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SEDIMENTATION OF SUSPENDED SOLIDS FROM PIGGERY WASTES**

The present practice of using alum coagulation for piggery wastes pretreatment results in large quantities of poorly dewatering chemical sludge. The paper presents data from an in-depth study of plain sedimentation as a possible substitute for coagulation. Results from various plants are reported with a conclusion that, with short preaeration, sedimentation should be the preferred pretreatment method.

1. INTRODUCTION AND SCOPE

Large scale hog farms use water for flushing sewers and cleaning pens. The solids that are entrained in resulting wastewater consist of unused fodder, feces, urine, large incidental objects such as medicine bottles, etc. and some bedding material from the reproductive sector. Numerous studies have been aimed at documenting the need for primary solids removal prior to biological treatment. The results indicate definite improvement of aerobic processes performance after solids removal. The practice in piggery waste treatment for stream disposal in Poland has been so far confined to screening solids on vibrating screens [3] and, in cases of the Vidus type, activated sludge plants, alum coagulation is used as the primary solids removal process.

The need for retaining fine screens in front of all piggery wastes treatment trains has been documented rather conclusively based on full scale operational data [1]. The process of plain sedimentation has been considered as the subsequent step and as one that could be substituted for the costly chemical precipitation.

The aim of this research has been to document the applicability of sedimentation to suspended solids and organics removal from piggery wastes. The studies were also aimed at defining the optimum settling time for piggery wastes, at various initial solids

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concentrations — occurring naturally due to load variability. The effects of primary aeration on solids removal through settling will be determined. A novel method for data interpretation will be demonstrated.

2. METHODS

Field tests were performed at an industrial piggery (Agrokomplex type) of an annual production of some 14 000 hogs. Fresh wastewaters were collected from the sump under the vibrating screens with 1.5×1.5 mm openings. Settling tests were performed on site. The wastewaters prior to test have been subject to intensive mixing and particles were partly sheared due to mixing in the wet well and the processes of pumping and screening.

Two methods of settling tests were compared. One was based on the use of several 45 cm high graduated 1 l cylinders. A large sample of wastes was mixed and poured into cylinders. The cylinders were then mixed and the timing was started. The sample was collected by pipette from a depth of 25 cm below the surface at selected time intervals: 1 min, 3 min, 5 min, 10 min, 0.5 h, 1 h, 2 h, 3 h, 24 h, 38 h. Ten cylinders were used for each test, thus each cylinder represented one sampling time interval.

An alternative method was tried. It consisted of a 180 cm (ID 15 cm) high plexiglass cylinder with sampling ports at 40 cm intervals. The wastewater was sampled at preselected intervals at different depths in order to yield a plot of constant removals in coordinates of depth against the time of settling. Several trials with this method proved its inadequancy for representing the settling of pig wastes. Sampling difficulties were experienced, and since the major part of piggery wastes solids settles out in the first minute or so, it was almost impossible to plot the constant-removal-curves. Thus, the first method, based on multiple cylinders, was adopted. Figure 1 illustrates results obtained from the two methods on the same sample of wastes and verifies that practically no wall effects were experienced with the ID 6 cm cylinders when compared to the ID 15 cm column.

3. RESULTS AND DISCUSSION

Most of the settling tests had evidenced very rapid initial solids removal — in the first few minutes — followed by gradual settling of finer solids, which was practically completed within 90–120 min. The difficulties in comparing the relative rate of settling led to the development of the log-log plot of effluent suspended solids (or BOD and COD) versus time, according to the equation:

$$S_t = S_1/t^a,$$

where S_t, S_1 are respectively, effluent concentration after time t and concentration after $t = 1$ min; t is settling time; a is the slope of the settling curve representative of rate at which pollutant removal occurs. The value of S_1 is the intersect of the curve with the ordinate at $t = 1$ min, a convenient time to record the first initial (immediate) removal. Table 1 shows numerical results of the total suspended solids (TSS) settling — presented and linearized graphically in figs. 2 and 3. The TSS removals, calculated as $(1 - S_t/S_0)$, indicate that removal is the most efficient in the first 30 min of the process and averages 75%. A one-hour settling results usually in an average 78% solids removal, while an additional hour yields an increase of only 3% up to N = 81%. Further sedimentation, beyond the two hour limit, yields only a 1% increase and at 3 h, N = 82% (fig. 6).

