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WASTEWATER CHARACTERISTICS OF A CATTLE ZOOTECHNICAL FARM – A CASE STUDY

BY

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Abstract. This research highlights the waste types and their principal characteristics produced from the main activities in an investigated livestock farm, especially collected wastewaters from different zootechnical activity sectors. Six monitoring sectors were selected to assess the level of polluting load from the discharged effluents. Constant control of the main imposed quality indicators (pH, COD, BOD, total solids, ammonia, extractible substances) is obviously required and periodically reported to water regulatory management authority, as well as the establishment of viable and efficient directions utilized for the wastes treatment and recovery on-site (direct possible use). The limiting norms of the quality indicators controlled in a few sectors (mainly 4 control sectors) are far exceeded and the trend is to increase the polluting loads, which requires the adoption of serious local treatment measures and the continuation of monitoring the quality status of the effluents generated on the livestock farm.

Keywords: environmental protection, wastewater, livestock farm, quality indicators.

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1. Introduction

Livestock farming practices in Romania have been accompanied by a significant increase in waste production which places a heavy burden on the environment. Thus, environmental pollution has become an important limiting factor for the sustainable and efficient development of modern agriculture and connected industries all over the countries (Biagini and Betta, 2024; Richards and Yabar, 2023; Tinitana-Bayas *et al*., 2024; Valverde-Orozco *et al*., 2024; Verlicchi *et al*., 2019; Xiaoyuan *et al*., 2024; Zaki *et al*., 2023). Therefore, the Romanian livestock industry was rapidly developed because of population growth, market demand, and good practice policy support. The production pattern has gradually changed from household farms into large-scale and high-intensity farms, such that a large-scale pig farm which raises 50×10^4 pigs, a cattle farm for milk which has 10 x 100 cattle and a poultry farm with 100×10^4 chickens.

A special attention was giving to collected and uncollected wastewaters (WWs) produced in different zootechnical activity sectors onto the farm emplacement. Generally, the statistics indicated that the chemical oxygen demand (COD_{Cr}) and NH_4-N (ammonia) discharges from livestock industry sources commonly account for 45% and 25% of total discharges, respectively. This environmental pollution caused by the high organic and inorganic loads of zootechnical effluents has become an important limiting factor for sustainable and efficient development of the agriculture- and zootechny-based industries in Romania (Filote *et al*., 2021; Zimmo *et al*., 2002; Zaharia, 2022).

Usually, animals such as cows are raised in modern shelters where a proper microclimate is maintained, which must ensure maximum milk and weight gain in a minimum time. The normal trend in the removal of waste and liquid residues from cattle consists, on the one hand, in maintaining the best possible hygienic and sanitary conditions in the shelters, and on the other hand in saving labor and energy, the costs of which are included in the costs of the final product, milk, meat and/or derived products.

Since one of the ways of removing fresh residues / wastes from shelters uses the washing water (i.e. either use of the jet, or through the "water cushion" system in which the fresh residues / wastes fall through the interspaces of the discontinuous floor - grill type), the characteristics of the effluents produced in each sector of activity and the ones which are stagnant in the collectors of each building or sector of activity acquire a special importance, and compliance with the quality requirements imposed on the wastewater discharged or taken over by an operator to the local municipal wastewater (WW) treatment plant becomes mandatory in maintaining a sustainable environmental management of the livestock farm.

This paper aims to present and briefly discuss the main characteristics of all effluents produced in a cattle farm specialized in milk production, collected from all sectors of activity on the farm site. Information regarding the compliance

with the quality requirements of the aquatic environment nearby imposed by the authorized water management responsible will be presented and discussed in comparison with the quality norms inscribed in the environmental legislation corresponding to the quality of the treated wastewater discharged by an economic agent. Directions to be followed in order to comply with the quality norms of the WW discharged from the site of the investigated farm will be mentioned and immediate solutions which are imposed for its sustainable management will be underlined, too.

2. Experimental and study objective

2.1. Case study location: a Romanian zootechnical farm

It is evaluated a Romanian cattle zootechnical farm which is located near a small village (in Northern-Eastern part of the Moldavian macro-region No. 2), disposing of an available environmental and water management authorization. The livestock farm (cattle for milk production) / dairy farm has an average area of 25 ha with 6 animal production sheds (stalls) (3000 at the time of the authorization permit). The water consumed on the farm site comes from three controlled underground sources (4 boreholes) and from the local centralized water supply system. Commonly, the produced wastewater amount per head of animal and day is around 25-30 L.

