

AN INVESTIGATION OF THE EVAPORATION OF SOME VOLATILE SOLVENTS FROM DOMESTIC WASTE

C.J. JONES* and P.J. McGUGAN

Waste Research Unit, Chemical Technology Division, Harwell Laboratory, Nr. Didcot, Oxon, OX11 0RA (Gt. Britain)

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Summary

An experimental study has been made of the evaporation of acetone, isopropanol, perchloroethylene, white spirit, 1/1 v/v acetone-water, 1/1 v/v isopropanol-water and 1/1 v/v perchloroethylene-oil from a shallow pool 1 metre square or from pulverised domestic waste 0.5 metres deep and 1 metre square. The initial evaporation rate of the pure solvents from waste was generally 2 or 3 times greater than from a shallow pool. However, after 2-3 hours the evaporation rate from waste decreased to a value of ca. $2 \text{ g mol m}^{-1} \text{ h}^{-1}$ or less which was supposed to be controlled by the rate of diffusion of vapour through the waste layer. In contrast the evaporation of isopropanol-water or acetone water mixtures from waste was slower than from a pool of liquid over an initial 6 hour period. Perchloroethylene initially evaporated from waste more rapidly than from a pool when mixed with oil but the release rate from waste fell to values below that for a pool in 1-2 hours. The implications of these results are discussed with respect to theoretical predictions of vapour release from pools and the deposition of solvent containing liquid wastes on landfill sites.

Introduction

The deposition of liquid wastes containing volatile solvents at landfill sites poses a potential hazard to site operators in terms of both the toxicity and flammability of the vapours emitted from the wastes [1]. Mathematical models [2-5] may be used to estimate the rates of evaporation of volatile liquids from pools and the subsequent dispersion of their vapour. However, the effects of depositing solvents on domestic waste on their evaporation rate is unknown and is not covered by existing models.

A detailed study of the effects of temperature, wind speed, waste compaction and other parameters on the evaporation rate of landfilled solvents is beyond the scope of this paper. A simplified approach was instead adopted to compare the rate of evaporation of solvents from pulverised domestic waste with their rate of evaporation from a liquid pool under the same

*To whom correspondence should be addressed.

environmental conditions. In this way it was hoped to devise some recommendations about the safest method for solvent disposal by landfill, and to assess the validity of simple mathematical models.

Previous experiments on the evaporation of liquids from pools indicated that an area of one square metre was necessary to give data which could be reasonably extrapolated to larger pools tens of metres across. In addition a reasonably large sample size is required to allow a representative sample of waste to be used. Thus, for these experiments, an area of 1 metre by 1 metre and a waste depth of 0.5 metre was selected. The rate of evaporation of solvent could be monitored by measuring weight loss and, by having a 1 metre square pool of pure solvent and a 1 metre square waste sample close together in the open, a direct comparison of evaporation rates could be obtained.

Experimental

The containers for the solvents and the waste were constructed in the form of square open trays of side 1 metre. The shallow tray for the solvent only experiments was 3 cm deep and made from welded aluminium sheet. The 0.5 metre deep tray for waste was constructed from aluminium sheet bolted to a Dexian framework and fitted with a liner made of polyethylene sheet. In all two shallow and four deep trays were made for the experiments.

The evaporation of the solvents was monitored by the weight loss of the trays and their contents as a function of time. Pressure transducers appeared to offer no advantages in sensitivity over mechanical weighing methods so the latter were adopted. The tray containing refuse was suspended from scaffolding by means of two 200 kg capacity spring balances. A similar arrangement for supporting the shallow tray proved too unstable, the solvent being lost over the sides of the tray. Thus three 25 kg capacity top-loading balances were used to support the shallow tray from beneath.

Technical grade solvents were used and the substances selected for the experiments were acetone, isopropanol, perchloroethylene and white spirit. Pulverised domestic waste was obtained from the South Cambridgeshire District Council site at Thriplow and when placed in the 0.5 m³ tray generally had a density of ca. 350 kg m⁻³. Solvent or solvent containing mixtures with water or used engine oil were poured over the surface of the waste and the weight of the tray measured at intervals throughout the day. A solvent to waste load of about 10% by weight was used in the experiments. A blank run carried out on waste containing no solvent indicated that evaporation of water from the refuse might result in an error of ca. 5% in the evaporation rates measured. The temperatures of the solvent pool and top 15 cm of the waste were monitored and showed variations over a range as much as 10°C in any one experiment.

The results of the experiments were plotted as graphs of weight per cent solvent lost against time. The evaporation rate of the pure solvent could be calculated from the slope of the linear plot obtained. In the case of mixtures

or solvents on waste curves were obtained and mean evaporation rates for the first 10 minutes and a period from 200 to 440 minutes were obtained from the graphs. The rate of evaporation of solvent from a pool of pure liquid is independent of depth except for any effect the liquid depth has on the transfer of heat to the surface to offset evaporative cooling. In the case of mixtures the depth does affect the evaporation rate and care was taken to apply the same quantity of mixture to both the refuse and the shallow tray.

