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PERCEPTION OF SEPTIC TANKS IN THE ENVIRONMENT: AN OVERVIEW

Laboratory and field studies on septic tanks carried out in various countries of the world found in literature were comprehensively reviewed. The biochemical oxygen demand (BOD) and suspended solids (SS) data gathered during the literature survey were analyzed for performance function in terms of the constituent removal efficiency. The computer software (Cricket graphics) was used to process the data to develop trends and performance models for the different countries, namely, the United States of America, Canada, Sri-Lanka, India, Brazil, Zambia and Nigeria.

Results show that on a global basis, the average suspended solids removal efficiency of septic tanks irrespective of the type is 80% in warm climate countries such as Nigeria, giving values generally greater than 80%. The biochemical oxygen demand removal efficiency averages globally to 68% at operational retention times less than 2.8 days. The ranking of parameters that affect performance of septic tanks is in the order of importance of effective volume, flow rate and retention time.

1. INTRODUCTION

The perception of septic tank by researchers is based on its performance in a given environment and the state of knowledge of the system's behaviour. BABBITT [1] and SHETTY [2] perceived septic tank in temperate climate as a mere sedimentation tank for storage of sludge over a period between cleaning intervals. The papers of PHADKE et al. [3], MARA and SINNATAMBY [4], CHAMPIKA [5] and OKEREKE and COTTON [6] reveal that septic tank, particularly in hot climate countries, functions much more than a waste collection tank. It behaves as a sludge accumulation tank and a waste digestion chamber. In essence, septic tank is a low-cost sewage or water-borne waste anaerobic treatment plant for management of sewage of individual household or collection of households.

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In developed countries such as the United States of America, the United Kingdom and Japan, the multi-compartment, mainly, 2-compartment septic tanks are used in isolated buildings in the countryside not connected to the sewerage system. The Klargester dome-pot shaped septic tank of three vertically arranged compartments is used currently in isolated buildings in England. In developing countries such as those of the Asia sub-continent and Nigeria, the septic tank system is an individual household necessity in the urban or sub-urban settlements. It is easier to afford low-cost waste plants in poor economies than sewerage system in terms of cost and feasible management requirements to reduce the potential harm that may be caused by sewage in the environment. Whereas septic tank is a low-cost sewage management system, it is important to know the levels of contaminant removal achieved by the existing types in various economies to assess the potentiality as waste disposal system.

The objective of this research work is to review the existing data on septic tanks in various countries of the world given in literature with a view to aggregating the current level of knowledge and for establishing the achievable average performance in terms of overall percentage constituent removal under various identifiable parameters that affect septic tank function. This will provide clear behavioural perception of septic tank for future research, particularly in the tropics where it is popularly used.

2. METHODOLOGY

A comprehensive literature research was carried out at Loughborough University of Technology, mainly and WEDC (Water Engineering and Development Centre) departmental libraries. Literature materials were also sourced from the University of Leeds, Federal University of Technology, Owerri (Nigeria) and the International Foundation for Science resource centre. Research works on the existing septic tank models in different countries of the world were obtained from, notably CHOI [7], NOTHIGHAM and LUDWIG [8], WEIBAL [9], LUDWIG [10], PETER et al. [11], LEROY [12], ACKERS [13], HICKEY and DUNCAN [14], MAJUNDER et al. [15], OLSSON [16], BAILEY and WALLMAN [17], OTIS et al. [18], VIRARAGHAVAN [19], BRANDES [20], NICOLL [21], BARNES and WILSON [22], CHAMPIKA [5] and OKEREKE and COTTON [6]. Others are OLIVEIRA [23], FITZGERALD [24], PHADKE et al. [3] and SEABLOOM et al. [25]. The data of SS and BOD concentration with the corresponding retention time, flow rate and tank effective volume from these papers were tabulated according to the country of location of the study-septic tank, namely, Sweden, USA, Canada, Japan, Switzerland, Brazil, India, Sri-Lanka, Zambia and Nigeria. The septic tank efficiencies were then calculated for each of the septic tanks in the study locations using the following equations:

$$\% \text{ SS removal} = \frac{SS_I - SS_e}{SS_I} \times 100 \quad (1)$$

where SS_I and SS_e are the average influent and effluent suspended solid concentrations;

$$\% \text{ BOD removal} = \frac{BOD_I - BOD_e}{BOD_I} \times 100 \quad (2)$$

where BOD_I and BOD_e are the average influent and effluent biochemical oxygen demands;

$$\% \text{ microbial kill} = \frac{M_I - M_e}{M_I} \times 100 \quad (3)$$

where M_I and M_e are the average faecal coliform populations per 100 cm^3 of influent and effluent, respectively. The efficiencies calculated were processed graphically by plotting efficiency with the variables of retention time, effective volume and flow rate with and without taking climatic temperature into account using Cricket graphic computer software.

3. RESULTS AND DISCUSSION

Figures 1a, 1b, 2a, 2b, 3a, 3b show the various graphs of contaminant removal efficiency versus retention time of septic tanks in different countries. The countries of location of the septic tanks are put in figure 1b. From figure 1a and 1b, it can be said that the average efficiency of septic tanks irrespective of the type is 80% on a global basis. Although there is wide variation from this average value from country to country ($\sigma_n = 20\%$), the septic tanks in warm countries often give SS removal efficiency higher than 80%. The world-wide average BOD removal, as reflected in figures 2a and 2b, is 68%. Like the SS, there is always wide variation of percentage BOD removal between cold and hot countries (situations). The septic tank performance is better in warm climates than in cold climates by 40% on the average. This view upheld here has been expressed by authors like MARA et al. [4]. From these figures, it can also be seen that the operational retention time (actual retention time) is a function of the incoming flow at the time and clear water space in tank.

About 40% of the septic tanks, which are in use, operate at an average retention time of 24 h. Design retention times used in most countries range from 1 to 3 days. From figures 3a and 3b, the obvious inference that can be drawn is that the increased retention time has little or no effect on septic tank performance. This trend or picture created in figures 3a and 3b is remarkable when looked at in relation to figures 4a, 4b, 7a 7b and the work by OLIVEIRA [23] in North-East Brazil. OLIVEIRA [23] studied the performance of communal septic tank and found that the overall retention time as low as 0.40 day gave BOD and SS removal of 67% and 78%, respectively. On increasing the retention time to 0.75 day there was a marginal increase in BOD removal to 70% and decrease in SS removal to 76%. A 2-compartment septic tank with overall retention time of 0.75 day had BOD and SS removal efficiencies of 72 and 82%, respectively.

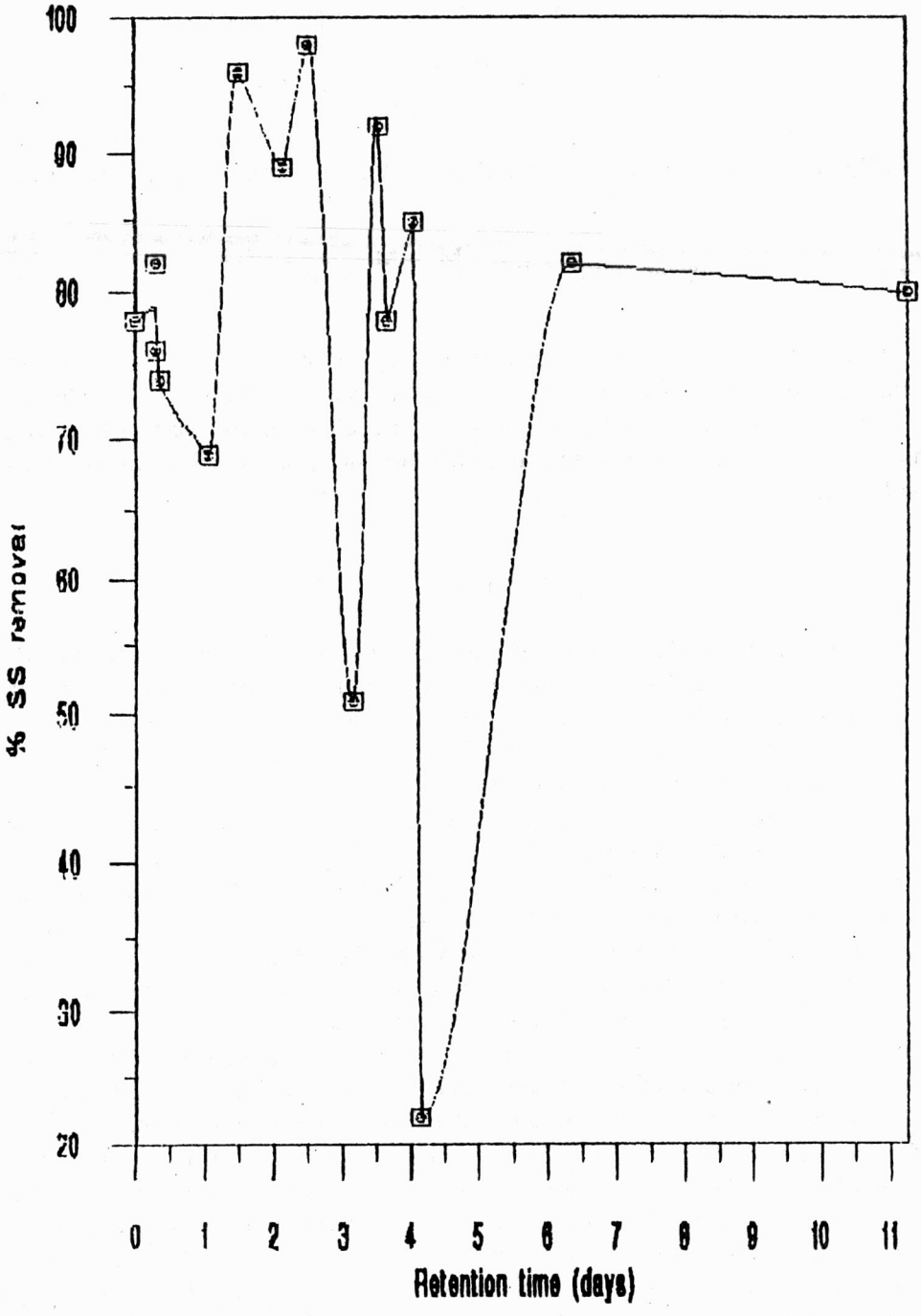

Fig. 1a. % SS removal versus retention time irrespective of type and country of location of septic tank

