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SEWAGE SLUDGES DISINFECTION

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Abstract

There is an hygienic risk in using biological sewage sludges for agriculture. Systematic analysis carried out on sludges samples obtained from purification plants in East and South part of France, show the almost uniform presence of pathogenic microorganisms. Some of it survive more than 9 months after soil application.

Conventional process for disinfection : liming and heat are not suitable for agricultural use. On the other hand, irradiation involves no modification in structure and composition of sludges.

Radiation doses required for disinfection vary according to microorganisms. If some of them are eliminated with rather light doses (200 krad) mycobacteria, viruses and eggs of worms resist to more important doses.

Security dose is estimated around 1000 krad.

I. INTRODUCTION

Interest of sewage sludges application in agriculture is very fully proved. Concentration in organic matters and in mineral fertilizers go to make an interesting improvement.

Spreading on cultivated areas constitutes an elegant way for disposal of a product ordinarely considered as an encumbering waste, generating varied nuisances.

Independantly of chemical toxicity problems due to heavy metals, it is necessary to consider elimination of any microbial risk. Sludges include, or are liable to include some pathogenic microorganisms, dissemination of which, in the soil and on vegetation and crops could originate propagation of diseases for cattle and for people.

Systematic survey of sludges samples, obtained from purification plants in East and South part of France, have been performed during 1976. 71 samples spread over one year were obtained from following towns : Aix-en-Provence, Marignane, Vitrolles, Ginasservis, Manosque and Pertuis. 42 others have been obtained during two campaigns in february, marsh and april, and in july-august from plants of Eulmont, Dombasles, Fleville, Nancy, Charmes, Epinal and Saint Dié.

Plants characteristics are reported in table I.

The results of sludges analysis are collected in tables II and III.

All the samples contain from 10^4 to 10^5 pyocianic bacillus Samples from 3 plants contain Salmonella, Mycobacteria are detected in 30 to 60 % of samples from all the plants at counts varying from 10^3 to 10^5.

Ascaris eggs, the only parasite found out during study, are isolated in sludges from 5 plants.

In conclusion, non stabilized sludges, sampled from all of the investigated plants include pathogenic microorganisms.

Moreover these microorganisms survive during a variable time after soil application. Results obtained concurently with detection of pathogenic organisms are given in table IV.

E. Coli count decreases of only 3 logs after 9 months stay in soil. After 5 months burying, Salmonella have disappeared until zero count, number of microorganisms regularely decreases following time.

Mycobacteria stay remarkably stable. Counting gives constant results all the 9 months examination long.

Ascaris embryonary eggs give larva in two weeks. These one stay alive for 3 months. Segmented eggs were hatched after 2 months. Larva survived 3 months.

2. SLUDGES DISINFECTION METHODS

Various process may be considered for sludge sanitation. No one is absolute in the conditions of current application. The most used of them present, from an agricultural point of view, major disadvantages.

. Heat [1]

With some sporulated organisms, effective disinfection is observed only from 120°C in wet heat and for a contact time of 20 mn.

Ascaris eggs are more sensitive to heat in liquid sludges than in dried ones. It is necessary to reach 70°C during 10 mn or 80°C during 5 mn to obtain eggs destruction.

Rising temperature induces coagulation for part of organic matters and involves removing of the greatest part of nitrogen included in sludges. In consideration of the important volumes to be treated, this process appears quite expensive .

. Liming [1] [2]

Liming represents a quite effective technique of disinfection for current bacteria. Rising pH value to 12 allow to attain residual bacteria count respectively equal to 0.34 % for Coliforms, 0.63 % for Streptococus and 0.49 % for Clostridia spora.

This process is inactive against mycobacteria and Ascaris eggs.

Viruses are inactivated at 100 %.

On the other hand, rising of pH value makes limed sludges unsuitable for agricultural purposes in neutral or chalky soils. Moreover, recent studies point out that liming contributes to plant assimilation of some toxic heavy metals.

. Irradiation

This technique has been dealt with in several studies and many publications, pecularly during last symposium organised by AIEA in MUNICH [3].

Teachings drawn from these studies are ambiguous. Generally authors have not devoted to a systematic study of elimination of various microorganisms present in sludges, but have been satisfied with following evolution of one test bacteria, usually a Salmonella, that is pecularly radiosensitive. This fact explains relatively light doses recommanded for sludge disinfection, doses that are located around 300 to 400 krad.

It appears, in fact, that lethal doses vary considerably from one microorganism to another. Definition of the radiation dose suitable for disinfection or pasteurization of sludges, needs that microorganisms that are encountered or susceptible to be encountered in sludges, be considered on the whole. Results of such an examination are presented in this paper.

3. RESEARCH OF LETHAL DOSES FOR SOME PATHOGENIC MICROORGANISMS ENCOUNTERED IN SLUDGES

3.1. Methods

Irradiations are carried out in an Ammonite 407 type irradiator, built by Service d'Application des Radio Elements et des Rayonnements at the Centre d'Etudes Nucléaires de GRENOBLE (France).

Radiation source is made of 2 cesium chloride disks (^{137}Cs) with 2 x 4.750 Ci activity, emitting 0.662 Mev photons. ^{137}Cs period is 30 years.

A small barrel allows to position samples to be irradiated in front of the two sources. Dose rate in the middle of the chamber is 0.7 mRad/h. The dose uniformity in the useful volume is $\pm$ 20 %.

The cultures of microorganisms are incorporated to sludge before irradiation. Count is then effected on reference sample and on irradiated sample. Results are expressed in percentage of residual microorganisms.

Irradiation of pure cultures is effected in liquid medium (nutritive broth).

Owing to the unreliability of elution methods for viruses adsorbed on sludges, irradiation of viral cultures has been practiced in aqueous phase (Domestic sewage previously sterilized).

3.2. Bacteria

. Bacteria tests of fecal pollution

Results are reported on table V. Numbers presented indicates the mean value of several measures, the number of which varies from 60 to 15, according to the dose application. For every series of measure, the mean value of counts in reference sample and in irradiated samples is given.

It appears that a 1800 krad dose is inadequate to destroy the whole microorganisms. A decrease of 4 logs in count of coliforms and Streptococus is obtained for 800 krad. A comparable decrease in Clostridia count is obtained only for 1600 krad.

