

REASONABLE NUMBER OF ANAEROBIC CHAMBERS ON WASTE TREATMENT PLANT FROM PIG RAISING SECTOR

Duong Quoc Huy¹, Vu Hai Nam²

1. Center for Training and International Cooperation
Vietnam Academy for Water Resources

Abstract: *The pig raising industry in Vietnam currently tends to shift from a small scale to a concentrated raising with different farm-scales. Along with that trend, the problem of environmental pollution from livestock production in rural areas is becoming more and more serious due to the high density of livestock in one location while waste treatment methods are still simple (mainly biogas) and can not fully treat the pollution problem. Currently, there are many technologies applicable for waste and wastewater treatment in pig-raising sector, including: (i) natural treatment solution which is cheap but requires a lot of space (ponds, lakes, wetland, etc.); (ii) high treatment efficiency (Aerotank, MBR, JOHKASOU) using less space requirement but expensive; and (iii) semi-natural treatment technologies that combines two biological treatment processes (anaerobic, aerobic) to limit the disadvantages and take advantages of the two above mentioned technologies. This paper presents the results of research on selection of a reasonable number of anaerobic treatment modules, including: Anaerobic Baffle Reactor (ABR) and Anaerobic Filter (AF) of the wastewater treatment plan in pig-farm raising sector as a basis for standardizing the technological solution of wastewater treatment for small and medium-scaled in the North Central Region in Vietnam.*

Keywords: *Pig raising, Wastewater treatment plant, Anaerobic, Aerobic.*

1. INTRODUCTION

The pig raising plays an important role in Vietnam with contribution over 60% value of the livestock sector. In 2020, the pig raising sector in Vietnam reached 22.028 million pig heads¹. There are two forms of pig raising, including: (i) household scale; and (ii) farm scale. The pig raising now is shifting from household scale to farm scale. Number of pigs raising households/farms in whole country was about 4,13 million in 2011, reduced to 3,4 million by 2016 and 2.5 million by 2017, and reached only about 2 million in 2020². The scale of pig raising in households and farms is shown in Figure 1.

Along with the development of the number of pig farms as well as the number of pig heads, a

large amount of wastewater and waste from pig raising production activity discharge into the environment. The environmental pollution around the pig farm is shown in Figure 2 below [2].

A large amount of water was used for pig raising activities and generated a significant amount of solid waste and wastewater daily. If it is not treated, it will become a polluted sources, causing negative impacts on the environment, society, health and production, etc. in the pig raising production area.

Currently, there are many technological solutions applied for treatment of waste and wastewater from pig raising activities including: (i) biological treatment with natural conditions solution, it is cheap but a big space required (ponds, lakes, wetland), (ii) proactive

Receipt Date: October 10th, 2022

Review Approval Date: November 19th, 2022

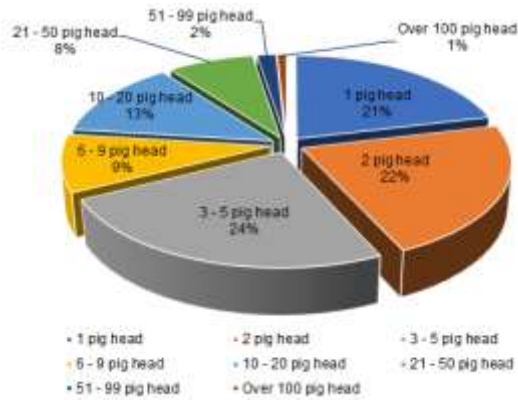
Publish Approval Date: November 30th, 2022

¹ Gso.gov.vn

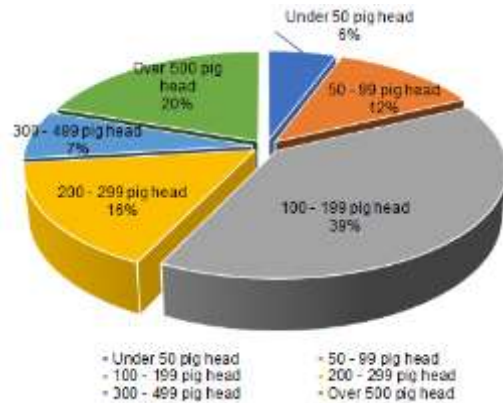
² <https://nhachannuoi.vn/nganh-chan-nuoi-lon-vuot-thach-thuc-tang-suc-canh-tranh/>

treatment solutions, it is expensive but a small area required for construction (Aerotank, MBR, JOHKASOU...); and (iii) biological solutions with combination of anaerobic,

aerobic treatment processes in natural or artificial conditions to solve the disadvantages as well as take the advantages of the mentioned above technological solutions.



