

INVESTIGATION ON THE EFFICACY OF WASTEWATER MANAGEMENT UNITS ON A PIG FARM

ISTRAŽIVANJE DJELOTVORNOSTI JEDINICA ZA UPRAVLJANJE NA FARMI SVINJA

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SUMMARY

The efficacy of a waste management unit with mechanical and biological separation steps was evaluated with regard to decontamination of effluents (mixture of manure, urine and technological water) on a pig farm with capacity of 5,500 pigs using parameters included in the national ecological legislation.

It was established that:

- The highest concentrations of analyzed parameters in farm effluents (BOD₅, total solids, total nitrogen, total phosphorus, total fats) were measured between 8.00 and 10.00 AM, as compared to the other hours of the day.

- The waste management units exhibited a low efficacy of purification as followed: in the BOD₅ test: 50.5% – 52.2 %; total solids: 67.9 – 68.3 %; total nitrogen: 13.9 – 16.6 %; total phosphorus: 10.1 – 10.4 % ; total fats: 71.2 – 72.2 %.

- Wastewaters exceeded the reference quality limits for the various parameters as followed: for BOD₅ (upper limit <400 mg/l) 1.8 times; total solids (upper limit <200 mg/l) – 5.18 times; total nitrogen (upper limit <35 mg/l) – 7.4 times; total phosphorus (upper limit <15 mg/l) – 1.8 times. Only the fats content was within the reference range (upper limit <120 mg/l).

Key words: pig farm, wastewater, waste management units, parameters, quality, ecological evaluation

INTRODUCTION

From ecological standpoint, pig farms are artificial ecosystems with the highest level of anthropogenic transformation compared to all other kinds of animal farms. This transformation allows the use of intensive rearing technologies in pig farms,

but at the same time, is a prerequisite for the considerable waste generation, i.e. a potential factor

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of environmental pollution (Petrov and Marinova, 1983; Lapierre and Brette, 1981; Jongbloed et al., 1999; Katsarov et al., 2001; Petkov et al., 2001).

One of the main approaches in reducing the negative environmental impact of pig farming is the utilization of waste management systems. The studies, performed so far in large pig farms (pig farming complexes) showed that such systems comprise about 25% of farm costs, are related to high operation costs and insufficiently effective decontamination (Bogoev et al., 1977; 1985; MPSC, 1991).

By now, pig farms of relatively small capacity (20-50 sows) constitute a significant proportion of all pig breeding farms in Bulgaria. The new ecological legislation requires that wastewaters from all industries, including pig farming, should be decontaminated to a certain extent prior to be discharged in water reservoirs or sewage systems of the settlements.

The purpose of this study was to investigate and evaluate the efficacy of decontamination of effluents (manure, urine and technological water) of waste management units on a pig farm using parameters included in the national ecological legislation.

MATERIAL AND METHODS

The investigation was performed on a pig farm in the region of Stara Zagora, in the spring of the year 2000 (March-May). The farm capacity was 5500 pigs and the average number of animals by categories was: 350 sows, 35 boars, 2,600 piglets, 2,400 fattening pigs, 115 replacement sows.

The technological and drinking water was obtained from own water supplies - two pipe-cased drilled wells.

The sows (breeding, pregnant and lactating) were reared in individual boxes on solid (2/3 of the box) or slated (1/3 of the box) floors. All other categories of pigs were reared in common boxes with slated floors, 8-10 in a box.

Effluents of pig farm consisted of a mixture of manure, urine and technological water and were collected in ducts situated under the boxes. By collective ducts, effluents of each premise were discharged into a pit, located at the entrance of the waste management units (WMU). WMU were two-stage: with mechanical and biological separation

step. The mechanical stage included a rough screen and a curved hydroscreen, to separate larger mechanical particles in effluents. The biological step included a concrete platform, mechanically purified wastewaters were poured onto. There, effluents were decanted and partially mineralized, by separation into two fractions: solid (sediment) and liquid (supernatant). The liquid fraction entered the collection pit and then, through a duct, joined the wastewater treatment system of the city of Nova Zagora. The solid fraction was used for soil fertilization after drying up.