. Irradiation of pure cultures

Diagrams 3 to 10 show evolution of microorganisms count in sludge or in liquid media, according to the radiation dose applicated to different bacterial cultures.

It distinctly appears that most of bacteria are eliminated for relatively weak doses, included between 50 and 150 krad. That is especially the case for following enterobacteria : Salmonella typhimurium, Klebsiella, E. Coli, Proteus, Enterobacter.

On the contrary, mycobacteria in aqueous phase as in dry medium, are eliminated only with much most important doses, located around 1800 krad.

3.3. Viruses

In the same way, diagram 11 locates the radiation dose suitable for complete inactivation of poliovirus between 1.400 and 1.600 krad.

3.4. Ascaris eggs

In table VI are collected results obtained after irradiation of Ascaris megalocephala eggs, treated at various stage of development.

It is pointed out that only mobile embryonary eggs with smooth shell are destroyed for a dose lower than 400 krad. Eggs irradiated at every other stades of development stay alive for doses reaching 1800 krad.

CONCLUSION

It appears that the radiation dose suitable for sludge disinfection and securing good conditions for use, is higher than values currently admitted, from 300 to 400 krad. The security dose is more probably located around 1 Mrad.

This value keep compatible with industrial exploitation of the process. This being so, the cost of disinfection treatment of sludges obtained from a 100.000 inhab. purification plant, using an electron accelerator as a radiation source, works out at 0.16 FF/kg of dry matter. The cost of conventional conditioning of sludges on a plant of same importance is estimated between 0.48 and 0.50 FF/kg of dry matter.

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TABLEAU 1. Caractérisation des prélèvements de boues

1- 71 prélèvements répartis sur 1 an

Localité	Nombre d'hab.	Caractérisation des boues
AIX-EN-PROVENCE	60 000	boues secondaires moyenne charge
MARIGNANE	33 000	boues secondaires moyenne charge
VITROLLES	13 000	boues secondaires faible charge
GINASSERVIS	800	aération prolongée sans décantation primaire
MANOSQUE	20 000	boues secondaires moyenne charge
PERTUIS	10 000	boues secondaires moyenne charge

2- 42 prélèvements répartis en 2 campagnes

EULMONT	700	aération prolongée sans décantation primaire
DOMBASLE	5 000	aération prolongée
FLEVILLE	1 200	aération prolongée
NANCY	32 000	boues primaires + boues secondaires
CHARMES	6 000	boues primaires
EPINAL	20 000	boues primaires + boues secondaires
SAINT DIE	10 000	boues primaires

TABLEAU 2. Recherche des organismes pathogènes dans les boues de stations d'épuration Groupe 1.

Lieu de prélèvement	Nb de prélèv.	E.Coli		B.Pyocyanique		Salmonelles		Mycobactéries		Oeufs d'Ascaris	
		% échant. positifs	Nb/g boues	% échant. positifs	Nb/g boues	% échant. positifs	Nb/g boues	% échant. positifs	Nb/g boues	% échant. positifs	Nb/g boues
AIX EN PCE	12	100	$3,5.10^9$	100	5.10^4	0	0	37,5	5.10^3	0	0
MARIGNANE	22	100	6.10^{11}	100	7.10^5	14	3.10^2	50	3.10^3	37,5	3.10^1
VITROLLES	9	100	$8,4.10^4$	100	$5,8.10^5$	11	$8,5.10^2$	37,5	2.10^4	0	0
GINASSERVIS	12	100	$2,9.10^9$	100	$3,3.10^4$	0	0	45	$6,4.10^3$	27	6.10^2
MANOSQUE	13	100	$1,2.10^9$	100	$8,9.10^3$	0	0	30	$5,5.10^3$	7,5	1.10^3
PERTUIS	13	100	$5,7.10^8$	100	$1,5.10^3$	0	0	46	$8,5.10^3$	0	0

TABLEAU 3. Recherche des organismes pathogènes dans les boues de stations d'épuration Groupe 2.

Lieu de Prélèvement	Nb de prélèv.	E. Coli		B.Pyocyanique		Salmonelles		Mycobactéries		Oeufs d'Ascaris	
		% échant. positifs	Nb /g boues	% échant. positifs	Nb/g boues	% échant. positifs	Nb/g boues	% échant. positifs	Nb/g boues	% échant. positifs	Nb/g boues
CHARMES	6	100	$6,7.10^3$	100	2.10^4	0	0	33	1.10^4	0	0
EPINAL	6	100	$1,2.10^{11}$	100	$7,8.10^4$	16,5	$3,2.10^2$	66	5.10^3	33	1.10^2
ST DIE	6	100	$1,1.10^{10}$	100	$2,8.10^4$	0	0	33	$6,6.10^2$	0	0
NANCY	6	100	$1,8.10^9$	100	$1,4.10^4$	0	0	66	$1,7.10^5$	0	0
EULMONT	6	100	$1,1.10^9$	100	$2,4.10^5$	0	0	66	6.10^4	33	$3,7.10^3$
DOMBASLE	6	100	$1,7.10^9$	100	2.10^4	0	0	33	1.10^3	0	0
FLEVILLE	6	100	$2,6.10^1$	100	$1,1.10^4$	0	0	33	$1,4.10^5$	0	0

TABLEAU 4. Persistance de quelques germes pathogènes dans le sol

Date des prélèv.	E. Coli		Salmonella typhimurium		Salmonella London		Mycobactéries (BCG)		Oeufs d'Ascaris	Oeufs d'Ascaris
	Nb germ.	% résid.	Nb germ.	% résid.	Nb germ.	% résid.	Nb germ.	% résid.		
11.2.76	3.10^8		4.10^6		4.10^7		1.10^4		oeufs embr.	
25.2.	3.10^8	100	5.10^6	100	3.10^7	75	1.10^4	100	larves	
10.3	1.10^8	33	4.10^4	1	7.10^4	0,17	1.10^4	100	larves	
5.4	4.10^7	13	1.10^3	0,025	6.10^4	0,15	1.10^4	100	larves	
24.4	9.10^6	3	9.10^2	0,022	4.10^4	0,1	1.10^4	100	larves	oeufs segm.
11.5	9.10^5	0,3	9.10^2	0,022	$2,5.10^3$	0,006	1.10^4	100	larves	oeufs vivants
20.5	-	-	-	-	-	-	-	-	larves	oeufs vivants
3.6	3.10^5	0,1	8.10^2	0,002	2.10^3	0,005	1.10^4	100	larves	larves
8.6	-	-	-	-	-	-	-	-	larves	larves
15.6									absence de larves	larves
23.6	3.10^5	0,1	4.10^1	0,001	2.10^1	0,00005	1.10^4	100	"	"
19.7	$2,2.10^5$	0,07	0	0	0	0	1.10^4	100	"	"
11.9									"	"
12.11	$2,2.10^5$	0,07	0	0	0	0	1.10^4	100	"	absence de larves

TABLEAU 5. Irradiation des germes tests de pollution fécale
Pourcentage de germes résiduels.