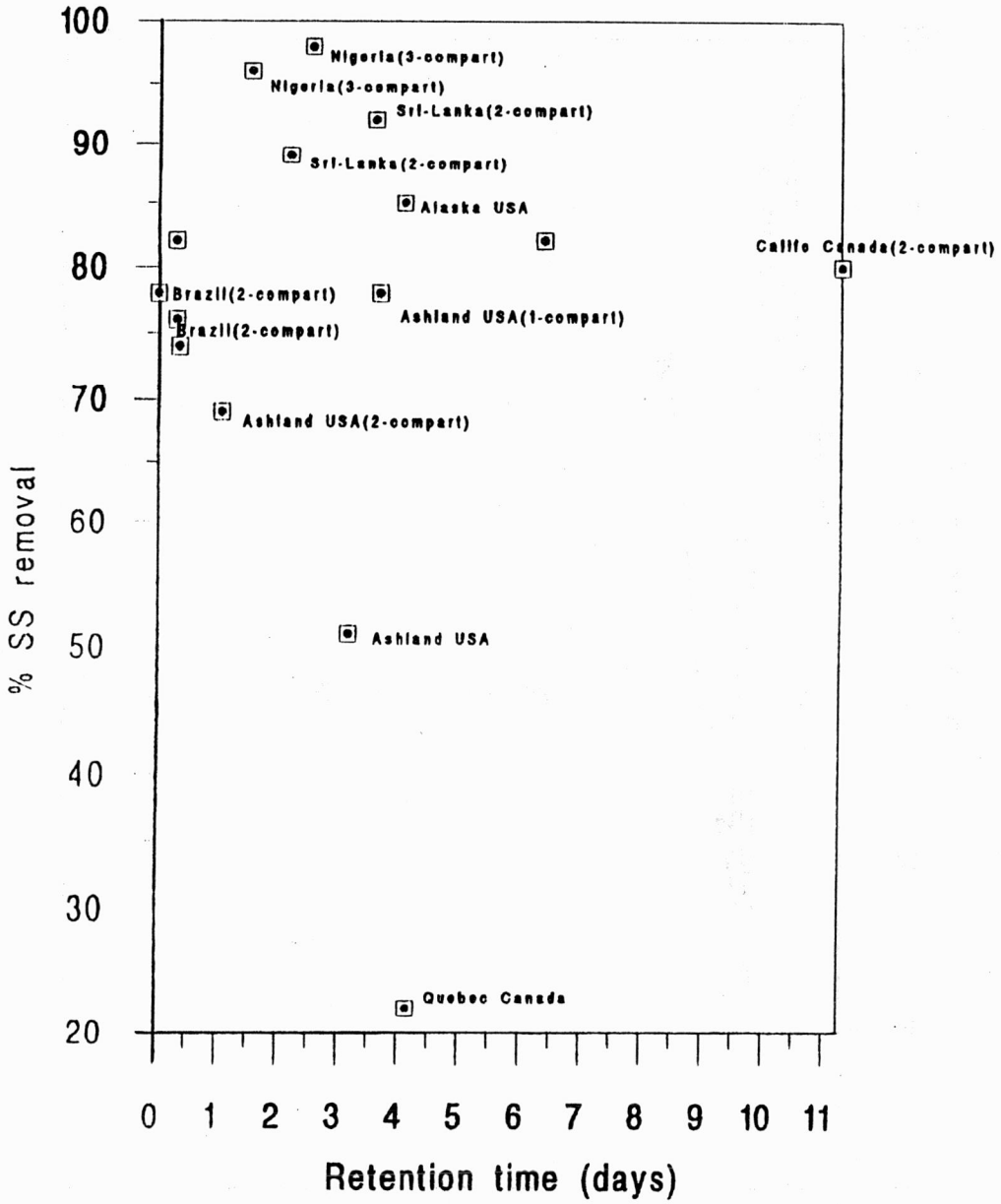

Fig. 1b. % SS removal versus retention time irrespective of the type and country of location of the septic tanks

The plots of figures 3a and 3b were made without regarding the number of compartments of the septic tanks and the country of location of the septic tanks (tempe-

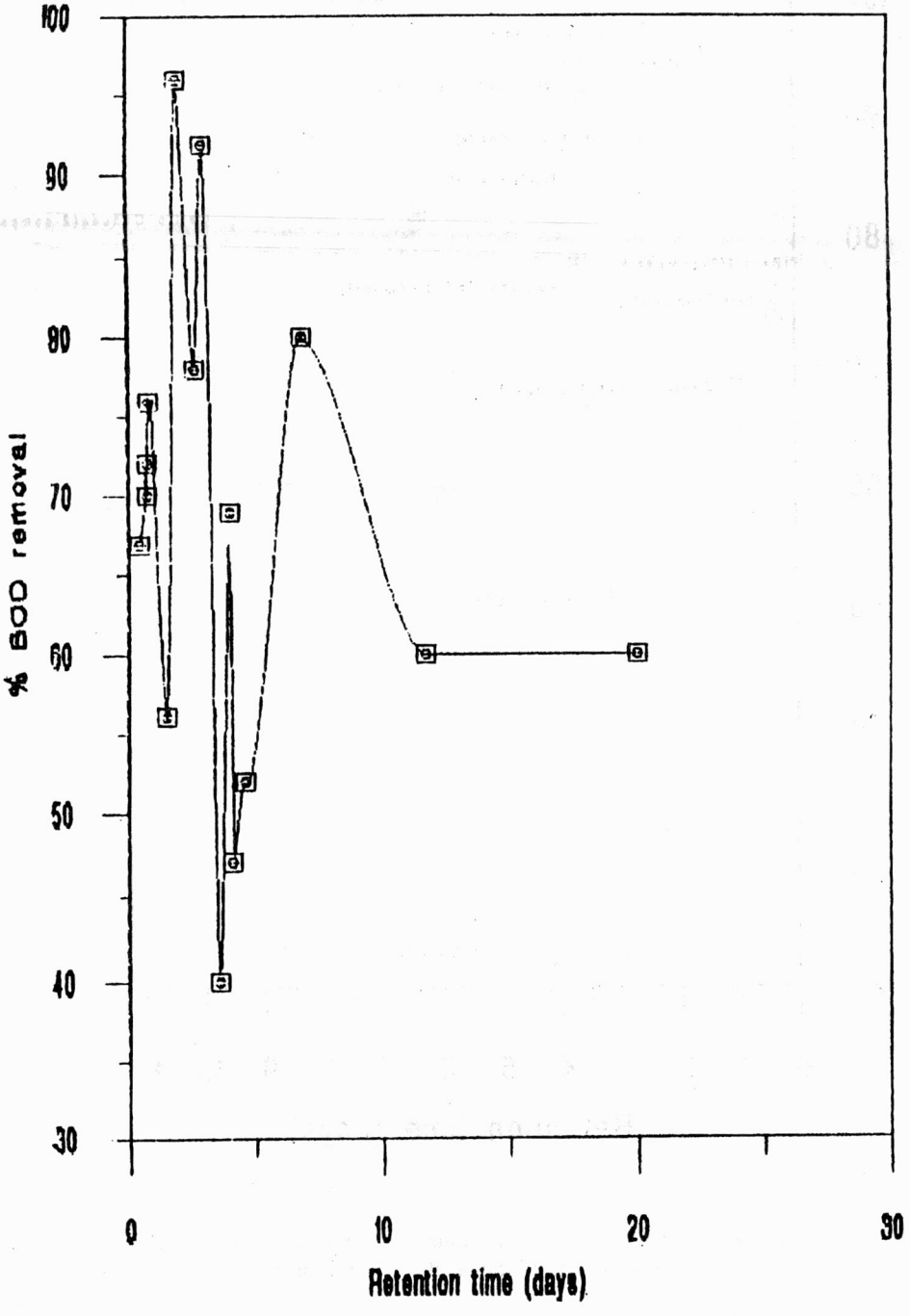

Fig. 2a. % BOD removal versus retention time
irrespective of type and country of location of septic tanks