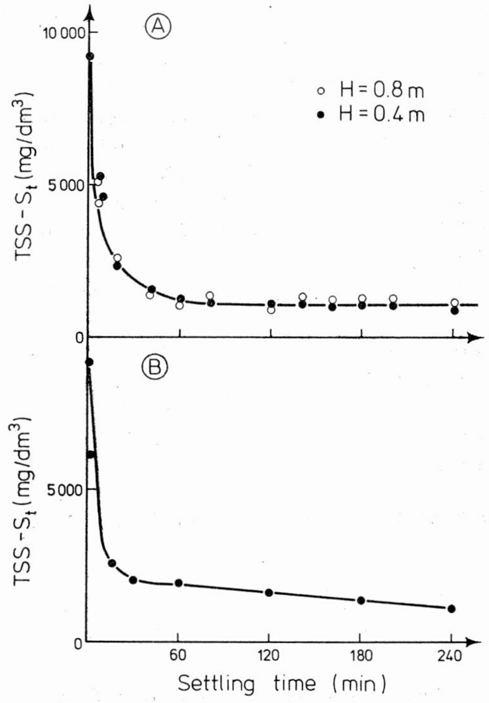

Fig. 1. Comparison of two settling test method: A — 1.8 m, ID 15 cm cylinder sampled at 0.40 m, 0.8 m; B — multiple 0.45 m, ID 6 cm at 0.25 m (20 IV 1978)

Rys. 1. Porównanie dwu testów na sedymentację: A — kolumna 1.80 m, 15 cm — pobór na głęb. 0,4 m; B — cylindry 0,45 m, 6 cm — na głęb. 0,25 m (20 IV 78)

The removal of organics, expressed as COD, BOD_5 and permanganate COD — denoted PV (permanganate value — table 2, figs. 4, 5), confirms the above conclusion. The average organic removals are stabilized into a plateau after two hours of settling.

Primary aeration was tried as a method of enhancing solids removal. Figures 2, 4 and 6A indicate the effects of 0.5 h aeration and a prolonged 19 h prearation. It was found that in both cases the primary aeration has increased the solids removal by some 4%. A more pronounced effect was evidenced by organics removals which were increased by over 10%. The comparison indicates that primary aeration, of very short duration, should be employed, e.g. as a method for mixing the wet-well contents.

Table 1

Suspended solids settling — operational parameters
Sedymentacja zawiesin — parametry pracy osadników

Parameter	Curve in fig. 2				Curve in fig. 3	
	No. 1	aerated No. 2	No. 3	aerated No. 4	No. 1	No. 2
	2	3	4	5	6	7
Settling rate (*a*)	0.19	0.19	0.19	0.19	0.19	0.19
S_1/S_0 (immediate settling)	0.54	0.44	0.58	0.46	0.39	0.52
$S_t = S_0$ $t = 0$	12500	12700	6770	6230	9245	2925
$S_t = S_1$ $t = 1$ min	6800	5600	3900	2850	3650	1520
$t = 0.5$ h	3400	3000	2000	1640	1950	1470
$t = 1$ h	2730	2650	1900	1440	1850	1350
$t = 2$ h	2660	2380	1600	1200	1560	1000
Solids removal (%) $t = 1$ min	46	56	42	54	61	48
$t = 0.5$ h	73	77	70	79	79	54
$t = 1$ h	78	80	72	77	82	59
$t = 2$ h	79	83	76	81	84	65
$t = 3$ h	80	84	78	82	85	66

Note: Column 7 is not included in the calculation of the average as it contains unusually low solids content due to an erroneous collection procedure.

Table 2

Removal of organics in settling tests
Usuwanie zawiesin organicznych w procesie sedymentacji

Parameter	Curve in fig. 4				Curve in fig. 5	
	1 (COD)	2 (COD) (aerated)	3 (BOD)	4 (BOD) (aerated)	1 (BOD)	2 (PV)
Settling rate (*a*)	0.07	0.07	0.09	0.10	0.06	0.07
Initial S_0 (mg/dm^3)	8880	10060	4150	4000	4000	1190
removal (%):						
$t = 5$ min	33	52	9	19	24	36
$t = 0.5$ h	50	55	26	35	31	—
$t = 1$ h	50	58	28	40	35	44
$t = 2$ h	50	65	30	40	40	51
$t = 3$ h	(49)	(60)	32	48	41	54

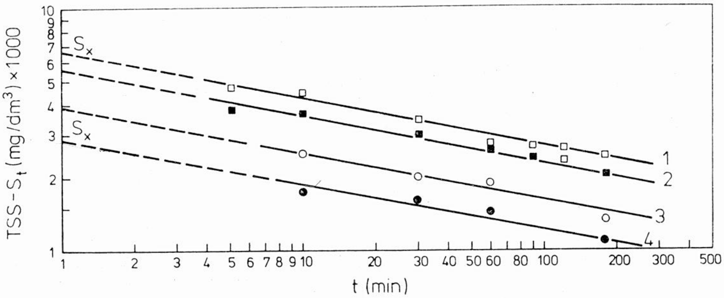

Fig. 2. Effects of preaeration on TSS removal (25 V 79):