Evaporation of solvents from domestic waste

Acetone

The data for the evaporation of acetone are presented in Table 1 and displayed graphically in Fig. 1. It can be seen from the graph that acetone is initially released almost twice as rapidly from waste as from a pool of the same area. However, the release rate decreases quite rapidly and after 3 hours has fallen to a level which may be controlled by diffusion of vapour through

TABLE 1

Data for evaporation of acetone

I. Solvent only

Initial weight of solvent 13.85 kg

Time (min)	0	5	15	45	75	105	330
Solvent lost (w/w, %)	0	5.8	8.7	27.4	44.0	58.5	97.5

Rate of evaporation $4.92 \text{ kg m}^{-2} \text{ h}^{-1}$

II. Solvent plus waste

Initial weight of solvent 14.5 kg

Weight of waste 121 kg

Time (min)	0	10	40	70	100	325	460
Solvent lost (w/w, %)	0	10.3	37.9	41.4	48.3	51.7	58.6

Rate of evaporation over first 10 min $8.70 \text{ kg m}^{-2} \text{ h}^{-1}$

Rate of evaporation from 200–440 min $0.11 \text{ kg m}^{-2} \text{ h}^{-1}$ i.e. $1.9 \text{ mol m}^{-2} \text{ h}^{-1}$

Mean wind speed ca. 6.7 m sec^{-1}

Ambient air temperature ca. 7°C

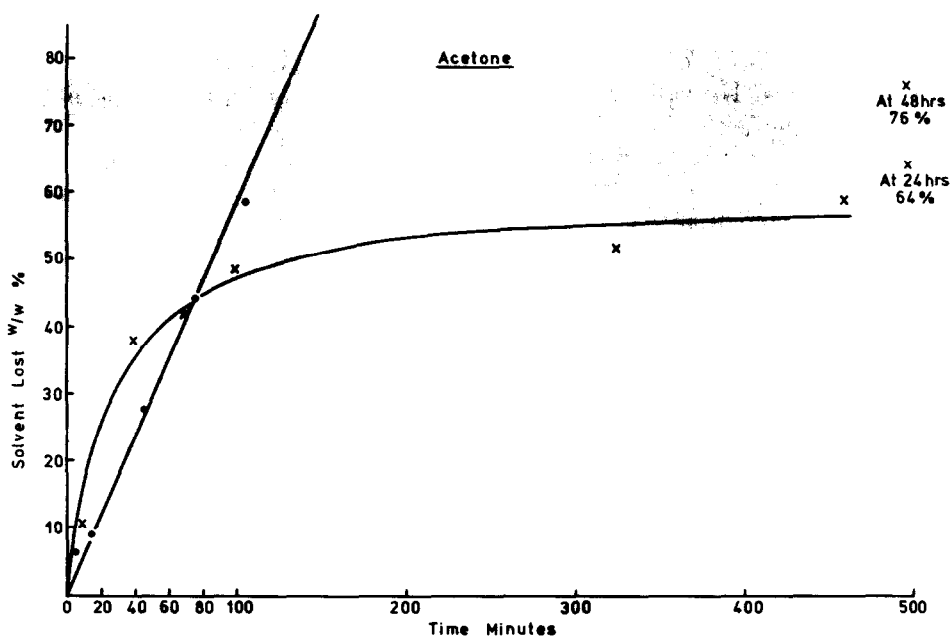


Fig. 1. Evaporation of acetone. • Acetone only. X Acetone plus domestic waste.

this waste. The rapid initial release from waste may result from the higher surface area offered for evaporation by the waste (a 'wick' effect) and from the heat capacity of the waste reducing the cooling effects of evaporation. Once the acetone has percolated into the bulk of the waste the release rate falls to a value of $1.9 \text{ g mol m}^{-2} \text{ h}^{-1}$.

The evaporation rate obtained for the acetone pool was an order of magnitude or so less than that predicted by a mathematical model [6]. It is likely that this discrepancy arises from the cooling of the acetone surface by evaporation which is not allowed for in the theoretical treatment. The experiment thus demonstrates that acetone may evaporate at significantly lower rates than predicted earlier. However, when deposited on waste the rate of evaporation is initially increased but within an hour decreases to rates less than that for a pool of pure solvent.

Isopropanol

The data for the evaporation of isopropanol are presented in Table 2 and Fig. 2. Isopropanol initially evaporated about 3 times more rapidly from waste than from a pool of liquid. The evaporation rate from waste fell below that from a pool within 2 hours to reach a rate of $2.4 \text{ g mol m}^{-2} \text{ h}^{-1}$, presumed to be diffusion controlled, between 200 and 440 minutes. This behaviour was quite similar to that observed for acetone although the evaporation rates were 3 or 4 times less. These lower rates probably result from both the lower volatility of isopropanol and the lower wind speeds prevailing during the experiment.