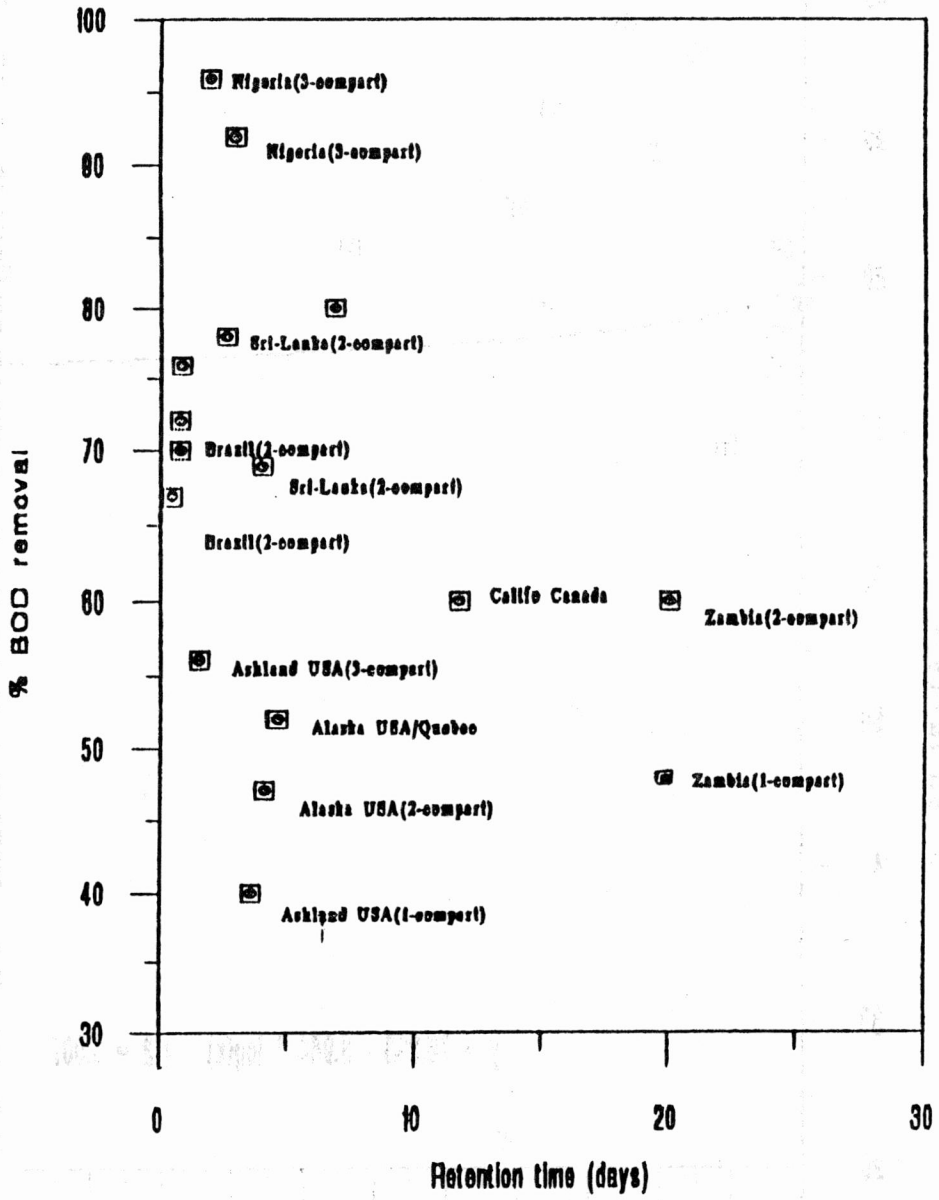

Fig. 2b. % BOD removal versus retention time of septic tanks irrespective of type and country of location

rature of the environment). So, it follows that any generalization of design standards for both hot and cold climates taken together is inadequate. This view arising thereof

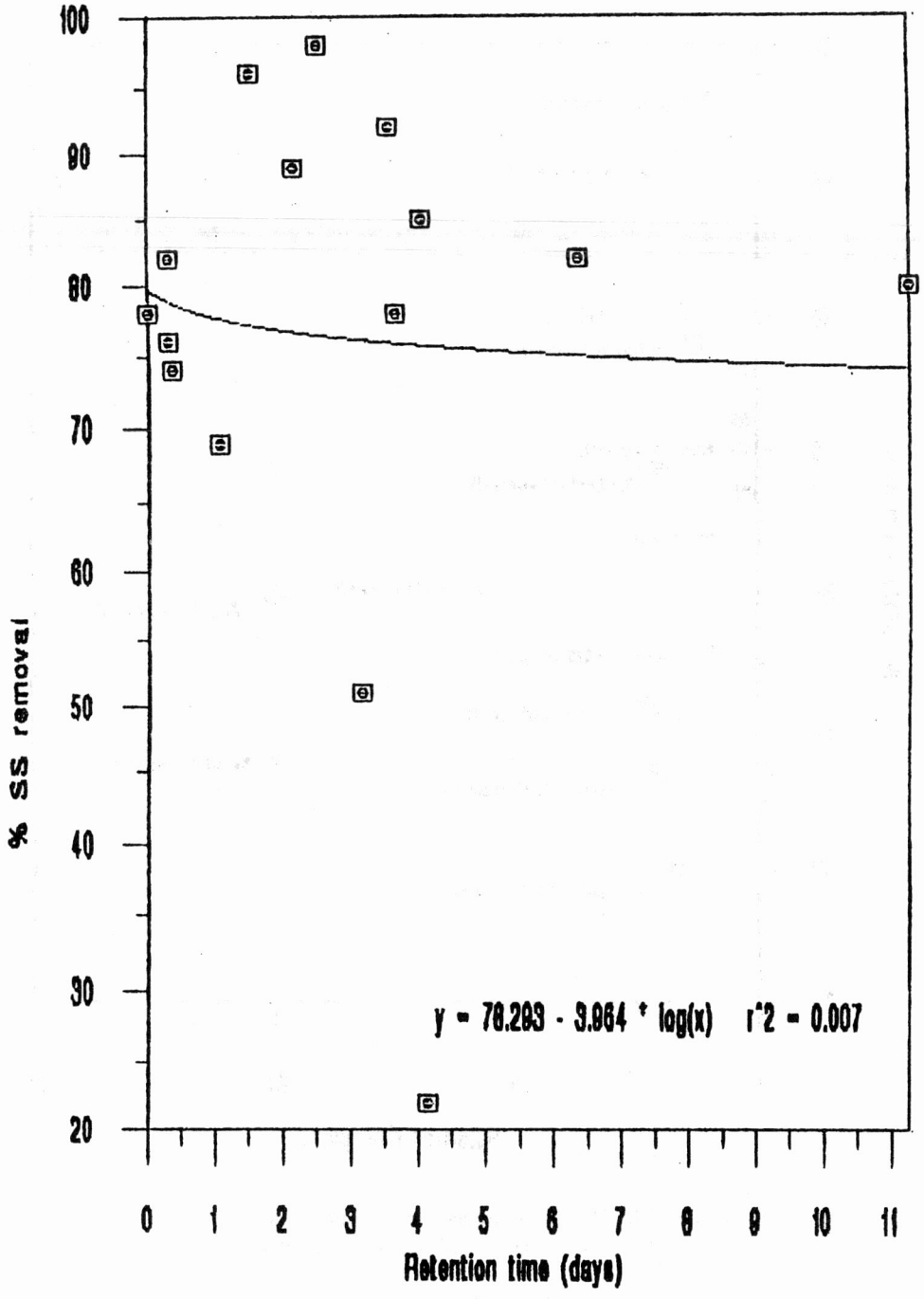

Fig. 3a. % SS removal versus retention time
irrespective of type and country of location of septic tank

