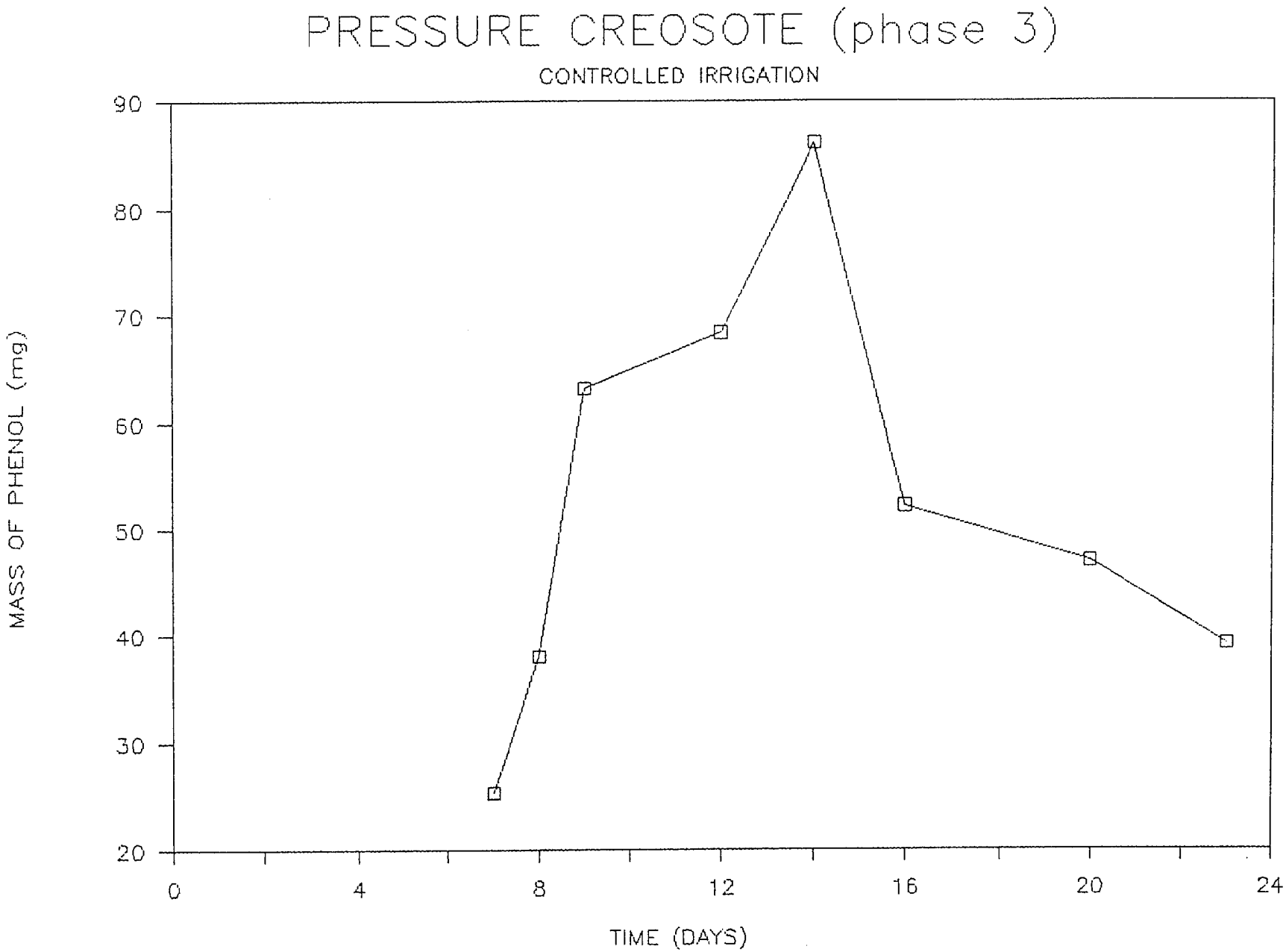

PRESSURE CREOSOTE (phase 3)
CONTROLLED IRRIGATION
MASS OF PHENOL (mg)
90
80
70
60
50
40
30
20
0
4
8
12
16
20
24
TIME (DAYS)

Fig 10

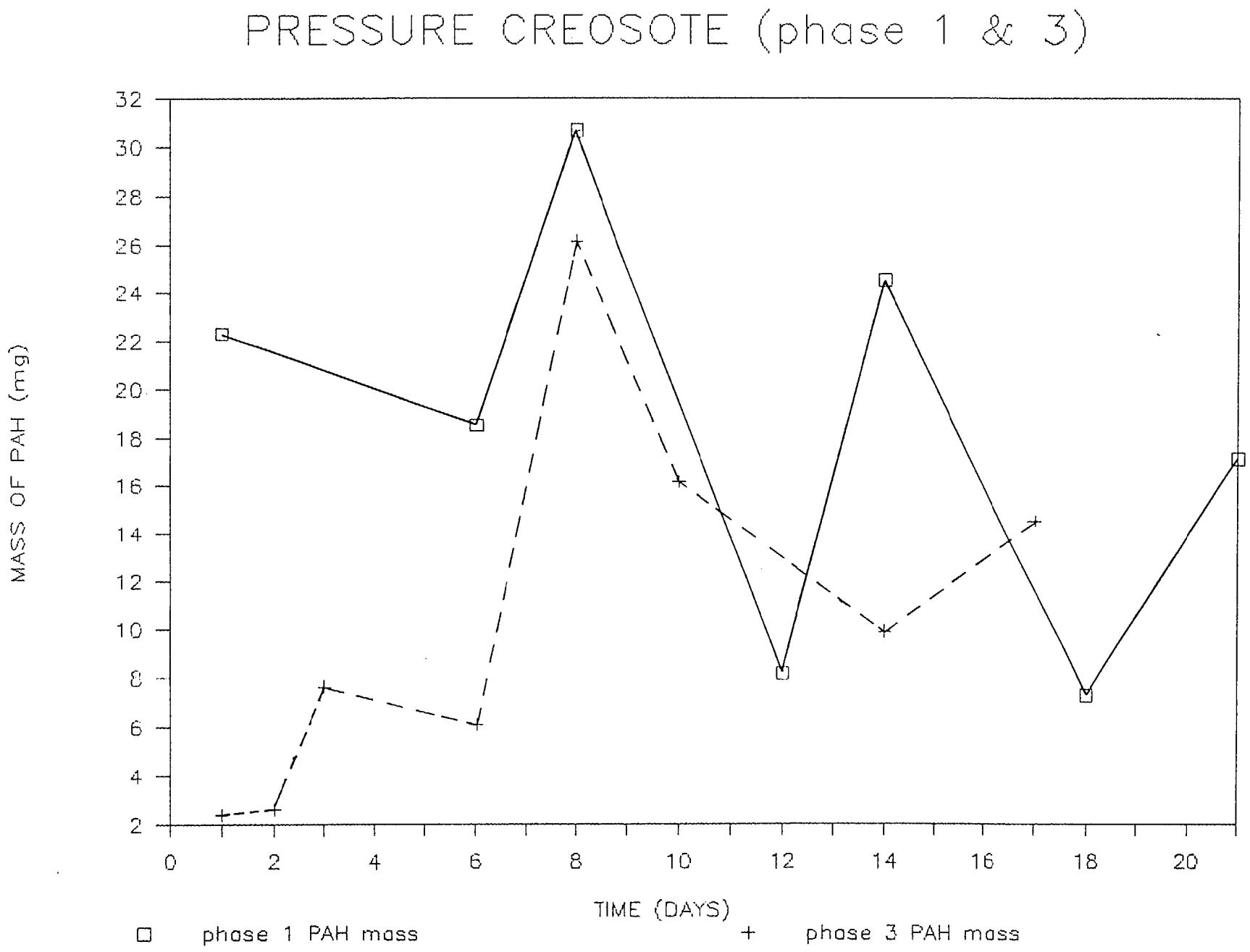

PRESSURE CREOSOTE (phase 1 & 3)
MASS OF PAH (mg)
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
2
4
6
8
10
12
14
16
18
20
TIME (DAYS)
phase 1 PAH mass
phase 3 PAH mass

Fig 11

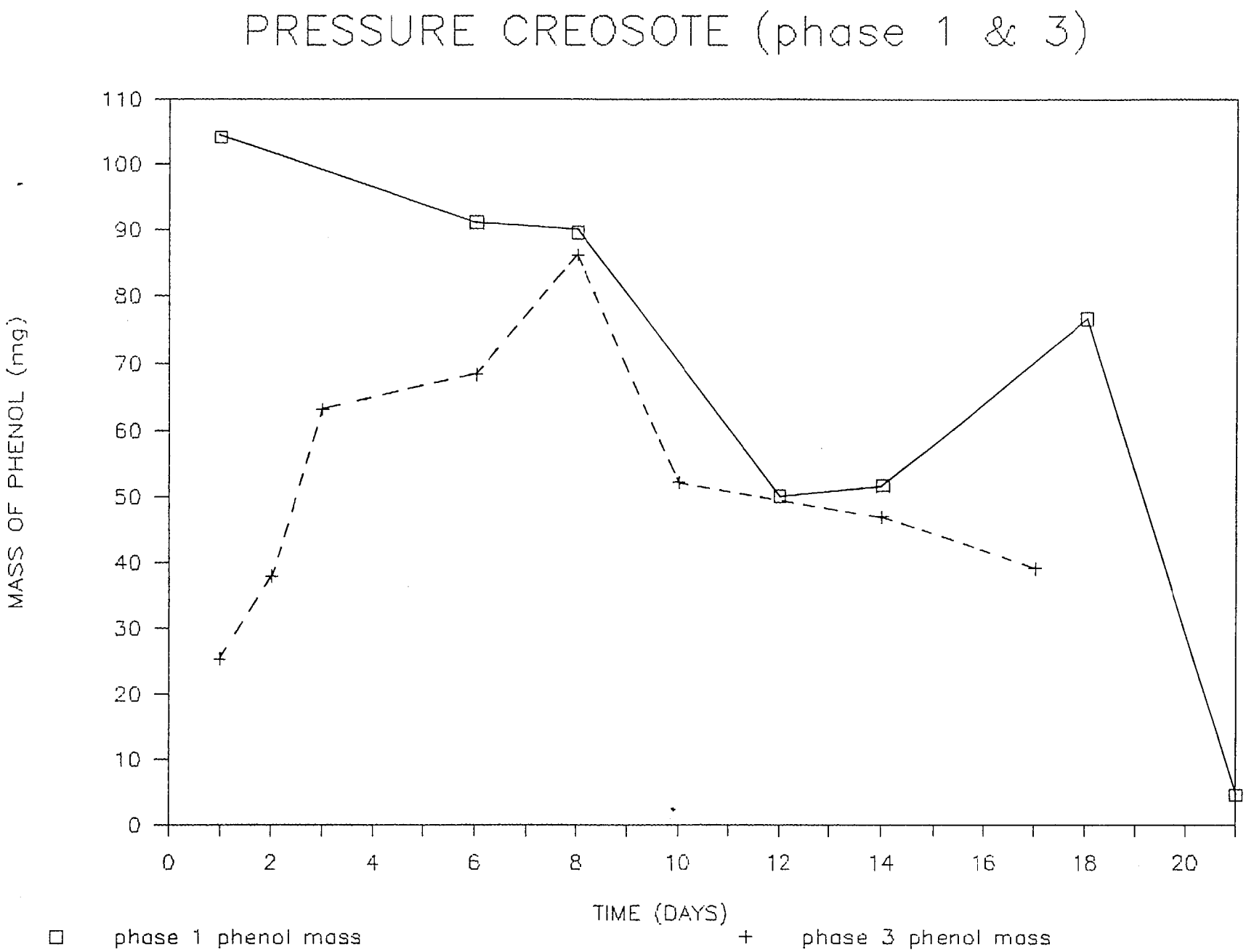

PRESSURE CREOSOTE (phase 1 & 3)
MASS OF PHENOL (mg)
110
100
90
80
70
60
50
40
30
20
10
0
0
2
4
6
8
10
12
14
16
18
20
TIME (DAYS)
phase 1 phenol mass
phase 3 phenol mass