The effluent rate from the pig farm was determined at 2-hour intervals through the following parameters: *flow rate* (l/s) and *amount* (m³/2 h);

Samples from effluents were obtained from two sites:

- *site 1*: the collection pit of the collective duct – before the entrance to the WMU;

- *site 2*: the collection pit behind the platform for decanting and sediment collection: at the exit from the WMU.

Samples of wastewaters were obtained from both sites, twice monthly, at 2-hour intervals, in pure glass containers of 1 dm³.

The analysis of samples was performed within 24 h after sampling by determination of: biochemical oxygen demand (BOD₅), total solids, total nitrogen, total phosphorus, total fats.

The following analytical techniques were employed:

- *BOD₅* (mgO₂/l) – as per Bulgarian State Standard 17.1.4.07-78;

- *Total nitrogen* (mg/l) – according to the method of Kjeldahl– 11374-86;

- *Total phosphorus* (mg/l) – as per Bulgarian State Standard 7210-83;

- *Total solids* (mg/l) – as per Bulgarian State Standard 17.1.4.04-80;

- *Total fats* (mg/l) – as per Bulgarian State Standard 16.714-96.

The efficacy of WMU was determined by comparative analysis, comparing concentrations of analysed pollutants *prior to* and *after* the WMU using the formula:

$$\text{WMU Efficacy (\%)} = (C_1/C_2) \cdot 100 (\%), \text{ where:}$$

C_1 – the concentration of the studied contaminant at the entry of the WMU;

C_2 - the concentration of the studied contaminant at the exit from the WMU.

The statistical analysis of data was done by Microsoft Excel (Microsoft Office 2000) and Statistics Version 4.0 (Analytical Software, 1992).

RESULTS AND DISCUSSION

Flow rate and amount of wastewater. The results on the flow rate and the amount of pig farm effluents are presented in Table 1. It could be seen that in 24 hours, the farm generated 125 m³ wastewater on the average that entered the waste management units (WMU). The maximum amount of wastewater – 62.64 m³ is generated between 8.00 AM and 12.00 AM, i.e. the period when the main activities related to pig care took place. For the other

20 hours, the generated amount of effluents was 62.36 m³ which was almost equal to that for the first 4 hours of the workday (8.00-12.00 AM).

The amount of wastewater during the dark hours (12 PM–8.00 AM) – 2.90 m³/2 h was determined by the technology as during this period, no activities related to animal care were performed. This flow rate was stable and thus determined a relatively constant load of waste management units during this period.

The primary amount – 103.68 m³ (91.37%) of effluents passed through the WMU between 8.00 AM to 12.00 PM, establishing a relatively heavier load during those hours, with peak load from 8.00 AM to 12.00 AM.

Efficacy of wastewater decontamination by the WMU. Table 2 presents the qualitative composition of wastewaters *at the entrance* and *after leaving* the WMU.

Table 1. Average values for the flow rate and the amount of the wastewater from the pig farm

Tablica 1. Prosječne vrijednosti stope otjecanja i količine otpadne vode s farme svinja

Number of sample collection Broj uzorka	Hours of measuring Sati mjerenja	Flow rate of the wastewater Stopa otjecanja otpadne vode Q l/sec	Amount of the wastewater Količina otpadne vode Q m ³ /2h
1.	08 ⁰⁰ - 10 ⁰⁰	4.50	32.40
2.	10 ⁰⁰ - 12 ⁰⁰	4.20	30.24
3.	12 ⁰⁰ - 14 ⁰⁰	1.00	7.20
4.	14 ⁰⁰ - 16 ⁰⁰	2.50	18.00
5.	16 ⁰⁰ - 18 ⁰⁰	1.20	8.64
6.	18 ⁰⁰ - 20 ⁰⁰	1.00	7.20
7.	20 ⁰⁰ - 22 ⁰⁰	0.75	5.40
8.	22 ⁰⁰ - 24 ⁰⁰	0.60	4.32
9.	24 ⁰⁰ - 02 ⁰⁰	0.40	2.90
10.	02 ⁰⁰ - 04 ⁰⁰	0.40	2.90
11.	04 ⁰⁰ - 06 ⁰⁰	0.40	2.90
12.	06 ⁰⁰ - 08 ⁰⁰	0.40	2.90
Average daylight hours values Prosječne vrijednosti sati dnevnog svjetla		2.16	103.68
Average night hour values Prosječne vrijednosti noćnog sata		0.44	21.30
Average 24 hour period values Prosječne vrijednosti u razdoblju 24 sata		1.44	125.0

