Agricultural Research Organization, Volcani Center
Institute of Soils and Water

WATER TRANSPORT AND STORAGE FOR GRAVITY POWERED IRRIGATION

Final Report

project No C5-049
A I D Grant No DHR 5544-G-00-0060-00

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Submitted to
The office of the Science Advisor, U S Agency for International Development

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Executive Summary

In the hilly parts of the Philippines, relatively small valleys are cultivated The yields obtained in such valleys can be significantly increased if water from neighboring hills can be diverted to the cultivated area The difference in elevation between the collecting areas and the field make it possible to utilize the water without using any pumping devices All that is needed is the construction of ditches that will lead the water to the field which will then be irrigated by flooding One objective of this project is to delineate efficient ways to maintain the ditches, preventing their erosion and their eventual clogging at the field end The other general objective of this project is to define simple procedures to seal storage ponds for the collected water at some height above the field , so that water can be used for irrigation a considerable time after rainfall Namely, when irrigation is most needed

In the first phase of the project it was determined in small scale runs that spraying ditches with oil refinery sludge prevents erosion and may limit weed growth in the ditches Further, it was shown that applying compacted sludge-soil mixtures to the bottom of water storage ponds reduces the rate of water loss by seepage by orders of magnitude as compared to the loss without treatment with the refinery sludge Since testing the use of the refinery sludge for maintenance of the water transport and storage network was the main objective of the project, the above results clear the way for larger scale on site tests which will finally culminate in full scale runs

In accordance with the original proposal, most of the work in the first phase of the project was done in Israel The Philippine partners were engaged in site selection for on-site studies and located potential sources of refinery sludge, samples of which were sent to Israel for analysis and tests

General

A Research Objectives

The overall objective of the work performed during the first phase of the research was to define, in small scale runs, the suitability of refinery sludges to serve as soil stabilizers and sealants The studges to be tested were two oil refinery sludges (Table 1) and a sludge from a lubrication oil reconstitution process which is characterized by a very low pH (<1)

Other inexpensive dispersants were checked both as reference sealing materials and as possible substitutes for the refinery sludges The sealants used were Na_2CO_3, sodium triphosphate and the commercial polyphosphate, Calgon

B Research Accomplishments

In the first phase of the project considerable time was devoted to the establishment of research procedures The experimental set-ups are detailed below In the latter part of this section the results obtained are presented

Permeameters were set at an outdoor site, each permeameter consisting of a soil column 60 cm in height and 30 cm in diameter A water application system which maintained a constant head was constructed The bottom of the soil columns rested on the local soil (a sandy loam) A schematic representation of the above-described permeameter is presented in Figure 1 The permeability as a function of time was recorded Smaller permeameters (5 cm i d) to which different heads (up to 25 psi) can be applied were also used to test the efficiency of the sludge as a sealant

Determination of the effect of the petroleum sludge on soil stability under the impact of rain drops was measured with the aid of a rain simulator Trays of soil treated with the petroleum sludge were exposed to rain in the rain simulator and on the basis of the preliminary results the following characteristics of the rain were selected for future tests Rain intensity 35 mm/hr, median water drop diameter 2 3 x 10^{3} m, median water drop velocity 6 7 m/sec, sum of kinetic energy of the water drops at a depth of 1 m over 1 m^2 22 9 kJoule The slopes of the trays filled with the treated soil were in the range of 5 to 33%

V shaped canal simulators (both a bench version and a 1 6 enlarged version) were constructed (Figure 2) This system enables the simulation of soil erosion along water channels as a function of water flow velocity and slope

In the Philippines, field scale application based on the finding of the work done in Israel, was performed at sites near Los Banos The sites are accessible to land transportation The

I Reduction of soil seepage

The objectives of of this part of the project were

1 To examine the efficiency of dispersive materials in sealing soil and soil-sand mixtures

2 Examination of the influence of drying - wetting cycles of the treated soil layers on their hydraulic permeability to water

Materials and Methods

Stage 1 - Column experiments

The laboratory experiments comprised measurements of the hydraulic permeability of soils and soil-sand mixtures which had been treated with dispersive materials Materials examined included loam soil from the Bilu site (containing about 3% clay), clayey loam soil (containing 15% clay) mixed with sand in 1 1 proportions, and mixtures of clayey alluvial soils (containing 50% clay) with sands in various proportions The soils were packed in plastic columns of 20-cm length and 5-cm diameter in a constant volume density of 1 35 g/cc Three dispersive materials which showed potential as sealants were examined in preliminary experiments 1 sodium carbonate, 2 sodium triphosphate, and 3 Calgon These materials were distributed in various proportions in the upper layer of soil in the column (3 cm) before it was saturated with water from the National Water Carrier (NWC) Saturation of the soil in the column was applied from below to prevent the trapping of air pockets in the soil, after saturation the flow was reversed so that its direction was from top to bottom The soil columns were connected to Mariot containers which enabled a constant head of water to be maintained at all stages of the experiment

The water which passed through the column was collected in the test tubes of a fractional collection apparatus, with each test tube collecting the volume of leachate released from the column at equal time intervals From knowledge of the head of water, the length of the soil sample, the diameter of the column and the volume of leachate which passed in unit time, it was possible to calculate the hydraulic conductivity of the soil, at saturation, for NWC water The hydraulic conductivity was also determined for soils without added dispersive materials (as controls)

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Stage 2 - Water infiltration experiments

The experiments were conducted with an infiltration gauge which comprised two components the first part was a reservoir containing the soil under test, which measured 60 and 28 cm in height and diameter, respectively, and the second part was a perspex pipe, 5 cm in diameter and about 1 m long, which served to measure the volume of water infiltrating in unit time, by means of a calibrated scale (the schematic structure of the infiltration gauge is presented in Fig 1) In the bottom of the infiltration gauge a layer of quartz sand was placed, on which was packed the soil under test The thickness of the soil layer was 20 cm after compaction to a volume density of about 1 5 g/cc The soils which were examined at this stage were the same soils which had been examined in the column experiments The dispersive material which was examined for sealing the soil was sodium carbonate, which had been found to be the most effective in reducing the hydraulic permeability in the column experiments

The variables which influence the water infiltrability of the tested soils were (a) the amount of dispersive material added per unit area (0, 0 5, 1 0 and 20 ton/ha), and (b) the manner of distribution of sodium carbonate spreading of the dry material on the soil surface, mixing into the upper soil layer to a depth of 1 cm and subsequently wetting the soil, or dissolving all the required quantity of sodium carbonate in water and spraying it on the dry soil surface

About 12 hours after the treatment with the dispersive material, water was added to the soil container so as to maintain a permanent head of water of about 10 cm above the soil surface On completion of the measurement, the soil was left exposed to the sun to dry and the influence of drying and wetting cycles on the water infiltration of the sodium carbonate-treated soil was examined

Results and discussion

Stage 1 - Column experiments

1 Sandy loam soil (Bilu)

The saturated hydraulic conductivity of this soil without dispersive materials, at the specified density was 348 mm/h (= 9 67x10^{3} cm/s) Such a hydraulic conductivity is very high and therefore, the infiltration rate under flooded conditions is high

The hydraulic conductivity of the soil was distinctly lower in the presence of sodium carbonate which had been added at a rate of 1 kg/m^{2} mixed into the surface After the passage of about 100 ml of NWC water (approximately equal to the pore volume), the hydraulic conductivity was reduced by four orders of magnitude to 3x10^{2} mm/h (less than 1x10^{6} cm/s) (Fig 3) A

similar result was obtained when the rate of sodium carbonate application was 0 5 kg/m^2 (Fig 3)

The hydraulic conductivity of the soil decreased in a similar manner when Calgon was present at a rate of 0 5 kg/m^2 The presence of sodium triphosphate also caused a decrease in the hydraulic conductivity, but at a lower rate and at a slower pace (Fig 3) We also examined the effect of a 1 1 (by weight) mixture of Calgon and sodium carbonate applied at a total rate of 1 kg/m^2 (Fig 3) The combination of these two dispersive materials was done in order to examine whether there was any complementary effect of the addition of Calgon (which adsorbs onto the outer surfaces of the minerals) and of the addition of sodium carbonate (which causes an increase in the electronegative charge of the pH dependend charge sites as a result of increase in pH and of sodium-calcium ion exchange) The results indicate that there is no advantage in the use of this mixture compared with the addition of sodium carbonate alone

2 Clayey loam

In this soil the clay content was about 15% The soil was mixed with sand from the Ashdod containment basin in a 1 1 ratio and the mixture was packed into a column The hydraulic conductivity of this mixture, without dispersive material (control) was 183 mm/h (5x10^{3} cm/s) The influence of the dispersive materials on the hydraulic conductivity of the mixture was examined The dependence of hydraulic conductivity at saturation on leachate volume is shown in Fig 9 Similarly to the findings in the case of sandy loam soil, here too there was a sharp diminution in the hydraulic conductivity The hydraulic conductivity in the presence of sodium carbonate at rates of 0 5 and 1 0 kg/m^2 decreased in both cases to 1x10^{2} mm/h (= 2 8x10^{7} cm/s) after the passage of about 50 mL (less than the pore volume) of tap water through the column Here also, the influence of sodium triphosphate was smaller than that of sodium carbonate

3 Clayey soil (Kfar Menachem)

The soil (50% clay) was mixed with sand from the Pi Gelilot containment basin at Ashdod in ratios of 2 1 and 4 1 The hydraulic permeability of these mixtures, as a function of the volume of leachate passing through the column in the presence of sodium carbonate or sodium triphosphate is presented in Figs 4 and 10 When the sand fraction in the mixture was 2/3 (Fig 4) the hydraulic permeability of the saturated soil without dispersive materials was 70 5 mm/h (1 96x10^{3} cm/s) The hydraulic permeability decreased appreciably (by about three orders of

magnitude) in the presence of the dispersants and after the passage of about 60 cc of tapwater through the column (less than the pore volume) The effect of sodium carbonate at a higher rate (1 kg/m^2) caused a steeper decline in hydraulic permeability than that in the soil which had been treated with sodium carbonate at a rate of 0 5 kg/m^2

The effect of sodium carbonate at a rate of 1 kg/m^2 on the hydraulic permeability at saturation was strong also when the sand fraction in the soil rose to 80% (Fig 10) The hydraulic permeability decreased from 159 mm/h (4 4x10^{3} cm/s) to 0 3 mm/h (8 3x10^{6} cm/s) after the passage of a volume of water equal to the pore volume In contrast to that, the effect of sodium carbonate on the hydraulic permeability of the mixture containing 80% sand was smaller when the sodium carbonate was distributed at a rate of 0 5 kg/m^2 The hydraulic permeability decreased only to about 2 mm/h (5 5x10^{5} cm/s)

Stage 2 - Water infiltration experiments

A Sandy loam soil (Bilu)

The infiltration capability of compacted sandy loam soil (Bilu) was 140 mm/h (Fig 5) under the measurement conditions described in Materials and Methods This infiltration rate was very high in spite of the relatively small head of water

The infiltration capability of the soil in the presence of sodium carbonate, distributed at a rate of 10 ton per hectar (mixed into the topmost 1-cm layer of soil) is also presented in Fig 5 This capability decreased at a steady rate of about 80 mm/h An increase of the rate of sodium carbonate application to 20 ton/ha greatly reduced the infiltration capability (Fig 11), which fell from 140 mm/h - in the absence of sodium carbonate - to 6 mm/h in its presence, during the first hour of flowing of tap water, and to a value lower than 1 mm/h after 40 h of flowing These results show that the distribution of sodium carbonate at a rate of 10 ton per ha on the surface of the soil is not uniform and that there are areas in which the application rate is too low, and that because of those areas the infiltration capability remains relatively high With increasing rate of sodium carbonate, there is a reduction in the area of the regions in which the sodium carbonate concentration is not sufficiently high Thus the reduction in the infiltration capability is significantly greater

The water infiltration capability was again examined after drying of the soil which had been treated with sodium carbonate (20 ton per ha) by exposure to the atmosphere The capability at the initiation of drying was lower than that of soil which had not been dried (by about 10 mm/h) and it diminished to below 1 mm/h during the second hour These results show that the

B Clayey loam soil

The infiltration rate of clayey loam soil under the conditions examined was 60 mm/h (Fig 14), a lower value than that obtained for sandy loam soil (Fig 5) When sodium carbonate was spread over the soil surface by spraying (10 ton/ha), there was a reduction in the infiltration rate by two orders of magnitude (Fig 14), and this state also prevailed after cycles of drying and wetting Thus, the influence of sodium carbonate on the infiltration rate of clayey loam is clear

C Clay soil (Kfar Menachem)

This soil contains about 50% clay and, therefore, its water infiltration capability is lower than that of loam soil The infiltration rate at the beginning of the process was 30 mm/h and within 3 h it had fallen to 9 mm/h (Fig 15)

Not only was the infiltration capability of the untreated soil much less than that of the loam soil, the influence upon it of sodium carbonate was less than that found for loam soil In the presence of sodium carbonate there was a diminution in the infiltration rate by one order of magnitude from the value found in the control The influence of the drying and wetting processes on the water infiltration capability of this soil was very small (Fig 15)

Conclusions

1 Dispersive materials such as sodium carbonate, sodium triphosphate and Calgon cause a significant reduction in the water infiltration capability of soil

2 These dispersive materials also reduce the water transport capability of soil when the clay content of the soil is low (below 10%)

3 Sodium carbonate was found to be the most effective material in reducing the hydraulic conductivity of the soil Its presence in the soil caused a change in the sign of the electric charge on the broken edges of the clay and, therefore, in the oxidation states of iron and aluminum, together with the increase in the percentage of adsorbed sodium These two changes intensify the degree of dispersion of the clay and therefore facilitate the movement of some of the clay particles to the depth of the profile where they cause plugging and a reduction in the hydraulic conductivity

4 Sodium carbonate was found to be the most effective material in reducing the infiltration capability of loam soils to water from the National Water Carrier and the clay content

(in the 3-15% range) has only a small effect on the effectiveness of this dispersant in reducing this capability

5 Spraying a sodium carbonate solution on the soil surface was found to be the best method for reducing the water infiltration capability of the soil It appears that spraying produces a more uniform distribution of the dispersant than the dry distribution method

6 The reduction in water infiltration capability of the soil by means of sodium carbonate persists, even after several cycles of drying and wetting

Field Experiments

These experiments were based on the results of the laboratory experiments

The field experiments were carried out only in the Pi Gelilot site The size of the containment basin section was 25 m^2 (5 m x 5 m), and within it the influence of sodium carbonate on water infiltration was examined The boundaries of the section were separated from the remaining area by a metal frame The sodium carbonate application rates were

(1) Control - no sodium carbonate,

(2) 10 ton per hectar (powder),

(3) 10 ton per hectar (solution),

(4) 20 ton per hectar (powder)

The concentration of sodium carbonate in the solution (treatment no 3) was 1 kg in 3 L

Infiltration measurements were performed by following the falling liquid level method (Fig 1)

II Use of sodium carbonate for soil sealing

Introduction

The working hyphothesis which was examined in this experiment was that it is possible to reduce the hydraulic permeability of a soil which has a clay content, even a low one, through the use of sodium carbonate After the successful conclusion of the reduced-scale laboratory experiments which showed that the use of sodium carbonate is most effective in soil sealing, seepage experiments were carried out in two basins with a loam soil (4x4 m at the bottom) and 2 similar basins with a sandy soil In the following, the sealing experiments in these basins are described

Description of experiments

The bottom and walls of one of each pair of basins were covered with sheets of polyethylene while only the walls of the second were covered with such sheets The bottom of both basins were sprayed with sodium carbonate solution at a concentration of 20%, using a quantity equivalent to a rate of 20 ton of sodium carbonate per ha As part of the sealing treatment the basins were flooded to a height of about 40 cm A month after this, the basins were flooded again to a similar height and the rate of loss of water was monitored

Results and discussion

a Loam soil The rate of seepage in both containment basins in the course of time is summarized in Table 2 and Fig 16 The seepage rate was smaller than the rate indicated by these data, because it included evaporation, which in the season during which the experiment was conducted, was greater than 0 5 cm per day

b Sandy soil The water level (corrected for evaporation1) in both basins, and its variation with time in both wetting cycles are presented in Table 3 In the first wetting cycle the rate of seepage from the control well was very fast and the water level fell from 40 cm to 9 cm within 22 hours In contrast to that, the seepage rate in the treated well was slow, and the fall was only 7 cm in the same period of time (from 40 to 33 cm) The low infiltration capability of the sodium carbonate-treated soil persisted after the complete drying of the soil surface More than that the sealing capability even improved in comparison with the first wetting cycle While the

control well emptied of water after about 30 hours from the time of filling, the water level in the sodium carbonate-treated well fell by only about 1 cm (a fall from 35 to 34 cm) in the same period of time The height of the water surface above the soil in the sodium carbonate-treated well fell by about 4 cm in 190 hours (about 8 days)

The field experiments demonstrated the effectiveness of Na_2CO_3 as a sealant material, thus corroborating the laboratory results