Fig 12

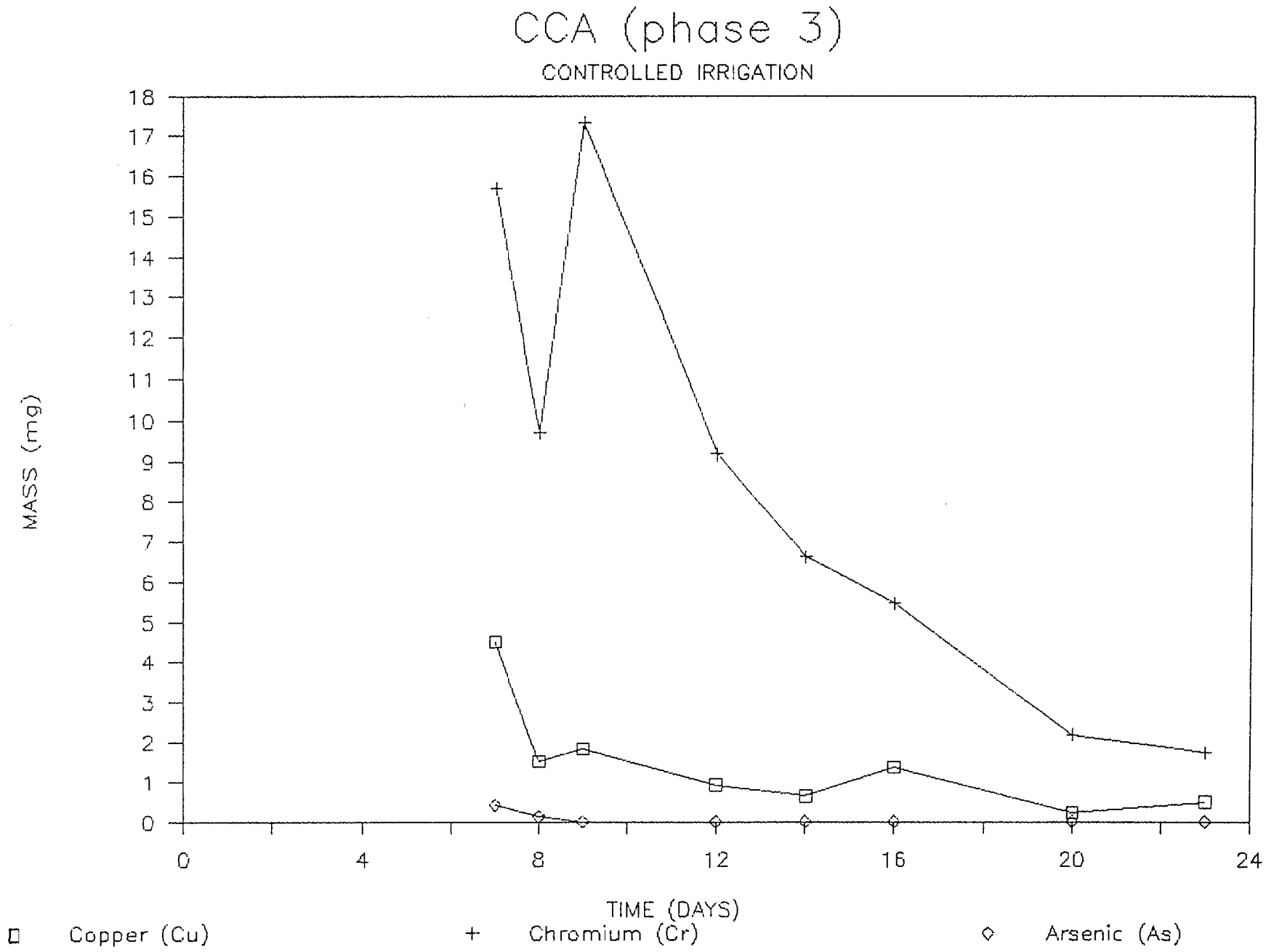

CCA (phase 3)
CONTROLLED IRRIGATION
MASS (mg)
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
0
4
8
12
16
20
24
TIME (DAYS)
Copper (Cu)
Chromium (Cr)
Arsenic (As)

Fig 14

downwards, as shown in Fig 15. The concentrations of zinc and HCH follow similar paths, with decreasing levels being present in leachate following the peak on day 9 (Fig 16 and 17).

Greatly reduced masses of PCP were leached from timber exposed during Phase 3 than during Phase 1. Of the PCP absorbed during treatment of timber for Phase 1, 1.1% subsequently leached out. During Phase 3 the level of leached PCP was reduced to 0.069% of the total taken up.

The amount of zinc leached from timbers in Phases 1 and 3 (as a percentage of the total zinc initially taken up) were very similar (0.45% in Phase 1 and 0.66% in Phase 3).

3.1.4 Leaching during Phase 2 (Natural Exposure).

In Phase 2 very small amounts of phenol are initially leached from the pressure applied creosoted timber (Fig 18), followed by a large slug recorded on day 7 (457.38mg). This one incident accounts for over 85% of the total phenol leached from the timber, whereas in Phase 1, the mass leached, decreases steadily from an initial peak. Of the total PAH leached out during Phase 2, 90% is washed out during two rainfall incidents (days 4 - 7 and 9 - 11) (Fig 19). Fifty percent less total PAH is leached from Phase 2 timber than from Phase 1 timber.

The concentration of phenol in runoff from the creosoted fence section in Phase 2 (Fig 20) remained under 10mg l^{-1} apart from on two occassions (54.4mg l^{-1} on day 7 and 18.2mg l^{-1} on day 9). The peak concentration recorded on day 7 of the trial relates to a mass of over 465mg of phenol - some 85% of the total mass of phenol leached from the timber during the whole of this trial. Following the major rainfall event prior to day 9 of Phase 2, the mass of phenol increased but not to the extent experianced following the rainfall on day 7 (Fig 21). The mass of PAH (Fig 22) leached from the fence section follows the pattern of phenol leaching from the fence; low initial and final amounts with a large slug following

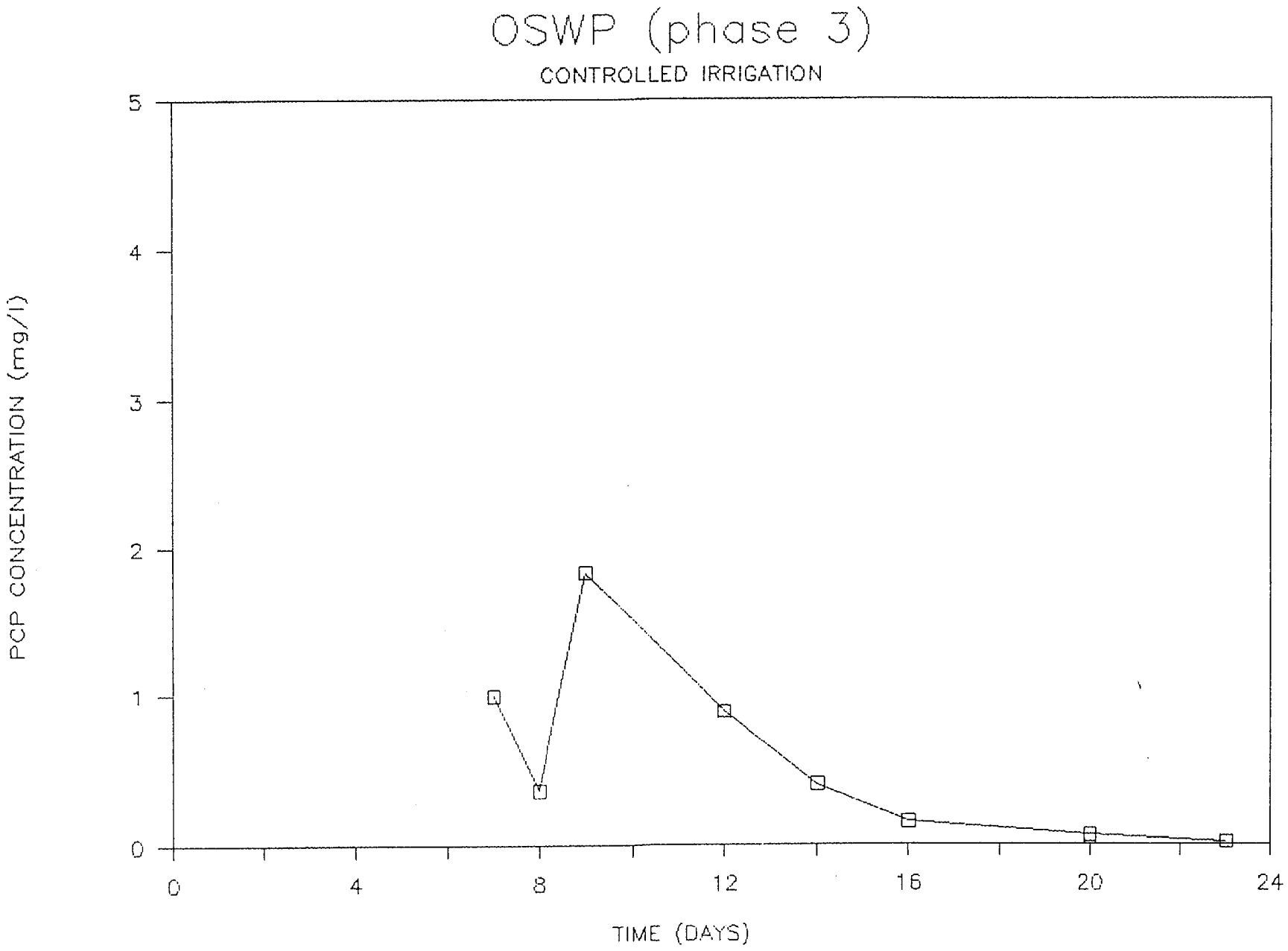

OSWP (phase 3)
CONTROLLED IRRIGATION
PCP CONCENTRATION (mg/l)
0
1
2
3
4
5
0
4
8
12
16
20
24
TIME (DAYS)

Fig 15

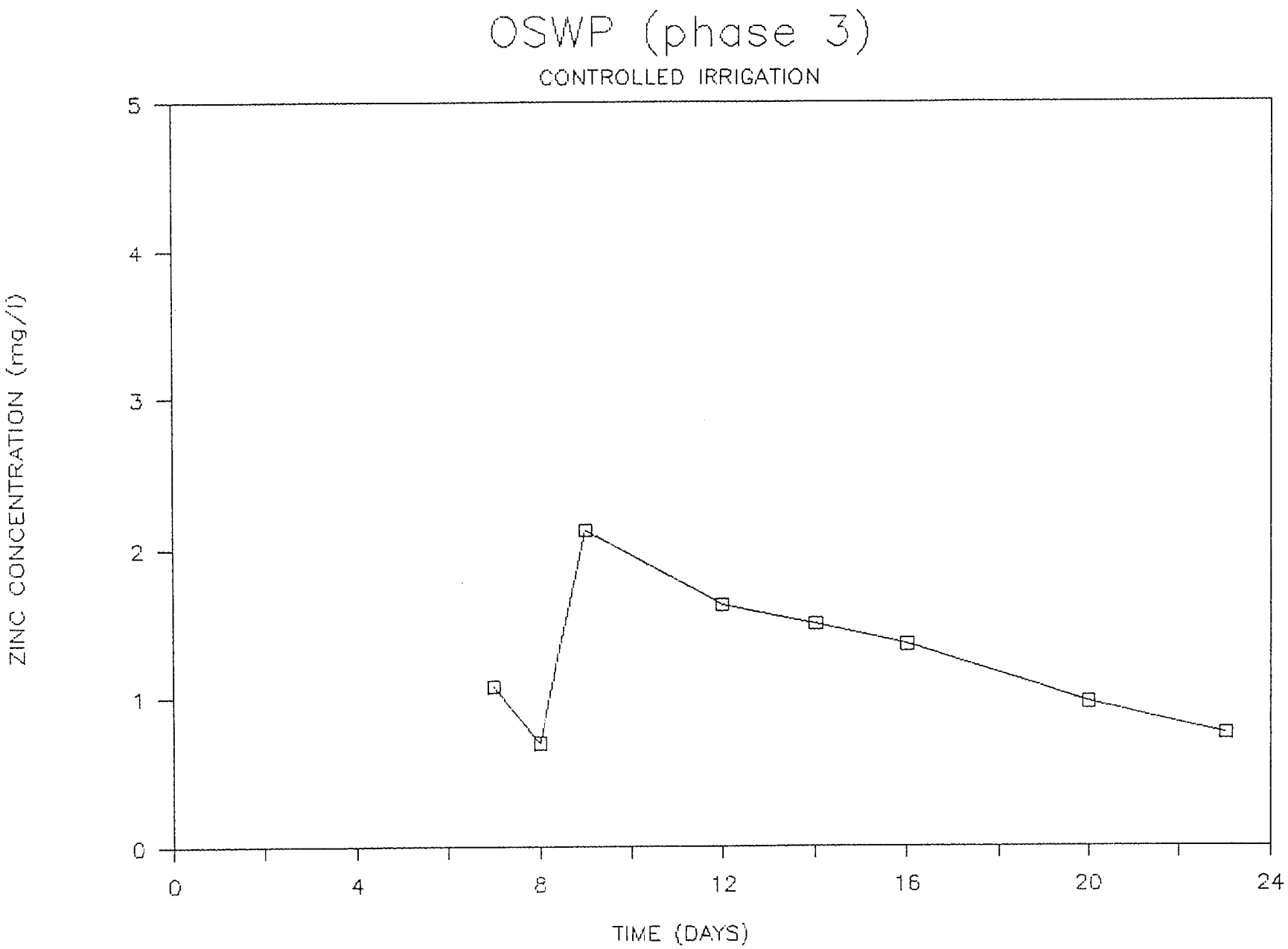

OSWP (phase 3)
CONTROLLED IRRIGATION
ZINC CONCENTRATION (mg/l)
0
1
2
3
4
5
0
4
8
12
16
20
24
TIME (DAYS)