The livestock farm has an internal sewage system for the produced wastewaters in each activity sectors (Fig. 1), i.e. six separate collectors in each farm building that are drained periodically (every 4 months) and two aerated lagoons for the entire urine produced (Zaki *et al*., 2023) (diluted with rainwater). The faecal wastes are locally treated and stocked on a concrete platform. Faecal waste and sewage are not applied to crop land and not directly discharged into the environment; thus, it minimizes the pollution of soil, surface water and groundwater (Voicea *et al*., 2020).

(a) (b)

Fig. 1 – Feeding (a) and cleaning (b) sectors of the studied zootechnical farm complex.

The wastewater flow in each farm building can vary in range of 1000 – 4300 L/day, and the registered mean and maximum WW flow is of 3.28 m^3/day and 4.30 m^3/day, respectively. The WW characteristics, meaning the values of imposed WW quality indicators, must be periodically controlled but at least two times per year reported to the water management authority.

2.2. Analysis methods used for the characterization of collected wastewater

For WW characterization were used a few specific quality indicators which were determined by internationally approved standards, mainly consisting in certain physical-chemical analytical analysis methods. Thus, the WW produced and collected in each farm building and rainwater collectors is usually twice controlled per year for certain quality indicators recommended by the water management authority such as pH, total solids (TS), chemical oxygen demand (COD_{Cr}), biochemical oxygen demand (BOD_5), ammonia and extractible substances (ES), analysed according with the international approved standards.

Determination of pH (pH units): the pH value is directly recorded and read using a Hanna pH-meter (Combo pH & EC waterproof).

Determination of COD_{Cr} (mg O_2/L): it was used the closed reflux, colorimetric method (SR ISO 15705) at small scale with closed tubes, based on WW sample oxidation at 150ºC for 2 h with help of a digestion/oxidant solution (i.e. 1.5 mL $K_2Cr_2O_7$ / $HgSO_4$ / H_2SO_4 solution, as catalyst was considered $HgSO_4$ and as oxidant – $K_2Cr_2O_7$) and chloride-inhibitor solution (Ag_2SO_4 / H_2SO_4) followed by cooling and absorbance reading at 600 nm under a blank prepared the same as the WW sample. Data calculation is considering the calibration curve COD_{Cr} (mg O_2/L) = f(A_{600}), plotted using potassium hydrogen phthalate as COD stock solution (i.e. 1000 mg O_2/L).

Determination of BOD_5 (mg O_2/L): it was used the standard method to determine the relative oxygen requirements of WW sample for degradation of its organic matter (carbonaceous demand) during 5-d incubation period and presence of microorganisms as well as the oxygen used to oxidize inorganic matter such as sulfides, ferrous iron and even reduced forms of nitrogen (nitrogenous demand). The seeding (e.g., domestic wastewater with a population of microorganisms) and dilution (with phosphate buffer, $MgSO_4$, $CaCl_2$ and $FeCl_3$, standard check for NH_4Cl and glucose-glutamic acid) procedures provide an estimate of BOD_5 at pH 6.5 to 7.5. The dissolved oxygen (DO) is measured initially and after incubation (using the standard iodometric method with azide modification, or membrane electrode method), and BOD is computed from difference between initial and final DO.

Determination of total solids content (TS) (mg/L): the standard gravimetric method was used by filtration on solid paper support of a certain WW sample volume and after support drying and weighting at room temperature, followed by calculation of retained solids amount per sample volume.

Determination of ammonia content (mg NH_4^+/L): it was used the standard spectrometric method (SR ISO 7150-1) based on absorbance measurement at 650 nm of WW sample treated sodium salicylate and hypochlorite in the presence of sodium nitroso-prussiate (i.e. sodium nitroso-penta cyanoferrate (III)). The ammonia content is calculated using the calibration curve $C_{N\text{-}NH4+} = f(A_{650})$.

Determination of extractible substances in organic solvent (***ES***) (mg/L): it was used the gravimetric method based on extractible substances' extraction using as organic solvent the petroleum ether. After solvent evaporation at room temperature the used extraction vessel is weighted and ES content calculated.