III Refinery sludge as a soils sealant and stabilizer

a Laboratory experiments- sealing

The efficiency of refinery sludge A (Table 1) as a sealant was tested in detail The sludge was mixed with various soils or related media, namely, quartz sand, sandy soil (6% clay), low grade bentonite and low grade kaolinite The mixtures were compacted by applying to them pressures of 0, 3, and 5 kg/cm^2 The effect of exposure of the mixture to wetting and drying was tested by drying the mixtures at 35°C for various periods up to 60 days In the mixture of the sludge with the sand and sandy soil at 10-40% sludge content, no cracks were formed The higher the applied pressure before the drying process began, the higher the sludge content that could be added without crack formation The pure sludge or mixtures with sludge content over 40% cracked upon drying Bentonite addition increased the tendency of the mixtures to crack, but up to 10% kaolinite could be added without affecting cracks formation The fraction of kaolinite in the mixtures which did not cause cracking increased with the pressure applied before drying

The sludge adsorbed strongly to soils Up to 20% W/W sludge in the sandy soil and even larger fractions in heavier soils were irreversibly adsorbed

The sludge forms an emulsion with water, so that it could be brought to viscosity levels (around 1000 centistokes) which enabled its application by spraying The viscosity was, however, a strong function of the temperature, being at 22°C, 50% lower than at 18°C this fact can be utilized in the design of effective and convenient application procedures for the sludge

When the sludge-soil mixtures were kept at field capacity or at higher moisture contents, the sealing effectiveness of the sludge was not reduced at all after 6 weeks of incubation

As stated above, when the treated soil was exposed to drying, craking of the treated layer took place at sufficiently high sludge or clay contents Adding calcium containing additives such as gypsum at rates of 0 2-0 6 kg/m^2 to the sludge treated area often prevented the cracking

Criteria for evaluating the sealant were defined (Table 4) and the various systems studied were evaluated according to these criteria

The results obtained with the small (5 cm i d) permeameters are summarized in Table 5 The data indicate that the rate of penetration of water is inversely related to the amount of sludge

added per unit area The actual amount of sludge to be added is thus a function of the required degree of sealing

It was shown that if necessary, sealing can be improved without increasing the sludge content by adding to the sealing layer a non-expanding clay, such as kaolinite at a rate of 0 2-0 4 kg/m^2

b Laboratory and small scale runs- soil stabilizing

The efficiency of refinery sludge A as a stabilizer in the maintenance of the water conveyance systems was tested in small scale runs The sludge was shown to be very effective in stabilizing slopes against erosion and in addition, it reduced vegetation growth, an advantage in the maintenance of the water conveyance ditches

A quick test for the initial screening of systems according to their stabilization efficiency was developed soil samples were placed in petri dishes and sprayed at different rates with the refinery sludge The dishes were put at a 50% incline in a shaker filled with water to half the height of the plates The shaker was operated at 70 cycles per minute for 24 hours The test was repeated after the plates were incubated at 35°C for 11 days In unsuccessful treatments, the soil in the dish collapsed The minimum loads of refinery sludge A which passed the above test in different soils are summarized in Table 6 Untreated reference soils collapsed within 5 minutes of shaking

A long term test of the effect of sludge addition was run as follows Trays measuring 20x50 cm were filled with soil (Bet Dagan red-brown sand, dune sand mixed with Heletz limestone, Gilat loess, or gromosol from Sedeh Yoav) The soils in the trays were sprayed with sludge A in a quantity equivalent to 20 ton per ha and placed in a trough at a 1 3 slope The trays were immersed to their mid-height in water After 10 months the trough was drained and the trays were left in the dry trough Trays which were filled with soil which had not been sprayed received a similar treatment, and served as controls

From visual observation, it appeared that there had been improvement in the structure of the soil which had been treated with sludge A, in comparison with the non-treated soils This was indicated by the lower sensitivity of the treated soils to erosion

Rain simulator tests were conducted using a nozzle type simulator capable of generating rainfall with a high kinetic energy (22 9 kJ m^3) as previously described by Morin and Benyamini (Morin, J , and Y Benyamini 1977 Rainfall infiltration into bare soils Water Resources Research 13 813-817) The rainfall simulated had the following properties median

drop diameter- 2 3 mm, median drop velocity- 6 74 m s^{1}, rainfall intensity- 10 4 μm s^{1} The trays' dimensions were 30X50 cm and 4 replicates were run simultaneously Soil aggregates (<4 mm) were packed in the tray in a 2 cm thick layer over a layer of coarse sand The trays were placed in the rain simulator at a 10-33% slopes and the soil in them was then saturated with tap water from below and finally exposed to simulated rainfall consisting of deionized water

The rain simulator tests showed that the sludge-treated soils (a dune sand, a sandy soil and a loessial soil) did not erode under the influence of 4 hours of rain even at a 33% slope The above results were obtained when sludge was added to the soil at a range of 2 kg/m^2 The stability of the soil was kept even after the soil underwent eight cycles of drying for seven days and then rewetting

The effect of the sludge on plant growth was tested by observing the emergence of wheat and oat seedlings through a sludge treated silty sand layer The tests were conducted in petri dishes Emergence in the treated soil was reduced as compared to untreated soil The reduction in emergence was directly proportional to the rate of sludge application Yet, although sludge application is likely to reduce vegetation, the observed reduction in emergence was not sufficient to make the application of sludges effective enough to serve as a sole vegetative growth prevention procedure

The canal simulators were also used for testing stability As a reference, polymers such as polyacrylamide (PAM), which are well known soil stabilizers, were also tested (e g , Fig 17 and Table 7)

c Influence on vegetation

One of the most promising uses of refinery sludges is the stabilization of slopes and unstable soils for periods up to 2 years to facilitate the establishment of natural or other plants Therefore, the effect of the sludge and similar materials on existing plant cover and flowering capability was examined It was found that in all the plants which were examined (lettuce of cv Miriam and various wild plants) the existing cover was severely injured by spraying directly onto it In contrast, no signs of injury to the existing plant cover were noticed as a result of spraying onto the soil surface and not directly onto the canopy itself

Spraying Sludge A did not prevent emerging but did reduce it There was a reduction in the density of the plants' stand and this reduction progressively increased as the quantity of

sprayed material increased The reduction in the rate of emergence was greater in oats and chrysanthemums than in barley and lettuce

In spite of the reduction in emergence of certain plants, it is possible, through the correct choice of the vegetation and of the spraying technology, to stabilize even steep slopes and at the same time to maintain healthy emergence of plants Observations on red-brown sand soil indicated that erosion of seeds from slopes was reduced in the presence of Sludge A, enabling the plants to establish themselves In contrast, in the unsprayed control plot the soil surface was completely bare due to of erosion of the wheat seeds which were broadcast on it

d Field observation

d 1 Brown-red sand soil Observations were carried out at the Bet Dagan site, on a 1 3 5 slope The soil was light in the upper horizon, while at lower depths there were clayey lenses Plots of 9-sq m area were sprayed with sludge A as follows one plot was sprayed with 20 ton/ha and another plot with 20 ton/ha of a suspension of 50% sludge A in water, i e , 10 ton/ha of sludge, but only on the upper half of the plot, the lower half was not sprayed at all An unsprayed control plot was also designated After 270 mm of rain, a distinct difference was observed in the behavior of the various plots There remained a relatively uniform crust of sludge A on the surface of the plot which had been sprayed with 20 ton/ha There were no signs of erosion The emergence of the natural vegetation was restricted In the plot of which the upper half had been sprayed with 10 ton of sludge A per ha there was no uniform layer of sludge but there were aggregates of soil, coated with sludge A, in the upper half of the plot In the upper half of this plot erosion was relatively slight compared with the control plot or the unsprayed part of this plot The plant emergence and growth in the upper (sprayed) half of this plot were better than in the plot which had been sprayed with 20 ton/ha In the control plot there were rills in the soil and layered erosion from the upper half which accumulated at the bottom of the slope The eroded material was rich in the sandy fraction of the upper horizon of the soil and caused the exposure of the clayey lenses in which rills were observed As mentioned above, these effects were not observed at all in the plot which had been sprayed with 20 ton/ha, and only slightly in the upper half which had been sprayed with 10 ton/ha The layer erosion of the sandy fraction in the control plot and its absence from the treated plots confirm the potential of the sludge A treatment for preventing erosion from sandy slopes

As a result of the erosion described above, the upper half of the control plot was left bare, while a very dense stand developed in the lower half In comparison, the distribution of plant growth in the treated plots was uniform

d 2 Experiments on loess soil Experiments were carried out on a larger scale in two sites one near Kibbutz Lahav and the second near Ma'agar Sansanna The soil in both sites was loess, namely, soil lacking structure and rich in silt The setup of the experimental sites are described in Figs 18 and 19 The slope in the Lahav site was 1 3 5 and that in the Ma'agar Sansanna site was 1 3/4 The sites were exposed to one storm which was measured at Ma'agar Sansanna (30 mm in 1 day) and to a further brief storm (about 5 minutes at an intensity of 38 mm/h measured in the Ma'agar Sansanna site) Although the rainfall in this very warm year was not sufficient to cause appreciable erosion even in the control plots, it was possible to draw rational conclusions from the condition of the plots 10 weeks after spraying and after the rainfalls mentioned above

At that time, the Lahav site was covered with vegetation which comprised mainly aftergrowth of barley, oats and other plants, at a relatively low density Vegetation was observed both in the treated plots and in the control plot The most abundant vegetation was in the control plot The density of vegetation decreased as the amount of sludge added increased It should be emphasized that the stand in the plots which had been sprayed with sludge was uniform, while in the control plot, the vegetation was concentrated in well-defined depressions along the slope In the plot which had been sprayed with less than 10 ton/ha, there was a concentration of growth along depressions resembling those in the control plot, but the intensity of the phenomenon was much less than in the control plot

In the Sansanna site there was no vegetation at all in either the treated plots or the control plot On the other hand, there were differences in the structure of the upper layer of the soil Whereas the soil surface in the control plot was covered with a well developed crust, in the treated plots aggregates formation was observed which became more pronounced as the amount of sludge added increased Thus, whereas the influence on the structure in the plot which had been sprayed with 10 ton/ha appeared to be minimal, there was an appreciable influence in the plots which had been sprayed with 15 or 20 ton/ha Erosion damage was continued to be monitored on loess soil slopes at Lahav and Sansanna, which had been sprayed with sludge A for a number of seasons In the second year there were again no significant rainstorms in the area, but even after the limited amounts of rain which did fall, differences were clearly discernible between the stabilized plots and the controls This was especially conspicuous on the Sansanna plot, which had the steeper slope

Whereas in the Sansanna site there had not been any vegetation in either the experimental plot or the control plot, in the case of the Lahav plot (which had a more moderate slope), there was

a mixture of barley and wild plants, with no noticeable difference in vegetation between the control and the treated plots In the Bet Dagan site (brown-red sand - slope 1 4), a significant difference in erosion between the treated and the control plots was seen, even three seasons after the stabilization treatment

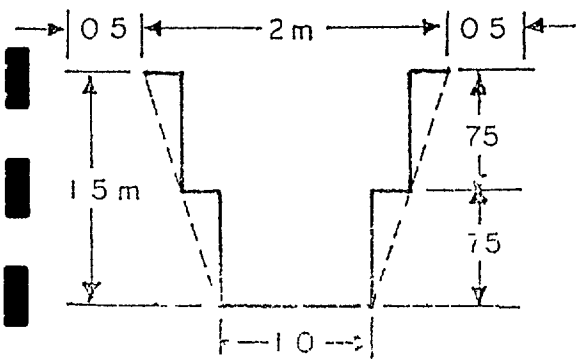
CONCLUSIONS

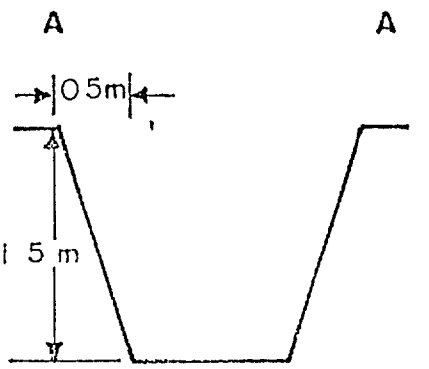
1 There is no doubt that refineries sludge stabilizes slopes which are treated with it, against erosion Although the durability of the treatment was not determined, there is no doubt that it is effective for years

2 The sealing capability of refinery sludge was proven in laboratory experiments In sites subject to drying and wetting processes, other sealing methods (such as Na_2CO_3 application) seems preferable In sites in which wetting is permanent, using refinery sludge as a sealant is an effective, low cost procedure

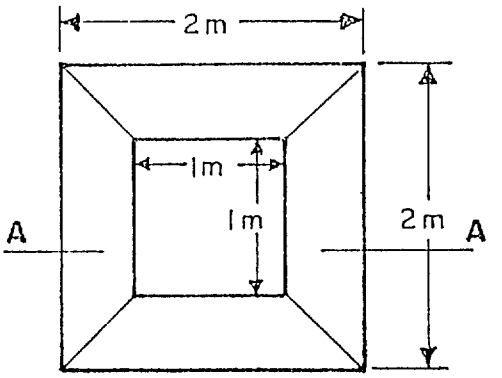
Note In order not to postpone any further the submission of this report, we attach the results of the Philippines group in graph form only and will submit the text as soon as it arrives from the Philippines