Fig 16

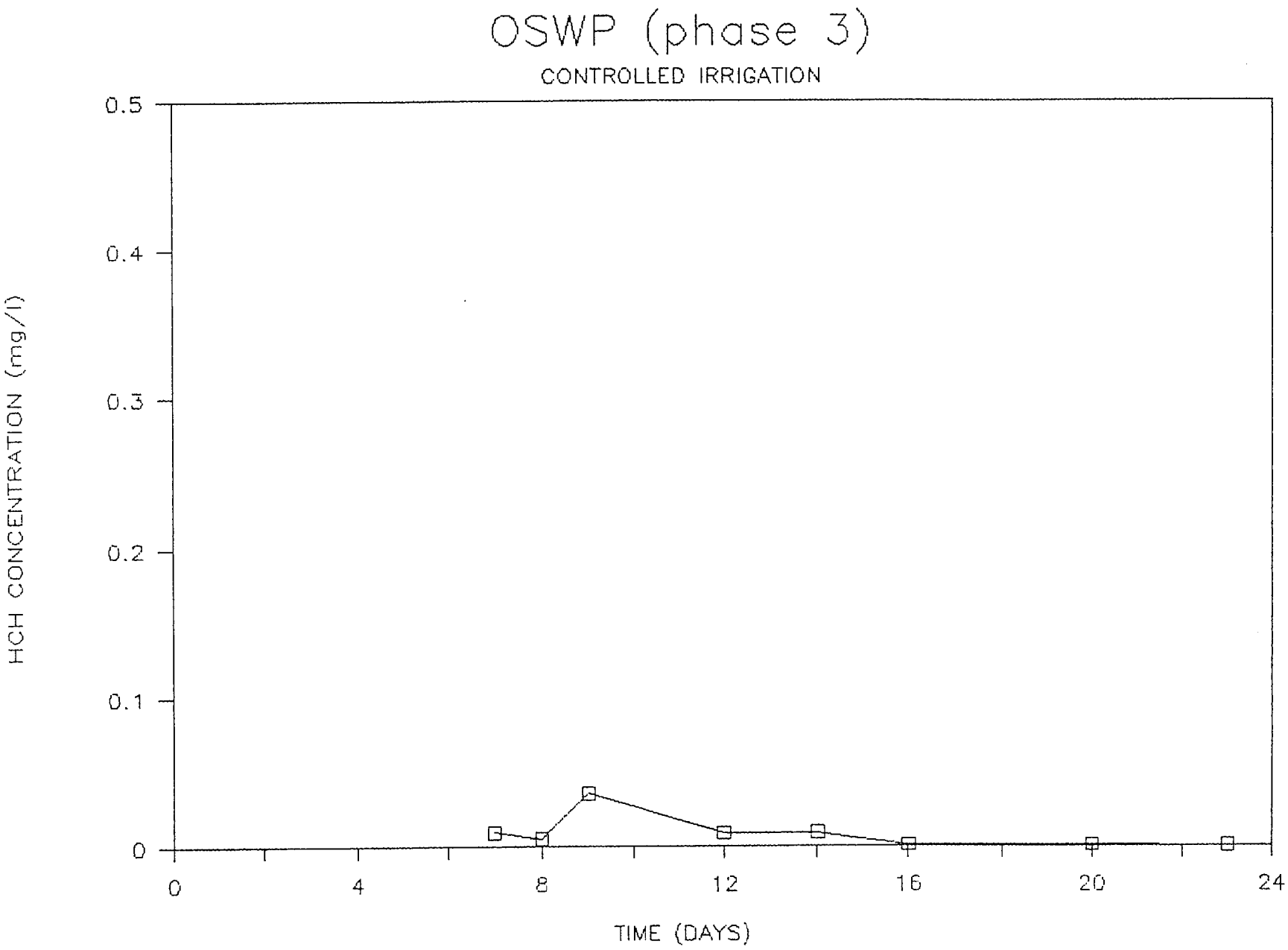

OSWP (phase 3)
CONTROLLED IRRIGATION
HCH CONCENTRATION (mg/l)
0.5
0.4
0.3
0.2
0.1
0
0
4
8
12
16
20
24
TIME (DAYS)

Fig 17

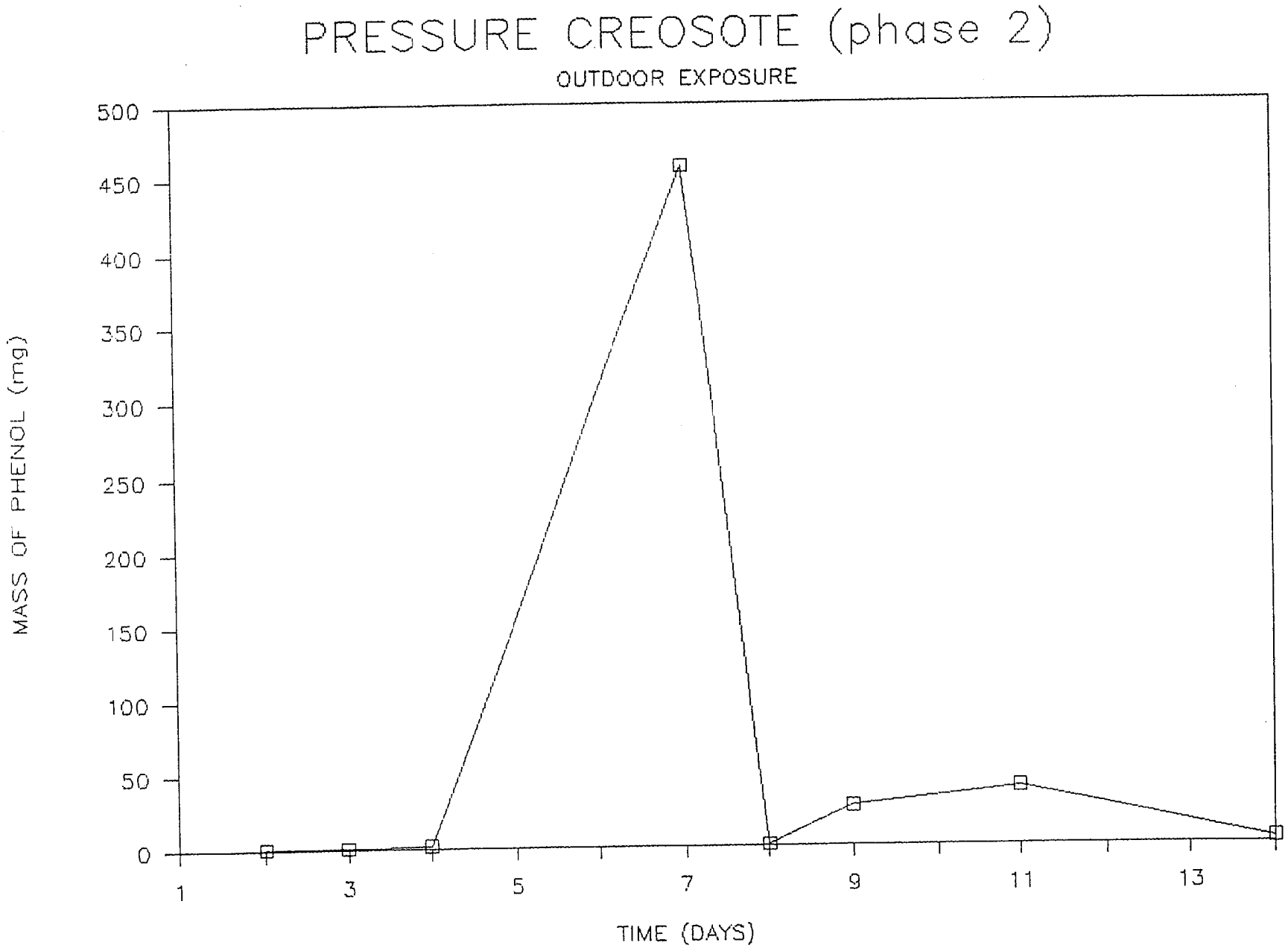

PRESSURE CREOSOTE (phase 2)
OUTDOOR EXPOSURE
MASS OF PHENOL (mg)
500
450
400
350
300
250
200
150
100
50
0
1
3
5
7
9
11
13
TIME (DAYS)

Fig 18

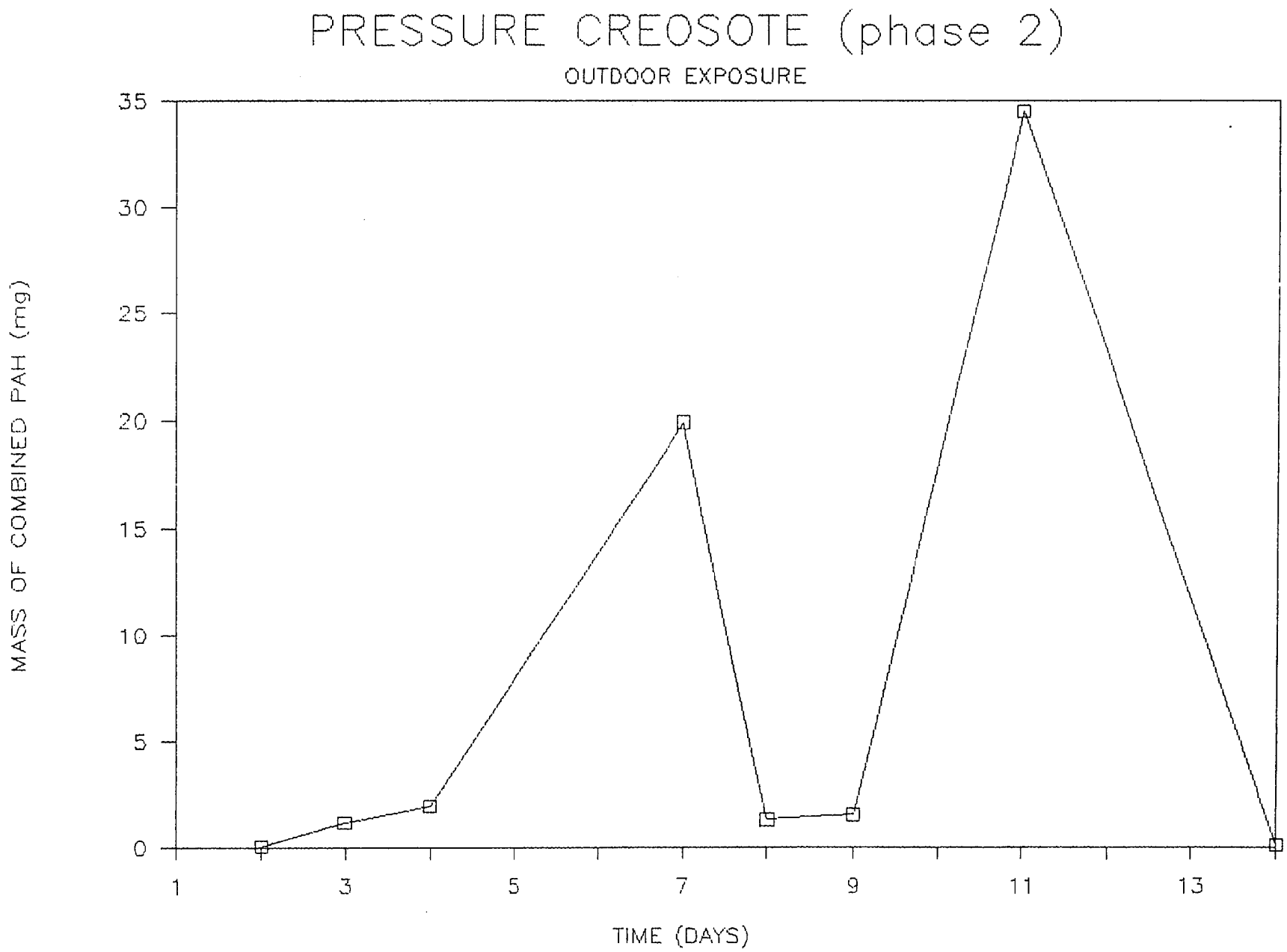

PRESSURE CREOSOTE (phase 2)
OUTDOOR EXPOSURE
MASS OF COMBINED PAH (mg)
35
30
25
20
15
10
5
0
1
3
5
7
9
11
13
TIME (DAYS)