TABLE 2

Data for evaporation of isopropanol

I. Solvent only

Initial weight of solvent 18.25 kg

Time (min)	0	30	45	60	120	180	370
Solvent lost (w/w, %)	0	2.5	3.5	5.0	11.2	18.1	30.1

Rate of evaporation $1.10 \text{ kg m}^{-2} \text{ h}^{-1}$ *II. Solvent plus waste*

Initial weight of solvent 19.5 kg

Weight of waste 177 kg

Time (min)	0	40	60	120	180	385
Solvent lost (w/w, %)	0	6.4	10.3	11.5	14.1	16.7

Rate of evaporation over first 10 min $3.22 \text{ kg m}^{-2} \text{ h}^{-1}$ Rate of evaporation from 200–440 min $0.15 \text{ kg m}^{-2} \text{ h}^{-1}$ i.e. $2.4 \text{ mol m}^{-2} \text{ h}^{-1}$ Mean wind speed ca. 0.5 m sec^{-1} Ambient air temperature ca. 12°C Solvent pool temperature ca. 13°C Waste surface temperature ca. 18°C *Perchloroethylene*

The data for the evaporation of perchloroethylene are presented in Table 3 and Fig. 3. The rates of evaporation of perchloroethylene were intermediate between those observed for acetone and isopropanol. Again the initial release rate of perchloroethylene from waste was higher than from a pool of liquid, by a factor of ca. 2 in this case. The release rate from waste decreased to a value less than for a pool within $1\frac{1}{2}$ hours to reach of rate of $2.2 \text{ g mol m}^{-2} \text{ h}^{-1}$ between 200 and 440 minutes.

White spirit

The data for the evaporation of white spirit are presented in Table 4 and Fig. 4. This was the least volatile of the solvents studied and exhibited rather

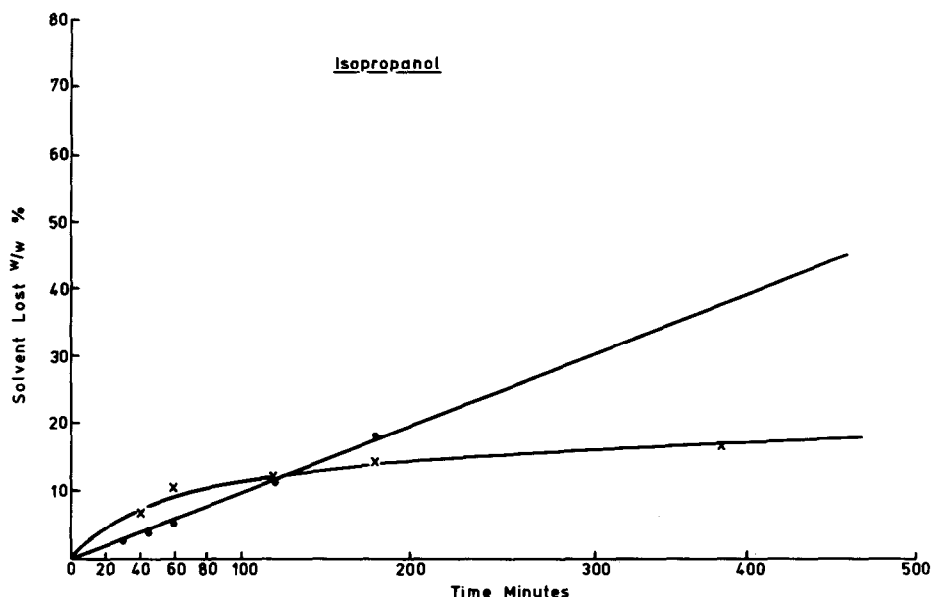


Fig. 2. Evaporation of isopropanol. • Isopropanol only. × Isopropanol plus domestic waste.

different behaviour. Since white spirit is not a pure substance but a mixture, the more volatile components evaporated rapidly from the pool of liquid to give a high initial evaporation rate. This then decreased over a period of 10–20 minutes to give a linear release rate of $0.29 \text{ kg m}^{-2} \text{ h}^{-1}$ for the less volatile components. The initial release rate from waste was much higher than for a pool of liquid but again the rate decreased to fall below that from a pool of liquid within 3 hours. At this stage the release rate was $0.8 \text{ g mol m}^{-2} \text{ h}^{-1}$, about half that observed for the more volatile solvents. However, the supposedly diffusion controlled release rate of white spirit from waste was only about 3 times less than the release rate from a pool of liquid. This ratio was approximately 10 for the more volatile solvents.