Table 2. Average values of the investigated indices of the wastewater from the pig farm

Tablica 2. Prosječne vrijednosti istraživanih pokazatelja otpadne vode s farme svinja

	BOD ₅ mgO ₂ /l		Total solids mg/l Ukupne krute tvari		Total nitrogen mg/l Ukupni dušik		Total phosphorus mg/l Ukupni fosfor		Total fat mg/l Ukupna mast	
	site 1	site 2	site 1	site 2	site 1	site 2	site 1	site 2	site 1	site 2
08-10	6048.3	2880.3	11142.4	3482.1	849.8	752.0	73.0	65.7	878.4	244.2
10-12	5056.8	2408.5	9804.8	3064.4	802.3	705.1	71.9	64.7	835.2	232.1
12-14	613.2	392.1	1715.2	535.9	206.4	172.0	22.0	19.8	327.6	91.4
14-16	1705.2	912.1	5401.6	1688.1	448.8	374.1	39.9	35.9	417.6	115.9
16-18	588.1	289.1	2060.8	644.3	248.4	207.0	27.1	24.3	266.4	74.4
18-20	571.2	271.9	1744.0	545.2	207.6	173.2	21.1	18.9	316.8	88.1
20-22	558.6	265.8	1670.4	522.1	180.1	149.8	19.4	17.4	237.6	66.3
22-24	491.4	234.1	1526.4	476.8	154.8	129.1	17.2	15.4	172.8	48.5
00-02	466.2	226.2	1168.1	365.2	127.2	106.3	16.0	14.4	82.8	22.5
02-04	478.8	228.1	1184.1	370.1	128.4	107.4	16.3	14.6	90.0	25.1
04-06	462.0	220.4	1177.6	368.2	129.6	107.9	16.2	14.5	86.4	24.4
06-08	470.4	223.7	1200.0	374.7	130.8	109.0	16.2	14.4	93.6	25.3
Average daylight hour values - Prosječno sati dnevnog svjetla	2163.1 ± 2368.9	1060.0 ± 1114.0	4791.3 ± 4118.8	1497.4 ± 1287.2	420.5 ± 291.4	361.9 ± 261.6	39.2 ± 23.7	35.2 ± 21.4	468.5 ± 271.4	130.3 ± 75.3
Average night hour values - Prosječno sati noćnog svjetla	473.8 ± 11.7	226.5 ± 5.1	1251.2 ± 154.3	391.0 ± 48.1	134.2 ± 11.6	111.9 ± 9.6	16.4 ± 0.5	14.7 ± 0.4	105.1 ± 38.0	29.2 ± 10.9
Average 24 hour period values - Prosjek u razdoblju 24 sata	1453.2 ± 1953.9	712.7 ± 928.0	3316.3 ± 3547.5	1036.4 ± 1008.7	301.2 ± 261.0	257.7 ± 232.3	29.7 ± 21.1	26.7 ± 19.0	317.1 ± 275.2	88.2 ± 76.5

* site 1- before the entrance of the waste management units WMU; site 2 - on the exit from the WMU

The highest concentrations of all studied contaminants were observed between 8.00 and 12.00 AM, when the highest amounts of effluents were generated. The values of studied parameters at the entrance of the WMU for this period of time were comparable with data reported by others (Voycheva, 1985; Yordanov et al., 1985; Voermans, 1993; Venglovsky et al., 1994; Nicholson, 1994). It could be concluded that regardless of farm capacity and the composition of the compound feed, the composition of wastewaters with relation to studied parameters prior to be decontaminated, was similar.