1 — fresh, *2* — after 0.5 h preaeration (24 V 78), *3* — fresh, *4* — 19 h preaeration

Rys. 2. Wpływ wstępnego napowietrzania na usuwanie zawiesin całkowitych (25 V 79)

1 — świeże ścieki, 2 — po 0,5 h wstępnego napowietrzania, 3 — świeże ścieki, 4 — po 19 h wstępnego napowietrzania

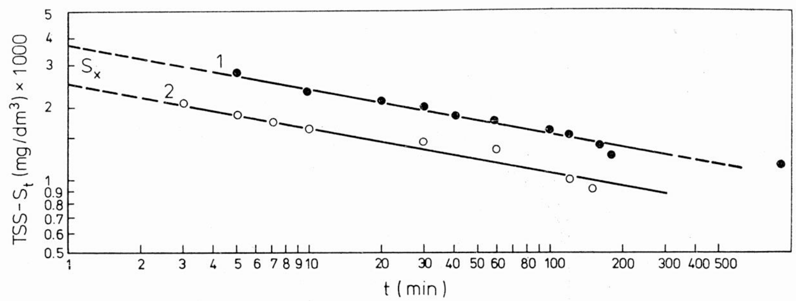

Fig. 3. Solids removal in sedimentation of unscreened wastes:

1 — 4 V 1978; *2* — 11 V 1978

Rys. 3. Usuwanie zawiesin ze ścieków pobranych przed sitami

1 — 4 V 78; *2* — 11 V 78

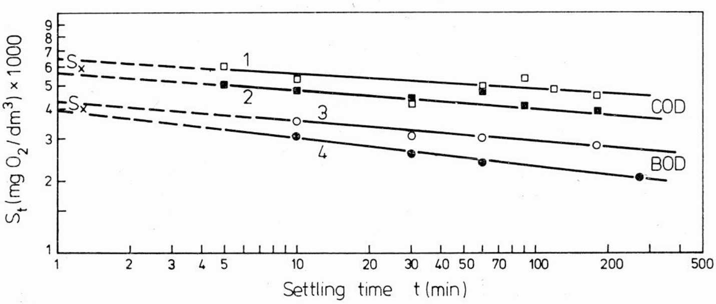

Fig. 4. BOD or COD removal in sedimentation (25 V 79):

1 — raw, *2* — after 0.5 h preaeration (24 IV 78), *3* — raw, *4* — after 19 h preaeration

Rys. 4. Obniżka BZT lub ChZT w czasie sedymentacji (25 V 79):

1 — surowe, *2* — po 0,5 h napowietrzaniu (24 IV 78), *3* — surowe, *4* — po 19 h napowietrzaniu

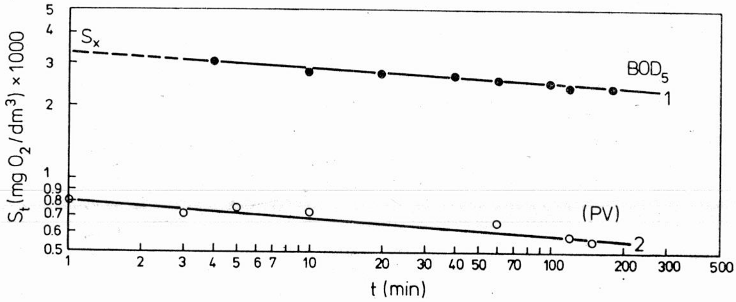

Fig. 5. BOD_5 or permanganate value removal in sedimentation:
1 — 4 V 78, *2* — 11 V 78

Rys. 5. Obniżka BZT_5 lub utlenialności w procesie sedymentacji
1 — 4 V 78, *2* — 11 V 78