Fig 19

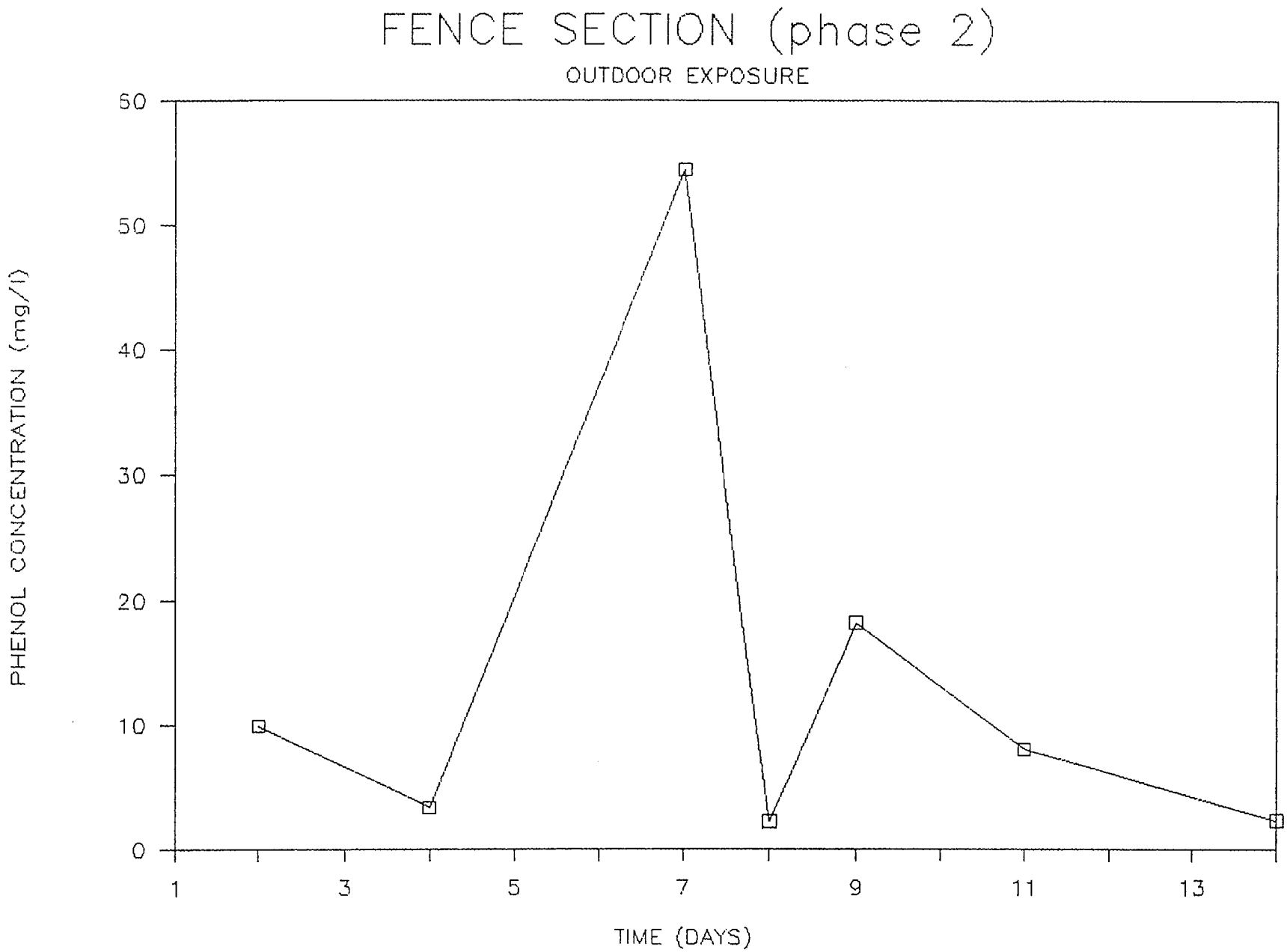

FENCE SECTION (phase 2)
OUTDOOR EXPOSURE
PHENOL CONCENTRATION (mg/l)
60
50
40
30
20
10
0
1
3
5
7
9
11
13
TIME (DAYS)

Fig 20

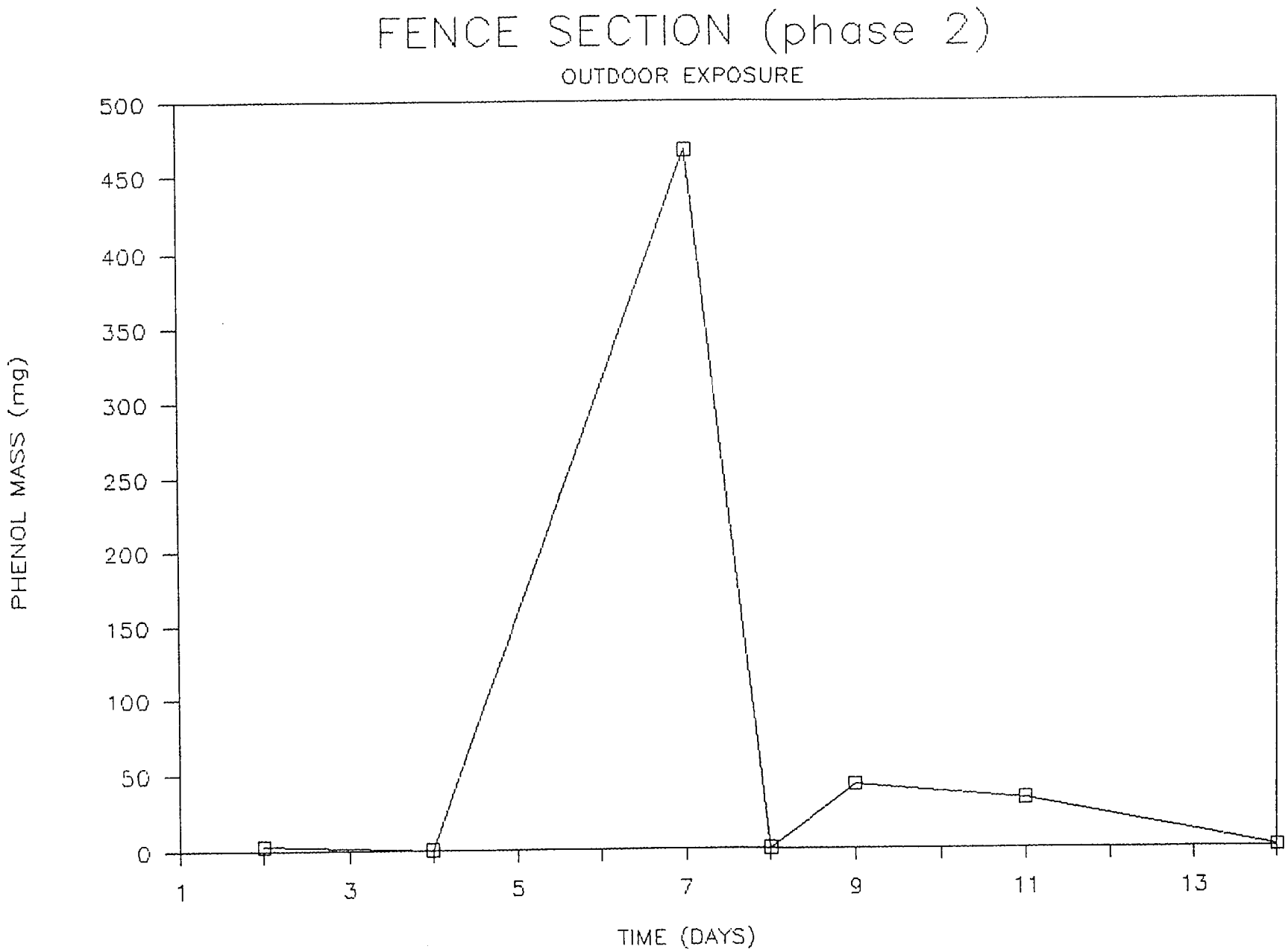

FENCE SECTION (phase 2)
OUTDOOR EXPOSURE
PHENOL MASS (mg)
500
450
400
350
300
250
200
150
100
50
0
1
3
5
7
9
11
13
TIME (DAYS)

Fig 21

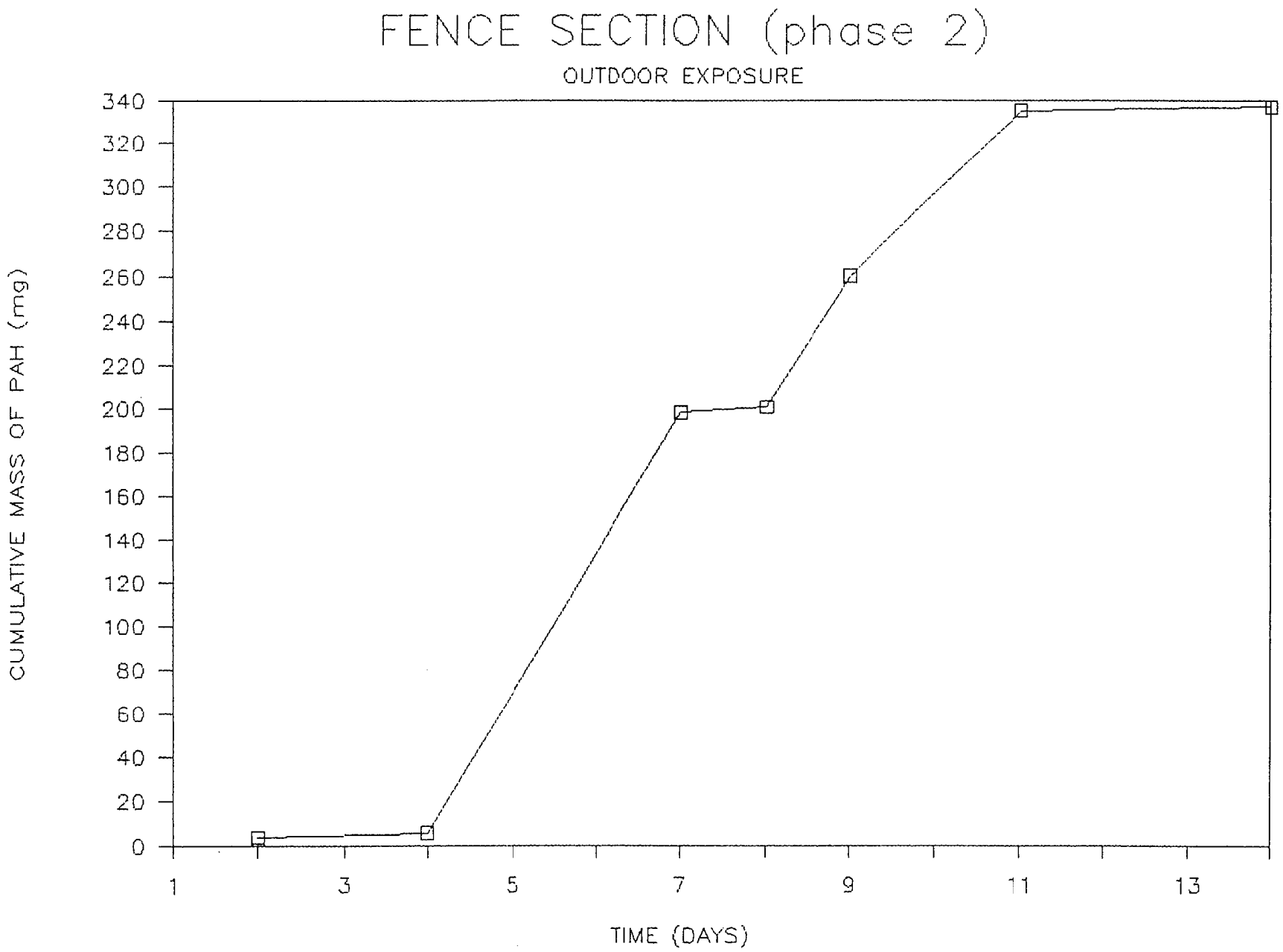

FENCE SECTION (phase 2)
OUTDOOR EXPOSURE
CUMULATIVE MASS OF PAH (mg)
340
320
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0
1
3
5
7
9
11
13
TIME (DAYS)

Fig 22

the first large rainfall event and a smaller (but still elevated) mass after the second large rainfall incident.