In general, the day-night dynamics of tested wastewater contaminants was characterized by two stages:

Stage one – between 8.00 AM and 08.00 PM, when the main technological processes in the farm are performed and the major amount of effluents are generated, and when the pollutant concentrations were higher;

Stage two – from 8.00 PM to 8.00 AM, when no activities take place, the amount of generated effluents is considerably lower and therefore, the levels of contamination are lower (1.48 times for BOD₅, 1.44 times for total solids, 1.40 times for total nitrogen, 1.32 times for total phosphorus and 1.48 times for total fats), as compared to the time between 8.00 PM and 8.00 AM.

This specifics of the quality and intensity of effluents production determined the various workloads of the waste treatment units for the different hours of the day.

The results for the efficacy of waste management units in the studied pig farm are shown in Table 3. It could be seen that WMU efficacy ranged in narrow limits for daylight hours, night hours and on the average for the entire 24-hour period. This could be attributed to the fact that the decontamination effect was dependent on performance specifications of the system and practically was not influenced by the amount and the quality of wastewaters. In the light of this fact, it is questionable whether the existing rate of decontamination on the farm provided by WMU is sufficient or not.

farm of a capacity of 5,500 pigs, but overpopulated with 7,500 pigs. The capacity of this farm is comparable to that, investigated by us in the present study. The author established a high efficacy of waste management system in general: 99.1–99.6 % for BOD₅, 97.8–99.1% for total solids and 99.4–99.7% for ammonia. It could be seen that WMU efficacy in our study was considerably inferior to that from Voycheva's report. It could be therefore concluded that not only the farm capacity, but the type and the performance quality of the respective waste treatment system, are important.

Ecological evaluation of the wastewater. The maximum allowed concentrations of substances in production wastewaters, discharged in municipal sewage system, where pig farm effluents belong to,

Table 3. Efficacy of purification of the wastewaters from the pig farm

Tablica 3. Djelotvornost pročišćavanja otpadnih voda s farme svinja

Parameters	Efficacy of the waste management units - %				
	BOD ₅	Total solids Ukupne krute tvari	Total nitrogen Ukupni dušik	Total phosphorus Ukupni fosfor	Total fat Ukupna mast
Average daylight hour efficacy Prosječna djelotvornost dnevnog svjetla	51.0	67.9	13.9	10.2	71.2
Average night hour efficacy Prosječna djelotvornost noćnog sata	52.2	68.3	16.6	10.4	72.2
Average 24 hour period efficacy Prosječna djelotvornost u razdoblju 24 sata	50.5	68.1	14.4	10.1	71.7

The data reported by Voycheva (1985) on the efficacy of waste management units with biological purification step on industrial pig farms in Bulgaria during the 90-ties of the last century showed that with regard to primary controlled parameters, it was as follows: for BOD₅ - 81.2 %; for total solids - 88.8 % and for ammonia - 64.2 %. These data are indicative for the better potential for decontamination of effluents from production premises in pig farms in the existing WMU compared to the WMU performance in the investigated farm. Another aspect however is that in many instances, expensive waste treatment systems did not meet the expectations of large-scale production units.

More interesting are data reported by Voycheva (1985) for a waste management system with mechanical and two-step biological separation on a pig

are settled in Regulation № 7/2000 (Gazette № 98) on the procedures for discharge of industrial waste water in sewage collecting systems of settlements.