Doses kRad / Germes	400		800		1200		1800	
	15		10		15		6	
Colibacilles	$6,3.10^{10}$ $1,4.10^{9}$	2,22	$1,02.10^{12}$ $5.03.10^{8}$	0,04	$4,39.10^{10}$ $7,33.10^{5}$	$1,7.10^{-3}$	$9,4.10^{11}$ $1,9.10^{6}$	$2,02.10^{-4}$
Streptocoques	$1,07.10^{9}$ $1,7.10^{7}$	1,63	$7,9.10^{10}$ $1,24.10^{8}$	0,15	$1,04.10^{9}$ $5,3.10^{4}$	5.10^{-3}	$1,5.10^{9}$ $2,08.10^{4}$	$1,38.10^{-3}$
Clostridies	$1,18.10^{6}$ $5,7.10^{5}$	48,5	$1,08.10^{6}$ $2,9.10^{4}$	2,73	$1,09.10^{6}$ $3,1.10^{3}$	0,29	$3,53.10^{5}$ $1,13.10^{1}$	$3,2.10^{-3}$

TABLEAU 6. Irradiation des oeufs d'Ascaris megalocephala

Dose kRad / Stades de dévelop.	400	800	1200	1800
Oeufs segmentés	+	+	+	+
Oeufs embryonnés immobiles à coque mamelonnée	+	+	+	+
Oeufs embryonnés mobiles à coque mamelonnée	+	+	+	+
Oeufs embryonnés mobiles à coque lisse	-	-	-	-