Comparison of leachate from the creosoted fence shows that both the mass of phenol and PAH increases by over 50% from Phases 1 and 2.

Fig 23 illustrates the downward trend with time of metal leaching from CCA treated timber during Phase 2. The chromium concentration is again the slowest to decrease (and actually shows a secondary peak on day 4), while the concentration of arsenic fell to zero after 4 days. Large masses of chromium and copper was leached from the timber following the first major rainfall event of days 4 - 7. During the same period the concentration of arsenic remains at zero (Fig 24). During the 14 days exposure, a total of 0.339g of combined copper, chromium and arsenic is leached from the timber compared with 95.94g initially taken up.

Masses of metals leached from timber treated with CCA preservative solution in Phase 2 were considerably less than from Phase 1. Of the total CCA absorbed during treatment in Phase 2, 0.35% of the solution is leached off compared with 1.2% from Phase 1.

The results for all determinands analysed for (but particularly PCP) from timber treated with OSWP during Phase 2 show considerable fluctuations in concentrations as shown in Figs 25, 26 and 27. The concentration of zinc remains around 28 mgl^{-1} for the first four days before falling to 6 mgl^{-1} on day 11 and then rising above 30 mgl^{-1} on day 14 (Fig 24). The concentration of HCH was consistently below 0.6 mgl^{-1} except for two occasions (days 4 and 11) when it rose to 3.188 and 4.389 mgl^{-1} (respectively). These two days account for over 96% of the total mass of HCH and PCP, and for over 63% of the total mass of zinc to be leached from the wood during Phase 2.

The proportion of preservative leached from timber is greater in Phase 2 than in Phase 1. In Phase 2, 1.19% of the zinc is leached out compared with 0.74% in Phase 1. The corresponding figures for

PCP are 1.55% in Phase 2 and 1.11% in Phase 1. Comparison of HCH leaching over Phases 1 and 2 was not possible as the chemical was unavailable for addition to the Phase 1 solution.

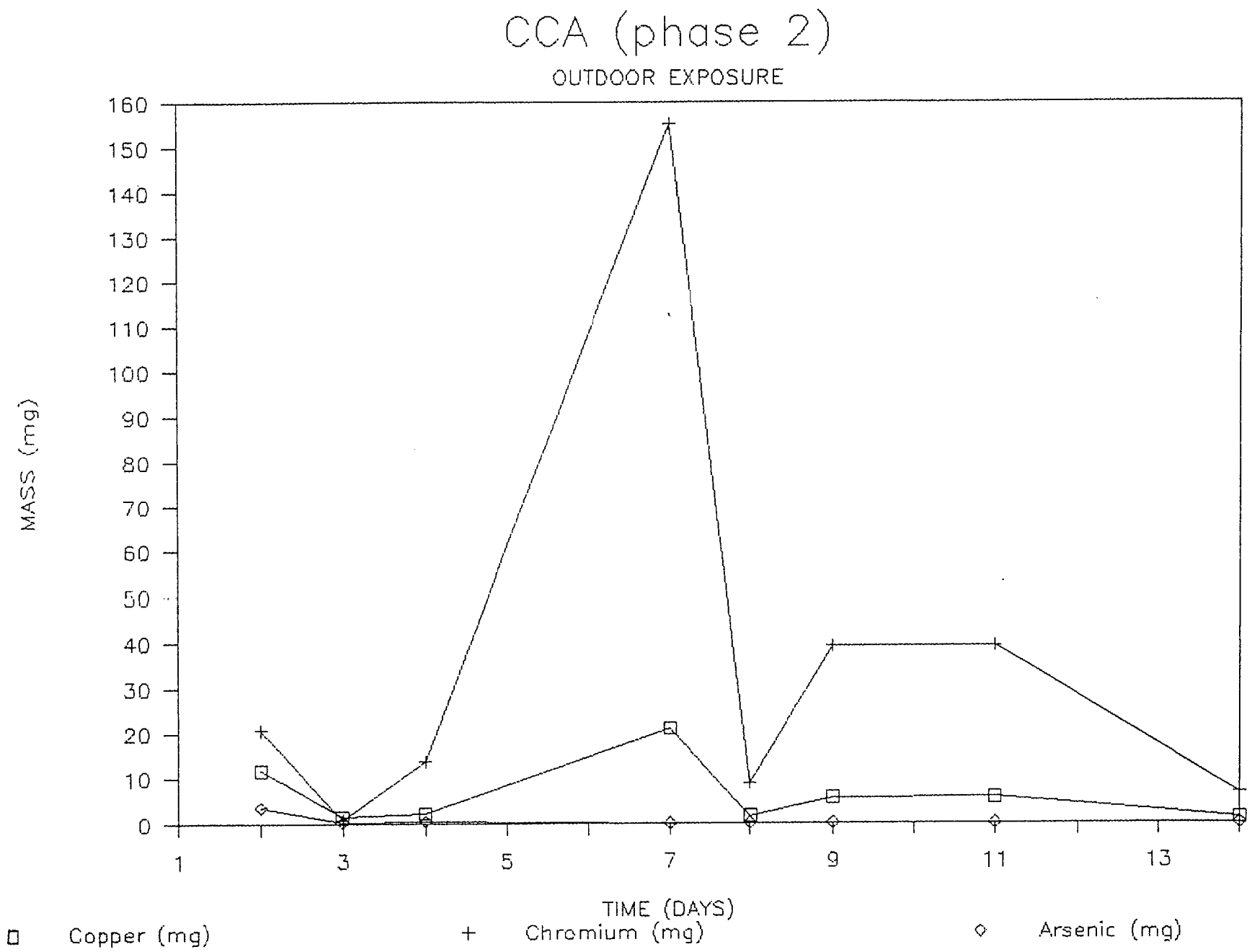

CCA (phase 2)
OUTDOOR EXPOSURE
MASS (mg)
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
1
3
5
7
9
11
13
TIME (DAYS)
Copper (mg)
Chromium (mg)
Arsenic (mg)

Fig 23

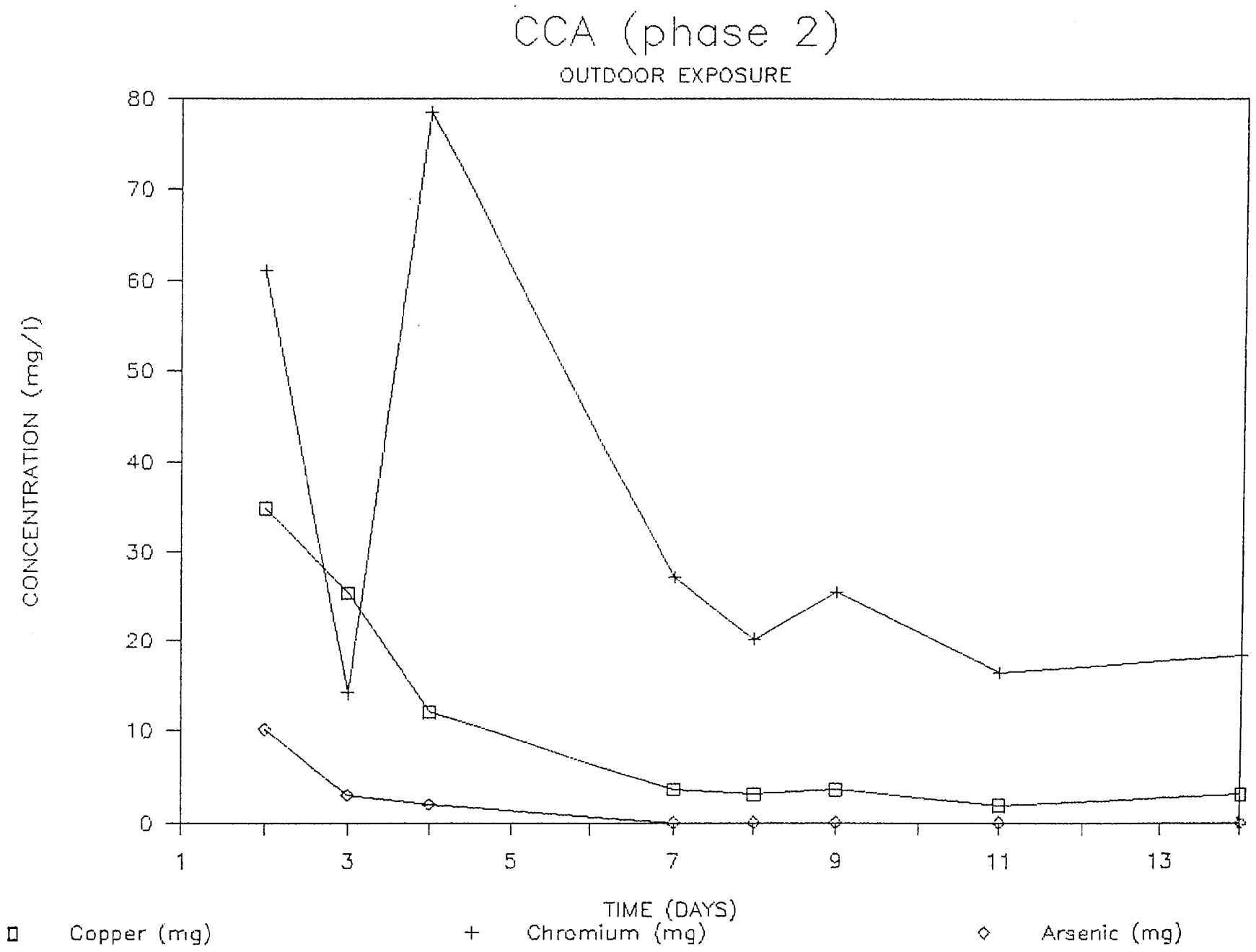
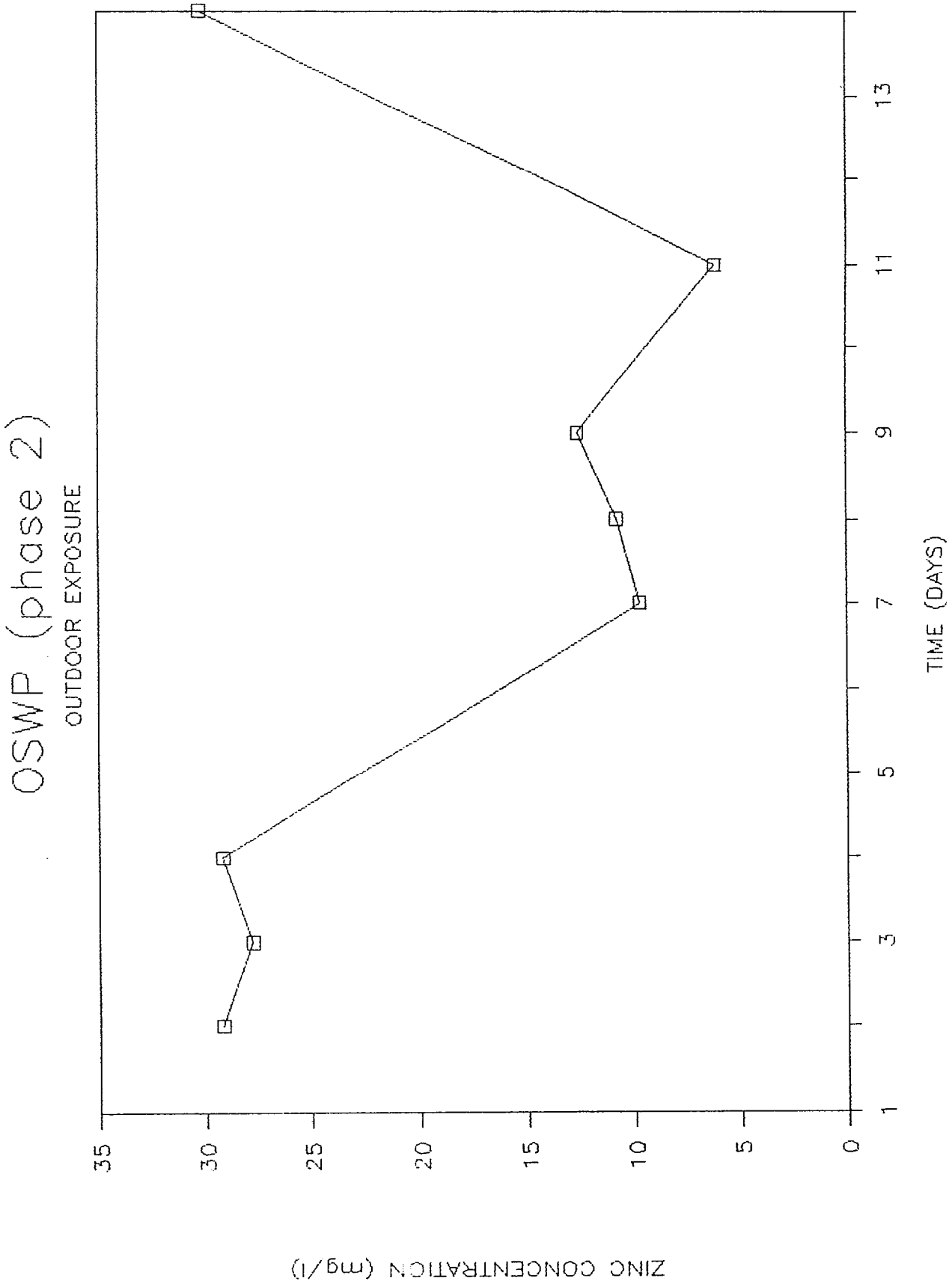