3. Results and discussion

The wastewater produced at cattle farms has a high concentration of pollutants that can negatively influence the quality of the receptors. The literature mentions an average amount of undiluted residues / wastes of 23 L/animal head x day, or 5 kg of residues / wastes (solid and liquid) per 100 kg of living animal weight, as an annual average of the daily amount excreted by animals, in general (Antoniu *et al*., 1987). In dairy cows, the daily quantity of residues/wastes represents 7% of the animal's weight, the humidity being 87.5%, the dry matter in feces is 5.7 kg/day, and in urine it is 0.48 kg/day. Urine represents about 30% of the total residue / waste.

Unlike pigs and other animals on a livestock farm, ruminants' stomachs contain bacteria that allow cellulosic feed to be used. Compared to the feed consumed, the quantities of manure produced by cattle are large. The urine produced by herbivores has a pronounced alkaline character. Growing animals and dairy farmers (Fig. 2) retain more nitrogen, phosphorus and calcium from their feed than fattening animals, which thus lose a large amount of nutrients in their excrement.

(a) (b)

Fig. 2 – Some activities onsite of zootechnical farm producing wastewater. (a) food preparation and support-bed cleaning; (b) milking activity sector.

In general, the literature reports high average concentrations of chlorides in waste (liquid and solid) from cattle (i.e., around 2500 mg/L) as well as high concentrations of other soluble ions (sodium, potassium, calcium) (Antoniu *et al*., 1998) that can influence a possible direction of recovery in agriculture of the treated wastewater produced on the cattle farm.

As consequence, the characterization of zootechnical WW or final effluent from each productive building is imposed and the values of some important quality indicators periodically reported to the water management authority centre for evaluation (especially, validation of respecting the imposed environmental norms in the farm compliance plan). The real pollution status due to the waste from cattle farm (liquid and/or solid) is expressed by physical-chemical and bacteriological indicators such as total suspended solids (TSS), COD, BOD_5, content of nutrients, total number of total coliforms, other bacterial population types etc.

For the studied zootechnical farm there were considered 6 sampling sectors for WW analysis, mainly from the 6 final collectors of buildings with specific activities such as 1-Administration building; 2-Protocol building; 3-Cafeteria shop building; 4-Milking parlor building; 5- Pharmaceutical warehouse building, and 6-Mechanical workshop building.

The mean annual values of the studied WW quality indicators controlled in the time period of 2022-2023 are summarized in Tables 1 and 2.

Table 1

Characteristics of collected wastewaters from the studied zootechnical farm in 2022

Quality Indicators								
BUILDING		**pH**	**COD (mg O_2/L)**	**BOD_5 (mg O_2/L)**	**TS (mg/L)**	**Ammonia (mg NH_4^+/L)**	**ES (mg/L)**	**Test method**
Year 2022	**1-Adminis-tration**	7.61 ±0.7	223.0 ±75	66.90 ±23	31.5 ±3.5	0.93 ±0.88	235.00 ±105.0	SR EN ISO 10523:2012
	2-Protocol	7.30 ±0.10	598.80 ±257.0	179.63 ±77.0	92.5 ±54	2.02 ±1.97	66.00 ±6.0	SR ISO 6060:1996
	3-Cafeteria	7.16 ±0.16	1550.5 ±263.5	775.16 ±132	132.5 ±39	113.02 ±113	107.00 ±46.0	SR EN ISO 5815-1:2020
	4-Milking parlor	7.36 ±0.37	4103.0 ±393	2051.0 ±197	443.5 ±19	210.52 ±210	185.00 ±60.0	SR EN 872:2005
	5- Pharma-ceutical warehouse	7.73 ±0.17	664.5 ±285.5	269.31 ±111	62.02 ±48	16.02 ±16	82.00 ±54.0	SR ISO 7150-1:2001
	6-Mechanic workshop	7.88 ±0.06	327.5 ±68.5	98.5 ±20	48 ±38	14.02 ±14	49.00 ±30.0	SR 7587:1996
	M.A.C.*	6.5-8.5	500.00	300.00	350	36.42	30.0	** norms (NTPA 2)*

As shown in Table 1 (for 2022 year), the values of analysed quality indicators exceed the maximum admissible concentration according to the

imposed norms only in the case of WW produced and collected from the milking parlor (4-building) for COD, BOD, TS, ammonia, ES and also cafeteria (3-building) for COD, BOD and ES, and all were indicating high organic compounds content and local presence of extractible substances from fuel and oils especially from mechanical maintenance and repairs' service.