Fig.3 - SALMONELLA TYPHIMURIUM

Recherche de la dose léthale

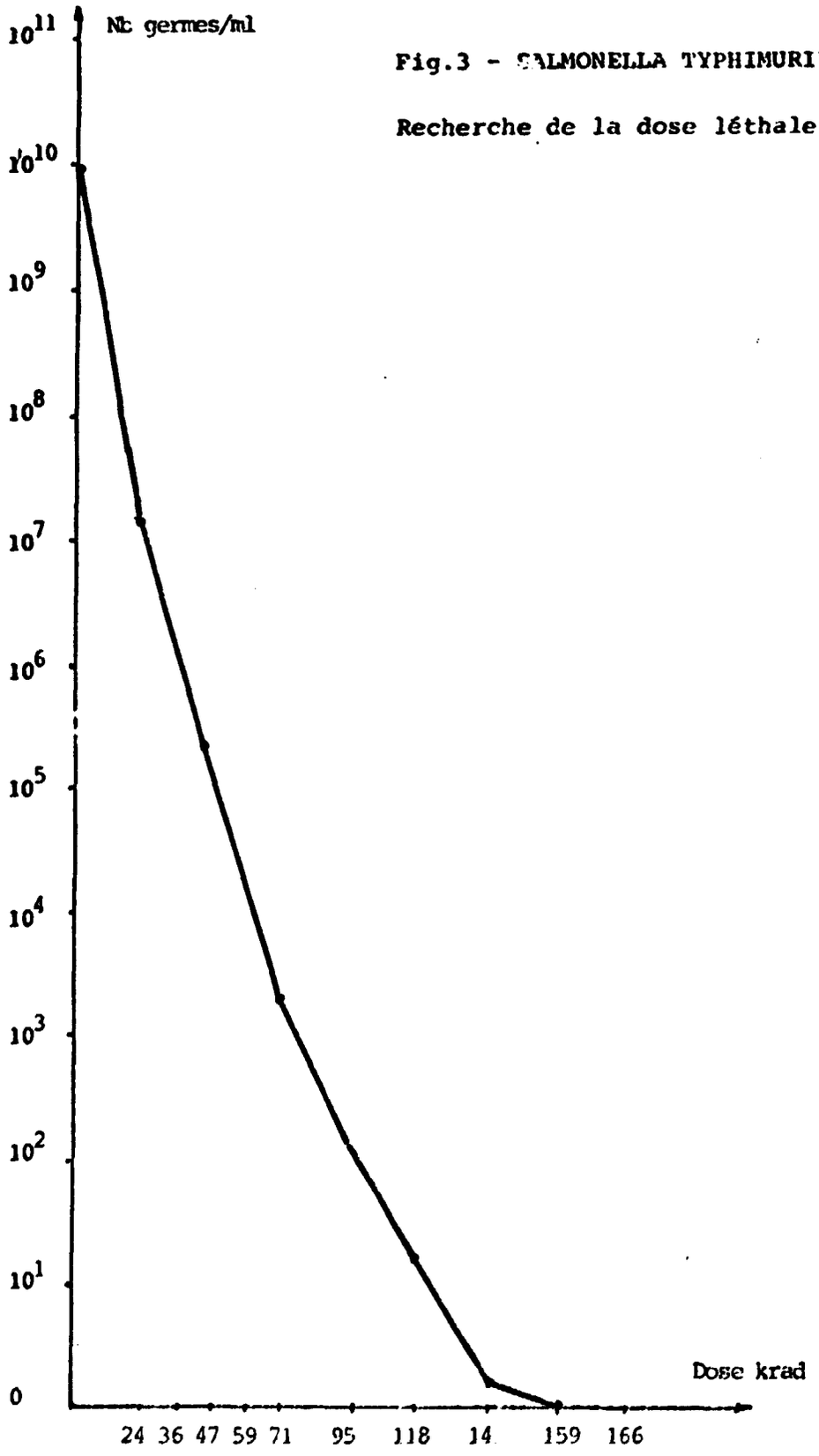


Fig.4 - KLEBSIELLA OZONAE

Recherche de la dose léthale