In contrast with acetone, the release rate observed for the pool of white spirit agreed well (within 0.20%) with that predicted by the theoretical model [6]. Since white spirit is much less volatile than acetone it is likely that the rate of heat transfer to the solvent surface is adequate to compensate for the effects of evaporative cooling. Thus for less volatile solvents, or perhaps those with very low latent heats of evaporation, the theoretical treatment appears reliable. Another notable difference between white spirit and the other solvents studied concerns the total proportion of solvent evaporated. The proportion of solvent lost from the liquid pool exceeded that lost from waste after about 2 hours for acetone, isopropanol and perchloroethylene. However, for white spirit the proportion of solvent lost from waste after 6 hours was still about twice that lost from the pool of liquid. Extra-

TABLE 3

Data for evaporation of perchloroethylene

I. Solvent only

Initial weight of solvent 20.2 kg

Time (min)	0	10	25	40	115	220
Solvent lost (w/w, %)	0	2.5	6.7	10.6	30.2	54.0

Rate of evaporation $3.13 \text{ kg m}^{-2} \text{ h}^{-1}$ *II. Solvent plus waste*

Initial weight of solvent 29.0 kg

Weight of waste 155 kg

Time (min)	0	20	35	110	215	305
Solvent lost	0	6.0	12.1	22.4	31.0	33.6

Rate of evaporation over first 10 min $6.09 \text{ kg m}^{-2} \text{ h}^{-1}$ Rate of evaporation from 200–440 min $0.36 \text{ kg m}^{-2} \text{ h}^{-1}$ i.e. $2.2 \text{ mol m}^{-2} \text{ h}^{-1}$ Mean wind speed ca. 10 m sec^{-1} Ambient air temperature 12°C Solvent pool temperature ca. 15°C Waste surface temperature ca. $12\text{--}20^\circ\text{C}$

polation indicated that about 24 hours might elapse before the proportion of solvent lost from a pool of liquid might exceed that lost from waste.

The following general observations emerge from the experiments on pure solvents. Firstly, the initial evaporation rate of a solvent deposited on waste is generally higher than if it had been deposited in a pool of the same area on a non-porous surface. Secondly, the release rate of the more volatile solvents from waste appears to become diffusion controlled after about 2 to 3 h. This diffusion controlled rate was measured at approximately $2 \text{ g mol m}^{-2} \text{ h}^{-1}$. Thirdly, for less volatile solvents exemplified by white spirit deposition on waste has a less pronounced effect on the long term evaporation rate. However, during the first 2 hours the increased evaporation rate from waste results in more effective removal of solvent to the atmosphere than would be achieved by lagooning.

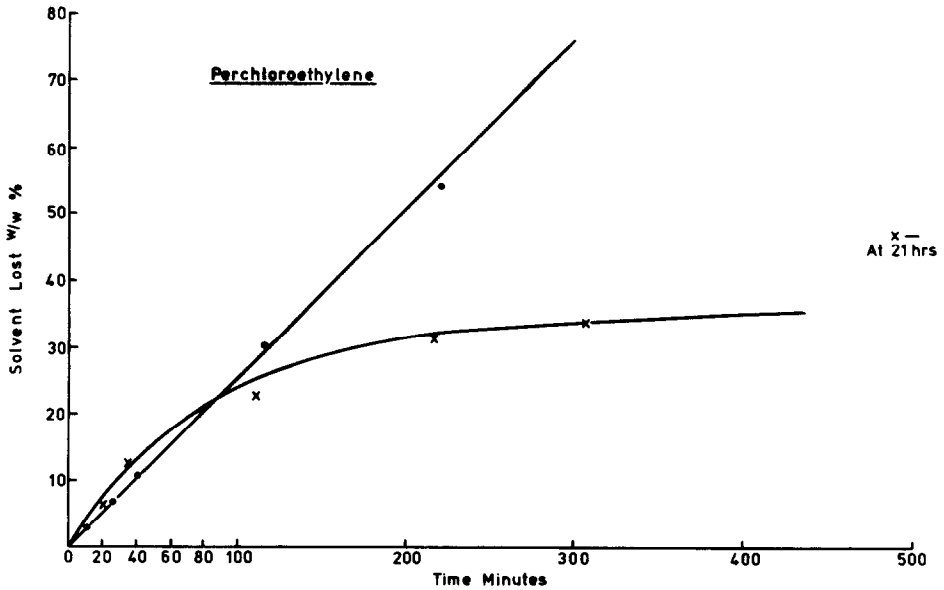


Fig. 3. Evaporation of perchloroethylene. • Perchloroethylene only. × Perchloroethylene plus domestic waste.

Evaporation of solvent—water or solvent—oil mixtures

Acetone—water

The data for the evaporation of a 1/1 v/v mixture of acetone and water are presented in Table 5 and Fig. 5. A detailed study of the change in composition of the mixture with evaporation was not possible and only total liquid evaporated was measured. The evaporation rate from the pool of liquid was initially about twice that from waste. However after ca. 6 hours the rate of evaporation from the pool had fallen to a value apparently less than that from waste. These results are the reverse of those obtained when acetone alone was studied (Fig. 1) and the reasons for this marked difference are not clear at present.