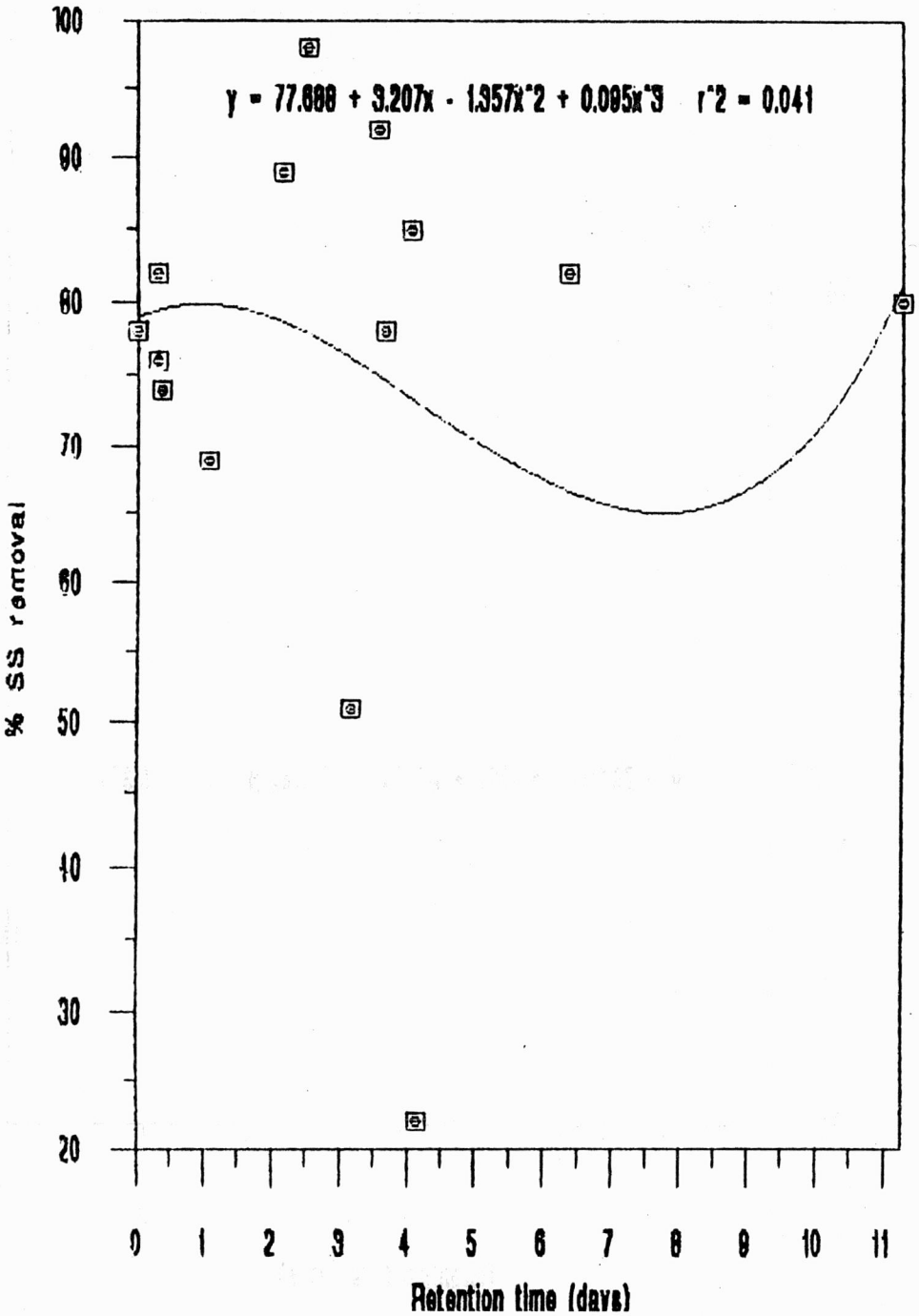

Fig. 3b. % SS removal versus retention time
irrespective of type and country of location of septic tank

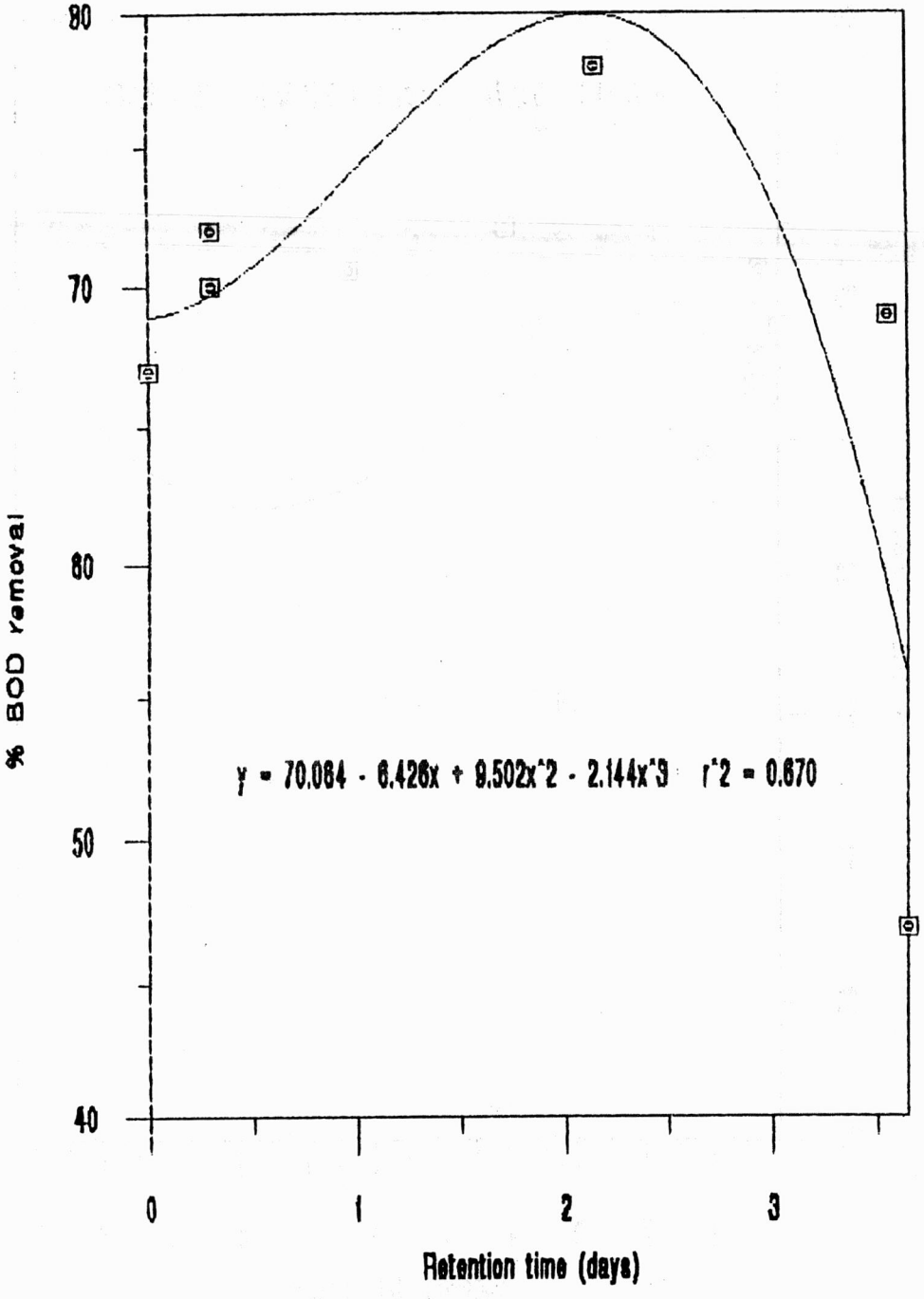

Fig. 4a. Variation of % BOD removal with retention time in 2-compartment septic tanks irrespective of type and country of location

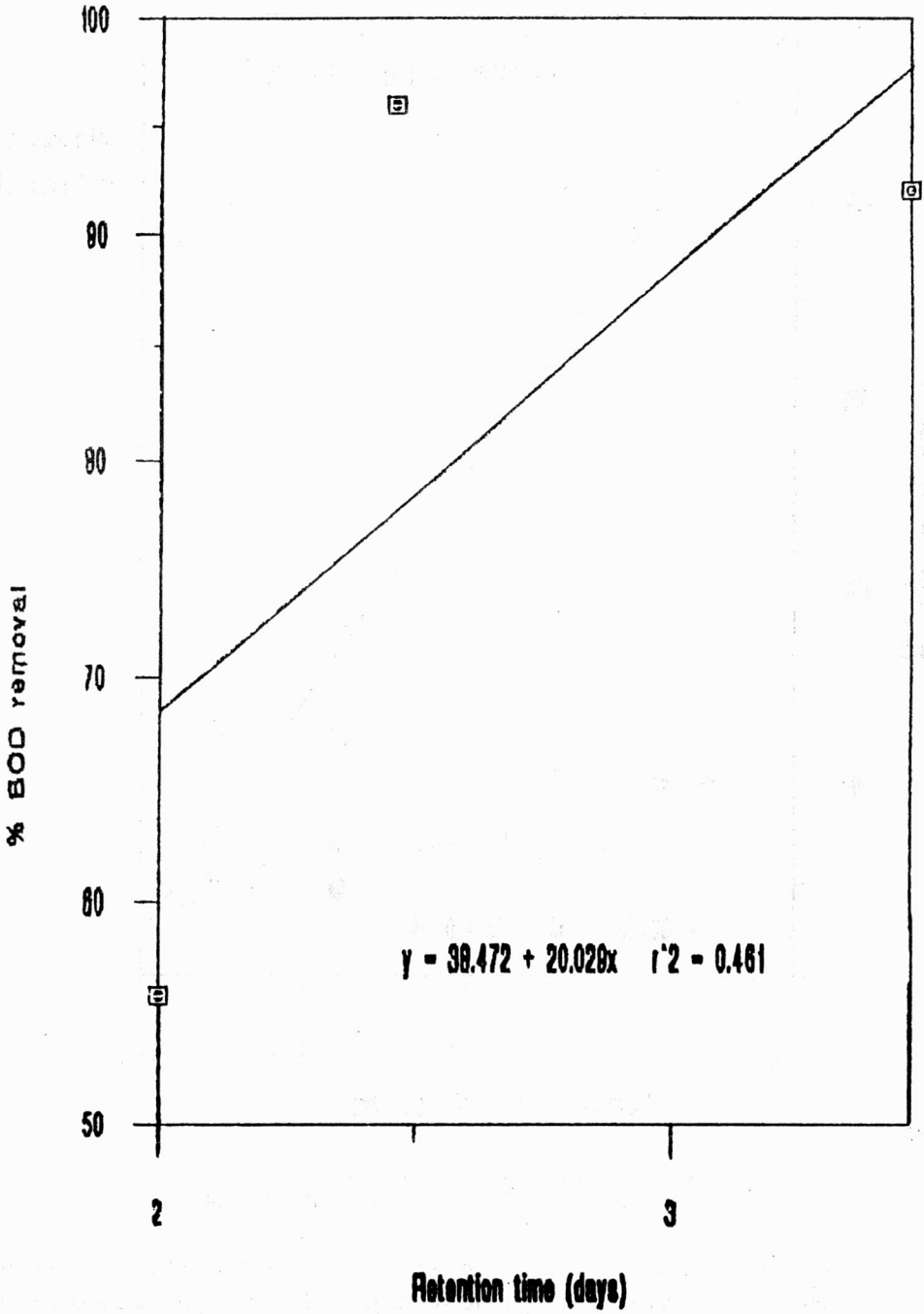

Fig. 4b. % BOD removal in 3-compartment septic tanks at various retention times in hot climate countries