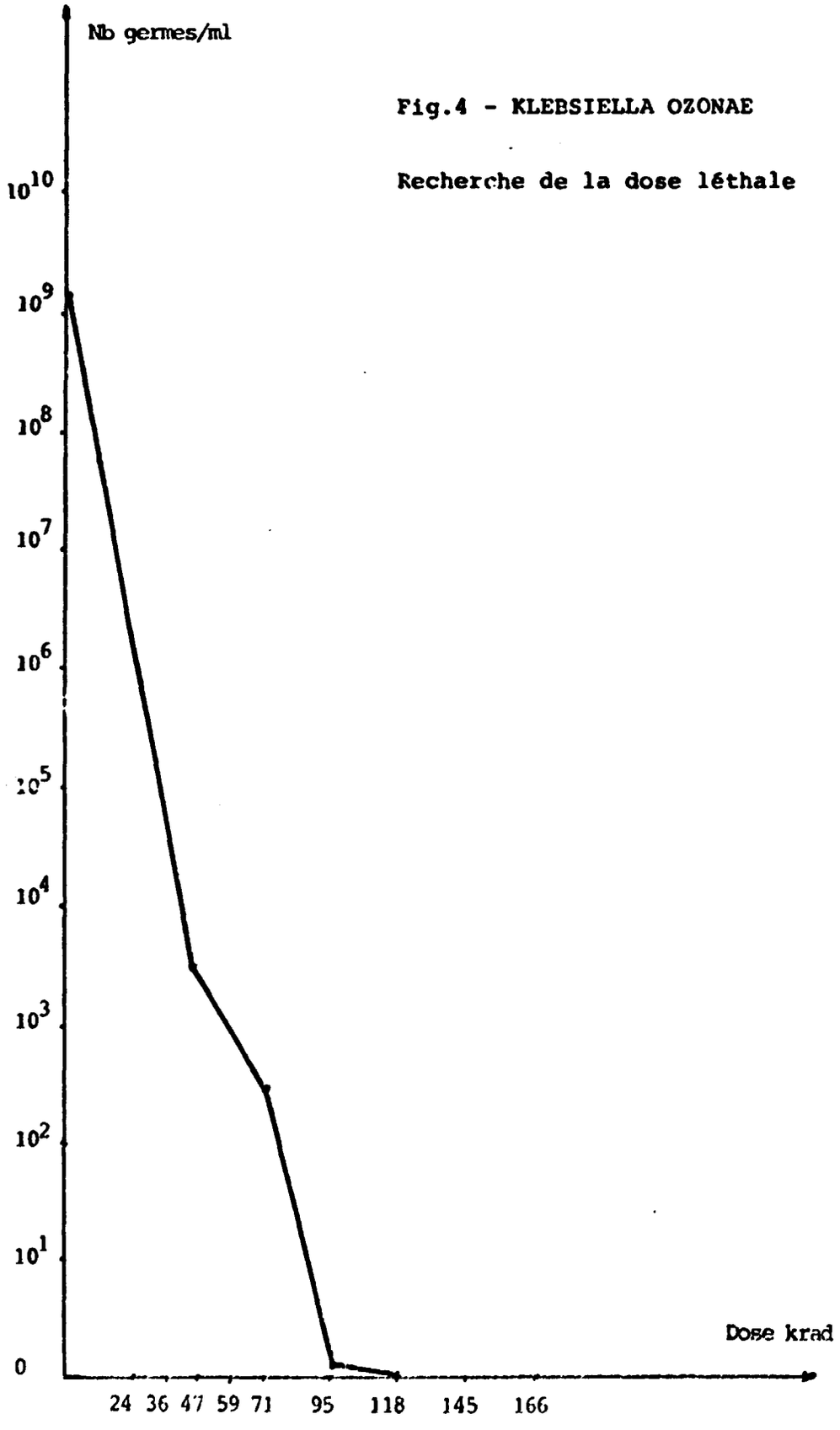


Fig.5 - KLEBSIELLA OXYTOCA

Recherche de la dose léthale

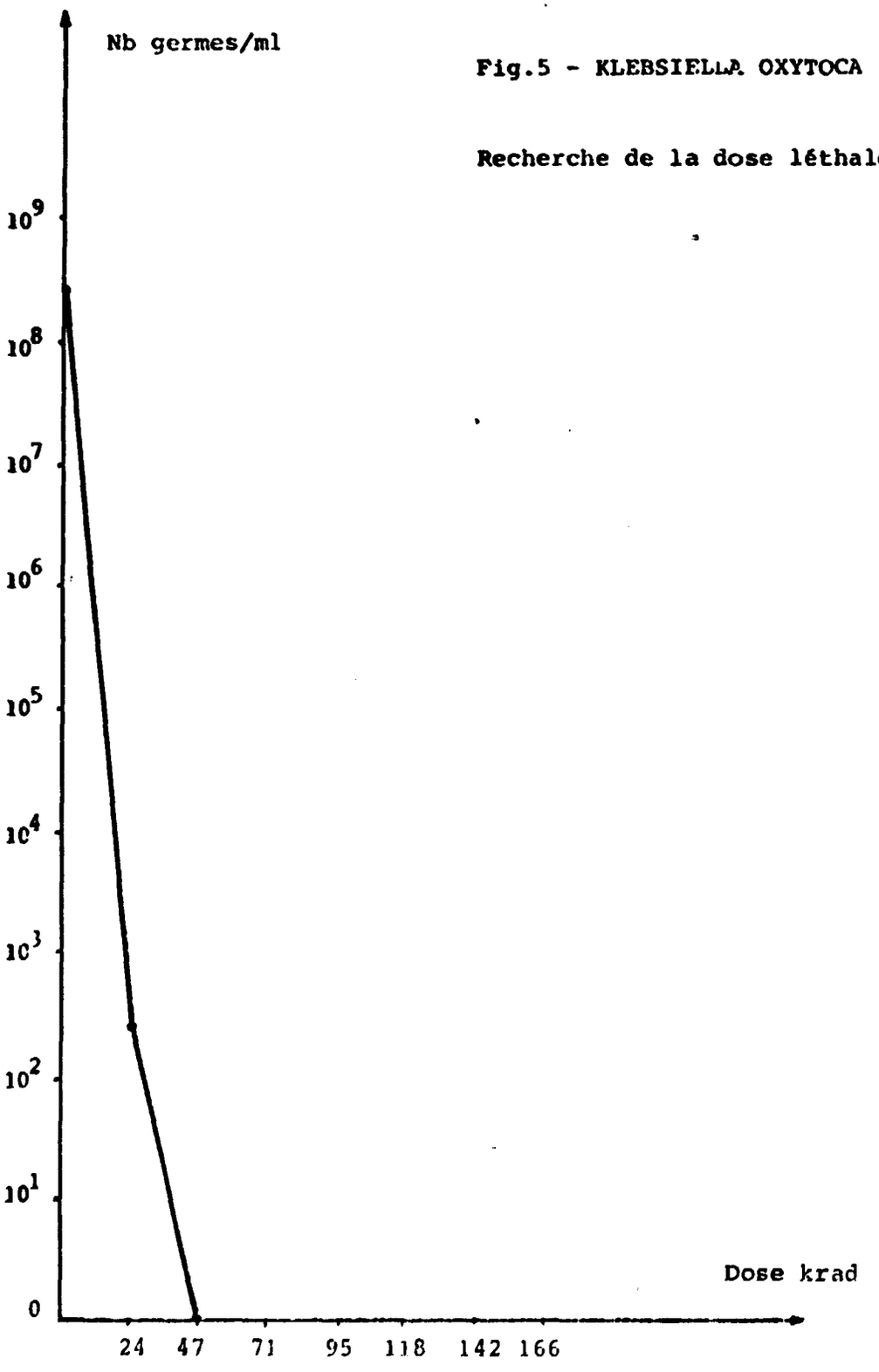


Fig.6 - KLEBSIELLA PNEUMONIAE