Isopropanol—water

The data for the evaporation of a 1/1, v/v mixture of isopropanol and water are presented in Table 6 and Fig. 6. In this case the initial rate of evaporation from waste was slightly higher than that from a pool of liquid but this rapidly decreased to fall below the evaporation rate for the pool within an hour. Again the mixing of the solvent with water results in waste having a greater effect in attenuating the release of vapour (cf. Fig. 2). In molar terms the evaporation rates of acetone—water and isopropanol—water from waste over the 200–440 minute period were similar, bearing in mind that at this time the effective molecular weight of the isopropanol—water mix-

TABLE 4

Data for evaporation of white spirit

I. Solvent only

Initial weight of solvent 14.25 kg

Time (min)	0	15	85	55	90	220	410
Solvent lost (w/w, %)	0	5.3	6.3	7.0	8.1	11.9	18.2

Rate of evaporation $0.29 \text{ kg m}^{-2} \text{ h}^{-1}$ (first 10 min excluded)*II. Solvent plus waste*

Initial weight of solvent 21.0 kg

Weight of waste 175 kg

Time (min)	0	15	45	65	100	230	420
Solvent lost (w/w, %)	0	19	25	26.2	29.8	31.0	35.7

Rate of evaporation over first 20 min $6.93 \text{ kg m}^{-2} \text{ h}^{-1}$ Rate of evaporation from 200–440 min $0.105 \text{ kg m}^{-2} \text{ h}^{-1}$ i.e. based on C_6H_6 0.8 mol $\text{m}^{-2} \text{ h}^{-1}$ Mean wind speed ca. 5 m sec^{-1} Ambient air temperature ca. 13°C Solvent pool temperature ca. 18°C Waste surface temperature ca. $20\text{--}30^\circ\text{C}$

ture will be higher than that of the acetone–water mixture. This rate was significantly greater than the diffusion controlled rate observed for the solvents alone and this may result from improved ‘wetting’ of the waste by water and transfer of liquid to the waste surface by capillary action.

Perchloroethylene–oil

Data for the evaporation of perchloroethylene from a 1/1 v/v mixture with oil are presented in Table 7 and Fig. 7. The initial rate of evaporation from a pool of mixture was approximately half that for a pool of pure solvent as might have been expected. Initially the solvent evaporated ca. 4 times more rapidly from the oil and waste than from the oil alone. In the case of pure perchloroethylene the evaporation rates differed by a factor of

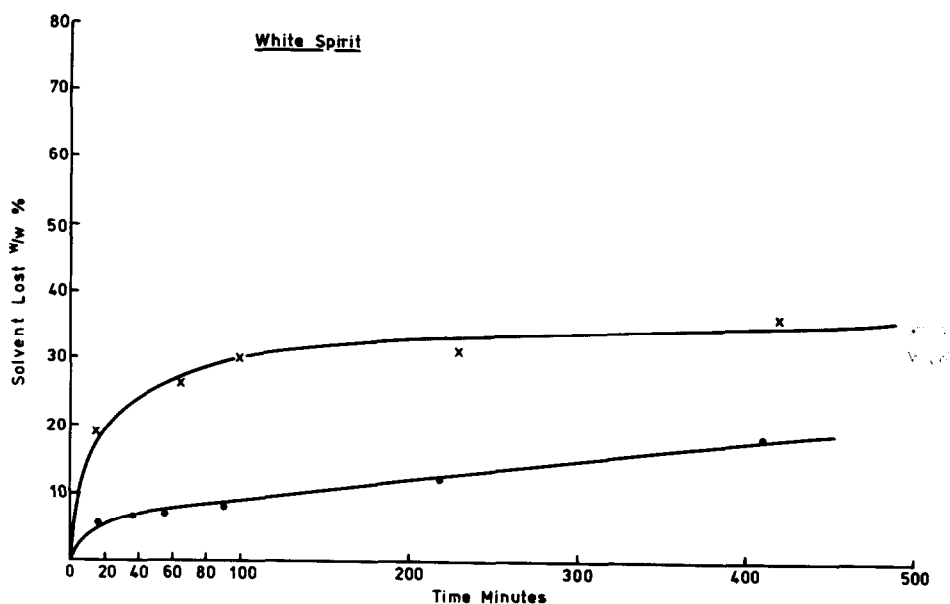


Fig. 4. Evaporation of white spirit. • White spirit only. × White spirit plus domestic waste.

only 2. Thus waste appears to have a greater capacity for increasing the initial rate of evaporation of perchloroethylene in the presence of oil than in its absence. However, in the period 200–440 mins, the molar release rate of perchloroethylene from waste treated with the oil mixture is only half that for waste treated with pure perchloroethylene.

The low volatility of white spirit coupled with the reduction in evaporation rate caused by mixing it with oil suggested that, with the existing experimental procedure, no meaningful results would be obtained for this mixture. Consequently no measurements were made for white spirit–oil mixture.