Graphical presentation of the results of work performed in the Philippines





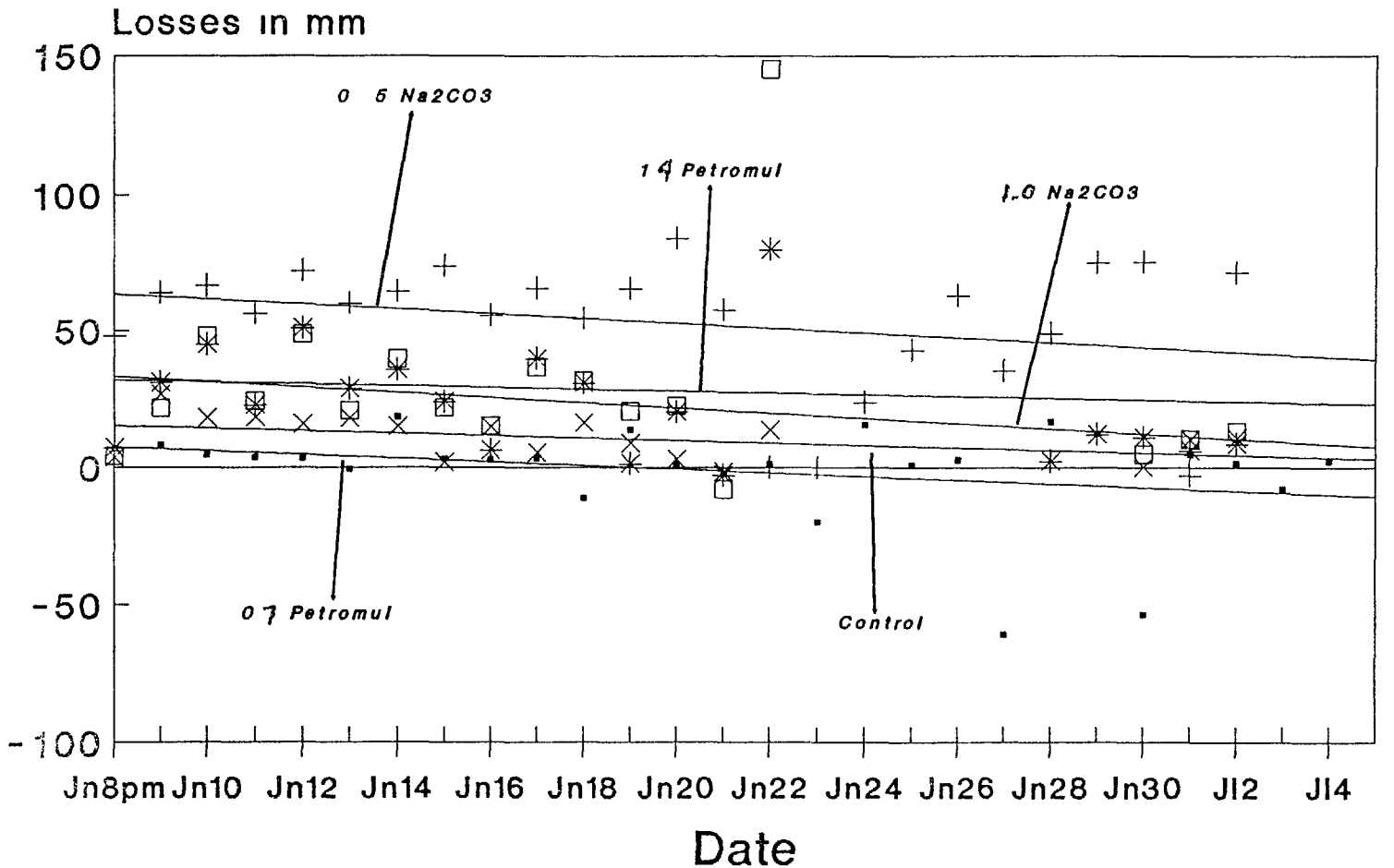
SECTION



PLAN

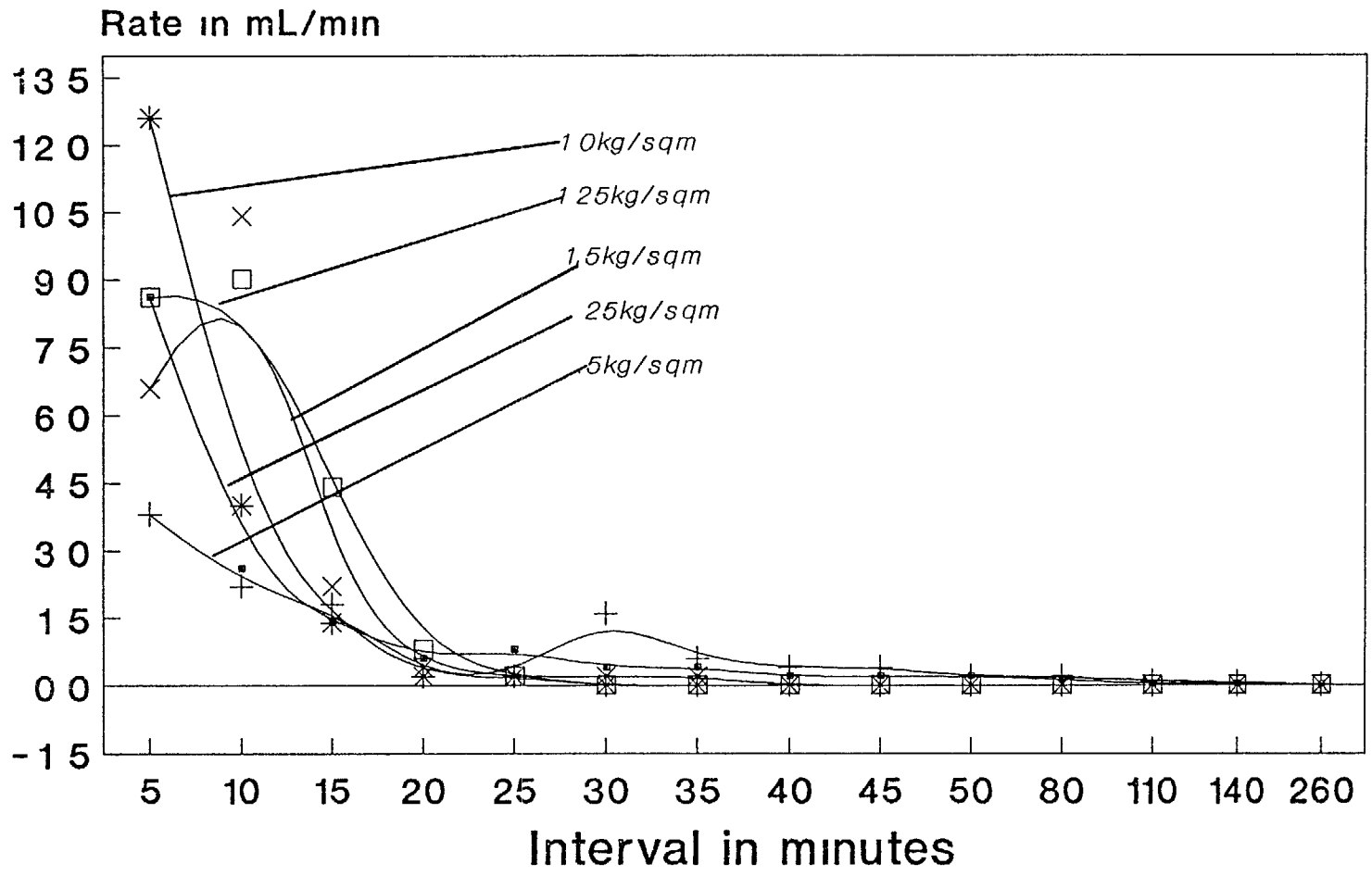
DESIGN OF POND
Scale 1.50 mts

Percolation & Seepage Losses in Guadalupe Clay Soil]



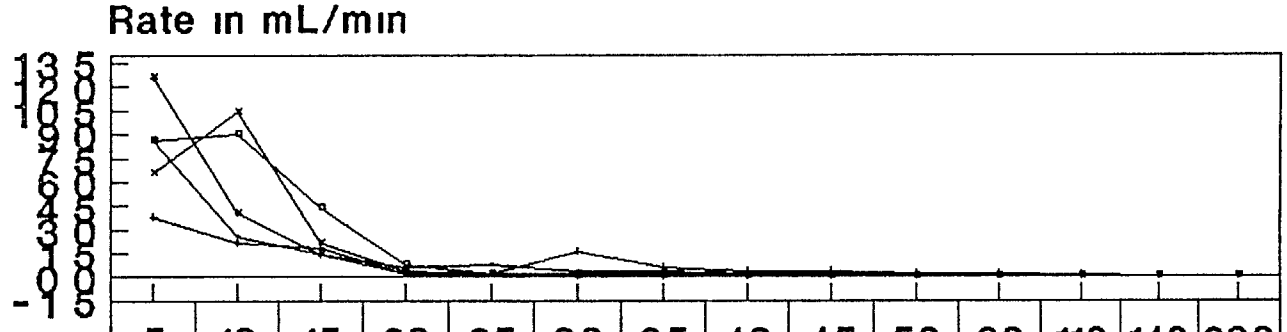
Na2CO3 is in kg/sqm Petromul is l/sqm
Rainfall & Evaporation are not evaluated

Fig.1 Percolation Losses at Different Levels of Sodium Carbonates



Data taken in the morning of 18 May 1994
a day after spraying

Fig.1-b Percolation Losses at Different Levels of Sodium Carbonates



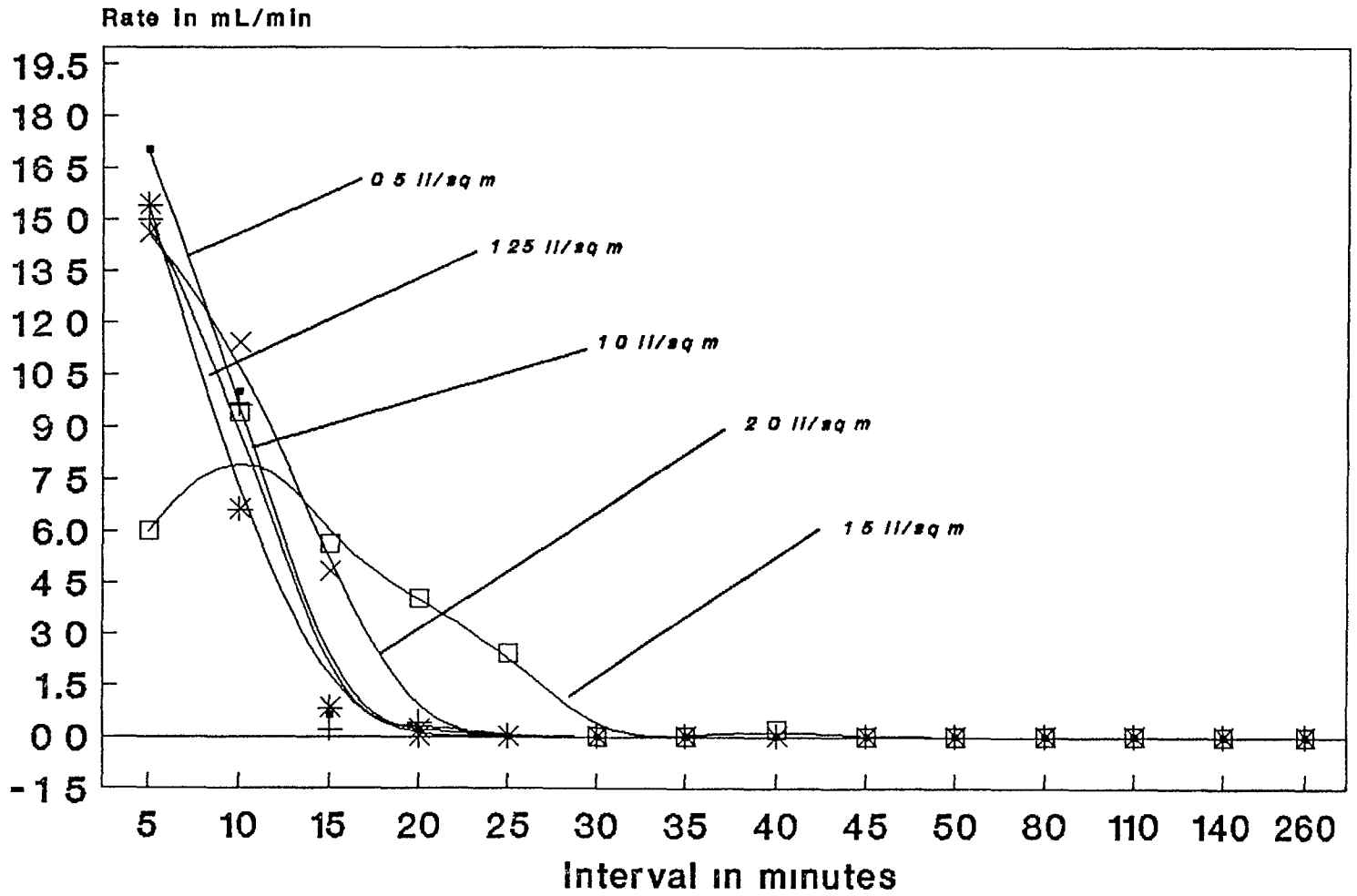
	5	10	15	20	25	30	35	40	45	50	80	110	140	260
0 25 kg/sq m	8 6	2.6	1 4	0 6	0 8	0 4	0 4	0.2	0 2	0 2	0 1	0 0	0 0	0 0
0 50 kg/sq m	3 8	2 2	1 8	0 2	0.2	1.6	0 6	0 4	0 4	0 2	0 2	0 1	0 1	0 0
1 00 kg/sq m.	12 6	4 0	1 4	0.2	0 2	0.0	0 0	0 0	0.0	0 0	0 0	0.0	0 0	0 0
1 25 kg/sq m	8 6	9.0	4.4	0 8	0 2	0 0	0 0	0 0	0.0	0 0	0.0	0.0	0.0	0.0
1 50 kg/sq m	6 6	10 4	2.2	0 4	0 2	0 2	0 2	0 0	0 0	0 0	0 0	0 0	0 0	0 0

Interval in minutes

0 25 kg/sq m — 0 50 kg/sq m — 1 00 kg/sq m — 1.25 kg/sq m — 1 50 kg/sq m

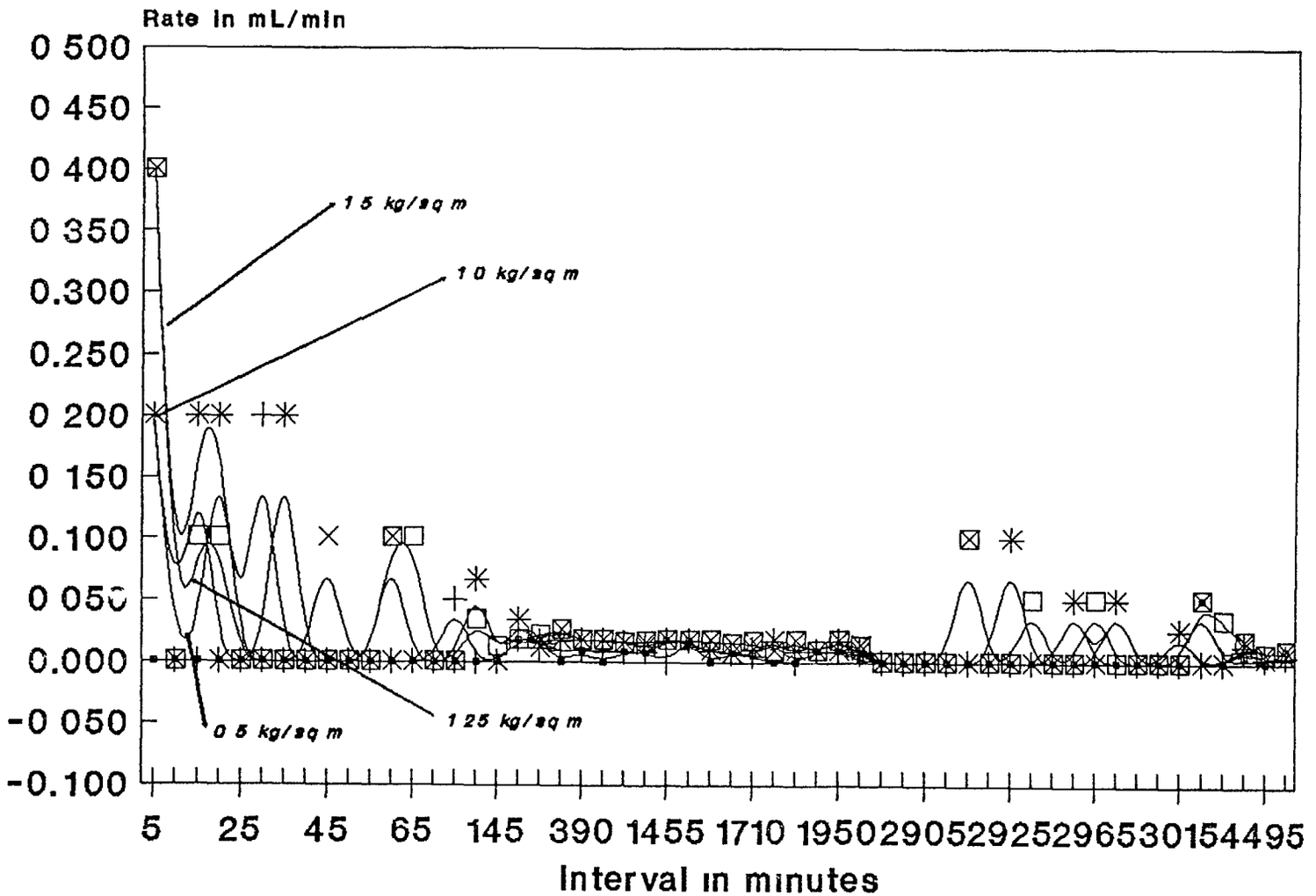
Data taken on the morning of 18 May

Fig.2 Percolation Losses at Different Levels of Petromul CSS-1



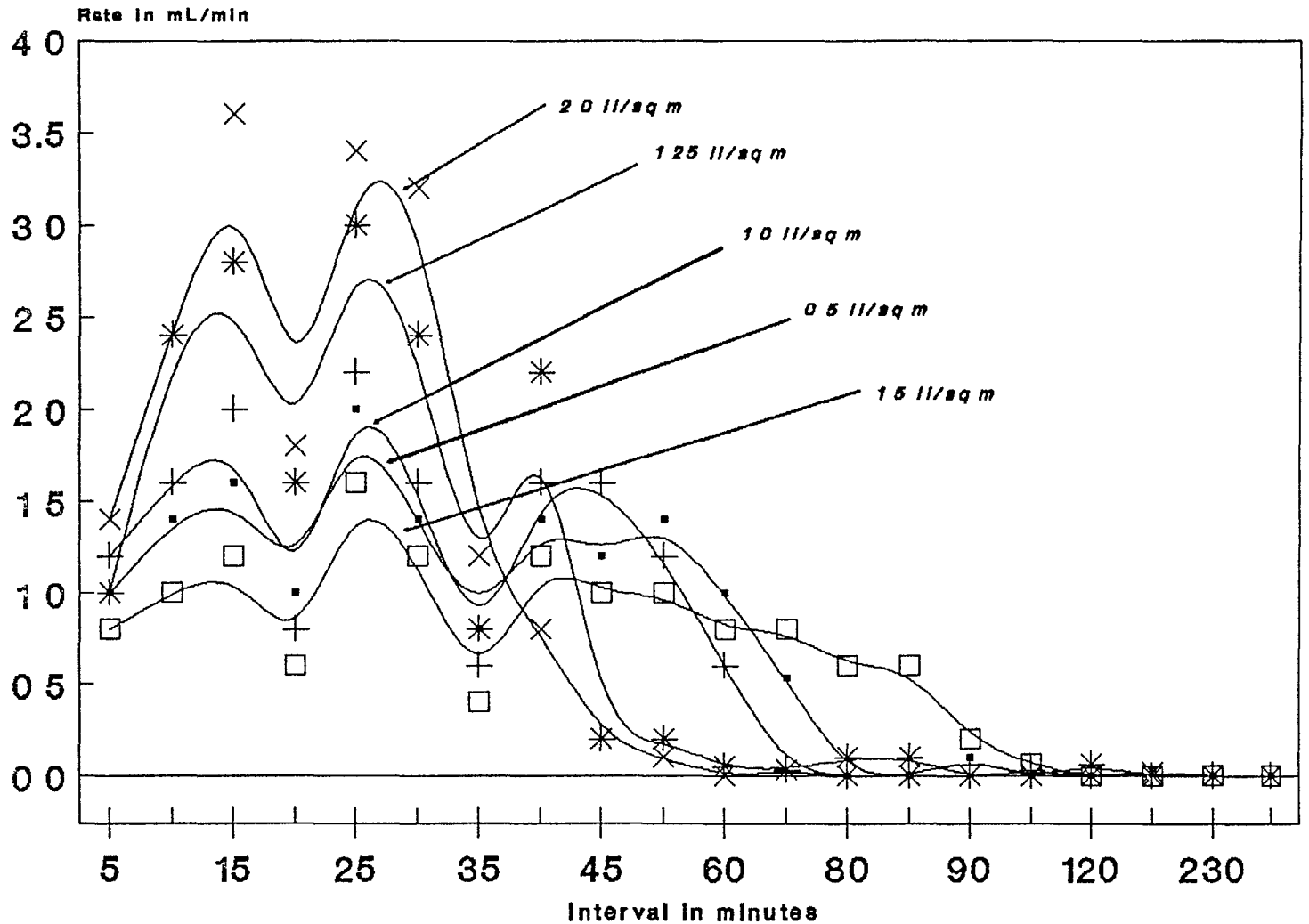
Data taken in the morning of 18 May 1994
a day after spraying 200 ml of water
was applied