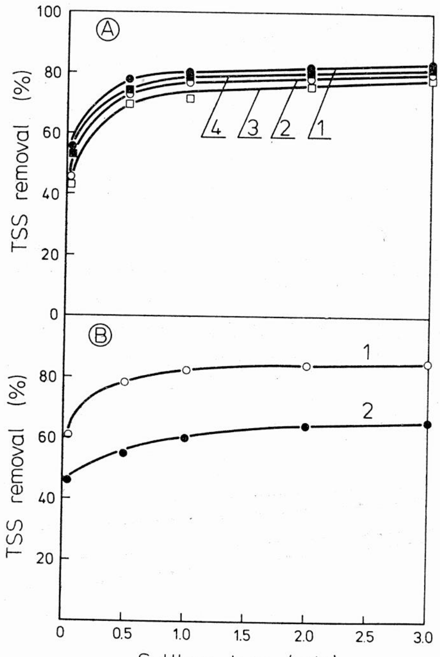

Fig. 6. Removals of total suspended solids (TSS) as affected by:
setting time (A): 1 (1979) fresh, 2 (1979) aerated, *3* (1978) fresh, *4* (1978) aerated; and initial concentration (B): *1* — $S_0 = 9245$ mg/dm^3, 2 — $S_0 = 2925$ mg/dm^3

Rys. 6. Obniżka zawiesin
w zależnaści od czasu (A): 1 (1979) surowe, *2* (1979) napowietrzane, *3* (1978) surowe, *4* (1978) napowietrzane; w zależności od stężenia początkowego (B): *1* — $S_0 = 9245$ mg/dm^3, 2 — $S_0 = 2925$ mg/dm^3

4. SUMMARY AND CONCLUSIONS

The imported piggery wastewater treatment technology applies screening and chemical coagulation as primary treatment. This research has attempted at showing that plain sedimentation (after fine 0.5 — 1 mm screening which results in the directly reusable by-product) can be effectively substituted for coagulation which consumes up to 20% of running costs (at an alum dose of 1000 mg/dm³). Figure 7 illustrates statistical analysis of 2-hour settling tests conducted at other plants with annual production ranging from 14 to 35 thousand hogs. The tests yielded an average decrease of total COD down to some 4300 mg/dm³, i.e. a removal of some 52 to 59%, which compares well with the results of this study.

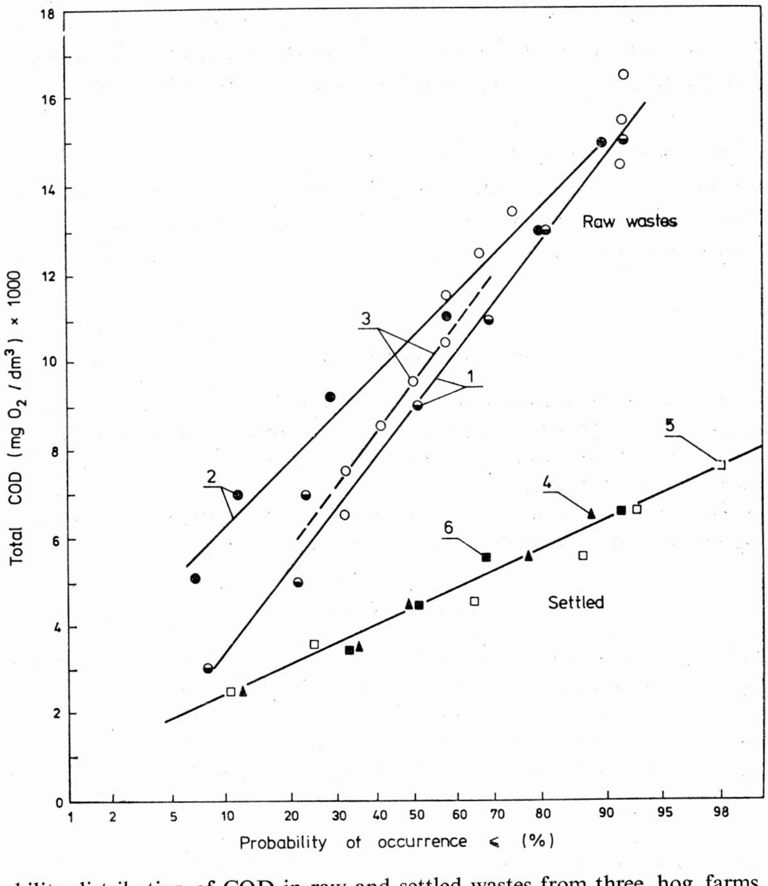

Fig. 7. Probability distribution of COD in raw and settled wastes from three hog farms — raw/settled; curves 1/4 — farm A; curves 2/5 — farm B; curves 3/6 — farm C

Rys. 7. Rozkład prawdopodobieństwa ChZT w surowych i sedymentowanych ściekach z 3 farm trzody chlewnej — surowe/sedymentowane; krzywe 1/4 — farma A; krzywe 2/5 — farma B; krzywe 3/6 — farma C

A full-scale study performed at farm A [2] with alum coagulation of very diluted wastes yielded the following removals: COD (total) — 62%; BOD_5 (total) — 39%; BOD_5 (soluble) — 26%; TSS — 82%. One has to take into account the fact that diluted wastewaters yield lower removals (e.g. table 1, col. 7), however, it is evident that coagulation adds very little in terms of additional removals. Another study [2] — at farm D (35 thous. hogs/a) — yielded 65% COD removal from screened, concentrated wastes.