The evaporative behaviour of solvent mixtures both in pools and absorbed in refuse is quite complex and a detailed consideration of the factors involved is beyond the scope of this paper. The general pattern of behaviour which emerges from the very limited experimental data obtained here may be summarised as follows. The water miscible, volatile solvent acetone appears to evaporate more slowly from refuse than from a liquid pool when mixed with water. The less volatile, water-miscible solvents isopropanol also evaporates more slowly from waste than from a pool when mixed with water. However, the waste is less effective in attenuating the evaporation of isopropanol mixed with water than of acetone mixed with water. The moderately volatile solvent, perchloroethylene, initially evaporates more rapidly

TABLE 5

Data for evaporation of acetone—water

I. Solvent and water only

Initial weight of solvent 7.6 kg

Initial weight of water 10.0 kg

Time(min)	0	15	30	45	120	235	355
Solvent lost (w/w, %)	0	10.2	16.5	20.2	35.8	44.6	49.4

Rate of evaporation of mixture $6.8 \text{ kg m}^{-2} \text{ h}^{-1}$ (over first 10 mins)*II. Solvent and water plus waste*

Initial weight of solvent 7.4 kg

Initial weight of water 9.5 kg

Weight of waste 225 kg

Time (min)	0	15	30	45	60	120	245	365
Solvent lost (w/w, %)	0	5.9	8.8	10.3	13.2	16.2	22.1	29.4

Rate of evaporation over first 10 min $3.7 \text{ kg m}^{-2} \text{ h}^{-1}$ Rate of evaporation from 200–440 min $0.47 \text{ kg m}^{-2} \text{ h}^{-1}$ Mean wind speed ca. 4 m sec^{-1} Ambient air temperature ca. 14°C Solvent and water pool temperature $4\text{--}18^{\circ}\text{C}$ Waste surface temperature ca. 33°C

from waste than from a pool when mixed with oil. However, the evaporation rate from waste decreases more rapidly and falls below that of a pool within 1–2 hours.

Conclusion

The results obtained in this study demonstrate the difficulty of making general remarks about the evaporative behaviour of solvent mixtures deposited at landfill sites. The picture is somewhat clearer for pure solvents but these, of course, should not appear at landfill sites for disposal. In terms of applying theoretical models of evaporation to landfilled solvents the follow-

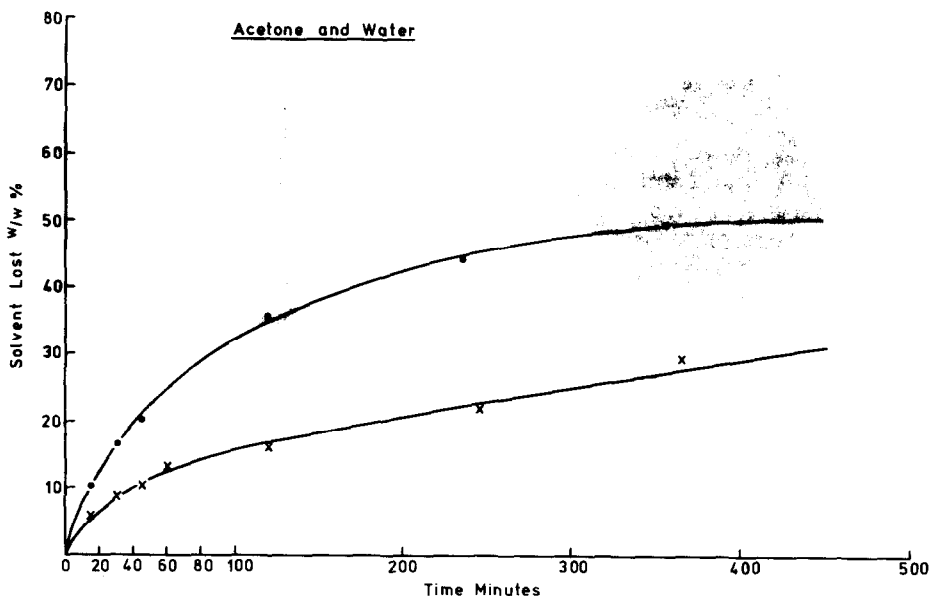


Fig. 5. Evaporation of acetone—water. ● Acetone and water only. × Acetone and water plus domestic waste.

ing paragraphs attempt to provide some 'rules of thumb' for extrapolating the calculated evaporation rates to landfill situations.

Calculations of evaporation rates which do not take account of heat transfer to the evaporating liquid are likely to be in error by as much as an order of magnitude for volatile solvents such as acetone. The calculations appear to work reasonably well for relatively involatile solvents such as white spirit. Thus calculations for volatile solvents (other than those with a very low latent heat of evaporation) will contain a margin of safety in that they over-estimate evaporation rates unless corrected for heat transfer.