Fig.7 Percolation Losses at Different Levels of Sodium Carbonates



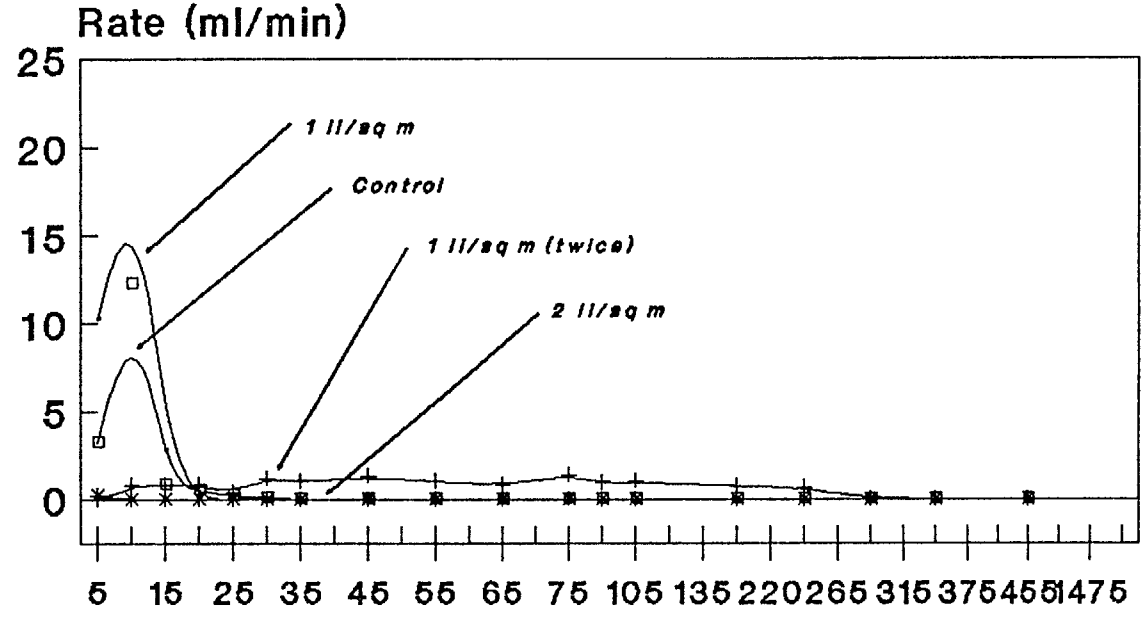
Data taken on May 23, 24 & 25

Fig 10 Percolation Losses at Different Levels of Petromul CSS-1



Data taken on 24 May 1994

31 Fig. Percolation Losses On Soil-Petromul Medium on 08 June'94

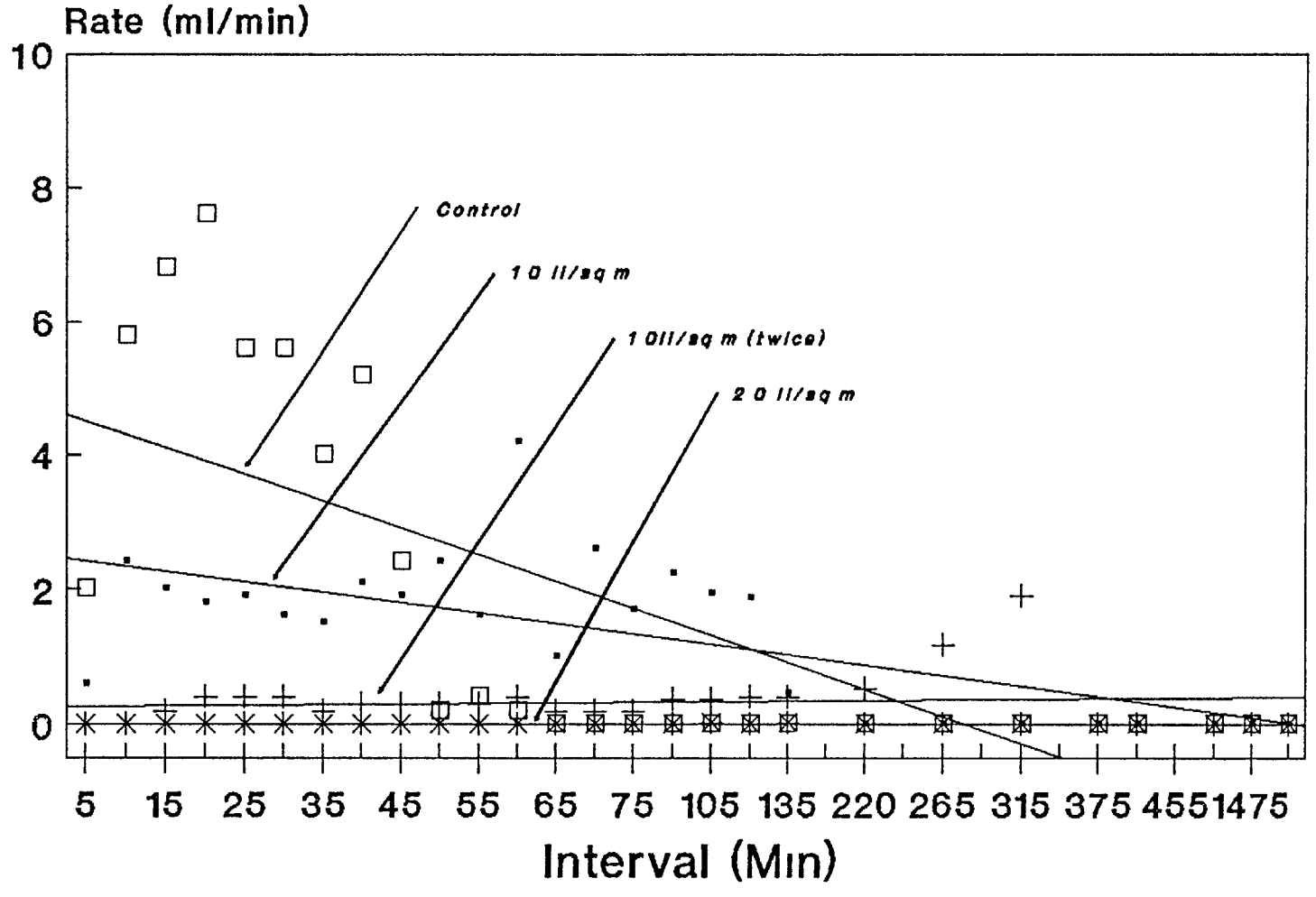


1l/sqm	10	22	8	0	0	0.05	0	0	0 05	0	0
1l/sqm(twice)	0	0.8	0.4	1	1	3	1	0 8	1 4	1	0
2l/sqm	0.2	0	0	0	0	0	0	0	0	0	0.036
Control	3.2	0 8	0 2	0	0	0	0	0	0	0	0

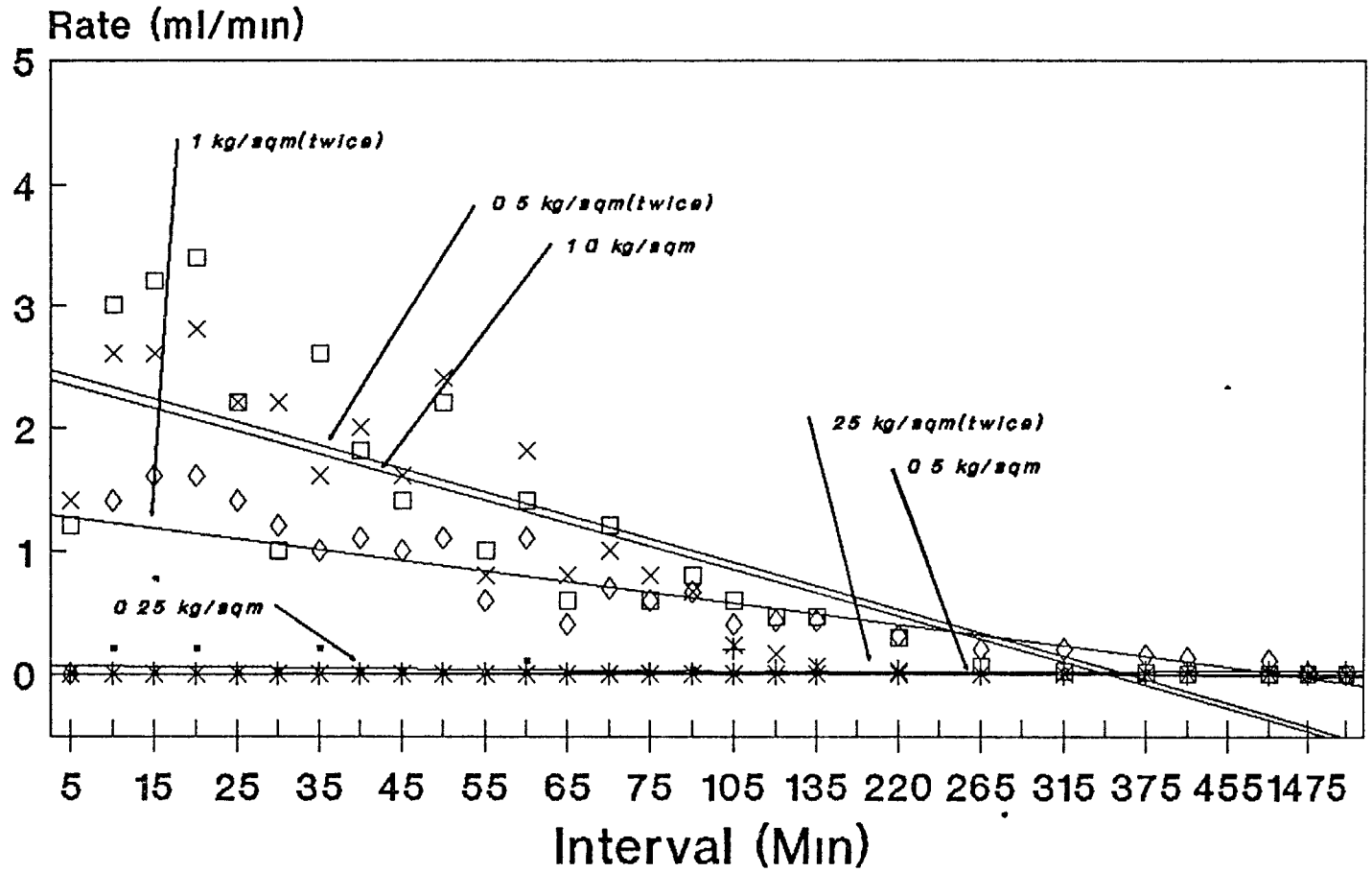
Interval (Min)

Twice means that the soil was sprayed
two times Interval is 24 hours

32 Fig.32 Percolation Losses On Soil-Petromul Medium Beginning on 09 June'94



33 Fig. 33 Percolation Losses On Soil-Sodium Carbonate Medium Beginning 09 June'94



Twice means sprayed two times, one after the other on a day interval

TABLES

Table 1 **Characteristics of the refinery sludges used**

Source	*sludge A - Haifa refinery*	*Caltex refinery*
Property	*Israel (ave 5 samples)*	*Philippines*
Water content (%W)	43	traces
Asphaltenes cont (%W)	8	0 86
Ash cont (%W)	12	0 37
Total S (%W in oil fraction)	2 7	1 72
Cl cont (%W in ash)	0 3	0 9
Na cont (")	n d	0 4
Mg (")	5 1	1 4
Al (")	n d	11 5
Si (")	21 3	31 9
S (")	3 7	0 16
K (")	n d	0 2
Ca (")	13 3	0 2
Ti (")	n d	0 46
U (")	0 02	0 1
Fe (")	8 1	2 3
pH (ash suspension)	7 1	6 4
pH (water extract)	7 0	6 8

Table 2 Rate of water loss from the containment basins (Ashdod terminal)

basin 2 without lining		basin 1 with lininig	
Head (cm)	time (h)	Head(cm)	Time (h)
23 05 93		23 05 93	
44 0	0 45	50 0	1 04
43 0	1 05	49 0	1 50
41 0	1 35	49 0	2 05
40 0	2 05	48 5	2 35
35 0	4 00	48 0	3 05
30 0	9 00	48 0	5 00
23 0	22 30	47 0	10 00
		43 5	23 30
24 05 93		43 5	24 30
40 0	23 30	43 5	25 00
39 0	24 00	43 0	29 00
35 0	28 00	42 5	34 30
32 5	33 30	42 0	46 00
25 0	45 00	38 0	94 00
16 0	93 00	36 0	104 00
14 0	103 00	36 0	123 00
13 0	122 00	32 0	172 00
11 0	171 00		
22 06 93			
40 0	0 00		
35 0	3 00		
31 0	8 00		
24 0	20 00		
20 0	32 00		
17 0	44 00		
16 0	45 30		
24 06 93			
38 0	47 30		
36 0	49 30		
29 0	57 00		
24 0	68 00		
20 0	75 00		
16 0	116 00		

Table 3 Change with time of the water level (corrected for evaporation) in the basin following two wetting cycles

Height of water surface, cm*		Time	Cycle no
Sodium carbonate treated	Control	(hrs)	
40	40	0	1
40	35	2 5	
39	29	6 5	
33	9	22	
35	46	0	2
35	37 5	4 5	
34	15	19 5	
34	9	24 5	
34	0	43 5	
32	0	67 5	
32	0	91 5	
32	0	115 5	
31	0	139 5	
31	0	163 5	
31	0	190 5	

* The accuracy of measurement was ± 0 5 cm

Table 4 **Quality criteria for sealing procedures**

1 Use criteria

1 1 Soil Types

1 2 Water quality

1 3 Storage condition (alternate wetting and drying or continuous wetting)

1 4 Maximum water stand

1 5 Water uses

2 Efficiency criteria

2 1 Sealing efficiency

2 2 Efficient life time

2 3 Homogeneity

2 4 Set-up technology

2 5 Reliability

2 6 Protection required

3 Limitations

3 1 Air contact

3 2 Exposure to U V irradiation

3 3 Large animal damage

3 4 Rodents damage

3 5 Insects damage

3 6 Mechanical equipment damage

3 7 Plant damage

3 8 Effects on water quality Toxicity to plants, toxicity to animals and humans and transmission of objectionable taste or smell to water

3 9 Ease of maintenance

3 10 Damage by water flow

4 Cost criteria

4 1 Cost of sealant

4 2 Transportation cost

4 3 Application cost

4 4 Cost of protection (if needed)

4 5 Amount of sealant per unit area

Table 5 **Sealing efficiency ahieved with Haifa refinery sludge (sludge A) in various soils[1]**

Soil	*Type and quantity of sealing mixture needed to achieve 0 3mm/day flow rate for 1m water stand[2] (Kg/1000m²)*	*Comments*
Loess (Gilat)	2000	No compaction Drying effect not determined
Loess (Gilat)	1600 + 400 gypsum[3]	Compaction - 25 ton/m² Sealing ability maintained after drying at 25°C, with slight recompaction
Loess (Gilat)	2000 + 300 gypsum + 250 Kaolinite + 240 bentonite	Compaction - 20 ton/m² Sealing ability not maintained after drying at 25°C
Loess (Gilat)	1600 + 600 gypsum	Compaction - 14 ton/m² Drying did not affect sealing
Sand (Mivtahim)	1500 + 240 gypsum + 200 kaolinite + 170 bentonite	Compaction - 20 ton/,m² Drying at 50°C did not reduce sealing, with sllight recompaction
Sand (Mivtahim)	3000 + 900 kaolinite	Compaction - 25 ton/m² Sealing lost after drying at 50°C
Sand (Mivtahim)	3000 + 450 kaolinite + 450 gypsum	Compaction - 25 ton/m² Effect of drying not determined
Sand (Mivtahim)	3000 + 1200 gypsum	Compaction - 15 ton/m² sealing ability reduced after drying