Special comparative findings for each analysed WW characteristics are mentioned below:

– For *pH*: the lowest value recorded was 7.16 at 3-Cafeteria and the highest value recorded was 7.88 at 6-Mechanic workshop. These values are in range with permissible limits of 6.5 – 8.5.

– For *COD* (mg O_2/L): the lowest value recorded was 223.0 at 1-Administration collector and the highest value recorded was 4,103.0 at 4-Milking parlor; values exceed by 8.20 times fold the M.A.C. and indicates a high organic load from which relative large fractions are biodegradable, meaning more than 50%.

– For BOD_5 (mg O_2/L): the lowest value recorded was 66.90 at 1-Administration building and the highest value recorded was 2,051.0 for 4-Milking parlour building; values exceed by 6.83 times fold the M.A.C. and are originated in biodegradable organics from metabolic animal activities, animal products and others. The ratio COD/BOD varied in the range of 2.00-12.33, and ratios higher than 4 indicate that WW may contain also non-biodegradable organics or refractory ones.

– For *TS* (mg/L): the lowest value recorded was 31.5 at 1-Administration and the highest value recorded was 443.5 at the 4-Milking parlour sector; values exceed by 1.26 times fold the M.A.C. and can be separated in time by different mechanical operations (sedimentation, filtration, flotation, etc.).

– For *ammonia* (mg NH_4^+/L): the lowest value recorded was <0.05 and the highest value recorded was 210.52 at the 4-Milking parlour sector; values exceed by 5.78 times fold the M.A.C. and are predominantly produced after degradation/ decomposition processes developed in the collectors (in stationary status) and mixture of urine with water washing, among others.

– For *ES* (mg/L): the lowest value recorded was 49 at the 6-Mechanical workshop sector (on a hill platform) and the highest value recorded was 185 at the 3-Cafeteria sector (downstream of the hill platform, collecting also a part of rainwater passed through the fuel deposit platform); values exceed by 6.16 times fold the M.A.C. and are explained by the presence of oils, fuel and fuel-derivate products.

It seems that there are exceeding of maximum admissible concentrations in four collectors from buildings of studied zootechnical farm in 2022, meaning protocol (2), cafeteria (3), milking parlor (4) and pharmaceutical warehouse (5) for COD and extractible substances (ES). All analysed quality indicators are exceeding the admissible norms only in the final collector from the milking parlor sector.

Table 2

Characteristics of collected wastewaters from the studied zootechnical farm in 2023

Quality Indicators								
BUILDING		**pH**	**COD (mg O_2/L)**	**BOD_5 (mg O_2/L)**	**TS (mg/L)**	**Ammonia (mg NH_4^+/L)**	**ES (mg/L)**	**Test method**
Year 2023	**1-Administration**	7.17 ±0.1	1041.92 ±623	312.43 ±186	153.00 ±139.0	3.52 ±3.47	68.00 ±20.0	SR EN ISO 10523:2012
	2-Protocol	7.61 ±0.23	944.82 ±164	277.92 ±65	117.00 ±87.0	11.52 ±11	70.00 ±24.0	SR ISO 6060:1996
	3-Cafeteria	6.85 ±0.13	2006 ±506	601.80 ±151	126.00 ±10.0	102.52 ±10	188.00 ±16.0	SR EN ISO 5815-1:2020
	4-Milking parlor	7.70 ±0.3	21728 ±634	10864 ±31	2565.00 ±121.0	174.52 ±174	108.00 ±4.0	SR EN 872:2005
	5- Pharmaceutical warehouse	8.10 ±0.21	288.28 ±37	87.0 ±11	49.00 ±41.0	22.0 ±22	67.00 ±15.0	SR ISO 7150-1:2001
	6-Mechanic workshop	7.80 ±0.05	381.73 ±115	114.5 ±34	54.00 ±42.0	18.52 ±18	34.00 ±4.0	SR 7587:1996
	M.A.C.*	6.5-8.5	500.00	300.00	350	36.42	30.0	**norms (NTPA 2)*

As shown in Table 2 (for 2023 year), the values of analyzed quality indicators exceed the maximum admissible concentration according to imposed norms only in the case of WWs produced and collected from the milking parlor (4-building) and cafeteria (3-building) for COD, BOD, TS, ammonia and ES. Some findings are underlined as follows

– *pH:* the lowest value recorded was 6.85 at 3-Cafeteria and the highest value recorded was 8.10 at 5-Pharmaceutical. These values are in the range of permissible limits (6.5 - 8.5).