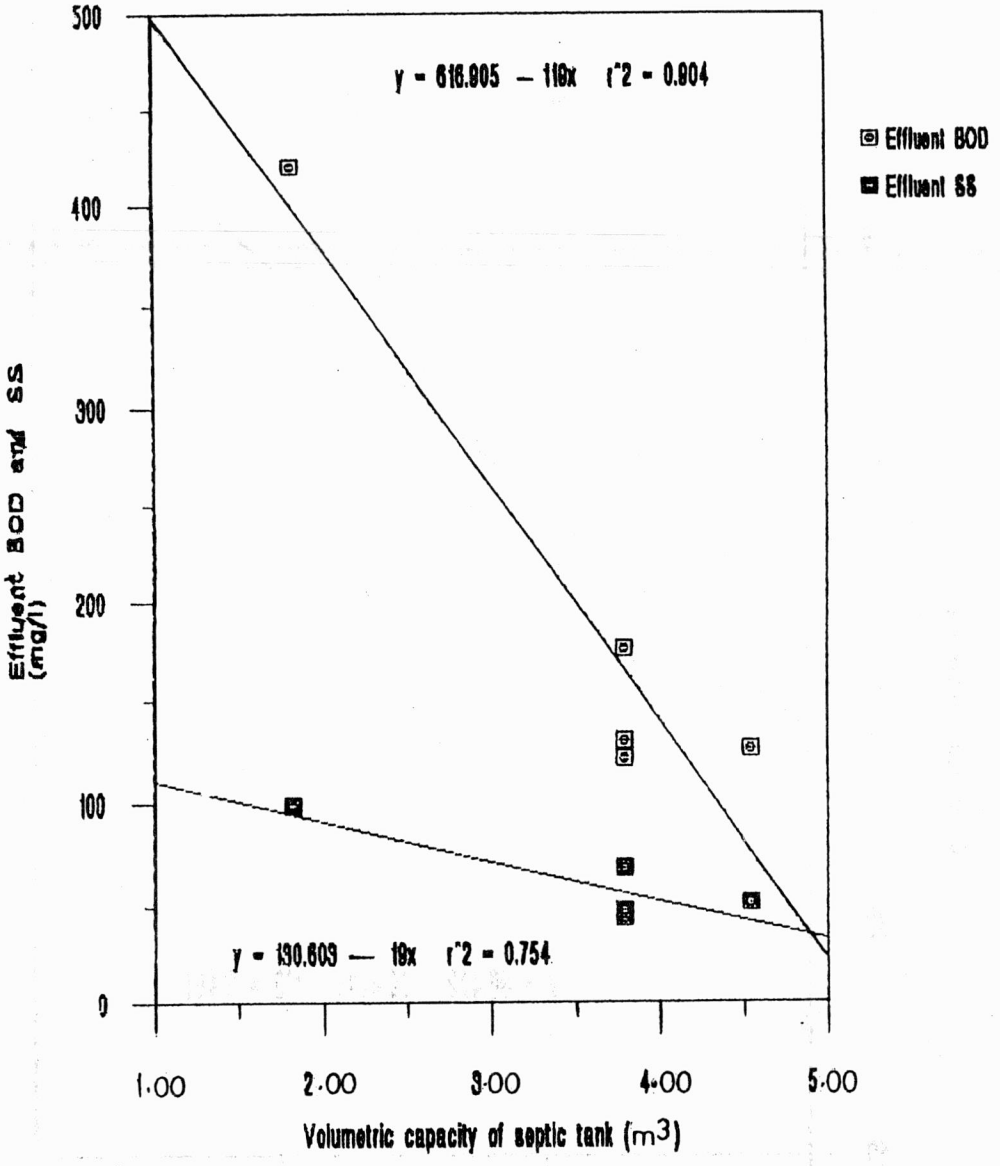

Fig. 5a. Effect of volumetric capacity of septic tank on effluent water quality in 1-compartment septic tank

is in agreement with BRADLEY [26]. Design of septic tank in the hot (tropical) climate that is based on practices in the temperate countries is found to give inconsistent performance. This is because the removal of SS in septic tanks in temperate climate is due to sedimentation, whereas the mineralization of the volatile fraction (and consequently enhanced sedimentation) is a major mechanism for SS removal in hot climate. The hot

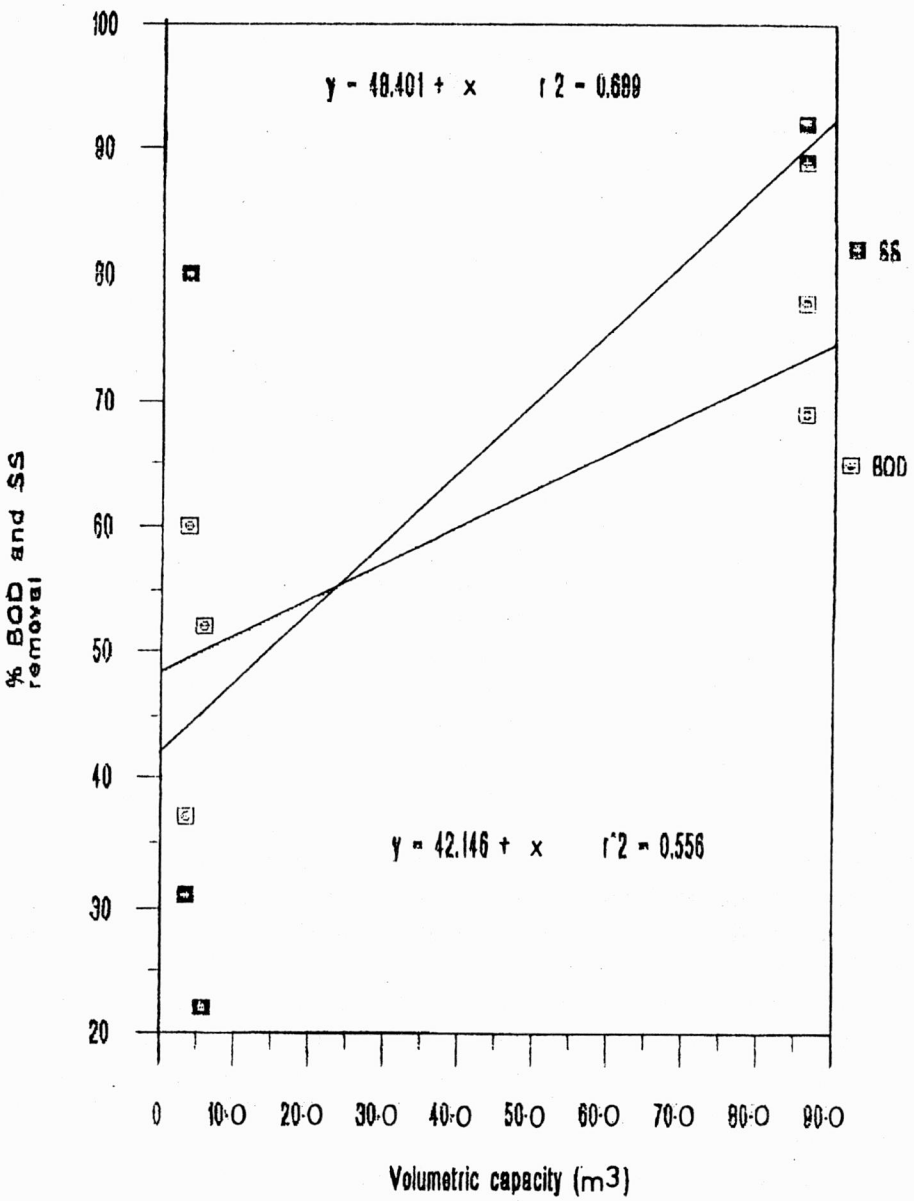

Fig. 5b. Effect of volumetric capacity of 2-compartment septic tank on % BOD and SS removal

climate condition enhances the kinetics of SS and BOD removal in septic tank. Increasing the retention time does not necessarily cause an increase in the BOD removal, particularly in a case where the tank functions primarily as sedimentation unit.

Figures 4a and 4b show the effect of volumetric capacity of septic tanks (1-compartment and 2-compartment systems) on performance in terms of BOD and SS removal from water. In the 1-compartment septic tank, the orders of correlation coefficient (r) for BOD and SS are 0.95 and 0.86, respectively, showing that the performance of septic tanks depends to a very large extent on the effective volume of the tank.