The evaluation of the compliance of wastewater quality with Regulation № 7/2000 showed that:

the daylight hour average values of BOD₅ at the exit of the WMU exceeded the reference limit of <400 mg/l 2.65 times; average night hour values were 1.77 lower than this limit and the average day-night values exceeded the norm 1.80 times;

the daylight, night and average day-night total solids concentrations exceeded the reference limit (<200 mg/l) 7.48, 1.96 and 5.18 times, respectively;

the daylight, night and average day-night total nitrogen concentrations exceeded the reference limit (<35 mg/l) 10.3, 3.2 and 7.4 times, respectively;

the daylight hour average total phosphorus concentrations exceeded the reference limit of <15 mg/l 2.3 times; average night hour values were within the permissible range and the average day-night values exceeded the norm 1.80 times;

the daylight hour average total fat concentrations exceeded the reference limit (<120 mg/l) 1.1 times; average night hour and day-night concentrations were under the permissible limit;

The comparison of wastewater quality with the norms of Regulation № 7/2000 showed that at the exit of pig farm's WMU, this quality did not respond to normative requirements for BOD₅, total solids, total nitrogen and total phosphorus. The wastewater fat content after leaving the WMU was within the reference range.

Therefore, the waste management units did not provide the necessary decontamination of farm effluents in order to be compatible with the requirements of Regulation № 7/2000 as seen from studied parameters.

CONCLUSION

On the basis of the results, the following conclusions could be made:

- The average day-night amount of effluents from a pig farm with capacity of 5.500 pigs was 125 m³, with 50.1 % of this amount being generated between 8.00 AM and 12.00 AM, i.e. the time when the main activities related to animal care were performed;

- The highest concentrations of analyzed parameters in farm effluents (BOD₅, total solids, total nitrogen, total phosphorus, total fats) were measured between 8.00 and 10.00 AM, as compared to the other hours of the day.

- The waste management units exhibited a low efficacy of purification as follows: in the BOD₅ test: 50.5%–52.2 %; total solids: 67.9–68.3 %; total nitrogen: 13.9–16.6 %; total phosphorus: 10.1–10.4 %; total fats: 71.2–72.2 %.

- Wastewater exceeded the reference quality limits for the various parameters as follows: for BOD₅ (upper limit <400 mg/l) 1.8 times; total solids (upper limit <200 mg/l) – 5.18 times; total nitrogen

(upper limit <35 mg/l) – 7.4 times; total phosphorus (upper limit <15 mg/l) – 1.8 times. Only the fats content was within the reference range (upper limit <120 mg/l).

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SAŽETAK

Ocjenjivana je djelotvornost jedinice za upravljanje otpadom s mehaničkim i biološkim mjerama u vezi s dekontaminacijom tekućeg stajskog gnoja (mješavina gnoja, urina i tehnološke vode) na farmi kapaciteta 5500 svinja, koristeći parametre nacionalnog ekološkog zakonodavstva.

Utvrđeno je da su:

- Najviše koncentracije analiziranih parametara tekućeg stajskog gnoja na farmi (BOD₅, ukupne krute tvari, ukupni dušik, ukupni fosfor, ukupne masti) izmjerene su između 8,00 i 10,00 prije podne u usporedbi s ostalim satima tijekom dana.

- Jedinice za upravljanje otpadom pokazale su slabu djelotvornost u pročišćavanju: u testu BOD₅ 50,5%-52,2%; u ukupnim krutim tvarima 67,9%-68,3%; u ukupnom dušiku 13,9-16,6%; u ukupnom fosforu 10,1-10,4%; u ukupnim mastima 71,2-72,2%.

- Otpadne vode premašile su granice referentne kakvoće u raznim parametrima: BOD₅ (gornja granica <400mg/l) 1,8 puta, ukupne krute tvari (gornja granica <200 mg/l) 5,8 puta; ukupni dušik (gornja granica <35 mg/l) 7,4 puta; ukupni fosfor (gornja granica <15 mg/l) 1,8 puta. Samo je sadržaj masti bio unutar referentnih granica (gornja granica <120 mg/l).

Ključne riječi: farma svinja, otpadna voda, jedinice za upravljanje otpadom, parametri, kakvoća, ekološka ocjena