Recherche de la dose léthale

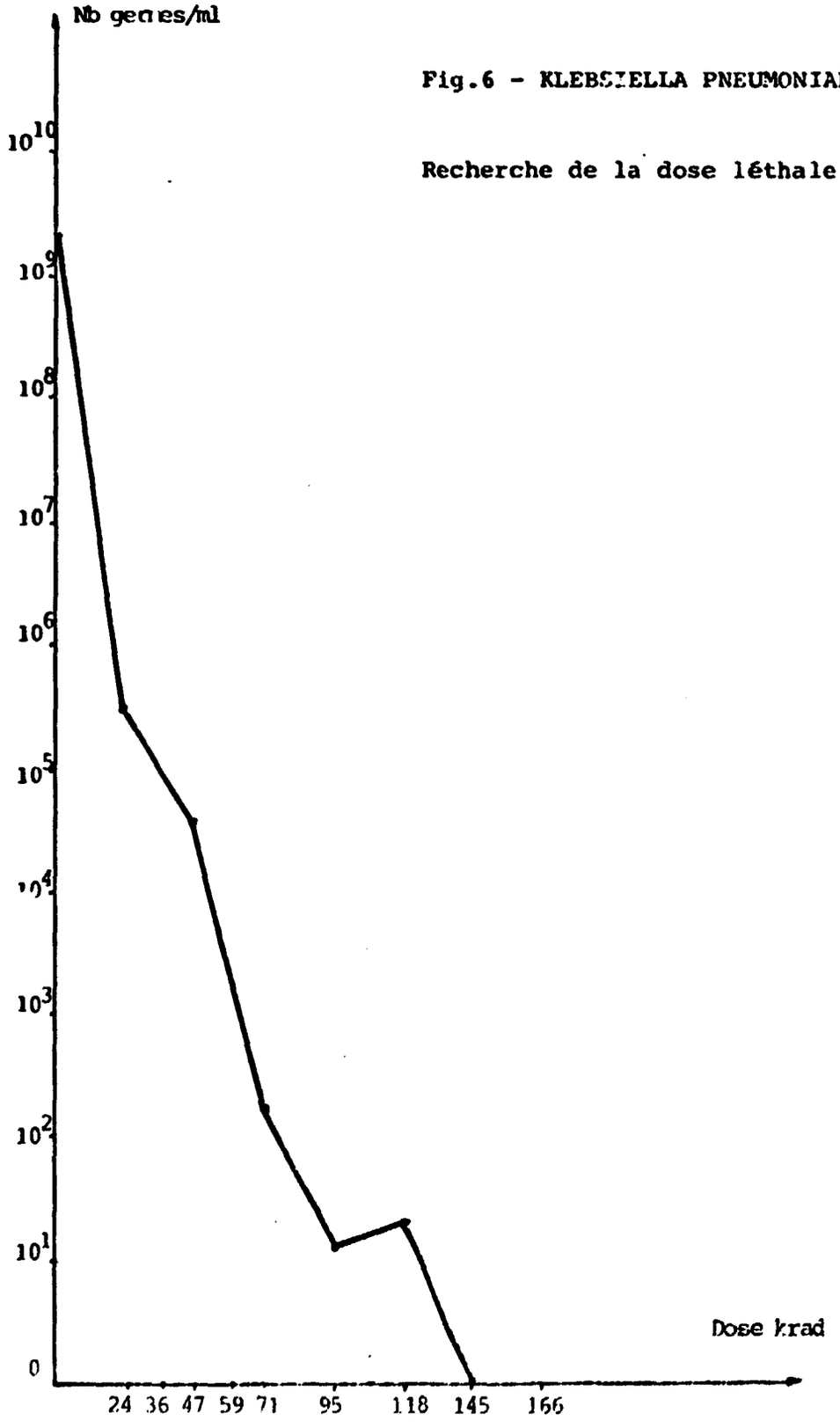


Fig. 7 - ESCHERICHIA COLI

Recherche de la dose léthale