By projecting the graphs (BOD relationship and SS versus volume of tank) in figures 4a and 4b to intersect the volumetric capacity axis, one finds that additional tank capacity, which is ten times that required for achieving 100% SS removal or 20 ppm SS effluent quality, is required to achieve the same level of performance in BOD removal. Therefore, cost effective septic tank design would appear to be better based on percentage suspended solids (SS) removal rather than BOD removal. This does not however suggest that importance should not be attached to removal of BOD in septic tank design in the tropics. Greater consideration to the removal of BOD should be given in the disposal (secondary treatment) than in the septic tank.

In the work of CHAMPIKA [5], there was data of the water quality parameters in the first and second chambers of the 2-compartment septic tanks that were studied under field conditions in Sri-Lanka without the influent characteristic concentration, probably because of lack of access to the influent samples for analysis. Though useful, the evaluation of overall septic tank performance basing on data from such a study is rather difficult. Figure 6 shows the effect of the flow rate on overall BOD and SS removal efficiencies in 2-compartment septic tanks irrespective of the type and the country of location. There is high correlation coefficient (r) of the order of 0.95 for BOD removal versus flow. This trend suggests that increase in flow could have dilution effect. It could also cause:

1. Re-distribution and homogenisation of the microbial population to some degree to enhance digestion rate (BOD removal) and solids gravity settlement.

2. Increase in the particulate collision that enhances agglomeration and sedimentation of particles.

CLEMENSHA [28], WEIBAL and STRAUB [9], BANMANN [27] have shown that greater contact between active particles and the supernatant improved the performance of septic tanks. From the foregoing, the ranking of the primary parameters, which affect performance of septic tanks, is in the order of importance as follows: volume, flow rate and retention time.

Figure 8 shows the effect of the suspended solids' loading rate on BOD removal in 2-compartment septic tank at Sri-Lanka. There is a fair correlation between SS loading and BOD removal ($r = 0.59$). In essence, the increase in organic loading contributes to greater bioactivity that ultimately enhances BOD removal and this is consistent with microbial growth curve. Effect of SS loading rate on percentage SS removal in 3-compartment septic tank at Owerri (Nigeria) is given in figure 10 and follows logarithmic function ($r = 0.71$). Figure 9 shows that percentage faecal coliform kill in 2-compartment septic tank in Sri-Lanka is of the order of 94% and depends on retention time. Now, the change in the faecal coliform population in the septic tank effluent at

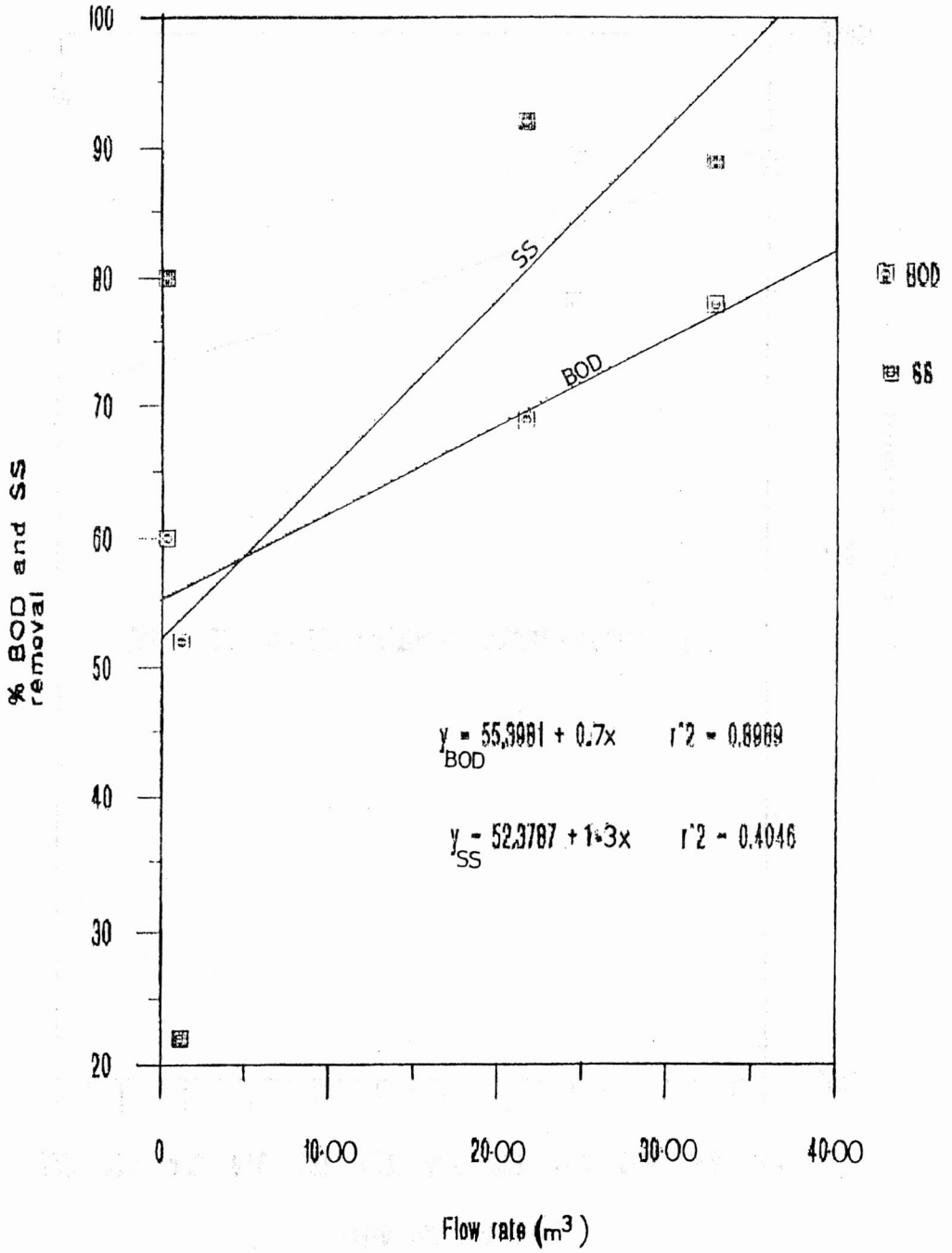

Fig. 6. Effect of flow rate on BOD and SS removal in 2-compartment septic tanks irrespective of location and type

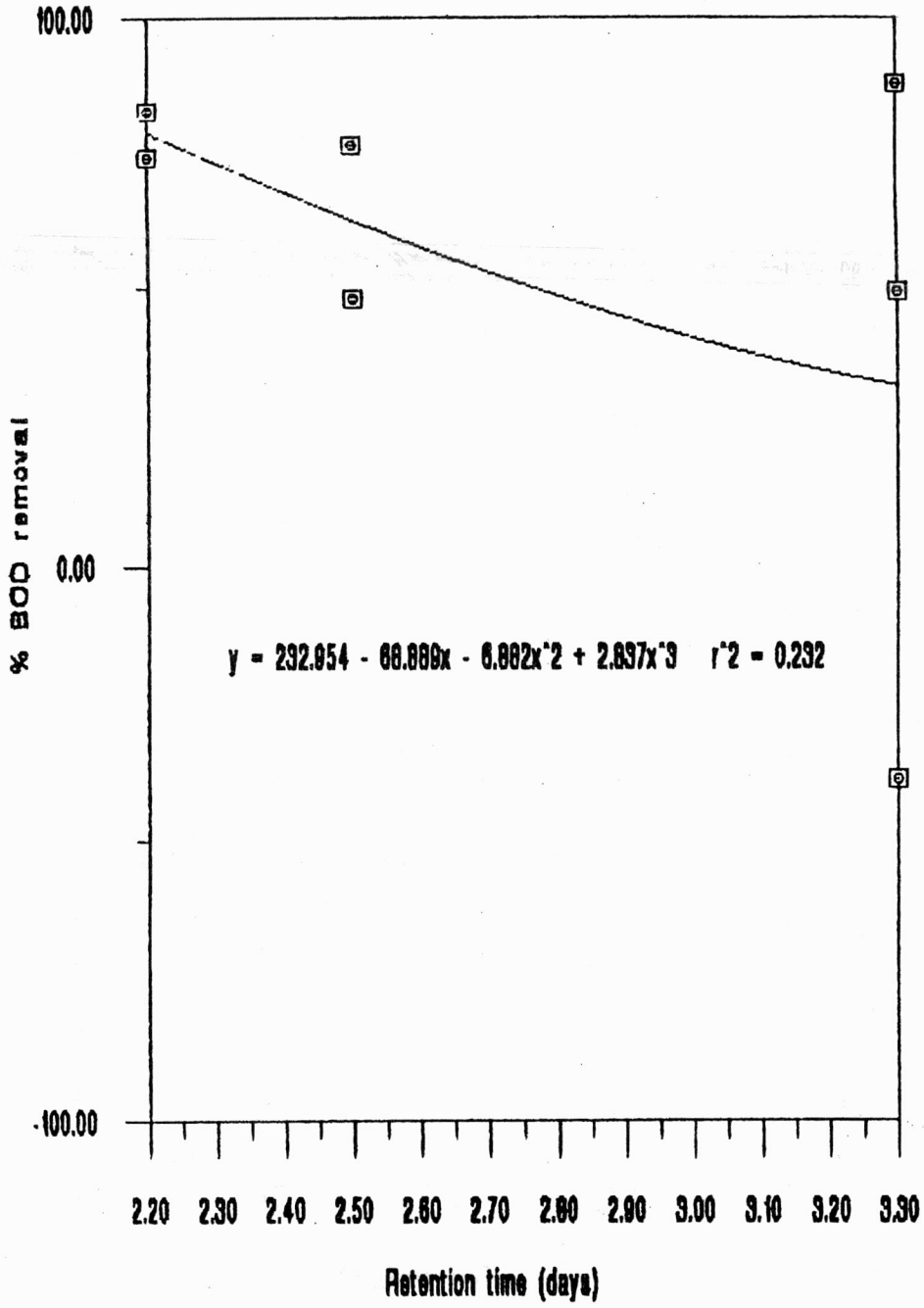

Fig. 7a. % BOD removal versus retention time
in 2-compartment septic tank at Sri-Lanka