Pig raising in households scale

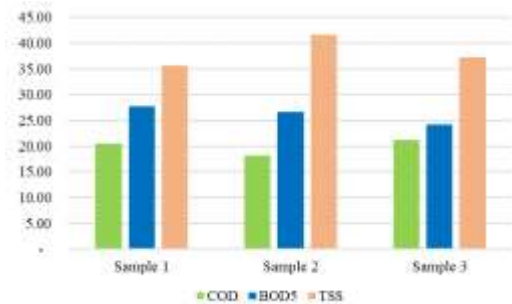


Pig raising in farm scale

Figure 1: Scale of pig raising in Vietnam (Source: gso.gov.vn, 2018)



Waste from pig farm of Mr. Tran Quoc Hoan, Nam Dan district, Nghe An province



Exceeding of concentration to the allowable value in QCVN 62-MT:2016 /BTNMT [1]

Figure 2: Wastewater from pig raising pollute the environment (Sources: VAWR, 2019)

The proposed solution to treat waste and wastewater from pig raising activities [3] in National Target Program on New Rural Construction was shown in Figure 3.

digester and/or settler chambers. The heavier density materials will settle to the bottom of the chambers as sludge, and the lighter density materials will float on surface as scums, the middle layer of wastewater will go to the next treatment modules; (ii) Anaerobic treatment process: anaerobic biological technology gives very high COD and BOD₅ treatment efficiency. The wastewater flow goes through activated sludge and/or anaerobic filtration layers with a controlled velocity. Reasonable activated sludge layer thickness, type of filter material as well as the reasonable dimensions of treatment components... will gives high treatment efficiency of COD, BOD₅, TSS

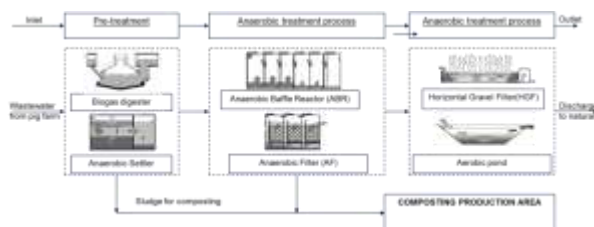


Figure 3: Proposed solutions for treatment of waste and wastewater from pig raising

The treatment solution includes 3 steps: (i) Pre-treatment process: by using biogas

parameters in wastewater from pig raising production; and (iii) Aerobic treatment process: after anaerobic treatment process, horizontal filtration process with plant in an aerobic environment is necessary to solve problems of odor, color and nutrients in wastewater, ensuring the treated water at output meets the criteria in Vietnamese standards before discharging into the environment or reusing for agricultural purposes.

In the proposed solution, the main polluted criteria such as COD, BOD₅ mainly treated in the anaerobic treatment process with two modules ABR and AF. The combination between these two components will make highly treated efficiency. Theoretically, the ABR chamber has a lower construction cost than the AF chamber, but the AF chamber has a higher treatment efficiency than the ABR one (shown in the next section). Thus, the combination of the reasonable number of ABR and AF chambers will not only give the treated efficiency but also get the optimal cost.

2. METHODOLOGY

2.1. Subjects of the study

The subjects of the study are the up-flow anaerobic baffle reactor (ABR) and up-flow anaerobic filter (AF) in terms of (i) treatment efficiency; (ii) construction costs; and (iii) the reasonable number of ABR and AF chambers in the waste treatment process.

2.2. Method

This study uses the calculating treatment efficiency and calculating construction cost methods independently based on the number of ABR and AF components to make a preliminary assessment of the treatment efficiency and construction cost of them. Then, conduct an assessment with combination of ABR and AF chambers number to determine the optimal combination in terms of treatment efficiency and construction cost.

2.3. Research tools

For wastewater from pig raising, a polluted

source with high organic pollution concentration, the tool to calculate the treatment efficiency of organic polluted wastewater treatment of COD and BOD₅ introduced in [5] was used in this study. Construction value of treatment chambers/reactors in the calculated cases according to regulations of construction.

2.4. Data

The data used in this study referenced to the results of field survey [2] at Mr. Tran Quoc Hoan's pig farm, Kim Lien commune, Nam Dan district, Nghe An province with value of polluted concentration at the outlet of pig-farm defined as:

Wastewater discharge: $Q = 15 \text{ m}^3/\text{day}$.