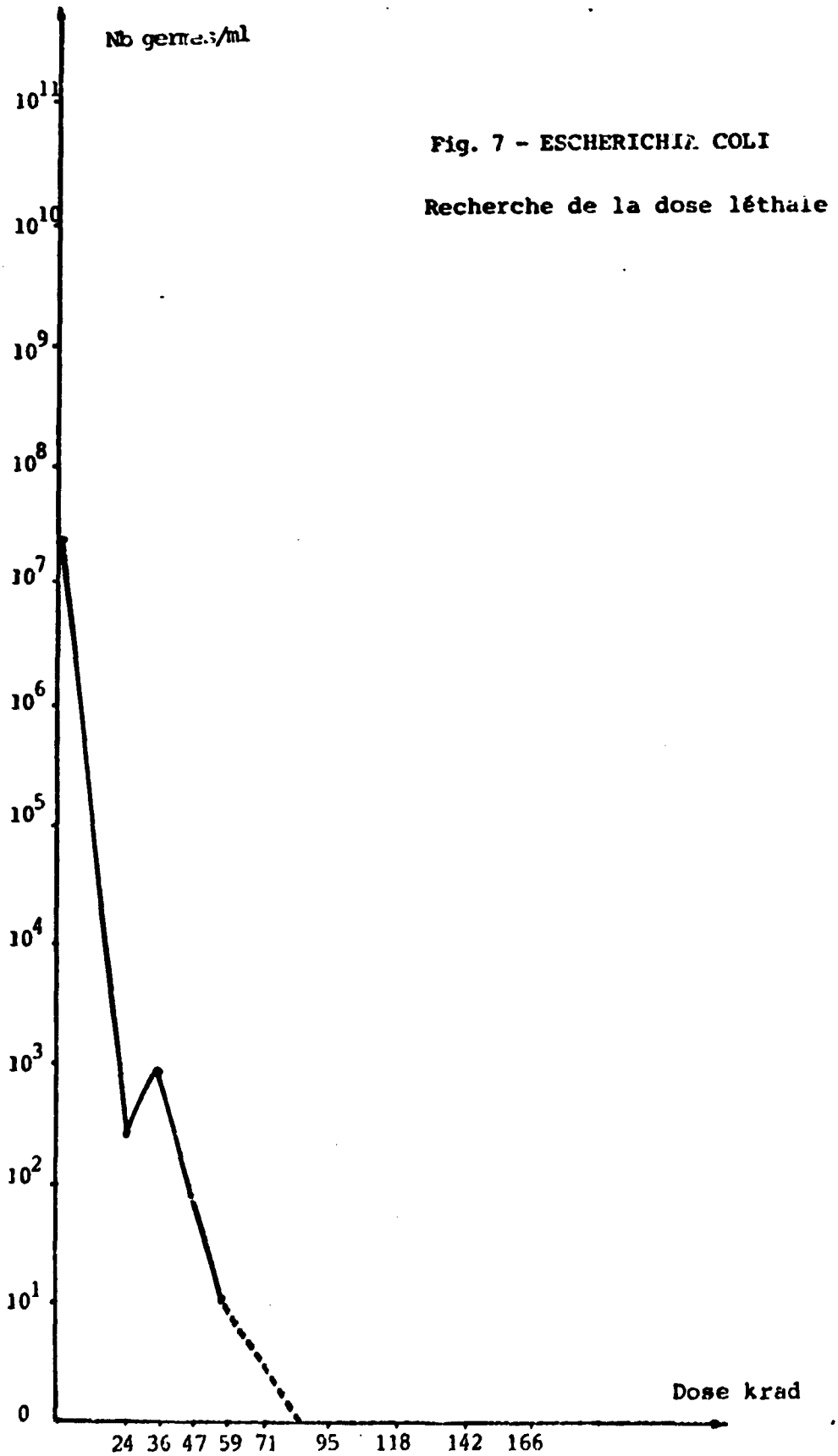


Fig.8 - PROTEUS MIRABILIS

Recherche de la dose léthale

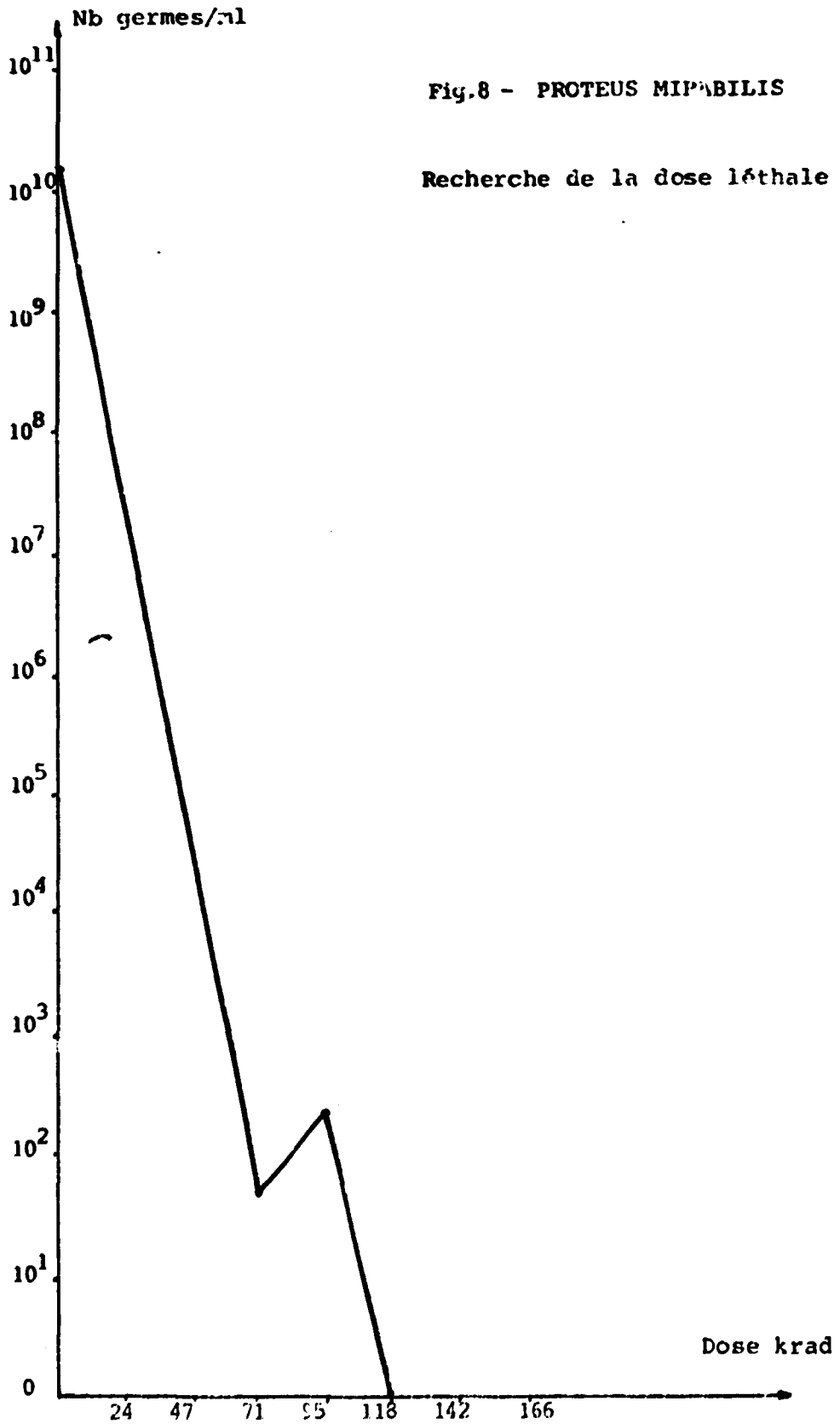
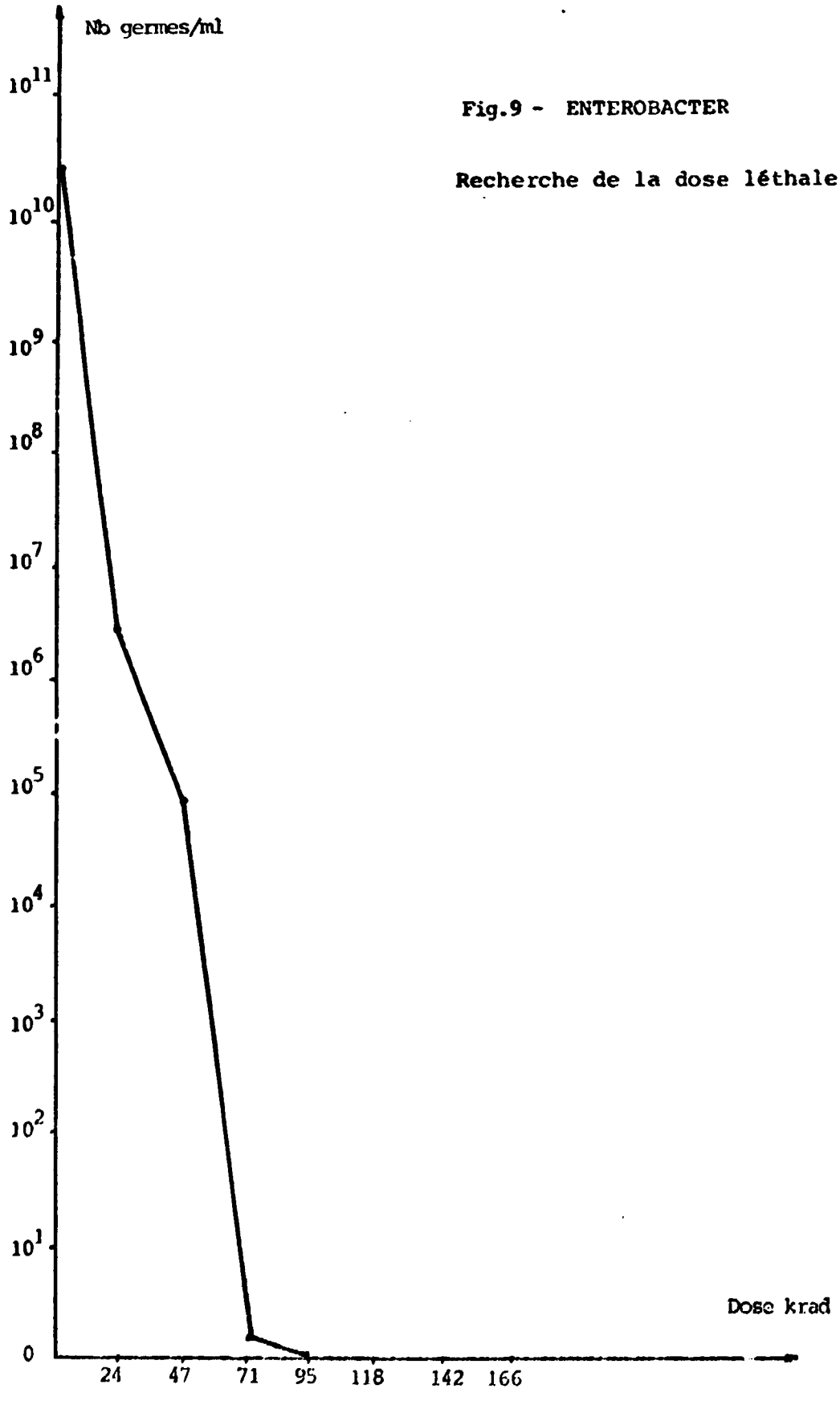