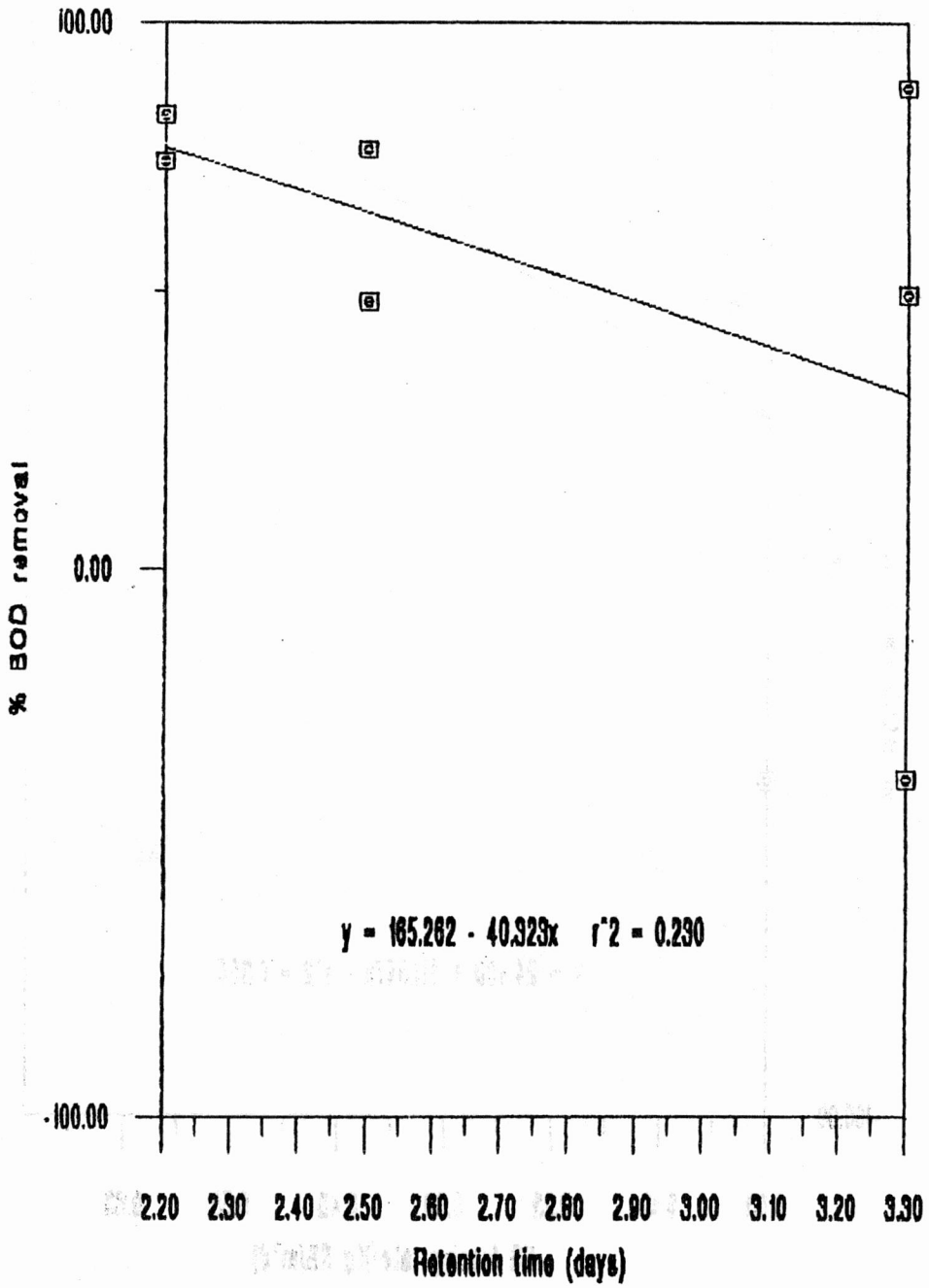

Fig. 7b. % BOD removal versus retention time
in 2-compartment septic tank at Sri-Lanka

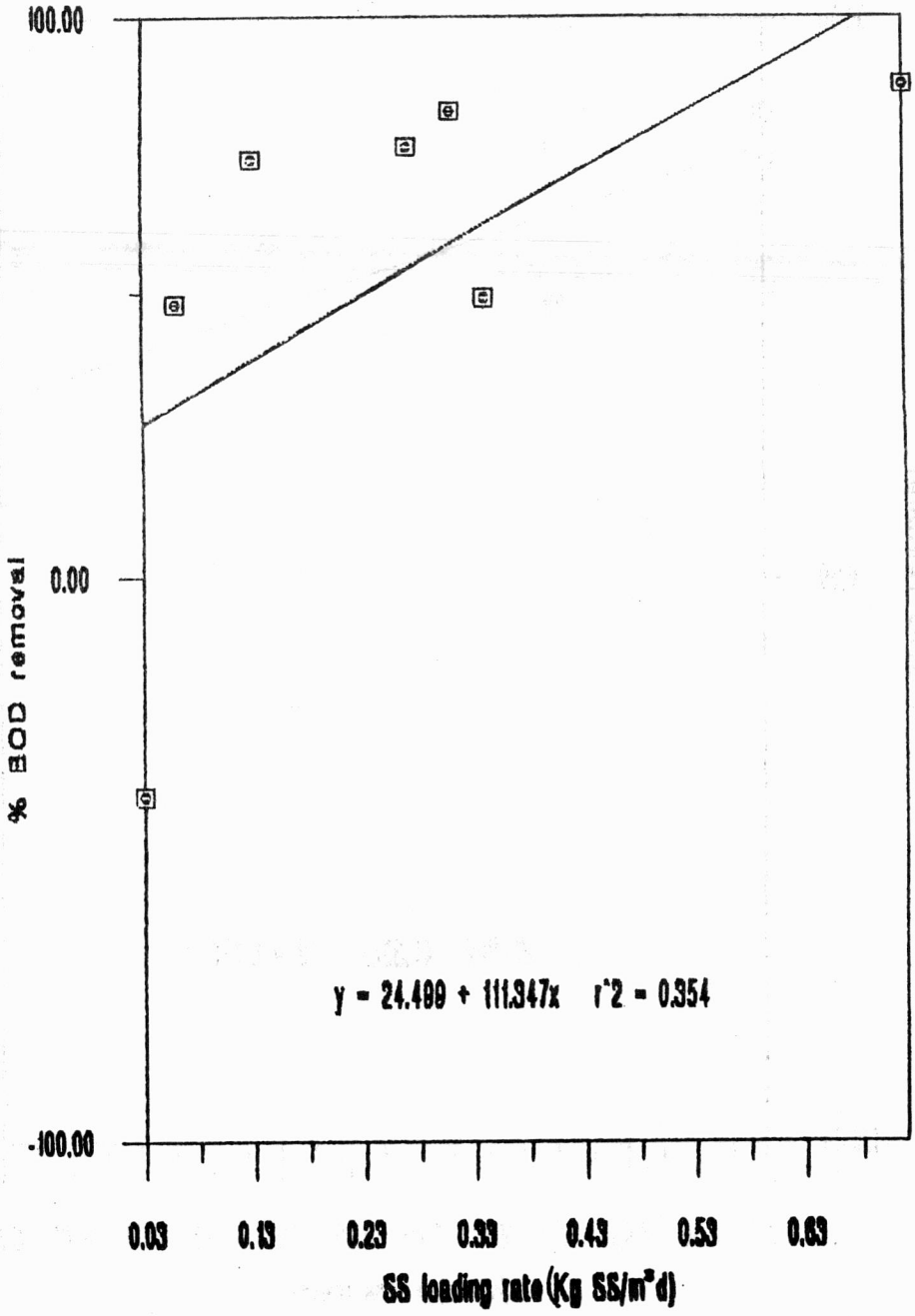

Fig. 8. % BOD removal versus SS loading rate in 2-compartment septic tank at Sri-Lanka