1 Measurements made in cells of 20 cm² surface area All measurements were made under 15 m water stand

2 All sealing mixtures were spread by pouring The rate of flow was inversely proportional to the amount of sealing material added When higher flow rates are acceptable, the amounts of sealing material added per unit area will be proportionately lower

3 The gypsum used was a by product of the phosphate industry and hence inexpensive

Table 6—— The minimum amounts of Haifa refinery (sludge A) proven effective in stabilizing soils against wave damage

Soil	Minimum amount (ton/1000m^2)
Sand (Mivtahim)	1 0
Sand (Hamra)	1 0
Loess (Gilat)	1 5
Clay (Sde Yoav)	1 5

Figure 7 Soil (sandy loam) erosion as measured in a canal simulator in the presence and absence of polyelectrolites

Distance cm	Soil erosion, g		
	Control [1]	PAM (50 %) [2]	P 101 (12 %) [3]
0	275 2	130 5	0 4
10	239 5	96 3	0 5
20	259 8	73 8	0 3
30	228 8	45 0	0 5
40	231 9	33 3	0 4
50	89 2	13 5	0 2
60	40 5	3 2	0 3
70	26 1	2 3	0 1
80	15 5	1 4	0 0
90	11 6	1 6	
100	7 8	1 1	
110	6 5	1 4	
120	5 5	1 2	
130	4 0	0 9	
140	3 6	1 1	
150	3 4	1 0	
160	2 7	0 8	
170	2 5	0 9	
180	2 1	1 0	

polymer	100 Kg/ha (3% in 2 portions)
canal length	1 5 m
height	9 cm (1 1)
cross sect	8 1x10^{3} m^{2}
flow rate	3 m^{3}/h
flow speed	10 cm/s

1) Water volume 2 m3/h
2) Water volume 9 m3/h
3) Water volume 12 m3/h

FIGURES

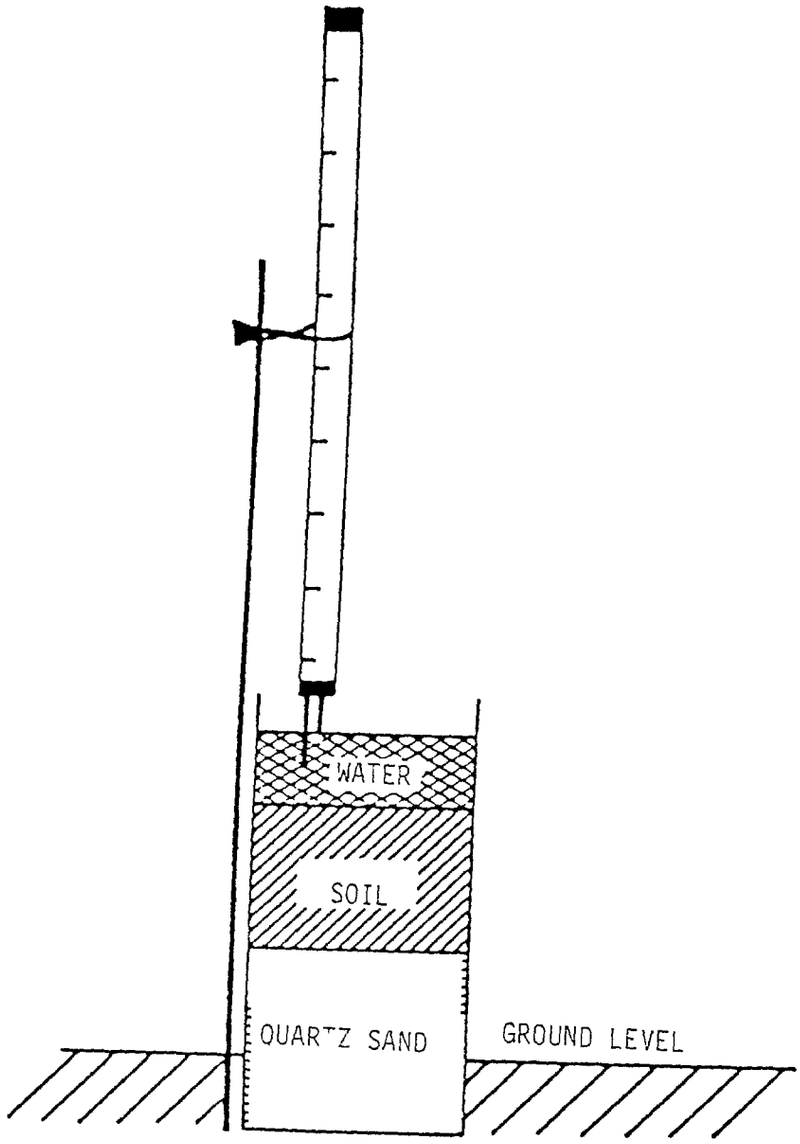


Figure 1 Schematic diagram of the permeameter

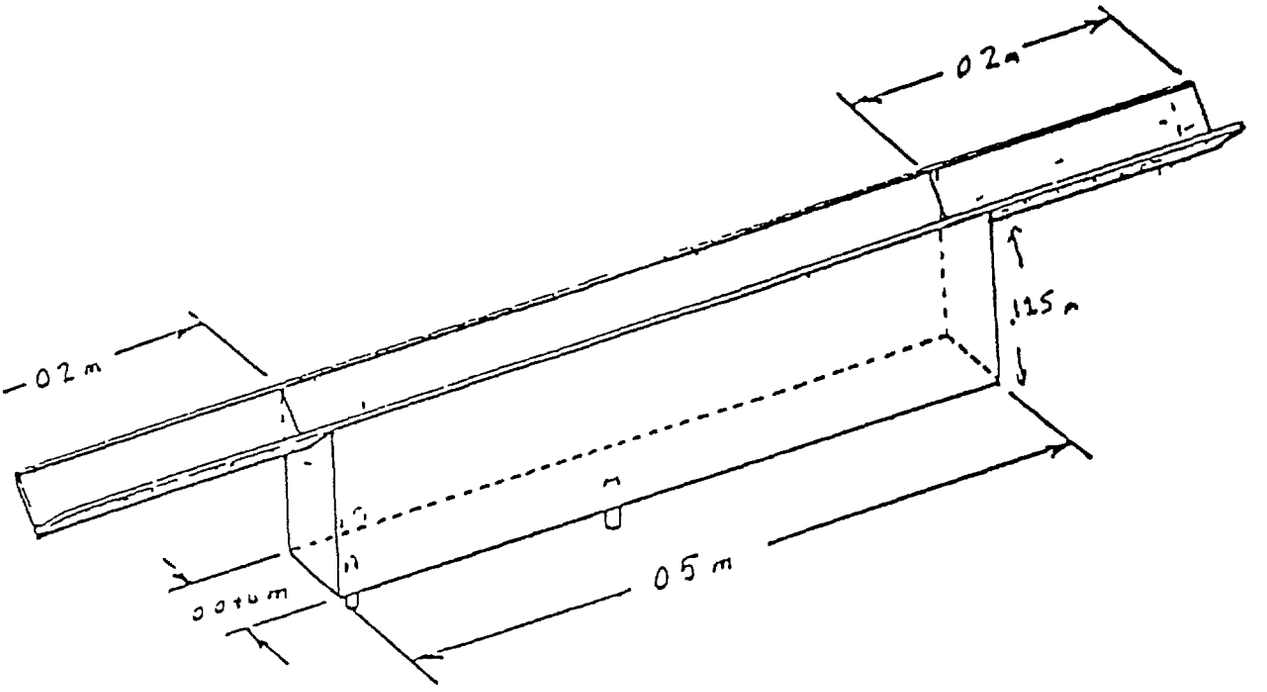


Figure 2 _ Diagram of the Cannel simulator (bench version)

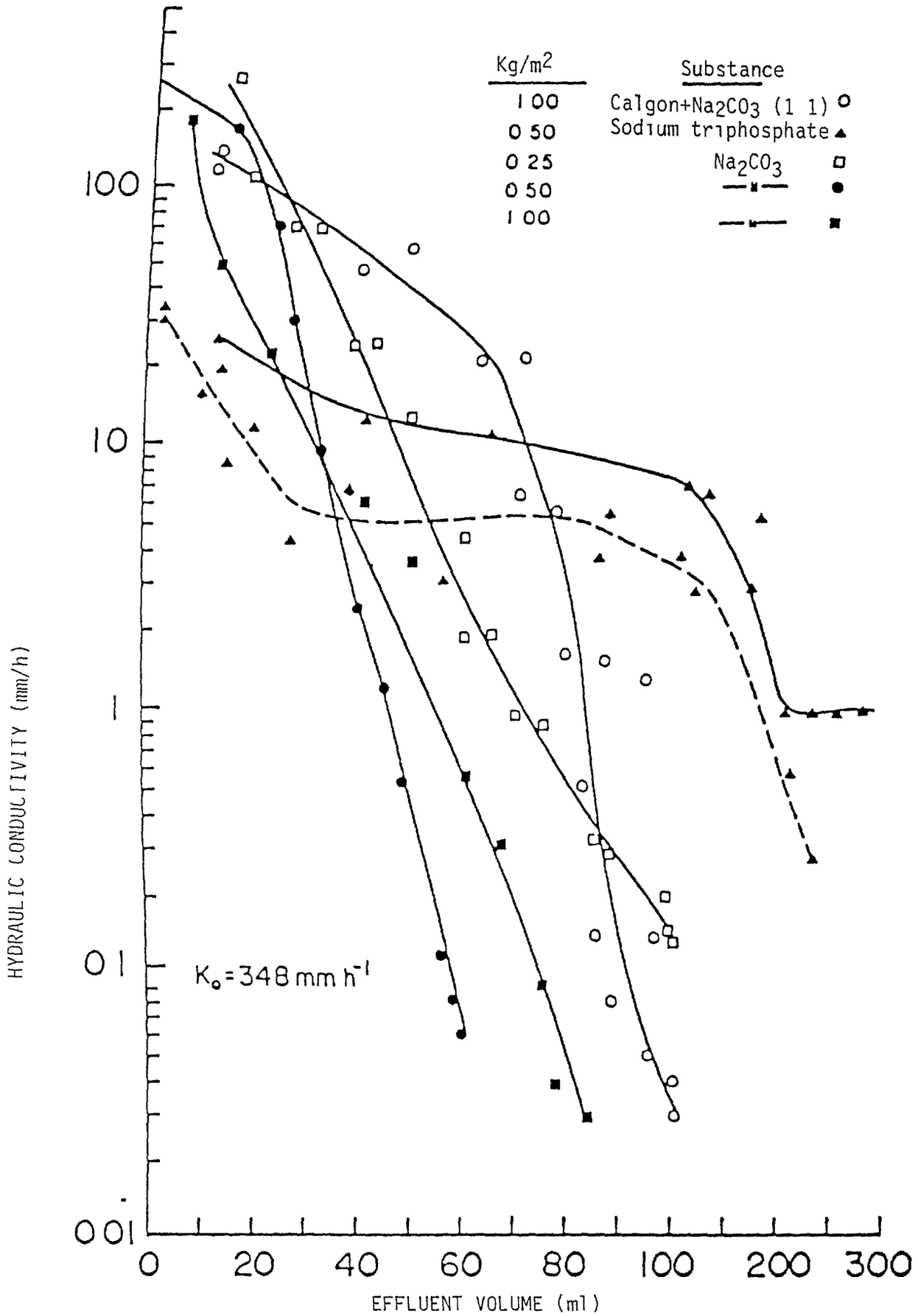


Figure 3 The effect of the dispersants on the hydraulic conductivity of a sandy soil (BILU) K_0 - Hydraulic conductivity in saturation of the untreated soil

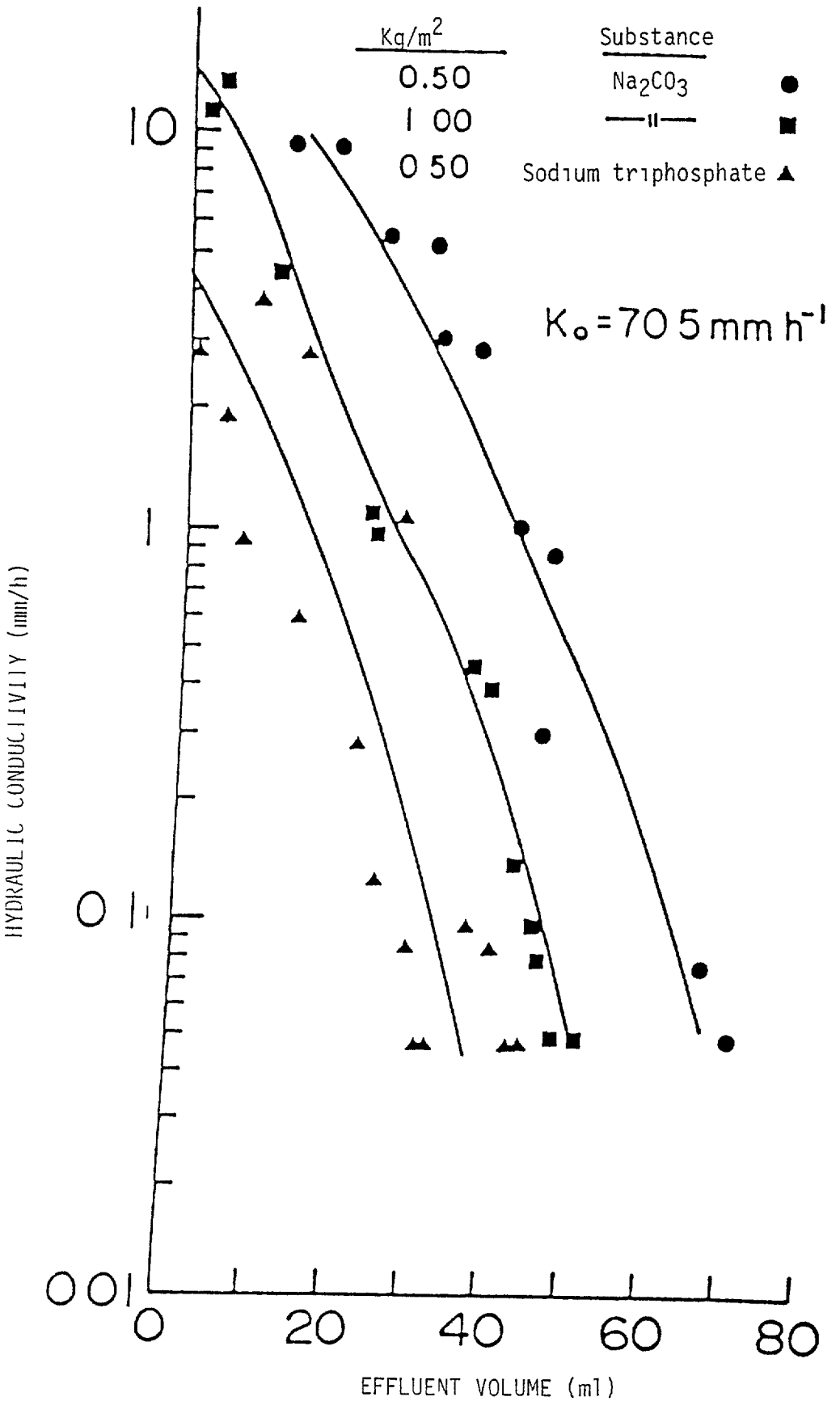


Figure 4 The effect of the dispersants on the hydraulic conductivity of a mixture of a clay soil and sand (1 2) K_o - Saturated hydraulic conductivity of the untreated soil