Wastewater concentration: COD = 6.172 (mg/l); BOD₅ = 2.808 (mg/l)

3.5. Treatment efficiency and construction cost of ABR and AF chambers

Anaerobic Baffle Reactor (ABR) allows the wastewater goes up and down by baffles in the reactor. The wastewater is continuously exposed and mixed with the activated sludge with a high density of anaerobic microorganisms at the bottom of each reactor, so that the decomposition of organic compounds in wastewater are strongly help treatment efficiency higher than conventional septic tanks. Anaerobic filter chamber (AF) with filter material plays a role of substrate for microorganisms to grow, forming microbial membranes in the chamber. Dissolved pollutants in wastewater are treated more effectively when it goes through the pores of the filter material and contacts with the microbial membranes. Therefore, the anaerobic treatment process should usually have a combination of both ABR and AF reactor/chamber.

The results of treatment efficiency calculation with COD, BOD₅ indicators according to the number of ABR, AF reactor/chamber [5] are shown in Figure 4 below.

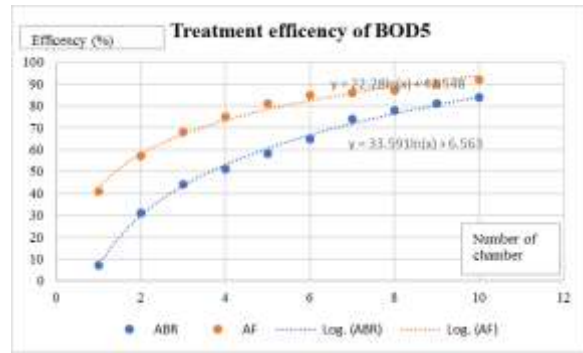
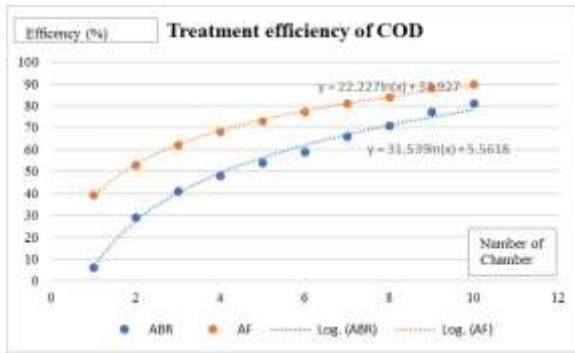


Figure 4: Relationship between treatment efficiency and number of ABR, AF

In the figure 4, it can be seen that: (i) The COD and BOD₅ treatment efficiency in ABR and AF reactor/chamber increases sharply and clearly when the number of reactor/chambers increases in the range from 2 ÷ 8 chambers for ABR and from 2 ÷ 6 chambers for AF, after that the increasing of treatment efficiency is low in spite of the increasing of number of chambers; and (ii) With the same number of chambers, the COD and BOD₅ treatment efficiency in the AF is 10 ÷ 35% higher than in the ABR (within the calculation range from 1 ÷ 10 reactor/chambers).

The results calculation of the construction costs according to the number of ABR and AF chamber with the current regulations on construction sector in this study are shown in Figure 5.

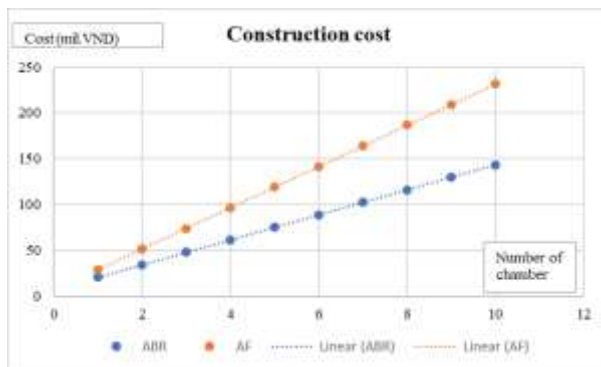


Figure 5: Relationship between construction and number of ABR, AF

From figure 5, it can be shown that the increase of construction cost is linear with the number of chambers. With the same number of chambers, the construction cost of AF is 1.5 ÷ 1.6 times higher than ABR.

It can be seen that the treatment efficiency of AF is 10% ÷ 35% higher than ABR chambers, but conversely, the construction cost of AF tanks is 1.5 ÷ 1.6 times higher than ABR tanks. Thus, determining a reasonable number of ABR and AF chambers in the combination solution will ensure the treatment efficiency as well as the optimal construction costs. The results of determining a reasonable number of ABR and AF chamber are presented in the section 3.2.