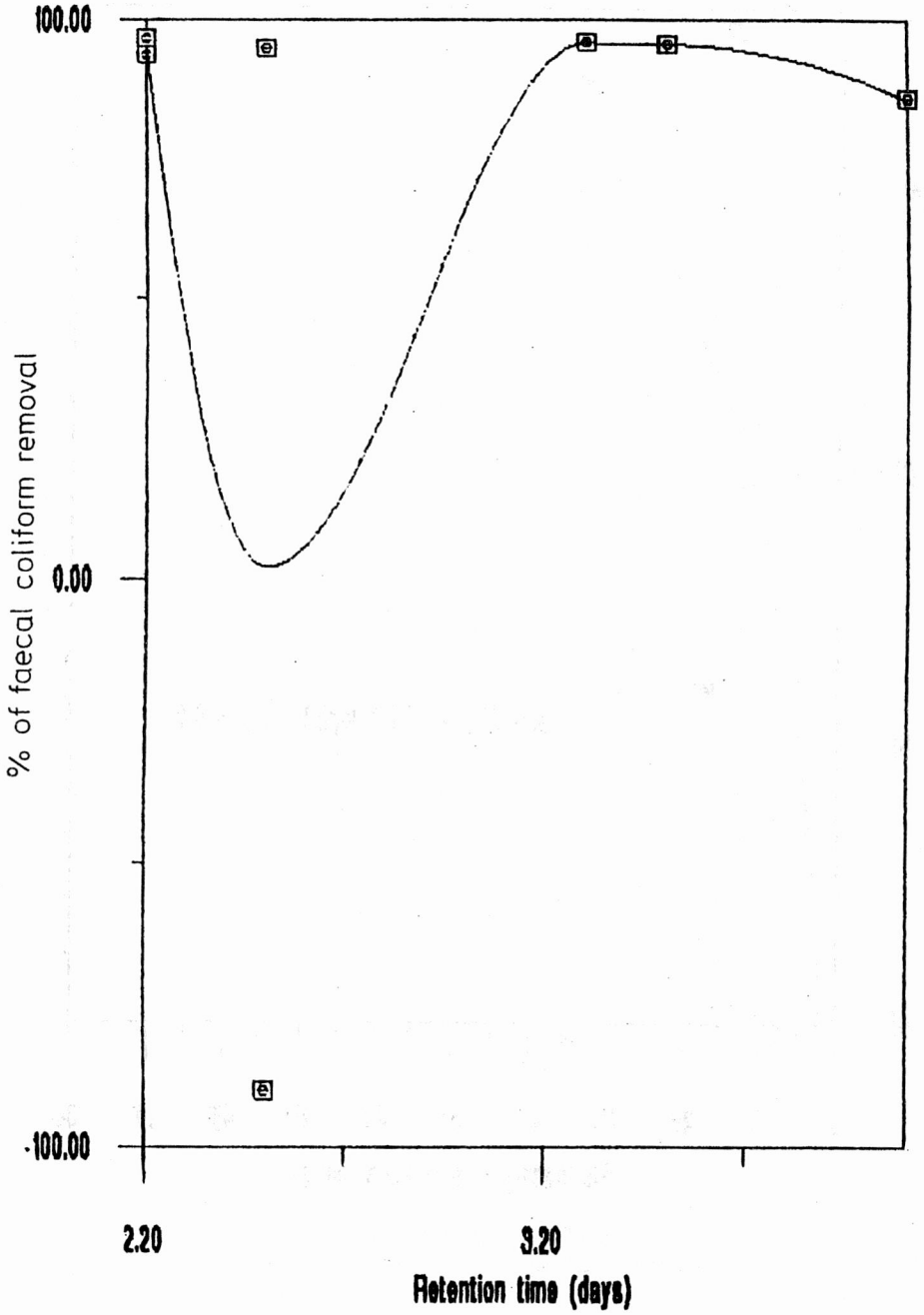

Fig. 9. % faecal coliform kill at various retention time in 2-compartment septic tank at Sri-Lanka

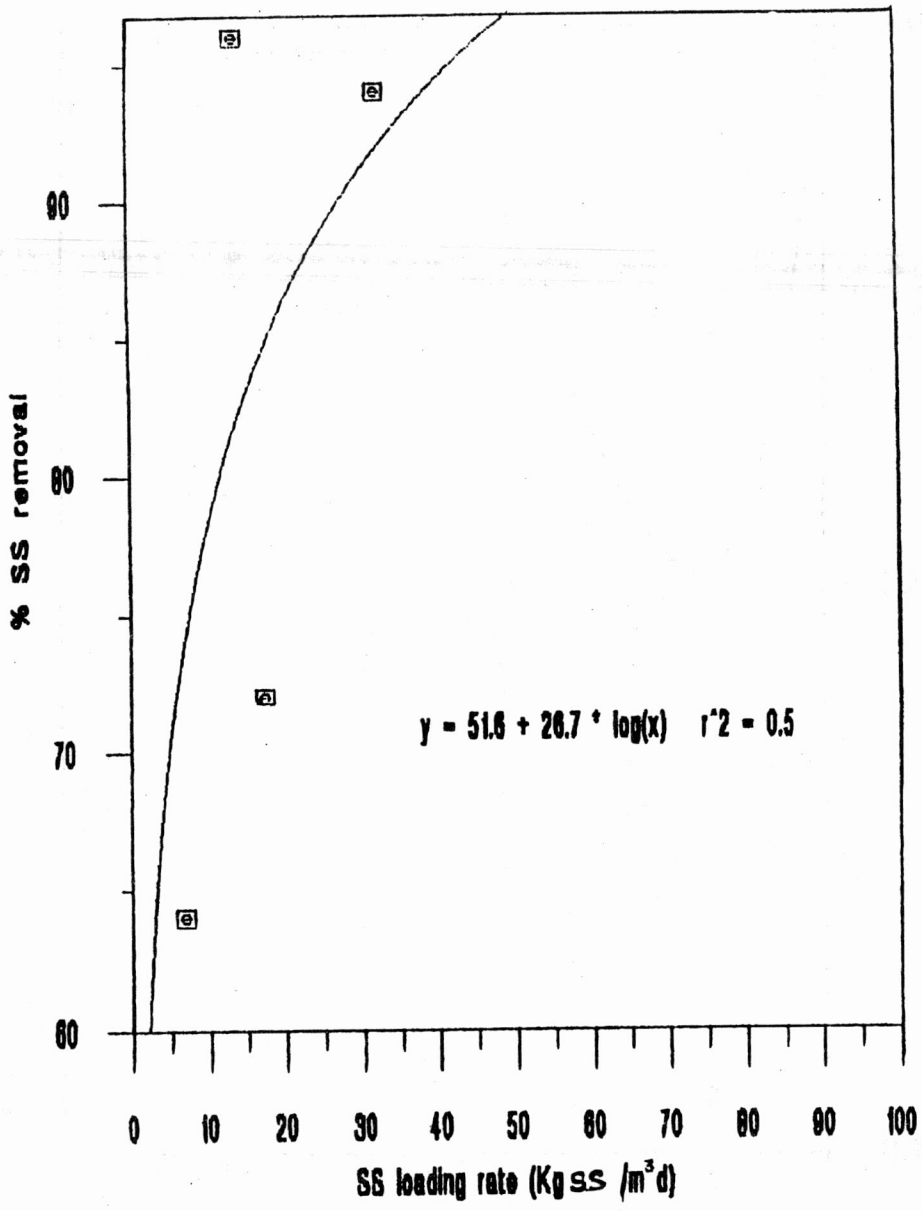

Fig. 10. Effect of SS loading rate on SS removal in 3-compartment septic tank at Owerri (overall)

any given retention time depends on the environmental state of the wastewater. Sometimes the environment could favour regeneration (increase) rather than destruction (decrease) of faecal coliform population. Whatever the cause of this trend may be, it is a subject for verification.

4. CONCLUSIONS

Septic tank in the hot climate countries such as Nigeria behaves as a small sewage treatment plant with the capacity to achieve above 68% BOD and 80% suspended solids removal. Under this performance, septic tank with compartments and good inlet and outlet arrangement, provides the secondary treatment unit (soakaway) effluent less loaded with suspended solids. That gives it greater potentiality to purify septic tank wastewater without undue risk of surface and groundwater pollution.

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PROBLEM SZAMB W ŚRODOWISKU – PRZEGLĄD

Wyczerpująco omówiono dane z literatury na temat laboratoryjnych i terenowych badań szamb w różnych krajach. Zgromadzone dane odnośnie do biologicznego zapotrzebowania tlenu (BZT) i zawiesin zostały przeanalizowane, aby można było powiązać wydajność komór z efektywnością usuwania zanieczyszczeń. Dane przetworzono komputerowo (*Cricket graphics*) i w ten sposób wyznaczono modele wydajnościowe w różnych krajach, tj. w Stanach Zjednoczonych, Kanadzie, Sri Lance, Indiach, Brazylii, Zambii i Nigerii.

Wyniki wskazują, że globalnie średnia efektywność usuwania zawiesin ciał stałych w szambach niezależnie od ich typu w krajach o gorącym klimacie (takich jak Nigeria) wynosi zazwyczaj 80%. Efektywność usuwania BZT wynosi przeciętnie ~68% dla czasu retencji krótszego niż 2,8 dnia. Znaczenie parametrów, które wpływają na działanie komór fermentacyjnych, jest uporządkowane od efektywnej objętości, szybkości przepływu do czasu retencji.