– *COD* (mg O_2/L): the lowest value recorded was 381.73 at 6-Mechanical workshop sector and the highest value recorded was 21,728 at the 4-Milking parlor sector; values exceed by 43.45 times fold the M.A.C. are due to all types of organic matter accumulated in time in the final WW collectors in which more than 50-70 % is biodegradable.

– *BOD_5* (mg O_2/L): the lowest value recorded was 87.0 at the 5-Pharmaceutical sector and the highest value recorded was of 10,864 at the Milking parlor sector; values exceed by 36.21 times fold the M.A.C. which indicates a possible future trend perspective for valorization of organics for biogas and other energetical products' production.

– *TS* (mg/L): the lowest value recorded was 49 at the 5-Pharmaceutical warehouse and the highest value recorded was 2,565 at the 4-Milking parlor

collector; values exceed by 7.32 times fold the M.A.C. and can be locally separated, if wanted.

– *Ammonia* (mg NH_4^+/L): the lowest value recorded was <0.05 and the highest value recorded was 174.52 at the 4-Milking parlor sector; values exceed by 4.79 times fold the M.A.C. and are caused by local biological treatment processes acting on site.

– *ES* (mg/L): the lowest value recorded was 34 for the 6-Mechanical workshop and the highest value recorded was 188 for 3-Cafeteria; values exceed by 6.26 times fold the M.A.C. and must be reduced by application of the prevention measures.