The deposition of liquids with a high volatile solvent content on domestic waste will increase the initial evaporation rate by a factor of perhaps 2–5 compared to a pool of liquid. However, after about three hours the evaporation rate may fall to a value of ca. $2 \text{ g mol m}^{-2} \text{ h}^{-1}$ based on a 0.5 metre deep layer of waste. Thus the acute vapour hazard to the site operators will be greater if the solvent is deposited on waste rather than lagooned. However, the chronic vapour hazard persisting after a few hours will be less than for a lagoon. Re-excavation of waste which has recently received quantities of solvent will result in a short lived release of vapour from liquid and vapour trapped in the waste. This could produce a toxic or fire hazard for a short period and care should be exercised when contemplating re-excavation of solvent contaminated waste.

Volatile solvents dissolved in water (exemplified by acetone) appear to evaporate less rapidly from waste than from a pool of liquid. The same ap-

TABLE 6

Data for evaporation of isopropanol-water

I. Solvent and water only

Initial weight of solvent 7.2 kg

Initial weight of water 10 kg

Time (min)	0	15	30	60	105	225	405
Solvent lost (w/w, %)	0	1.7	3.6	9.4	15.0	35.6	54.6

Rate of evaporation $1.54 \text{ kg m}^{-2} \text{ h}^{-1}$ (over first 10 minutes)*II. Solvent and water plus waste*

Initial weight of solvent 7.25 kg

Initial weight of water 10 kg

Weight of waste 174 kg

Time (min)	0	15	45	90	210	390
Solvent lost (w/w, %)	0	2.9	7.2	11.6	15.9	23.2

Rate of evaporation over first 10 min $1.90 \text{ kg m}^{-2} \text{ h}^{-1}$ Rate of evaporation from 200-440 min $0.65 \text{ kg m}^{-2} \text{ h}^{-1}$ Mean wind speed ca. 4.5 m sec^{-1} Ambient air temperature ca. 22°C Solvent and water pool temperature ca. 20°C Waste surface temperature $24-37^\circ\text{C}$

pears to be true for less volatile water miscible solvents (exemplified by isopropanol) though to a lesser extent. In this case the initial release rate may be slightly higher from waste than from a pool but decreases to lower values within ca. 30 minutes.

Volatile solvents dissolved in oil (exemplified by perchloroethylene) initially evaporate more rapidly from waste than from a pool. However, after a few hours the release rate from waste decreases substantially and may fall below that of a pool. Thus waste appears to attenuate release of solvent from aqueous mixtures, at least initially, but it initially promotes evaporation of solvent from oily mixtures.

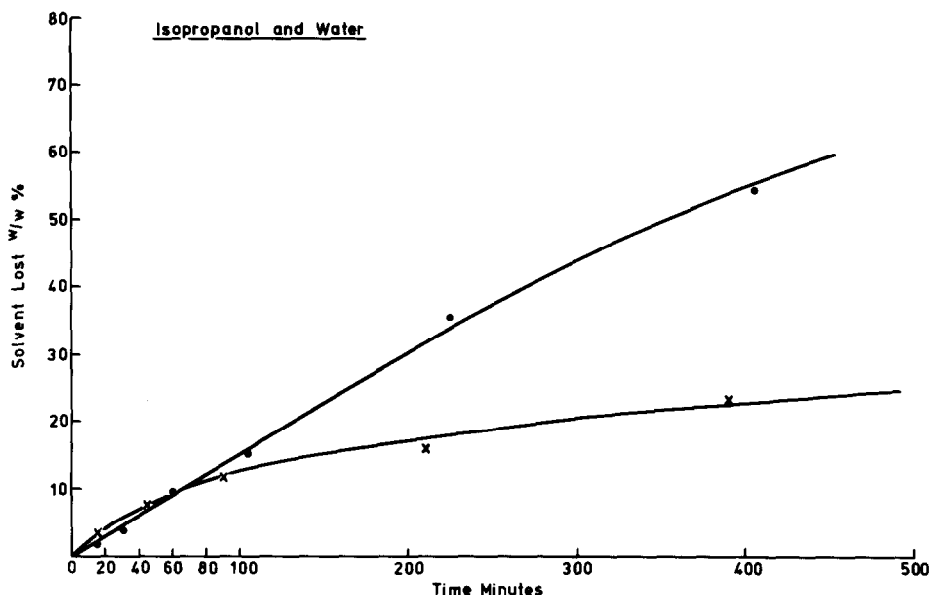


Fig. 6. Evaporation of isopropanol—water. • Isopropanol and water only. × Isopropanol and water plus domestic waste.