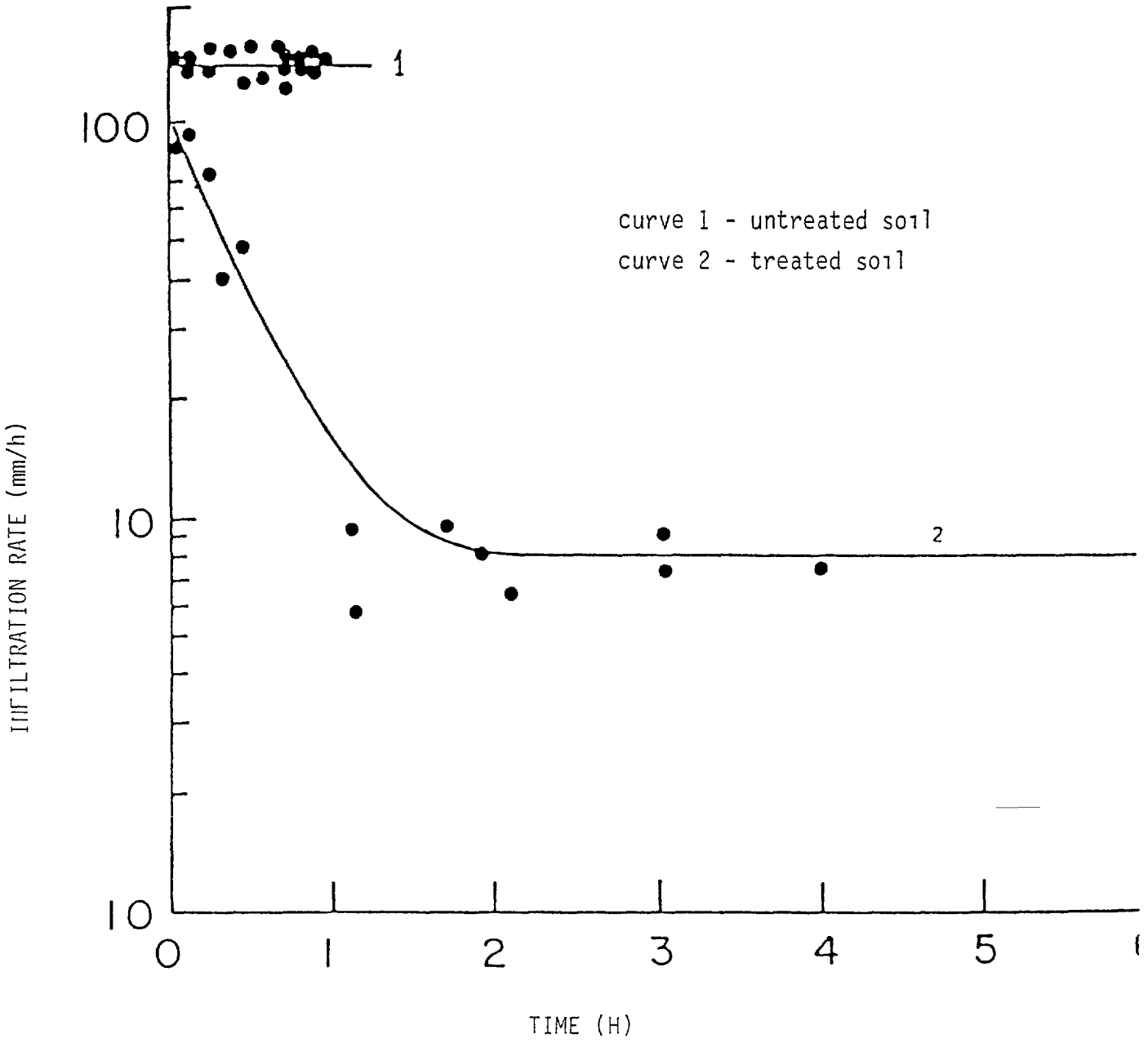


Figure 5 Effect of Na_2CO_3 on the infiltrability of a sandy soil Na_2CO_3 was added at a rate of 1 ton/1000m^2 by spreading and mixing with the top 1cm of the soil

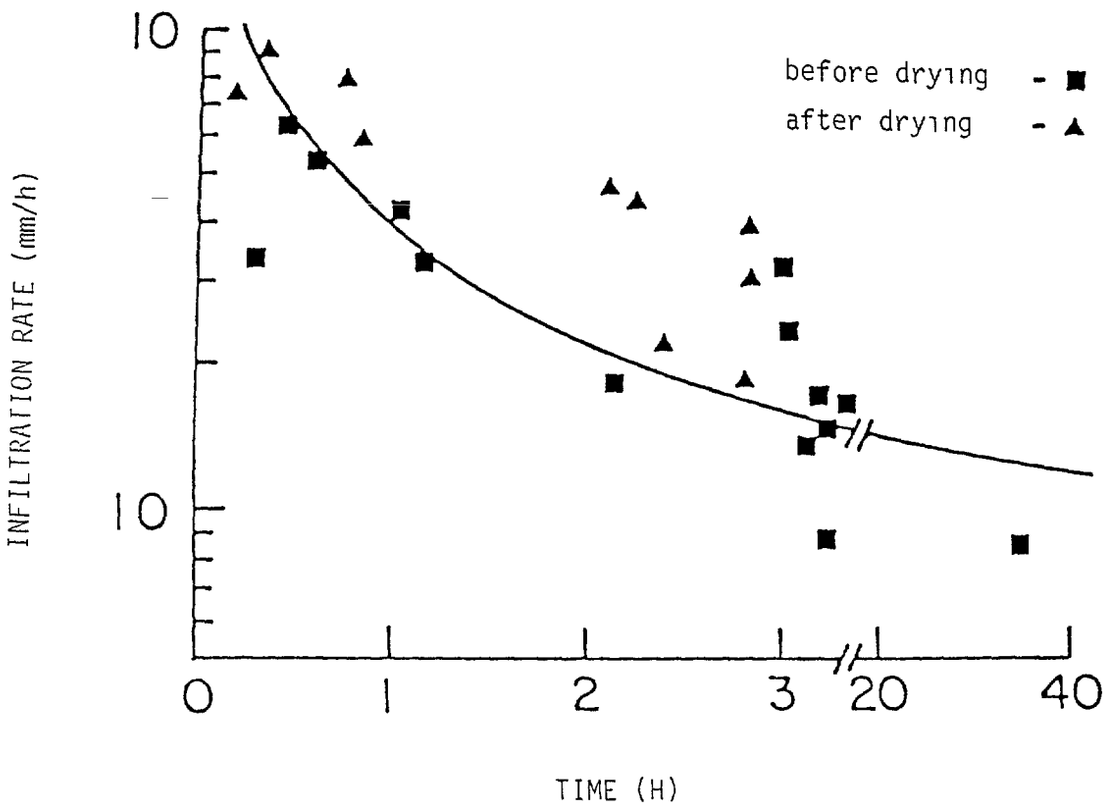


Figure 6 Effect of Na_2CO_3 and wetting and drying cycle on the infiltrability of a sandy soil as a fuction of time Na_2CO_3 at a rate of 1 ton/1000m^2 (dissolved in water at an equivalent volume of 5 m^3) was sprayed on the soil surface before the infiltration test has began

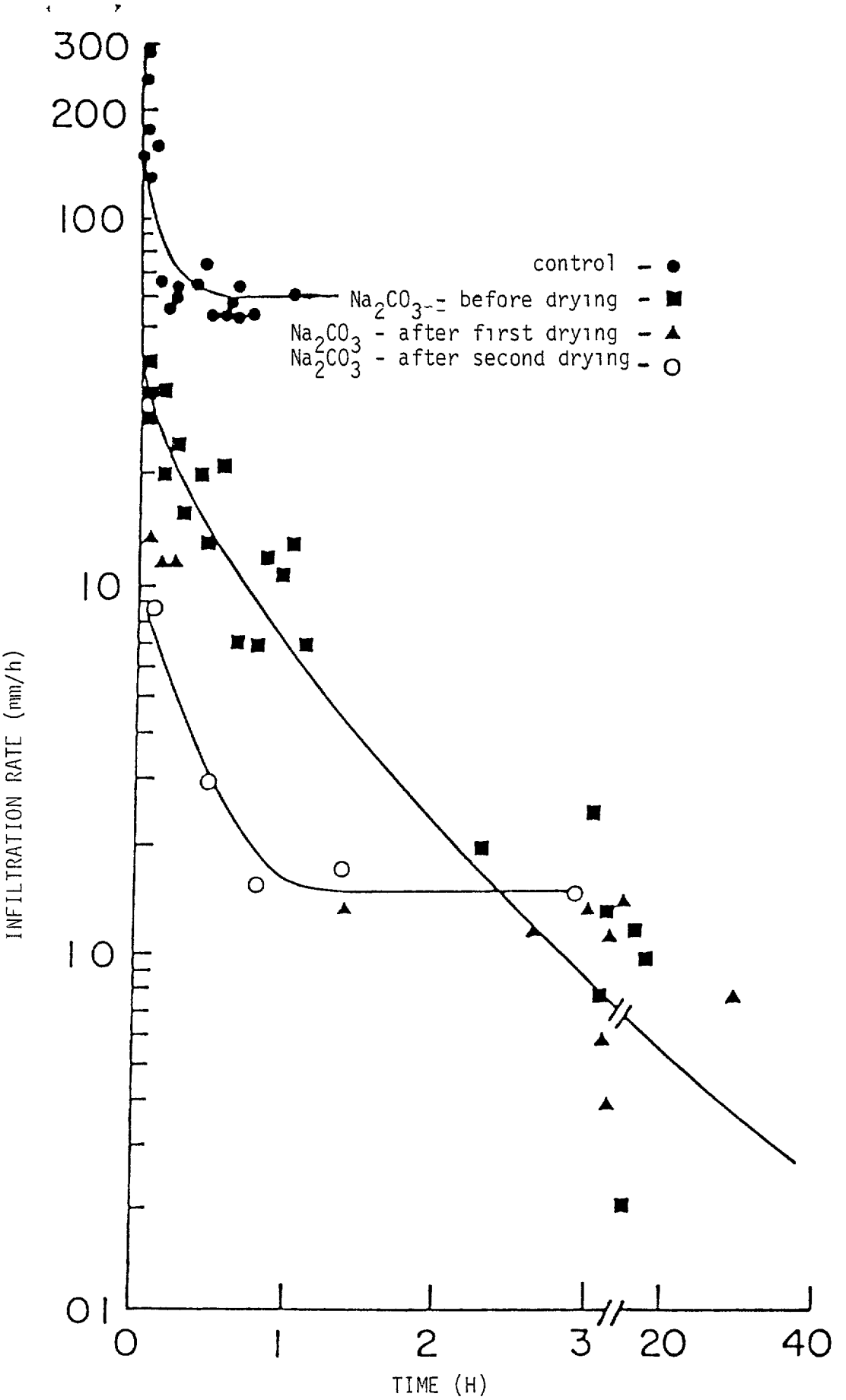


Figure 7 Effect of Na_2CO_3 and wetting and drying cycles on the infiltration rate in a sandy clay soil as a function of time Na_2CO_3 was added at a rate of 1 ton/1000m^2 (dissolved in water at an equivalent volume of 5m^3) by spraying on the surface before infiltration was measured

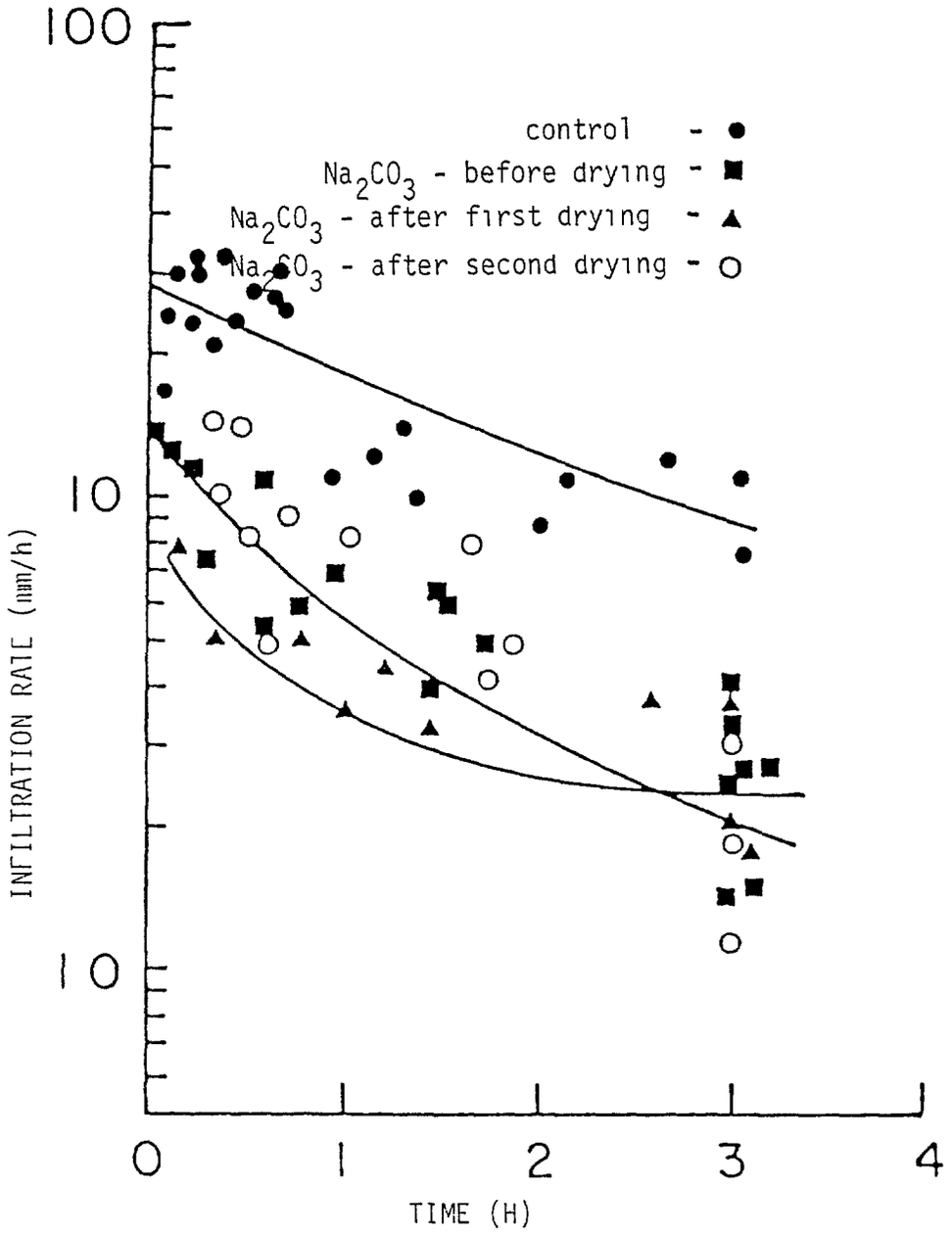


Figure 8 Effect of Na_2CO_3 and wetting and drying cycles on the infiltration rate in a clay soil as a function of time Na_2CO_3 was added at a rate of 1 ton/1000m^2 (dissolved in water at an equivalent volume of 5m^3) by spraying on the surface before infiltration was measured

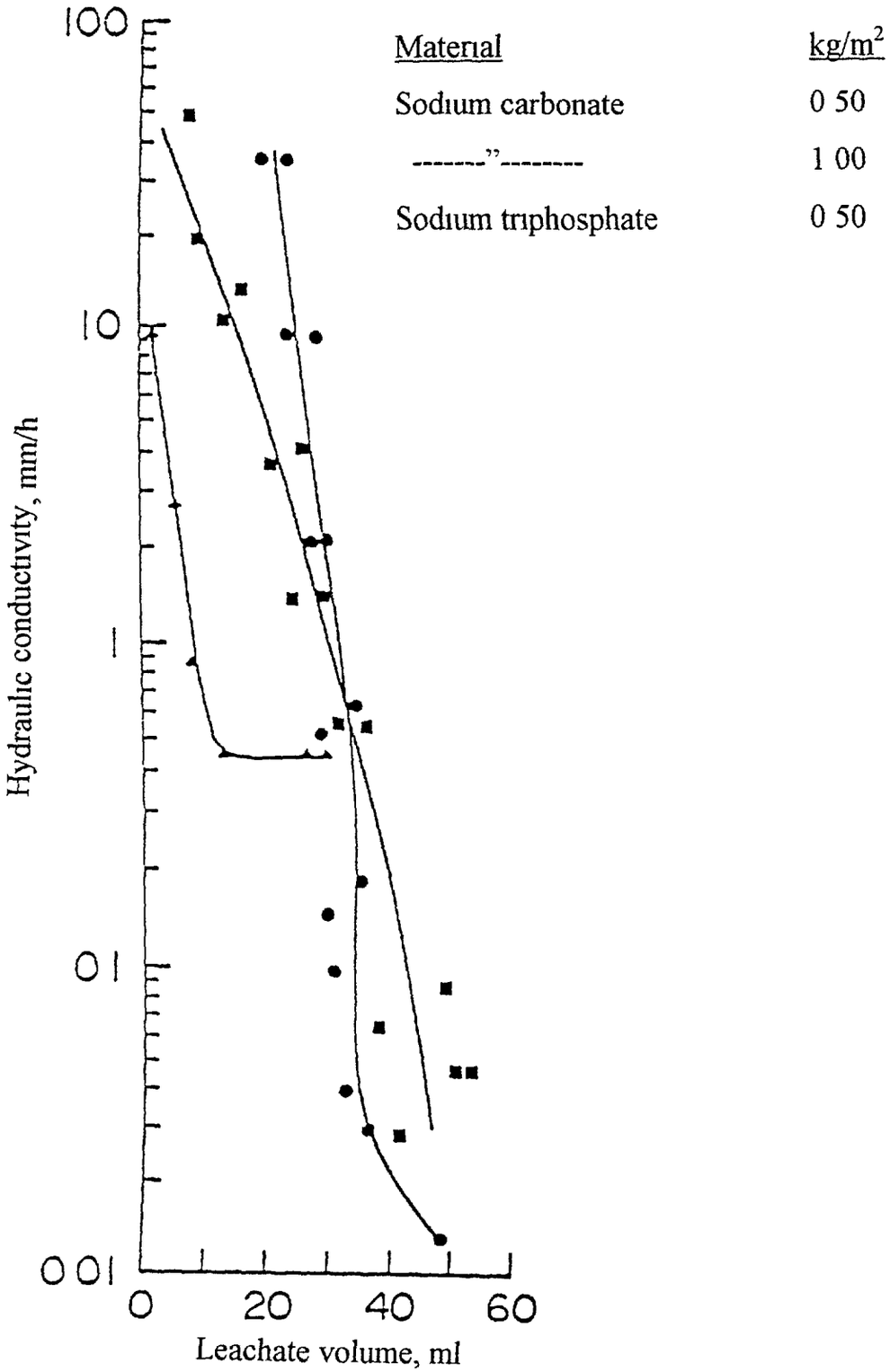


Figure 9 Influence of dispersive materials on the hydraulic conductivity of a mixture of loamy soil and sand in a 1 1 ratio, to National Water Carrier water (K_0 - hydraulic conductivity at saturation of untreated mixture)