CCA (phase 2)
OUTDOOR EXPOSURE
CONCENTRATION (mg/l)
80
70
60
50
40
30
20
10
0
1
3
5
7
9
11
13
TIME (DAYS)
Copper (mg)
Chromium (mg)
Arsenic (mg)

Fig 24

Fig 25


OSWP (phase 2)
OUTDOOR EXPOSURE
ZINC CONCENTRATION (mg/l)
35
30
25
20
15
10
5
0
1
3
5
7
9
11
13
TIME (DAYS)

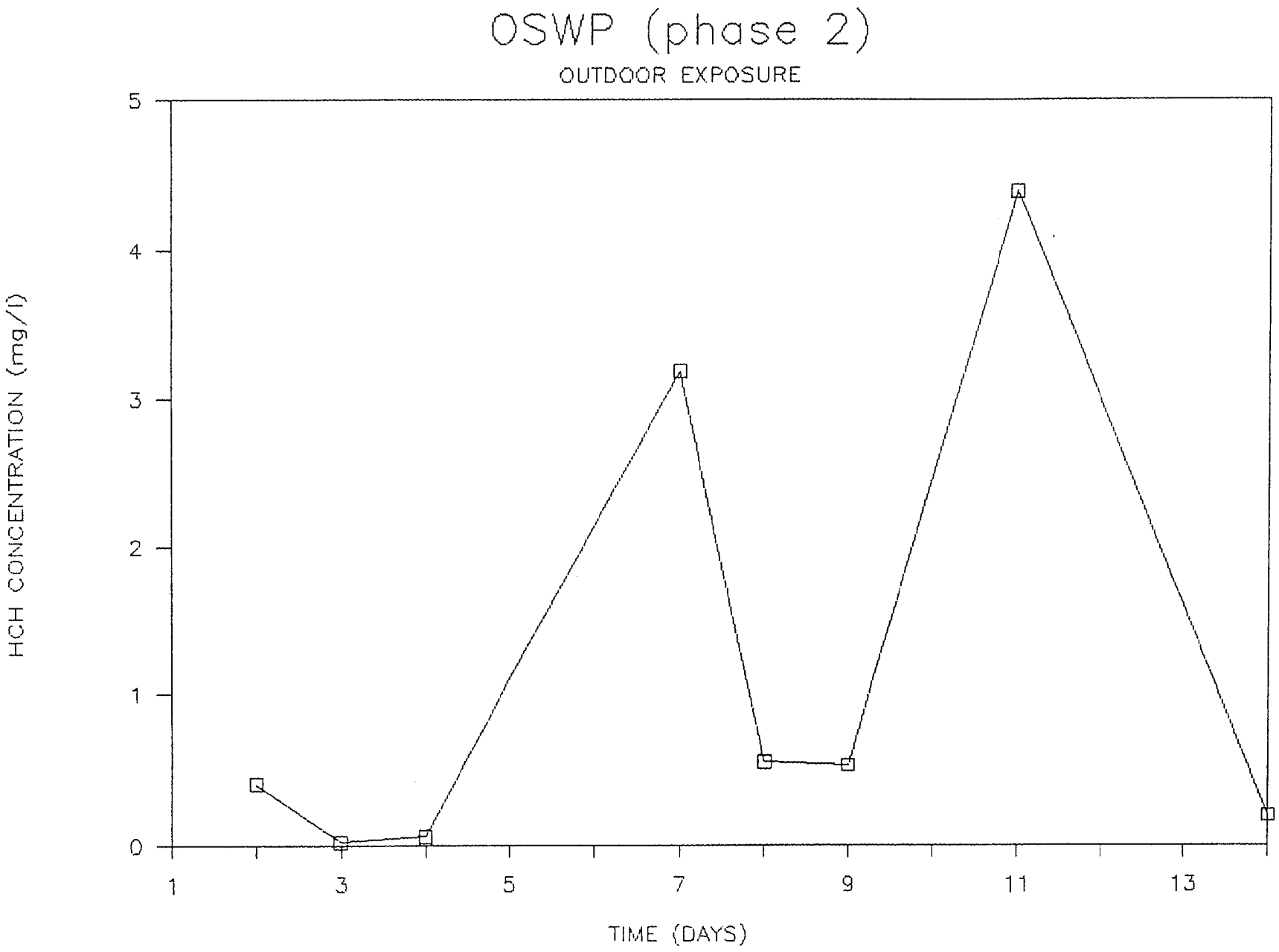

OSWP (phase 2)
OUTDOOR EXPOSURE
HCH CONCENTRATION (mg/l)
0
1
2
3
4
5
1
3
5
7
9
11
13
TIME (DAYS)

Fig 26

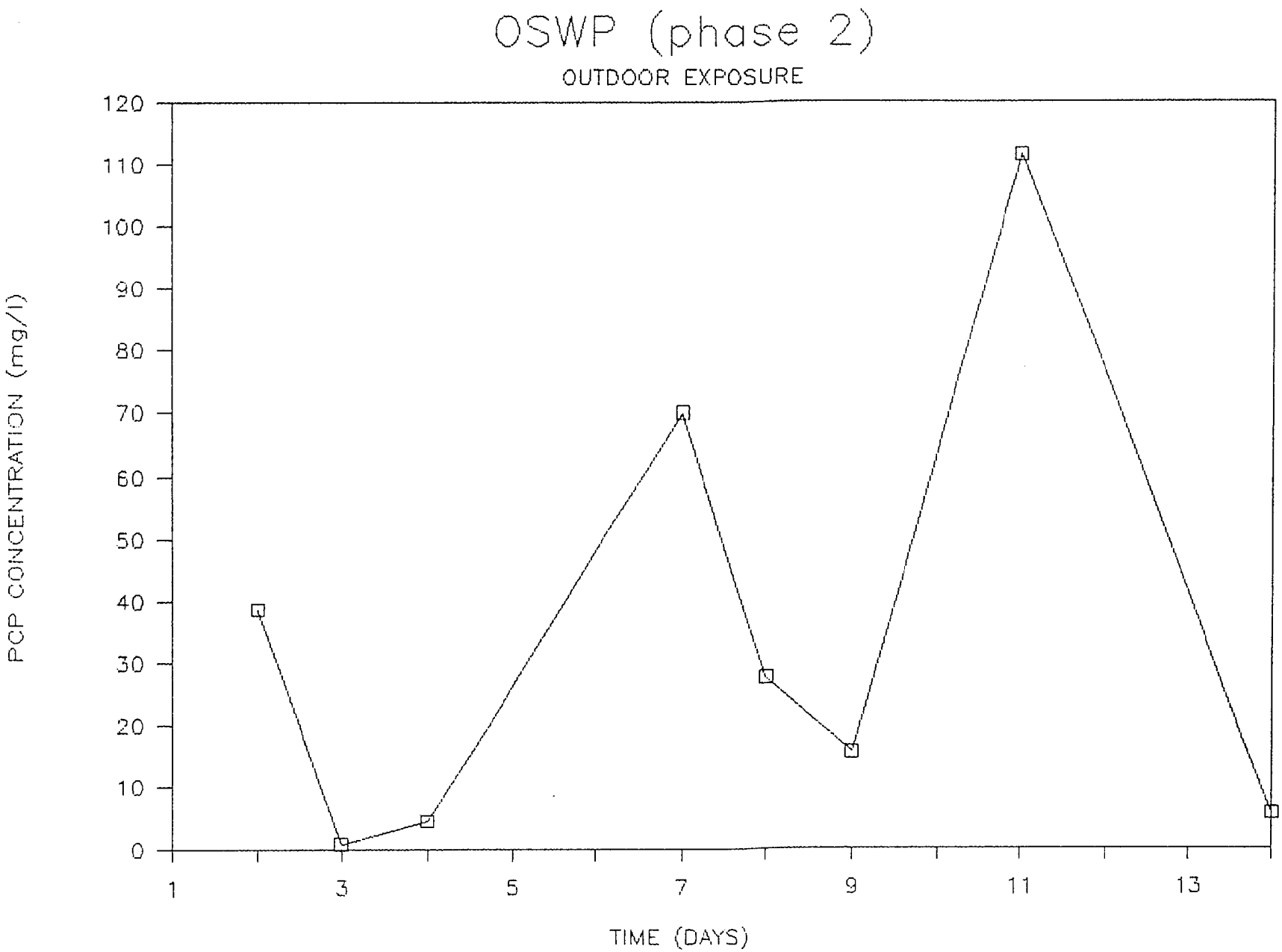

OSWP (phase 2)
OUTDOOR EXPOSURE
PCP CONCENTRATION (mg/l)
120
110
100
90
80
70
60
50
40
30
20
10
0
1
3
5
7
9
11
13
TIME (DAYS)

Fig 27

4. DISCUSSION

The results obtained here may not be completely representative of what may happen in practice because the volume to surface area ratio of timber treated during the experiments is greater than is likely to occur in the commercial situation and as such the concentration of preservative chemicals in any runoff is likely to be less than in the experimental situation. However, these experiments have identified the potential scale of the problem.

The major rainfall events recorded during days 4 - 7 and 9 - 11 of Phase 2 produce a similar (but larger) response in the amount of PCP leached from the timber. It should therefore be acknowledged that if the exposure rate had been greater, then larger masses of PCP may have been leached from the timbers in Phases 1 and 3.

It was originally intended that direct comparisons could be made between the results obtained from timber exposed to the natural conditions (ie Phase 2), with those obtained from timber exposed from timber exposed under controlled conditions (Phases 1 and 3). Unfortunatley, as the precipitation rate experianced during Phase 2 was so varied (Table 2), direct comparisons with other Phases of the experiment are limited. However, as precipitation is very rarely uniform over time and quantity, it is possible to draw some valuble conclusions from the results obtained.

The comparison of results from Phases 1 and 3 indicate that tempory storage of timber following treatment under cover has a distinct impact on the chemical characteristics of runoff.

For all preservative solutions tested (except zinc naphthenate), the total mass of chemical in runoff from Phase 3 was less than from timber in Phase 1. This is particularly well illustrated by the timber treated with the CCA water based preservative; while the uptake of copper, chromium and arsenic in Phases 1 and 3 was about the same, the amounts that were subsequently leached from Phase 3 were significantly reduced. 1.12% of the metals taken up in Phase

1 were leached from the timber during exposure but during the same period and level of exposure in Phase 3, only 0.078% of the metals were removed. The most dramatic decrease is exhibited by arsenic ; in Phase 1, the amount leached decreased rapidly after day 1 but was still present in runoff from the timber after 22 days. In Phase 3, arsenic was absent from the leachate after the second washing on day 8.

The steep drop in metals leached from timbers following initial exposure to water can be attributed to excessive preservative solution being washed from the timber. The rate at which the different metals are washed from the timber after this initial period is a function of the rate at which they become insoluble and are precipitated within the wood. It appears from the experiments that arsenic is the first to become insoluble, followed closely by copper. The rate at which chromium becomes precipitated within the wood is much slower than arsenic and copper and therefore explains the only slow reduction in chromium mass in the leachate following the first washing of timbers in all Phases.