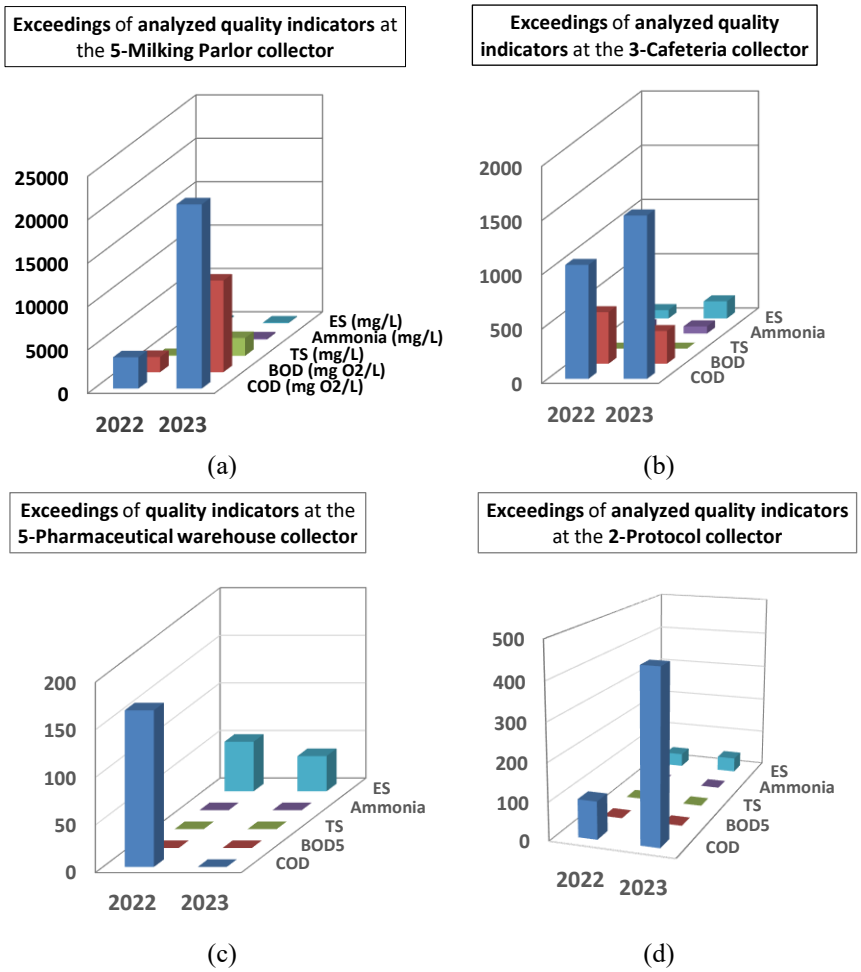

Fig. 3 – Exceeding values referring to C.M.C. of all analyzed quality indicators in 2022-2023 for some collectors. (a) 5-Milking parlor; (b) 3-Cafeteria; (c) 5-Pharmaceutical warehouse and (d) 2-Protocol building.

As can be seen from Tables 1 and 2, from all six control sectors organized on the livestock farm site for collecting wastewater produced from various activities performed, the values of the analyzed quality indicators vary within relatively wide limits in each annual calendar period and agricultural/livestock production season and exceed the maximum concentrations allowed by the environmental legislation in force as well as in the norms of the water management authorization as illustrated in Fig. 3. The exceeding values of COD, BOD and ammonia related to M.A.C. values are higher in 2023 than 2022 (except in the case of 5-Pharmaceutical warehouse collector), fact which imposed serious control and preventive measures. Moreover, alternative sustainable solutions for local pre-treatment of collected WWs are in view and preliminary laboratory pre-treatment processes and operations are initiated at reduced scale setup (laboratory scale) for obtaining the most adequate operating conditions in the case of each tested process and operation possible to be applied, or combination of them for further possible treatment modeling and optimization design.

The analyzed WWs characteristics of zootechnical farm recommend as beneficial the WWs treatment in each final collector from each farm buildings (especially in four special collectors) and also the sewage system extending and modernization for possible construction of a local mixed WW physical-chemical treatment station (e.g., main pretreatment steps can be flotation-(coagulation/ sedimentation)-adsorption-disinfection and a possible biogas station) in association with the efficient operating of the two existing aerated lagoons onto farm emplacement; in addition, solid agricultural waste can be used as single adsorbent, or in form of hybrid materials for different farm onsite facilities (construction, protection, adsorption treatment, or hybrid material).

4. Conclusions

1. Continuous control and constant monitoring of specific WW quality indicators is clearly required in the studied zootechnical farm. The values of periodic analysed quality indicators may help to adopt, insert and/or select the manner of treated WW use/valorise as irrigation water for agricultural activities nearby.

2. Directions for valorisation of potential treated wastewater on-site as well as of other solid wastes should be adopted for a sustainable environmental management of the livestock farm.

3. For the studied zootechnical farm it is recommended the initiation of collected WW treatment procedures (single or mixed processes/ operations, and even modernization of the sewerage system and construction of a combined WW physical-chemical treatment station for minimization of organic loads and extractible substances in the farm collectors).

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CARACTERISTICI ALE APELOR UZATE DINTR-O FERMĂ ZOOTEHNICĂ DE BOVINE – UN STUDIU DE CAZ

(Rezumat)

Această lucrare evidențiază tipurile de deșeuri și principalele lor caracteristici produse ca urmare a principalelor activități dintr-o fermă zootehnică, în special apele uzate colectate din diferite sectoare de activitate ale fermei zootehnice. Șase sectoare de monitorizare au fost organizate pentru evaluarea nivelului de încărcare poluantă a efluenților evacuați. Valorilor principalilor indicatori de calitate ai apelor uzate colectate (pH, CCO, CBO_5, conținut total de solide, amoniu, substanțe extractible în solvenți organici) sunt controlate constant și raportate periodic către autoritatea de gospodărire a apelor, fiind recomandată și stabilirea unor direcții și soluții locale de epurare a efluenților produși și de valorificare a deșeurilor la fața locului (utilizare directă pe amplasamentul fermei). Normele limitative ale indicatorilor de calitate controlați în câteva sectoare de monitorizare (în principal 4 sectoare de control) sunt mult depășite și tendința este de creștere a încărcărilor, fapt ce impune adoptarea de măsuri serioase de epurare/tratare locală și continuare a monitorizării stării de calitate a efluenților generați pe ferma zootehnică