To summarise some of the pros and cons of depositing solvent containing liquid wastes on domestic waste the following may be considered:

Pro:

- (i) Deposition of liquid waste on domestic waste can give a more controlled long-term release of vapour.
- (ii) Dispersion of solvent waste on domestic waste reduces the risk of a major leakage of liquid waste to an aquifer as could occur with a lagoon.
- (iii) Dispersion in domestic waste reduces the risk of rapid bulk reactions between reactive liquid wastes as might occur in a lagoon.
- (iv) Liquid absorbed in domestic waste does not present the drowning hazard of a lagoon on a site which may not be completely secure against trespassing children.

Con:

- (i) Deposition of liquid wastes with a high volatile solvent content on domestic waste may present a greater initial toxic vapour hazard than lagooning.
- (ii) Flammable solvents retained in domestic waste will constitute a continuing fire hazard which may be less obvious or controllable than that of a lagoon.

TABLE 7

Data for evaporation of perchloroethylene-oil

I. Solvent and oil only

Initial weight of solvent 16.3 kg

Weight of oil 7.75 kg

Time (min)	0	10	25	45	60	75	100	170	250	340
Solvent lost (w/w, %)	0	0.6	2.1	4.3	5.5	6.7	8.6	12.0	15.3	18.4

Rate of evaporation $1.44 \text{ kg m}^{-2} \text{ h}^{-1}$ (over first 20 min)*II. Solvent and oil plus waste*

Initial weight of solvent 16.3 kg

Weight of oil 7.2 kg

Weight of waste 1.67 kg

Time (min)	0	15	35	50	65	90	160	240	330
Solvent lost (w/w, %)	0	6.1	10.7	12.3	15.3	15.3	15.3	19.9	19.9

Rate of evaporation over first 10 min $5.64 \text{ kg m}^{-2} \text{ h}^{-1}$ Rate of evaporation from 200-440 min $0.176 \text{ kg m}^{-2} \text{ h}^{-1}$ i.e. $1.1 \text{ mol m}^{-2} \text{ h}^{-1}$ Mean wind speed ca. 2.5 m sec^{-1} Ambient air temperature ca. 22°C Solvent and oil pool temperature ca. $19-35^\circ\text{C}$ Waste surface temperature ca. 18°C

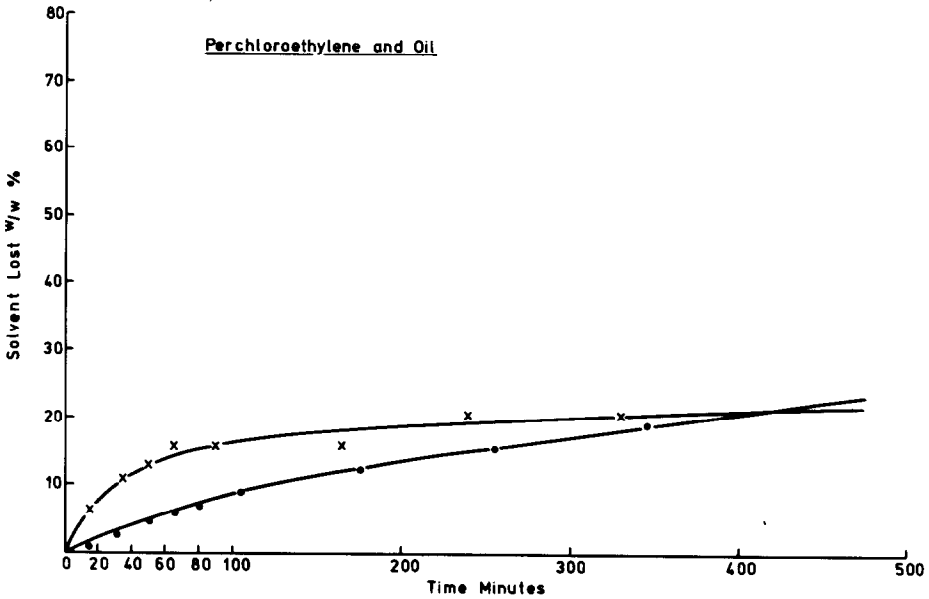


Fig. 7. Evaporation of perchloroethylene—oil. • Perchloroethylene and oil only. x Perchloroethylene and oil plus domestic waste.

- (iii) Volatile liquids may remain trapped in domestic waste for some time and could constitute a potential toxic or fire hazard if the waste is re-excavated.

Ideally solvents should be recovered from wastes and the residues incinerated as indicated in the Code of Practice, published by the Department of the Environment [1]. In cases where landfill disposal is unavoidable, this limited experimental study suggests the following procedures might be considered. Aqueous solutions of water miscible solvents such as acetone or isopropanol are best absorbed into domestic waste upon discharge at the site. Wastes containing high proportions of solvents or oily liquids containing water immiscible solvents such as halogenated organic liquids, are probably best lagooned in trenches. The trenches may then be back-filled with domestic waste to absorb the liquid, uncontaminated domestic waste may then be used to provide additional cover. These procedures would serve to minimise the concentrations of solvent vapour arising at the point of disposal.

Acknowledgement

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