Reductions in preservative leaching following storage also occurred for timber treated with OSWP. Similar masses of PCP were absorbed by the timbers in Phase 1 and 3, but over 17 times more PCP was leached from timber in Phase 1. While a reduction was recorded in the total amount of phenol and PAH leached from creosoted timber in Phase 3 when comparing with Phase 1, the extent to which this occcured was not as great as for the reduction experianced by the Cu, Cr, As and PCP.

Zinc is the only parameter that did not decrease in the amount leached following the 7 day storage period. However, as the total volumes and proportions leached are so small they can be said to be negligible, and it therefore appears that storage of timber does not reduce the already low masses of zinc being leached from timbers.

The comparison of results from Phases 1 and 2 show some interesting results; the large natural rainfall events of Phase 2 caused a greater amount of phenol to be washed from the pressure creosoted timber than from Phase 1, but 85% of this was leached in one incident. The same timber however yielded 50% less PAH than was washed from Phase 1 timber. This is probably due to the high aqueous solubility of the phenols and virtual insolubility of the PAHs.

It is surprising that this reduction occurs as an overall 57% increase in PAH runoff was recorded from the creosoted fence in Phase 2. Small amounts of PAH and phenols from the fence were also initially recorded relating to the initial low rainfall but a large slug of PAH (193g) was washed off following the heavy downpour upto day 7. This increase was not repeated in the PAH runoff from the pressure crosoted timber. It may be possible to attribute this apparent disparity of results to differences in the treatment process. This may have occurred through differences in locating the timber within the treatment vessel or in the amount of other timber that may have been present during impregnation (perhaps not allowing the creosote to flow freely around the wood).

The amount of copper and arsenic leached from CCA treated timber in Phase 2 was considerably less than from Phase 1. This was despite several large rainfall occurrences. As no rainfall was recorded during the first day of exposure and only small amounts fell for the next five days, it is reasonable to assume that low masses of As and Cu were leached because they had been converted to an insoluble form and therefore unlikely to be leached from the timber during the heavy precipitation that followed.

As in Phases 1 and 3, chromium was the most abundant metal in leachate from Phase 2. Large masses were still being leached from the timber halfway through the trial period whereas the amounts of copper and arsenic have subsided. This emphasises the fact that chromium remains soluble in the timber for longer than either copper or arsenic.

Comparison of results from timbers treated with OSWP in Phases 1 and 2 show that higher masses of PCP and zinc were leached in Phase 2 than from Phase 1. This can be attributed to the greater rainfall experienced in Phase 2 - this is particularly the case from days 4 - 7 and 9 - 11 when large masses of PCP and Zn were leached. Greatly elevated levels of HCH were also present in samples taken on these days.

Several anomalous figures were obtained during the experiments that could be misleading:

i. The highest concentration of total PAH recorded during Phase 1 from cresoted timber applied under pressure was 67.3mg l^{-1} (occurring after the final washing). This concentration however, corresponds to a mass of only 17mg. This peak concentration can be attributed to the fact that only 0.4 litres of water was applied to the timber.

ii. During Phase 1, two zero zinc levels are recorded in the leachate from OSWP treated timber (days 9 and 13). These results are out of synch with the downward trend experianced by the timber and must be assumed to be analytical errors.

iii. A slight increase in PAH runoff is recorded towards the end of Phase 1 from the hand creosoted fence. It must be assumed, that the slight increase in water application rate produced this anomaly in mass of PAH discharged. Due to the virtual insolubility of PAH, the rate at which it is leached from the timber may not be a function of the physical application of water.

iv. The peak of PCP mass recorded on day 19 of Phase 1 can be attributed to the elevated irrigation rate used to take the weekend period into account. This single slightly elevated irrigation event produced over 60% of the PCP that was leached during Phase 1.

In summary, the following observations can be made;

1. undercover storage of timbers following treatment results in lower masses of preservative being leached from the timber;

2. for CCA treated timbers, large amounts of preservative salts are leached on the first day following treatment;

3. arsenic followed by copper precipitate out at the fastest rates in timbers treated with CCA preservative. Chromium becomes insoluble at a slower rate than arsenic or copper and is therefore leached more readily from timber over a longer period of time;

4. phenols and PAHs are readily leached from wood treated with creosote (applied by hand). This is especially so immediately after treatment and following heavy rainfall;

5. heavy rainfall events cause higher masses of water-soluble preservative chemicals to be leached from timber.

APPENDIX 1

Volume of Runoff Collected from Creosoted Treated Timber(Phase 1).

Day	Volume of runoff collected from;	
	Pressure Applied Creosote(l)	Fence Section (l)
1	0.572	0.084
2		0.102
4	N/S	
5		0.344
6	0.456	
7		0.222
8	0.490	
9		0.328
12	0.298	
13		0.142
14	0.538	
15		0.430
18	0.650	
19		0.254
21	0.254	0.141
Totals	3.258	2.047

N/S - no sample available for collection.

Note: No data available for runoff from CCA and organic solvent treated timber.

APPENDIX 2

Volume of runoff measured from Phase 2(litres)

Day	CCA	Pressure Applied Creosote	Fence Section	OSWP
1	N/R	N/R	N/R	N/R
2	0.340	0.060	0.071	0.137
3	0.053	0.025	N/R	0.025
4	0.178	0.094	0.037	0.065
5	W/E	W/E	W/E	W/E
6	W/E	W/E	W/E	W/E
7	5.760	2.970	8.582	2.910
8	0.435	0.133	0.031	0.770
9	1.540	0.718	2.293	0.208
10	N/R	N/R	N/R	N/R
11	2.960	1.425	4.058	1.540
12	W/E	W/E	W/E	W/E
13	W/E	W/E	W/E	W/E
14	0.365	0.151	0.133	0.138
Totals	11.631	5.576	15.205	5.793

N/R - no runoff.

W/E - weekend - no sample collection possible.

Note; Due to high rates of preciptation and the consequent large volumes of runoff that occurred on some days, a representative sample (approximately 1 litre) was taken from the total collected volume and sent for analysis. The results (Appendices 11 - 32) have taken this into account and total mass and concentrations calculated on the basis of the above figures.

APPENDIX 3

Volume of runoff collected from Phase 3 (litres).

Day	CCA	OSWP	Pressure applied creosote
7	0.223	0.275	0.230
8	0.245	0.267	0.260
9	0.610	0.610	0.575
12	0.540	0.535	0.580
14	0.535	0.575	0.630
16	0.570	0.565	0.580
20	0.545	0.600	0.580
23	0.616	0.620	0.630
Totals	3.88	4.047	4.065

Notes;

1. Timber not exposed to water for first 7 days following treatment.
2. The fence section did not undergo exposure during phase 3.

APPENDIX 4

Relative metal percentages in CCA preservative solution used in treating timber:

Copper salt - 41.7%

Chromium salt - 42.0%

Arsenic salt - 16.3%

Uptake rate of CCA preservative (Phase 1)

Timber Number	Mass(g) Before	After	Uptake (g)
1	1191.9	2754.9	1563.0
2	1230.5	2780.3	1549.8
3	1498.5	3003.1	1504.6
4	1200.2	2757.1	1557.1
5	1335.9	2878.9	1543.0
6	1132.3	2743.2	1610.9
Total			9328.4
Mean			1554.7

9328.4g of preservative solution taken up, of which 3.035%(m/m) is CCA salts.

	Salt Uptake(g)	Metal Uptake(g)
Copper	118.06	30.22
Chromium	118.91	37.47
Arsenic	46.15	26.02
Totals	283.12	93.71

APPENDIX 5

Uptake rate of CCA preservative (Phase 2)

Timber Number	Mass(g) Before	After	Uptake (g)
7	1409.0	2900.2	1491.2
8	1272.8	2887.5	1614.7
9	1245.5	2836.0	1590.5
10	1230.4	2888.6	1658.2
11	1212.6	2895.9	1683.3
12	1246.0	2757.1	1511.1
Total			9549.0
Mean			1591.5

9549.0g of preservative solution taken up, of which 3.035%(m/m) is CCA salts.

	Salt Uptake(g)	Metal Uptake(g)
Copper	120.85	30.94
Chromium	121.72	38.36
Arsenic	47.24	26.64
Totals	289.81	95.94

APPENDIX 6

Uptake rate of CCA preservative (Phase 3)

Timber Number	Mass(g) Before	After	Uptake (g)
13	1188.2	2957.5	1769.3
14	1251.4	2917.2	1665.8
15	1310.7	2964.1	1653.4
16	1095.4	2833.6	1738.2
17	1285.7	2899.1	1613.4
18	1262.5	2839.1	1576.6
Total			10016.7
Mean			1669.45

10016.7g of preservative solution taken up, of which 3.035%(m/m) is CCA salts.

	Salt Uptake(g)	Metal Uptake(g)
Copper	126.77	32.45
Chromium	127.68	40.24
Arsenic	49.55	27.94
Totals	304.00	100.63

APPENDIX 7

Estimate of the uptake of creosote by European redwood sections

Average weight of untreated timbers =1260.6g

Average weight of treated timbers =1725.9g

Therefore, nominal uptake of creosote per section = 465.3g

Gross nominal uptake of creosote per phase =2792.1g

APPENDIX 8

Uptake rate of organic solvent wood preservative (Phase 1)

Timber Number	Mass(g) Before	After	Uptake (g)
1	1058.3	1120.2	61.9
2	1074.7	1133.7	59.0
3	1187.9	1266.5	78.6
4	1034.2	1066.5	32.3
5	1100.0	1166.6	66.6
6	1004.1	1056.1	52.0
Total			350.4
Mean			58.4

	Total Mass Retained(g)
PCP	17.577
Zinc	3.515

Note: The total uptake of OSWP solution by timber includes the preservative chemicals (PCP, zinc naphthenate and in Phases 2 & 3, HCH), as well as the solvent (Shell sol-E) (Appendices 8 - 10). It cannot be assumed that 100% of the solvent (S.G. 0.886) will have evaporated and therefore the mass of preservative solution in all Phases has been converted to the volume of solvent taken up in order to calculate a more accurate retention figure for the preservative chemicals.

APPENDIX 9

Uptake rate of organic solvent wood preservative (Phase 2)

Timber Number	Mass(g) Before	After	Uptake (g)
7	1179.8	1262.5	82.7
8	1112.1	1200.6	88.5
9	1057.6	1138.7	81.1
10	969.8	1057.8	88.0
11	1015.2	1091.1	75.9
12	1007.0	1086.7	79.7
Total			459.9
Mean			82.65

	Total Mass Retained(g)
PCP	24.876
Zinc	4.975
HCH	2.488

APPENDIX 10

Uptake rate of organic solvent wood preservative (Phase 3)

Timber Number	Mass(g) Before	After	Uptake (g)
13	1060.2	1124.9	64.7
14	1106.5	1137.1	30.6
15	1153.3	1191.2	37.9
16	881.4	939.5	58.1
17	1101.0	1156.9	35.9
18	1125.4	1216.2	90.8
Total			318.0
Mean			53.0

	Total Mass Retained(g)
PCP	15.952
Zinc	3.190
HCH	1.595

APPENDIX 11

Mass of CCA leached from timber in Phase 1

Day	Cu (mg)	Cr (mg)	As (mg)
1	272.000	225.000	245.000
2	26.750	38.500	16.750
5	44.400	59.200	27.600
7	9.500	25.500	2.000
9	5.400	27.000	0.200
13	2.000	21.700	0.700
15	2.500	36.500	0.500
19	2.350	38.528	0.000
22	0.599	6.836	0.081
Totals	365.499	478.764	292.831

APPENDIX 12

Mass of CCA leached from timber in Phase 2

Day	Cu (mg)	Cr (mg)	As (mg)
2	11.800	20.800	3.434
3	1.346	0.753	0.159
4	2.154	13.955	0.356
7	21.090	155.040	0.000
8	1.566	8.787	0.000
9	5.544	39.270	0.000
11	5.624	39.270	0.000
14	1.132	6.716	0.000
Totals	50.256	284.591	3.949

APPENDIX 13

Mass of CCA leached from timber in Phase 3

Day	Cu (mg)	Cr (mg)	As (mg)
7	4.505	15.699	0.401
8	1.519	9.702	0.123
9	1.830	17.324	0.000
12	0.918	9.180	0.000
14	0.642	6.634	0.000
16	1.368	5.472	0.000
20	0.218	2.180	0.000
23	0.485	1.725	0.000
Totals	11.485	67.916	0.524

APPENDIX 14

Mass of leachate from OSWP timber (Phase 1)