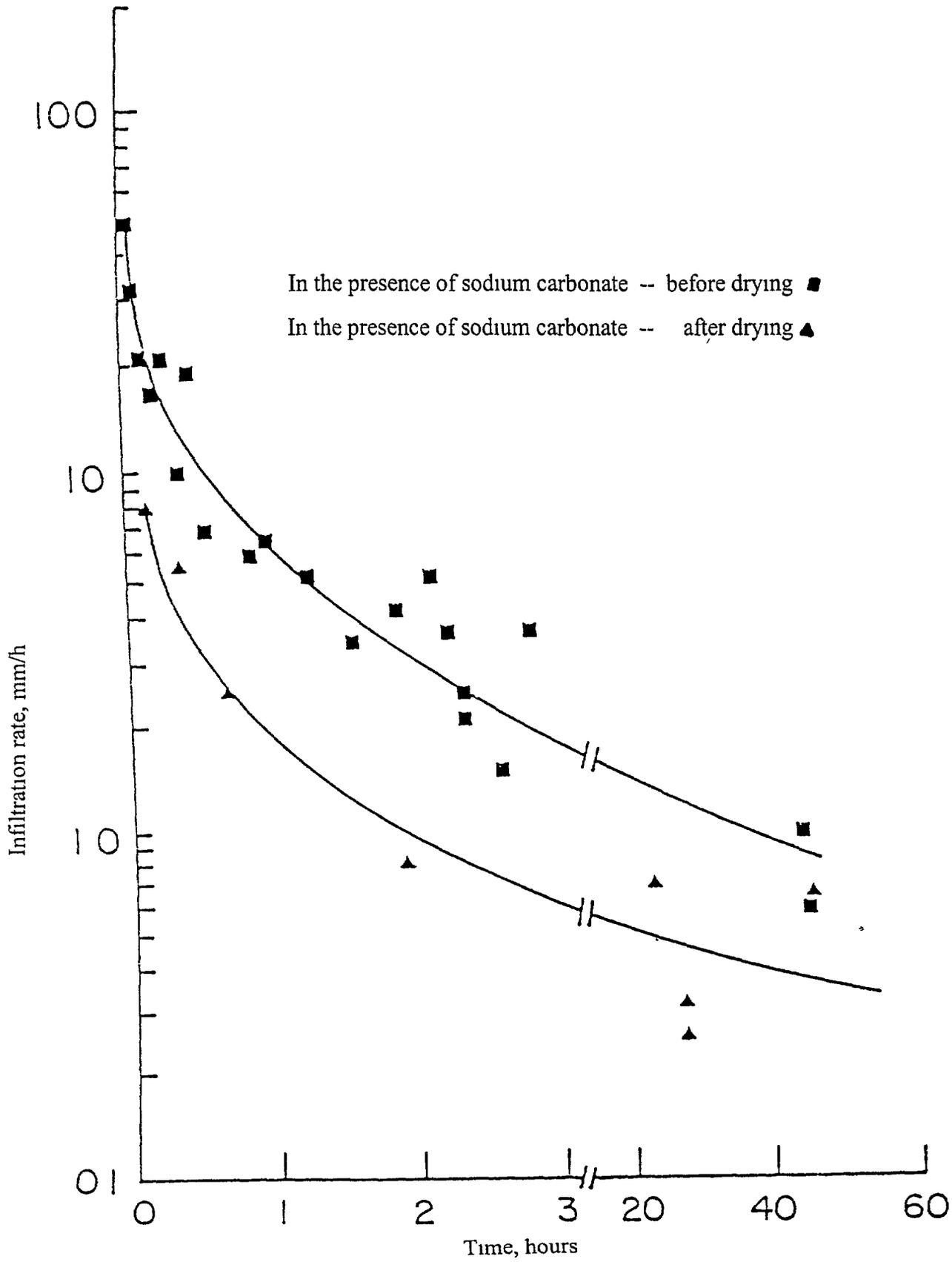


Figure 11 Influence of sodium carbonate and a drying/wetting cycle on the infiltration capability of sandy loam (Bilu) for National Water Carrier water Sodium carbonate at a rate of 2 ton/1000 m^2 was distributed on the soil surface and mixed into the topmost soil layer (1 cm)

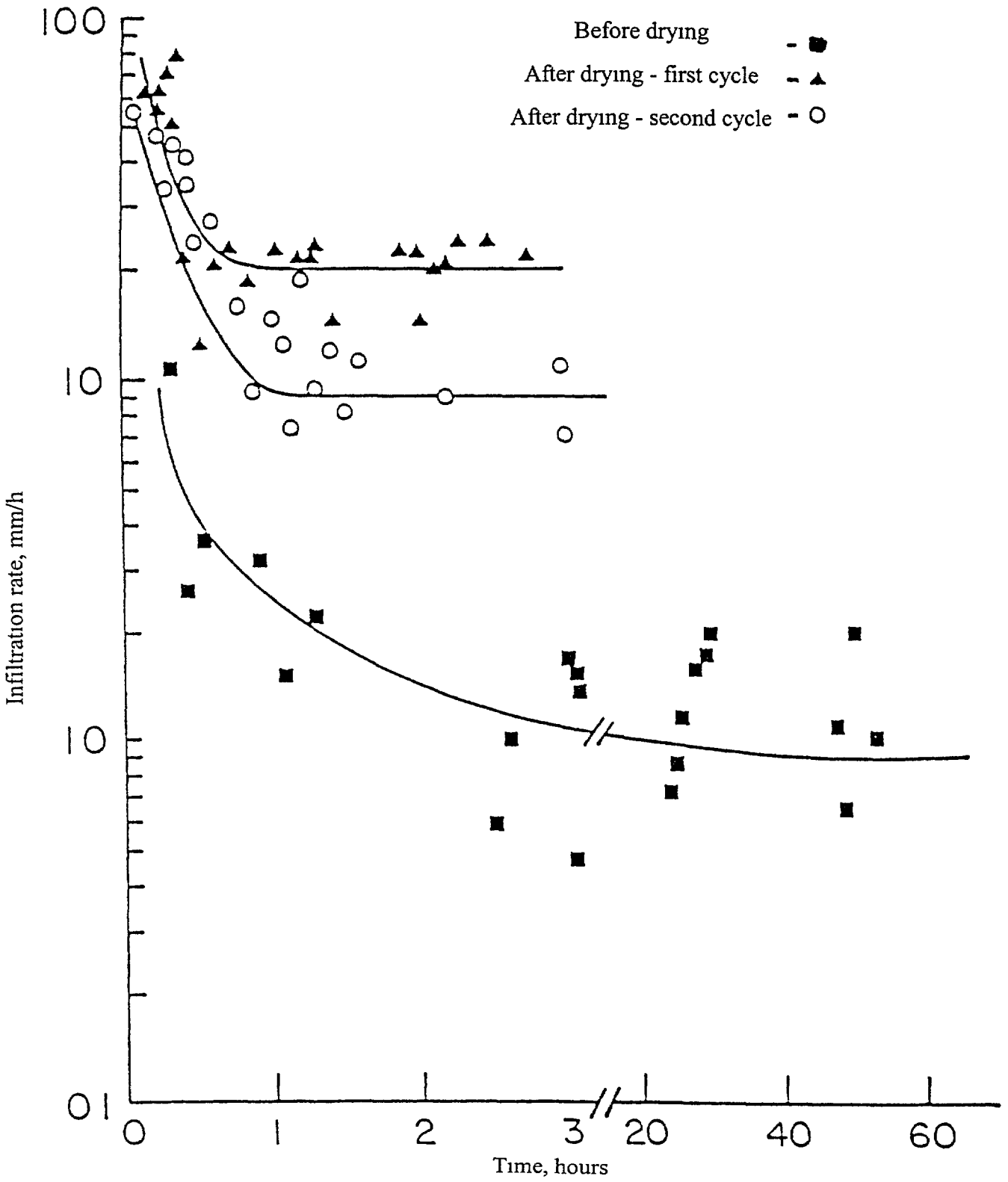


Figure 12 Influence of sodium carbonate and drying/wetting cycles on the infiltration rate of sandy loam soil for National Water Carrier water as a function of time Sodium carbonate at a rate of 0 5 ton / 1000 m^2(dissolved in water of a volume equivalent to 2 5 cub m) sprayed onto the soil surface before determination of the infiltration capability

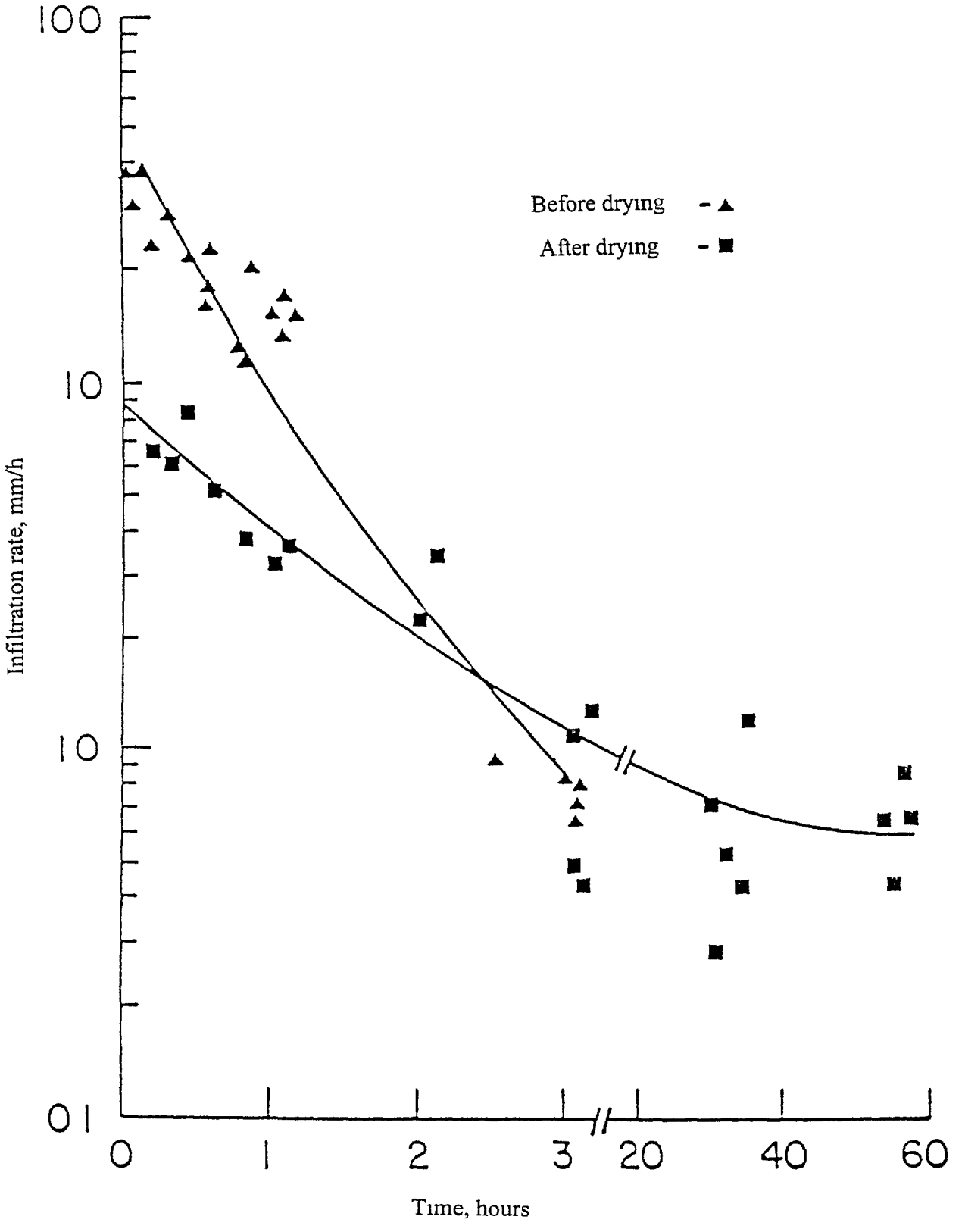


Figure 13 Influence of sodium carbonate and a drying/wetting cycle on the infiltration rate of sandy loam soil for National Water Carrier water, in the presence of a covering layer of sand(5 cm), as a function of time Sodium carbonate at a rate of 10 ton/ hectar (dissolved in a volume equivalent to 5 cub m of water) sprayed onto the soil surface before covering with the sand layer

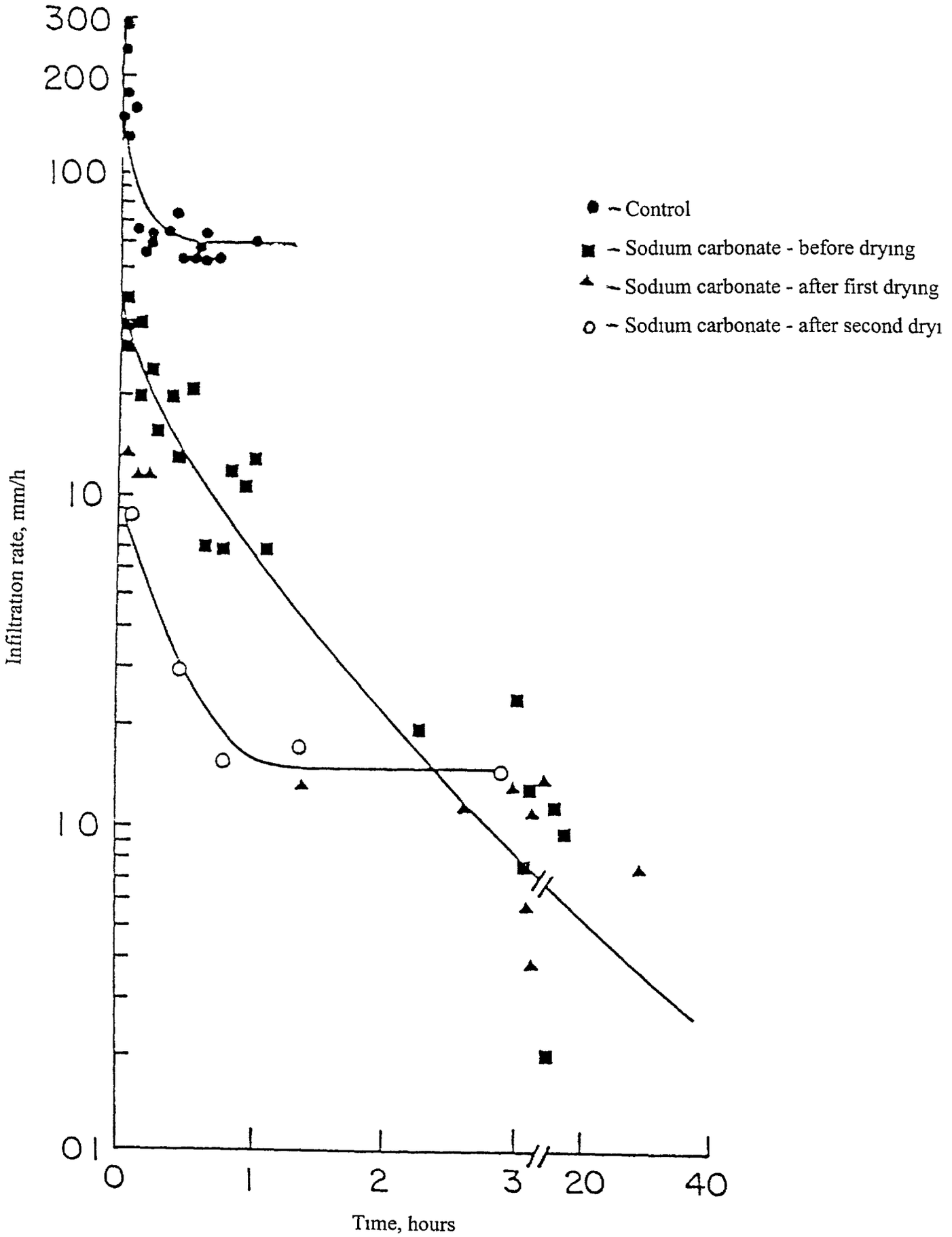


Figure 14 Influence of sodium carbonate and drying/wetting cycles on the infiltration rate of clayey soil for National Water Carrier water as a function of time Sodium carbonate at a rate of 10 ton/ha (dissolved in a volume equivalent to 5 cub m of water) sprayed onto the soil surface before determination of infiltration capability