The summary of findings is as follows:

1. In spite of removals lower than attained with alum coagulation plain sedimentation appears to be the most economical method of primary treatment leading to average removals expected: COD_{tot} — 55%; BOD_5 — 35%; TSS — 80%.

2. Primary advantage of sedimentation is the small volume of sludge and its good dewaterability when compared with chemical sludge.

3. Preaeration should precede settling and could be effectively combined with mixing of wet wells (presently turbine mixers are used that result in particle shearing and decrease the settling efficiency) and can yield up to a 5% improvement of solids removal.

4. Short half-hour preaeration is sufficient to yield a 10% improvement in organics removal.

5. The optimum settling time for piggery wastes, in quiescent, laboratory conditions, is two hours. Longer times yield only negligible improvements in removal efficiencies.

6. A novel method of presenting settling data was employed which allows for comparison of settling rates for various effluents — based on rate coefficient a in equation $S_t = S_1/t^a$.

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SEDYMENTACJA ZAWIESIN ZE ŚCIEKÓW Z FERMY TUCZU TRZODY CHLEWNEJ

Przedstawiono wyniki badań sedymentacji zawiesin ze ścieków z przemysłowej fermy tuczu. Próbki pobierano po sitach wibracyjnych. Porównanie efektu sedymentacji: bez napowietrzania wstępnego i po wstępnym napowietrzaniu, dowiodło celowości krótkiego napowietrzania wstępnego, rzędu 0,5 h. Stwier-

dzono, na podstawie badań ścieków z różnych ferm, że 2 godz. sedymentacja daje obniżkę rzędu 80% zawiesin i 50% CHZT. Za optymalny czas sedymentacji zawiesin uznano 2 godz. Zaproponowano interpretację wyników badań sedymentacji zgodnie z modelem $S_t = S_1/t^a$, gdzie S_t, S_1 oznaczają stężenie po czasie $t = t$ i $t = 1$, 1 — czas sedymentacji, a — współczynnik empiryczny określający prędkość sedymentacji.

ABSETZVERHALTEN VON ABWASSER-SCHWEBESTOFFEN AUS SCHWEINEMASTBETRIEBEN

Die untersuchten Abwasserproben wurden dem Abfluß von Vibrationssieben entnommen. Ein Vergleich des Absetzverhaltens der Abwässer — mit oder ohne Vorbelüftung — hat erwiesen, daß diese durchaus zweckbar ist. Vorgeschlagen wird daher eine Vorbelüftung der Abwässer während einer halben Stunde. Eine zweistündige Sedimentation der Abwässer (die aus verschiedenen Mastbetrieben stammten), gewährleistet eine 80%-ige Abnahme von absetzbaren Schwebestoffen und einen 50%-igen Abbau des CSB. Diese Zeit scheint optimal zu sein. Eine Interpretation der Ergebnisse kann im Sinne der Modellformel $S_t = S_1/t^a$ erfolgen, wobei S_t und S_1 die Schwebstoffkonzentrationen nach $t = t$, und $t = 1$, 1 — die Absetzzeit und a — ein empirischer Koeffizient der Absetzgeschwindigkeit sind.

СЕДИМЕНТАЦИЯ СУСПЕНЗИЙ ИЗ СТОЧНЫХ ВОД СВИНОВОДЧЕСКОЙ ФЕРМЫ

В статье приведены результаты исследований седиментации суспензий из сточных вод промышленной свиноводческой фермы. Пробы отбирались после вибрационных сит. Сравнение эффекта седиментации (без предварительной аэрации и после предварительной аэрации) подтвердило целесообразность кратковременной предварительной аэрации, порядка 0,5 ч. На основе исследований сточных вод различных ферм было выявлено, что двухчасовая седиментация даёт снижение порядка 80% суспензий и 50% ХПК. Оптимальным временем седиментации суспензий был признан период дух часов.

Предложена интерпретация результатов исследований седиментации по модели $S_t = S_1/t^a$, где S_t, S_1 обозначают концентрацию после истечения времени $t = t$ и $t = 1$, 1 — время седиментации, a — эмпирический коэффициент, определяющий скорость седиментации.