Day	Zn (mg)	PCP (mg)
1.000	4.400	9.300
2.000	3.200	11.200
5.000	3.800	6.800
7.000	3.400	6.200
9.000	0.000	6.600
13.000	0.000	10.500
15.000	2.500	4.800
19.000	2.098	127.535
22.000	0.824	13.239
Totals	16.822	196.174

APPENDIX 15

Mass of leachate from OSWP timber (Phase 2)

Day	Zn (mg)	PCP (mg)	HCH (mg)
2.000	4.000	5.293	0.056
3.000	0.695	0.018	0.000
4.000	1.898	0.295	0.004
7.000	28.227	203.654	9.277
8.000	8.316	21.226	0.427
9.000	2.621	3.245	0.110
11.000	9.548	171.642	6.759
14.000	4.168	0.781	0.027
Totals	59.473	387.154	16.660

APPENDIX 16

Mass of leachate from OSWP timber (Phase 3)

DAY	Zn (mg)	PCP (mg)	HCH (mg)
7.000	3.916	3.603	0.033
8.000	2.595	1.322	0.018
9.000	3.489	3.004	0.058
12.000	3.039	1.652	0.016
14.000	2.611	0.679	0.015
16.000	2.407	0.260	0.001
20.000	1.614	0.093	0.001
23.000	1.221	0.019	0.000
Totals	20.892	10.632	0.142

APPENDIX 17

Leachate from pressure applied creosoted timber (Phase 1 - mass)

Day	Phenol mg	nap mg	ace mg	flu mg	phe mg	fla mg	total PAH mg
1.000	104.104	14.529	0.000	2.231	4.462	1.087	22.309
6.000	91.200	8.709	0.000	3.009	3.831	2.964	18.513
8.000	89.670	9.800	0.000	6.811	8.036	6.027	30.674
12.000	50.124	0.000	0.000	2.652	3.248	2.264	8.164
14.000	51.809	10.329	0.000	6.563	7.639	0.000	24.531
18.000	76.700	0.000	0.000	1.885	2.925	2.470	7.280
21.000	4.496	11.227	0.457	1.524	2.616	1.270	17.094
Totals	468.103	54.594	0.547	24.675	32.757	16.082	128.565

APPENDIX 18

Leachate from pressure applied creosoted timber (Phase 3 - mass)

Day	Phenol mg	nap mg	ace mg	flu mg	phe mg	fla mg	total PAH mg
2.000	0.390	0.006	0.006	0.006	0.006	0.006	0.030
3.000	0.287	1.095	0.050	0.003	0.003	0.003	1.154
4.000	1.354	1.814	0.056	0.009	0.047	0.009	1.935
7.000	457.380	0.297	3.564	4.455	11.286	0.297	19.899
8.000	0.532	1.250	0.013	0.013	0.013	0.013	1.302
9.000	26.494	0.072	0.933	0.072	0.359	0.072	1.508
11.000	39.045	20.235	2.423	1.140	4.275	6.412	34.485
14.000	3.020	0.015	0.015	0.015	0.015	0.015	0.075
Totals	528.502	24.784	7.060	5.713	16.004	6.827	60.388

APPENDIX 19

Leachate from pressure applied creosoted timber (Phase 3 - mass)

Day	phenol mg	nap mg	ace mg	flu mg	phe mg	fla mg	total PAH mg
7.000	25.300	0.966	0.092	0.023	0.276	1.012	2.369
8.000	37.960	1.248	0.104	0.026	0.338	0.884	2.600
9.000	63.250	3.162	0.230	0.057	1.725	2.472	7.647
12.000	68.440	2.784	0.230	0.058	0.870	2.146	6.090
14.000	86.184	9.639	0.441	3.339	8.190	4.536	26.145
16.000	52.200	8.294	0.174	2.204	4.176	1.334	16.182
20.000	46.980	5.684	0.290	0.986	2.378	0.522	9.860
23.000	39.060	7.119	0.378	2.079	3.906	1.008	14.490
Totals	419.374	38.896	1.709	8.772	21.859	13.914	85.383

APPENDIX 20

Leachate from creosoted fence section (Phase 1 - mass)

Day	Phenol mg	nap mg	ace mg	flu mg	phe mg	fla mg	total PAH mg
1.000	66.600	69.434	3.839	10.046	11.457	0.588	95.364
2.000	19.200	2.672	3.815	9.578	6.242	0.000	22.307
5.000	36.300	0.000	0.000	3.815	1.173	0.000	4.988
7.000	2.240	0.000	0.000	0.977	4.529	0.000	5.506
9.000	9.410	0.000	0.098	0.525	0.689	0.000	1.312
13.000	0.426	0.000	0.000	0.156	0.554	0.199	0.909
15.000	1.075	0.000	0.000	0.344	0.000	0.000	0.344
19.000	0.508	5.740	0.076	0.279	1.930	0.000	8.025
22.000	0.380	3.102	0.056	0.085	1.495	0.014	4.752
Totals	136.139	80.948	7.786	25.805	28.069	0.801	143.507

APPENDIX 21

Leachate from creosoted fence section (Phase 2 - mass)

day	Phenol mg	nap mg	ace mg	flu mg	phe mg	fla mg	total PAH mg
2.000	2.549	2.549	0.007	0.085	0.213	0.667	3.521
4.000	0.122	1.621	0.004	0.037	0.097	0.004	1.763
7.000	466.861	175.931	0.858	0.858	14.589	0.858	193.094
8.000	0.068	1.838	0.003	0.003	0.465	0.003	2.312
9.000	41.733	53.885	0.229	0.229	4.815	0.229	59.387
11.000	32.464	72.232	0.406	0.406	1.623	0.406	75.073
14.000	0.259	1.695	0.012	0.012	0.113	0.012	1.844
Totals	544.056	309.751	1.519	1.630	21.802	2.179	336.994

APPENDIX 22

Concentration of CCA leached from timber in Phase 1

Day	Cu Conc mg/l	Cr Conc mg/l	As Conc mg/l
1.000	680.000	562.500	612.500
2.000	66.875	96.250	41.875
5.000	55.500	74.000	34.500
7.000	11.875	31.875	2.500
9.000	6.750	33.750	0.250
13.000	2.500	27.125	0.875
15.000	3.125	45.625	0.625
19.000	1.958	32.107	0.000
22.000	1.498	17.090	0.203

APPENDIX 23

Concentration of CCA leached from timber in Phase 2

Day	Cu Conc mg/l	Cr Conc mg/l	As Conc mg/l
2.000	34.806	61.176	10.100
3.000	25.396	14.208	3.000
4.000	12.101	78.399	2.000
7.000	3.661	27.200	0.000
8.000	3.100	20.200	0.000
9.000	3.600	25.500	0.000
11.000	1.900	16.400	0.000
14.000	3.101	18.400	0.000

APPENDIX 24

Concentration of CCA leached from timber in Phase 3

Day	Cu Conc mg/l	Cr Conc mg/l	As Conc mg/l
7.000	1.004	3.501	0.089
8.000	0.372	2.376	0.003
9.000	1.116	10.567	0.000
12.000	0.496	4.910	0.000
14.000	0.343	3.549	0.000
16.000	1.368	3.119	0.000
20.000	0.119	1.188	0.000
23.000	0.299	1.725	0.000

APPENDIX 25

Concentration of leachate from OSWP treated timber - Phase 1

Day	PCP Conc mg/l	Zn Conc. mg/l
1.000	23.250	11.000
2.000	28.000	8.000
5.000	8.500	4.750
7.000	7.750	4.250
9.000	8.250	0.000
13.000	13.125	0.000
15.000	6.000	3.125
19.000	106.279	1.748
22.000	33.098	2.060

APPENDIX 26

Concentration of leachate from OSWP treated timber - Phase 2

Day	PCP Conc mg/l	Zn Conc mg/l	HCH Conc mg/l
2.000	38.635	29.197	0.408
3.000	0.720	27.800	0.000
4.000	4.538	29.200	0.057
7.000	69.984	9.700	3.188
8.000	27.566	10.800	0.554
9.000	15.601	12.601	0.530
11.000	111.456	6.200	4.389
14.000	5.659	30.203	0.197

APPENDIX 27

Concentration of leachate from OSWP treated timber - Phase 3

Day	PCP Conc mg/l	Zn Conc mg/l	HCH Conc mg/l
7.000	0.991	1.077	0.009
8.000	0.353	0.693	0.005
9.000	1.830	2.128	0.035
12.000	0.884	1.626	0.009
14.000	0.390	1.501	0.009
16.000	0.147	1.360	0.001
20.000	0.056	0.968	0.001
23.000	0.012	0.757	0.000

APPENDIX 28

Concentration of leachate from creosoted timber (pressure applied) - Phase 1

Day	Phenol mg/l	nap mg/l	ace mg/l	flu mg/l	phe mg/l	fla mg/l	total PAH mg/l
1.000	182.000	25.400	0.000	3.900	7.800	1.900	39.000
6.000	200.000	19.100	0.000	6.600	8.400	6.500	40.600
8.000	183.000	20.000	0.000	13.900	16.400	12.300	62.600
12.000	168.200	0.000	0.000	8.900	10.900	7.600	27.400
14.000	96.300	19.200	0.000	12.200	14.200	0.000	45.600
18.000	118.000	0.000	0.000	2.900	4.500	3.800	11.200
21.000	17.700	44.200	1.800	6.000	10.300	5.000	67.300

APPENDIX 29

Concentration of leachate from creosoted timber (pressure applied) - Phase 2

Day	Phenol mg/l	nap mg/l	ace mg/l	flu mg/l	phe mg/l	fla mg/l	total PAH mg/l
2.000	6.500	0.100	0.100	0.100	0.100	0.100	0.500
3.000	11.500	43.800	2.000	0.100	0.100	0.100	46.100
4.000	14.400	19.300	0.600	0.100	0.500	0.100	20.600
7.000	154.000	0.100	1.200	1.500	3.800	0.100	6.700
8.000	4.000	9.400	0.100	0.100	0.100	0.100	9.800
9.000	36.900	0.100	1.300	0.100	0.500	0.100	2.100
11.000	27.400	14.200	1.700	0.800	3.000	4.500	24.200
14.000	20.000	0.100	0.100	0.100	0.100	0.100	0.500

APPENDIX 30

Concentration of leachate from creosoted timber (pressure applied) - Phase 3

DAY	phenol mg/l	nap mg/l	ace mg/l	flu mg/l	phe mg/l	fla mg/l	total PAH mg/l
7.000	110.000	4 .200	0.400	0.100	1.200	4.400	10.300
8.000	146.000	4.800	0.400	0.100	1.300	3.400	10.000
9.000	110.000	5.500	0.400	0.100	3.000	4.300	13.300
12.000	118.000	4.800	0.400	0.100	1.500	3.700	10.500
14.000	136.800	15.300	0.700	5.300	13.000	7.200	41.500
16.000	90.000	14.300	0.300	3.800	7.200	2.300	27.900
20.000	81.000	9.800	0.500	1.700	4.100	0.900	17.000
23.000	62.000	11.300	0.600	3.300	6.200	1.600	23.000

APPENDIX 31

Leachate from creosoted fence section - Phase 1

Day	Phenol mg/l	nap mg/l	ace mg/l	flu mg/l	phe mg/l	fla mg/l	total PAH mg/l
1.000	793.300	826.600	45.700	119.600	136.400	7.000	1135.300
2.000	187.900	226.200	37.400	93.900	61.200	0.000	418.700
5.000	105.600	0.000	0.000	37.400	11.500	0.000	48.900
7.000	10.100	0.000	0.000	4.400	20.400	0.000	24.800
9.000	28.700	0.000	0.300	1.600	2.100	0.000	4.000
13.000	3.000	0.000	0.000	1.100	3.900	1.400	6.400
15.000	2.500	0.000	0.000	0.800	0.000	0.000	0.800
19.000	2.000	22.600	0.300	1.100	7.600	0.000	31.600
22.000	2.700	22.000	0.400	0.600	10.600	0.100	33.700

APPENDIX 32

Leachate from creosoted fence section - Phase 2

Day	Phenol mg/l	nap mg/l	ace mg/l	flu mg/l	phe mg/l	fla mg/l	total PAH mg/l
2.000	9.900	35.900	0.100	1.200	3.000	9.400	49.600
4.000	3.300	43.800	0.100	1.000	2.600	0.100	47.600
7.000	54.400	20.500	0.100	0.100	1.700	0.100	22.500
8.000	2.200	59.300	0.100	0.100	15.000	0.100	74.600
9.000	18.200	23.500	0.100	0.100	2.100	0.100	25.900
11.000	8.000	17.800	0.100	0.100	0.400	0.100	18.500
14.000	2.300	15.000	0.100	0.100	1.000	0.100	16.300