Fig.9 - ENTEROBACTER

Recherche de la dose léthale



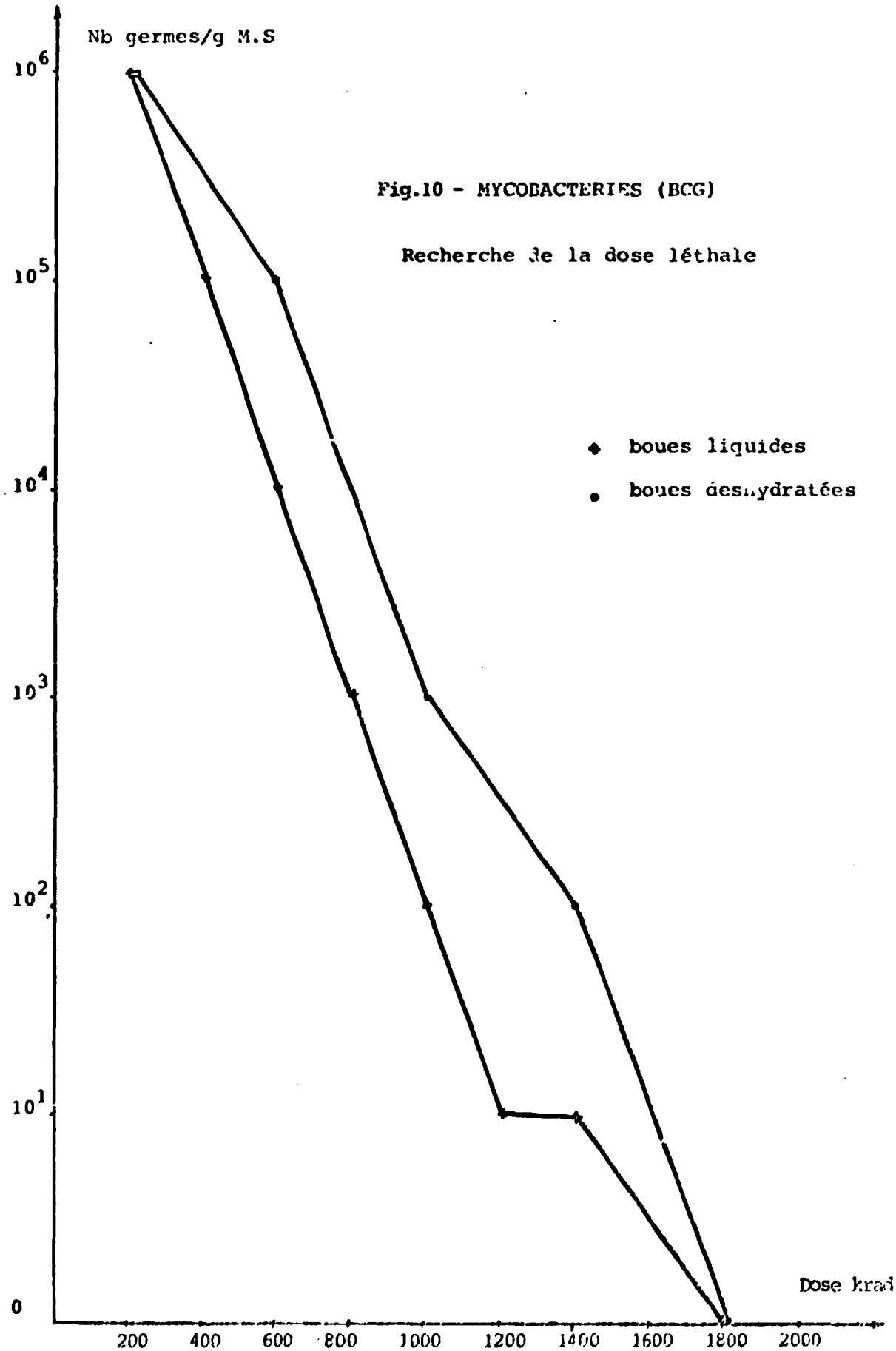


Fig.10 - MYCOBACTERIES (BCG)

Recherche de la dose léthale

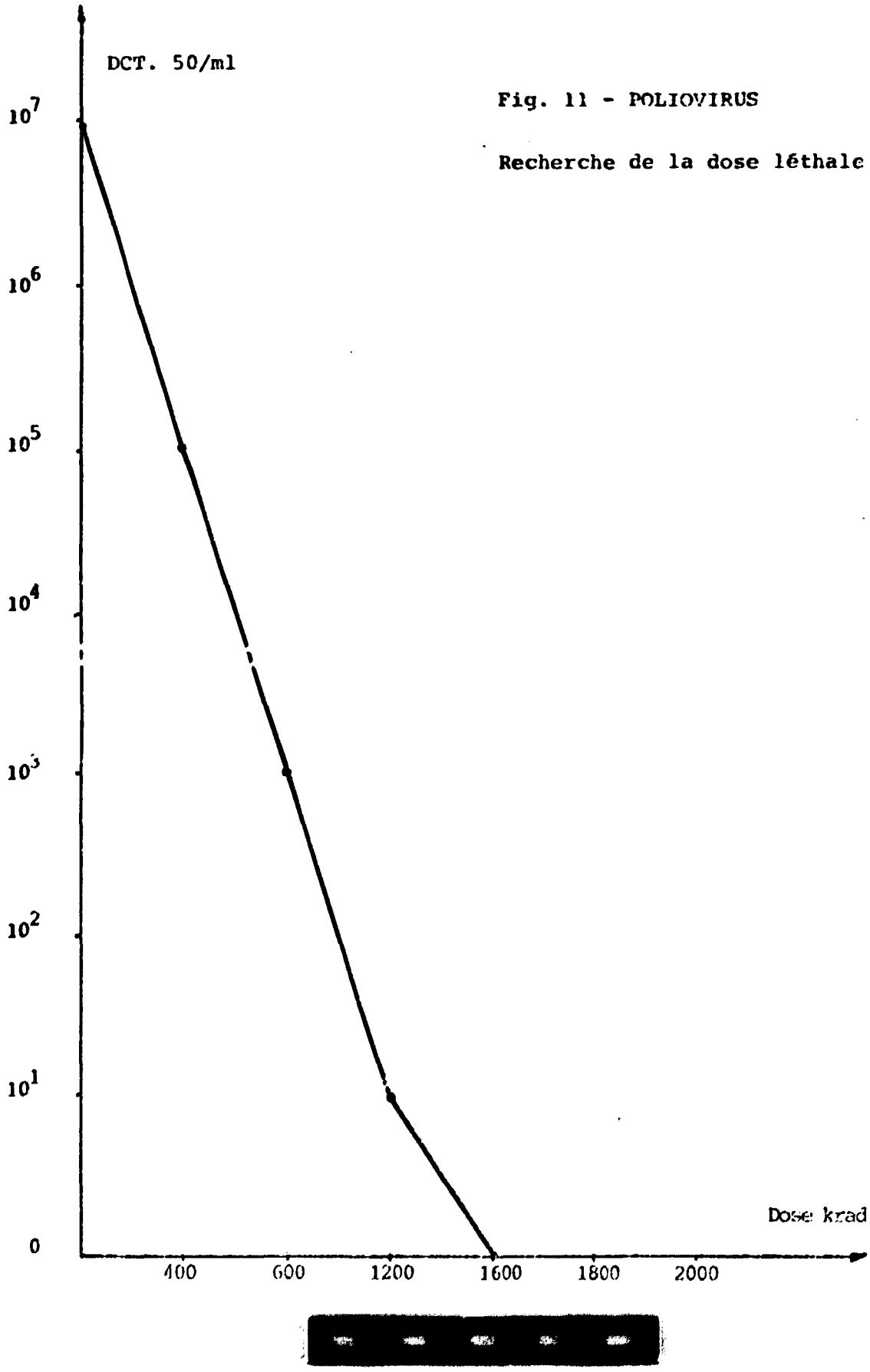


Fig. 11 - POLIOVIRUS

Recherche de la dose léthale