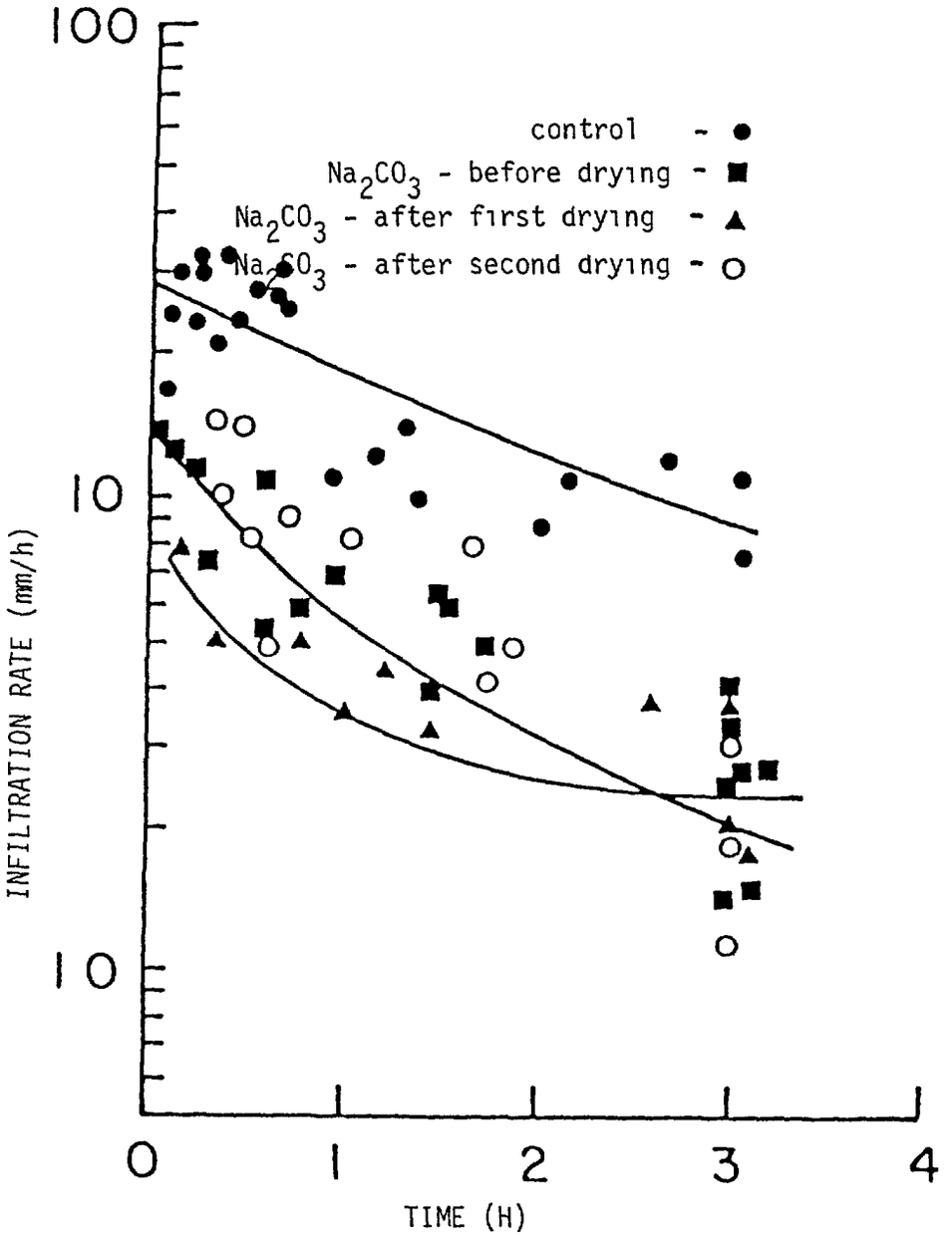


Figure 15: Effect of Na_2CO_3 and wetting and drying cycles on the infiltration rate in a clay soil as a function of time Na_2CO_3 was added at a rate of 1 ton/1000m^2 (dissolved in water at an equivalent volume of 5m^3) by spraying on the surface before infiltration was measured

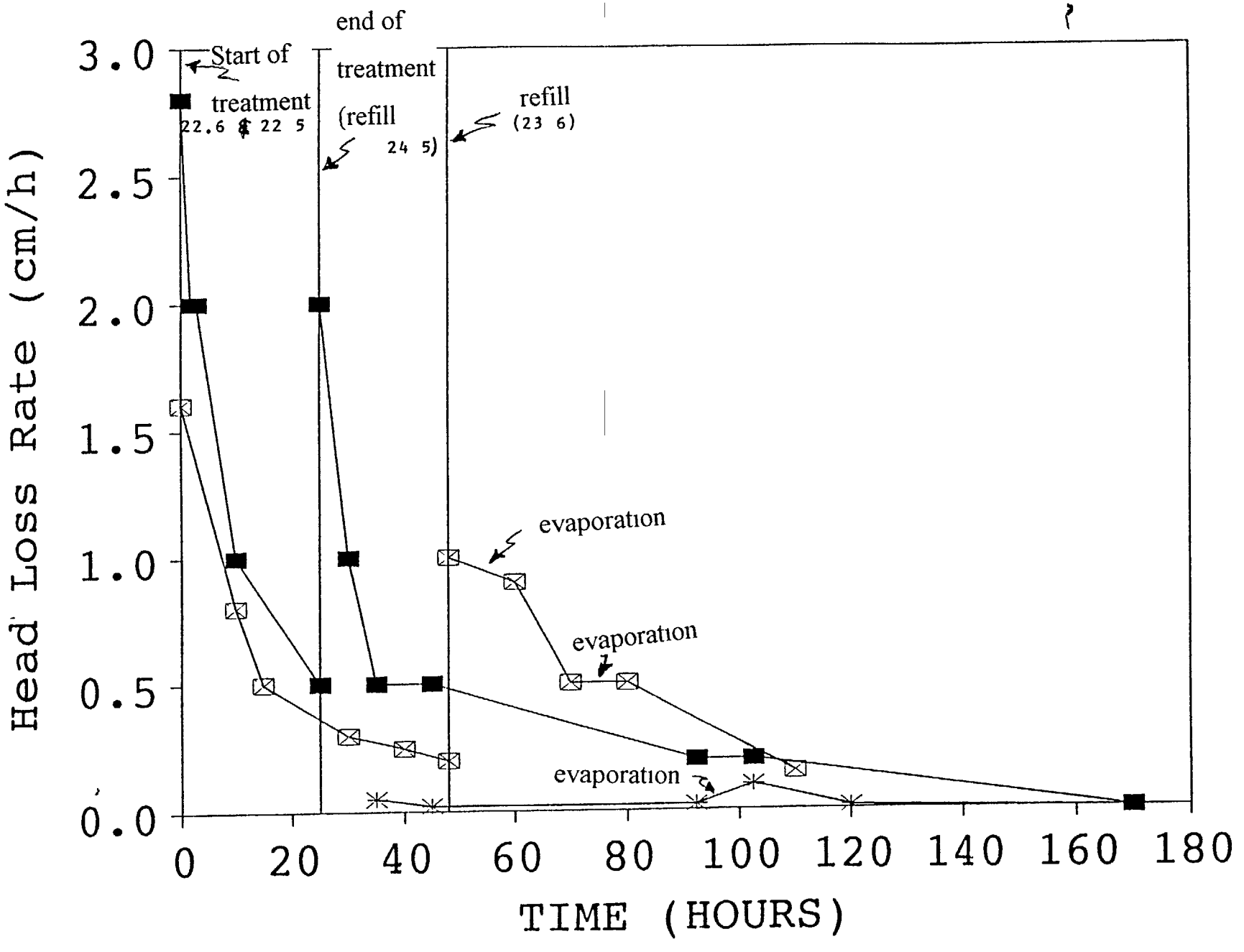


Figure 16 Water loss rate from containment basins (without covering, filled

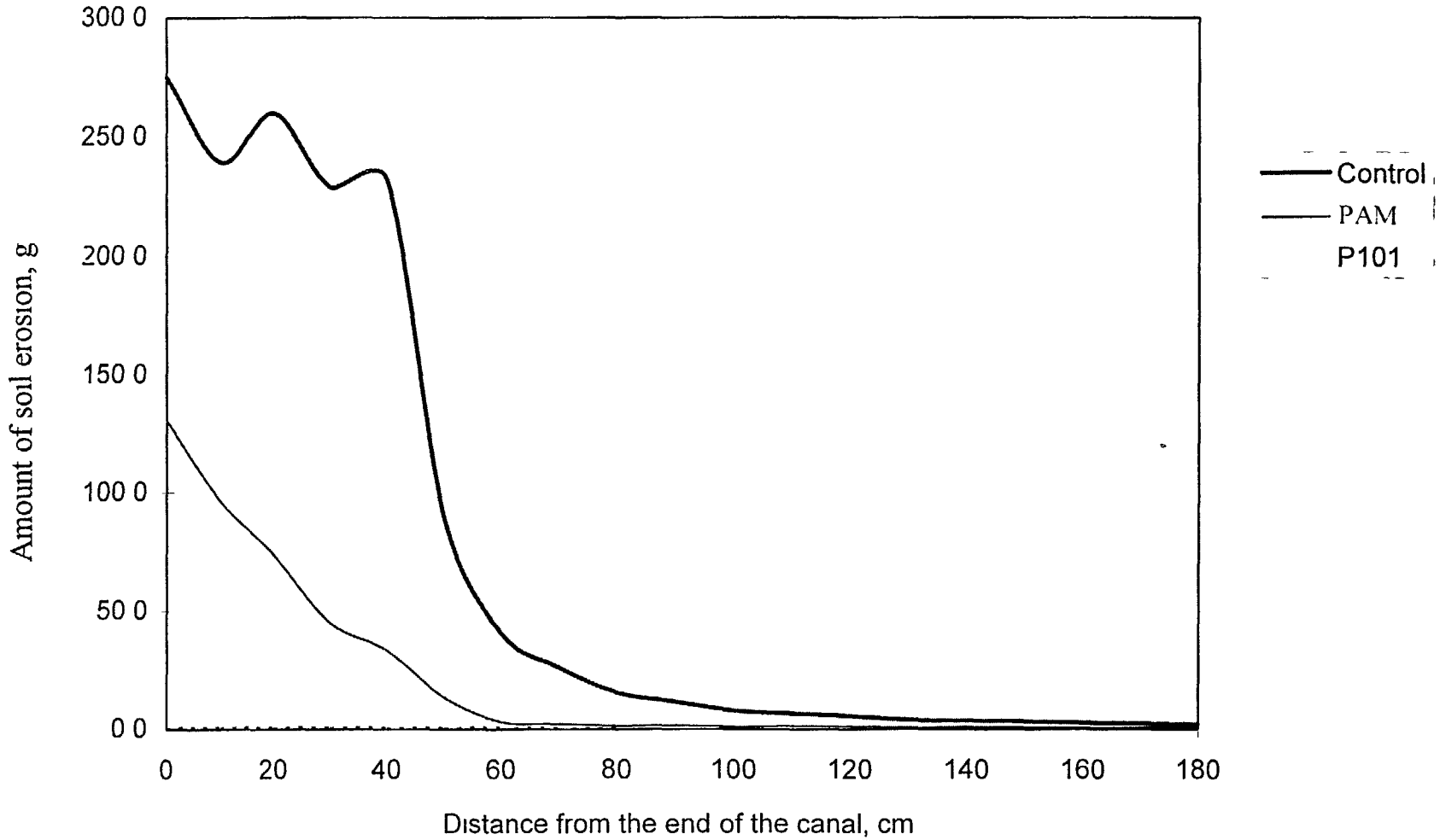


Figure 17 The effect of addition of polymers on erosion from a sandy loam soil

Figure 18.

Schematic of the experiment at the Ma'agar Sansona site

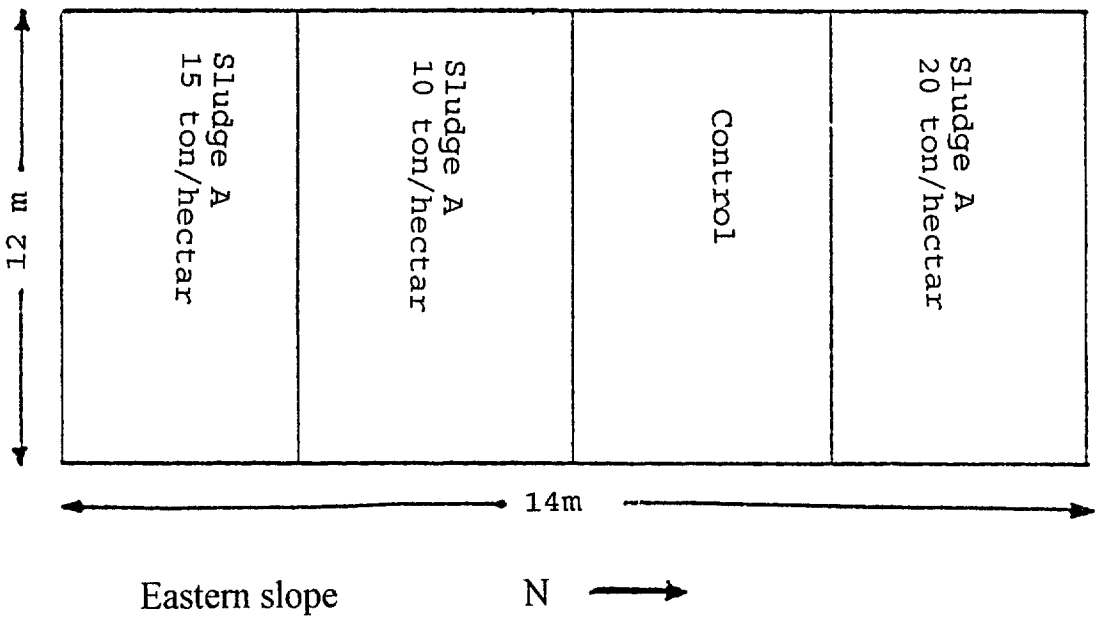
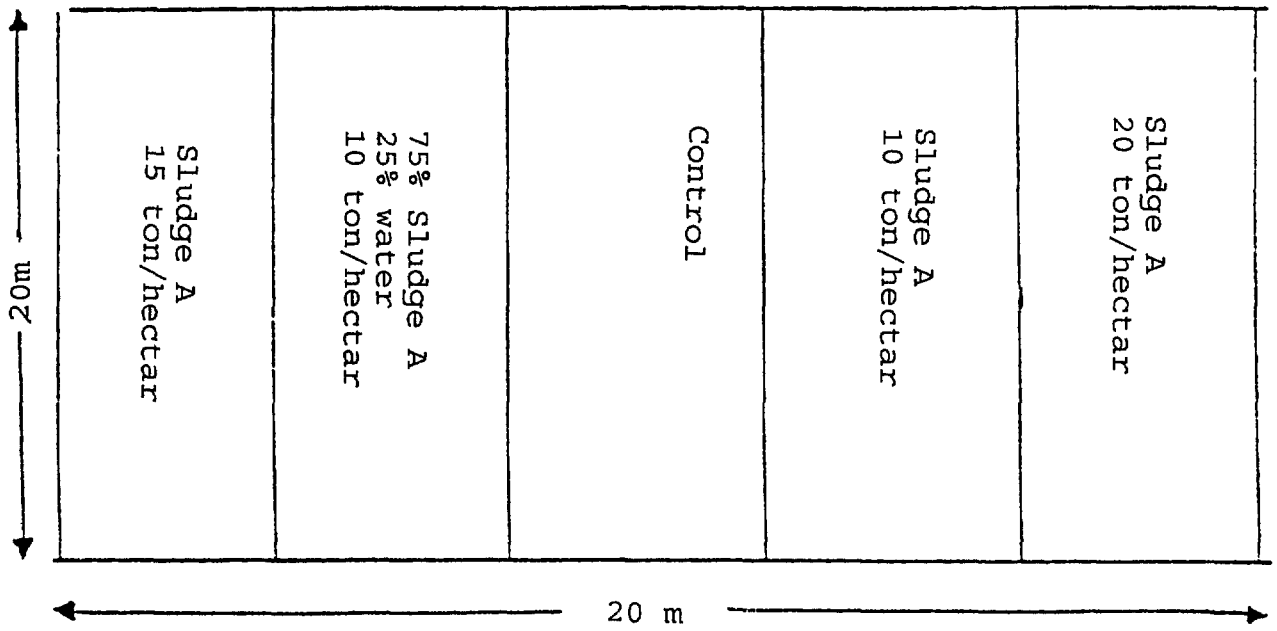


Figure 19

Schematic of the experiment at the Lahav site



Western slope N →