3. RESULTS AND DISCUSSION

3.1. Determining a reasonable number of ABR and AF chamber

Calculation results for combination scenarios including (1÷10) ABR reactor combined with (1÷10) AF chamber. For each scenario, the calculation of overall treatment efficiency of COD and BOD₅ indicators as well as construction costs was conducted. Then, the comparison between the calculated results of treatment efficiency for the organic pollutants and QCVN 62-MT:2016/BTMT [1] for livestock wastewater sector and was shown in Figure 6.

The combination scenarios located bellows QCVN 62-MT:2016/BTNMT line, the values of COD and BOD₅ indicators will meet the standards in cases of treated wastewater to be discharged into water sources which is not used for domestic water supply purposes (column B). There are many combination scenarios meet this condition as shown in the Figure 6.

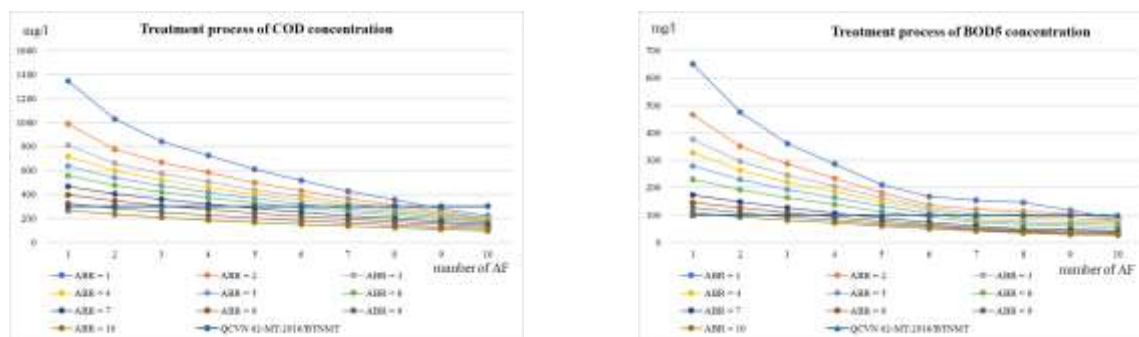


Figure 6: Effective treatment of COD, BOD₅ in calculation combination scenarios

However, in terms of the lowest construction costs while the treatment efficiency still ensured, the combination scenarios that need to be considered and evaluated will be located nearly below the QCVN 62-MT:2016/BTNMT line with a lowest of total number of chamber

(for example, a combination scenario of 6 ABR and 6 AF chambers ensures the 2 conditions mentioned above). The results of the combination scenarios that ensure the mentioned conditions along with construction costs are summarized in Table 1.

Table 1: Calculation results of combination scenarios of reasonable number of ABR and AF

Scenario	TH1	TH2	TH3	TH4	TH5	TH6	TH7	TH8
ABR (number of chamber)	8	7	6	5	4	3	2	1
AF (number of chamber)	4	5	6	7	8	9	10	10
COD (mg/l) at inlet	275	270	266	265	266	240	200	222
BOD ₅ (mg/l) at inlet	90	89	93	82	85	90	80	87
Construction cost (mil. VNĐ)	212,49	221,41	230,33	239,16	248,25	256,98	266,00	252,29
HRT (h)	46,5	47,2	47,9	49,8	50,8	51,5	52,8	53,0

In table 1, it can be seen that the TH1 scenario has the lowest construction cost and ensures the treatment efficiency requirements to meet the QCVN 62-MT:2016/BTNMT standard. Therefore, the TH1 scenario is proposed as the reasonable solution of number of ABR and AF chambers.

3.2. Discussions

The results of the study on determining a reasonable number of ABR and AF was applied in the pig farm of Mr. Tran Quoc Hoan, Kim Lien commune, Nam Dan district, Nghe An province in the National Target Program on New Rural Construction in the North Central region of Vietnam.

After the construction of the wastewater

treatment plant for pig farm completed, a sampling of wastewater at inlet/outlet points of each chamber/reactor of ABR and AF was conducted for the monitoring and evaluation of the performance [4]. The analysis results of wastewater samples were used for comparison with calculated results in section 3.2 which is shown in Figure 7.

The comparison shows that the treatment efficiency of COD and BOD₅ indicators between calculation and actual application are similar in each treatment processes with the difference in the range of 5% ÷ 15%. This means when the wastewater treatment plant goes into stable operation, the theoretical calculation results are relatively consistent with reality.

On the basis of theoretical calculation of treatment efficiency and construction cost of ABR and AF, the research team conducted an analysis for determining a reasonable number

of ABR and AF reactor/chamber in proposed technology for wastewater treatment of small and medium-sized pig farming with 08 ABR reactors combined with 04 AF chambers.

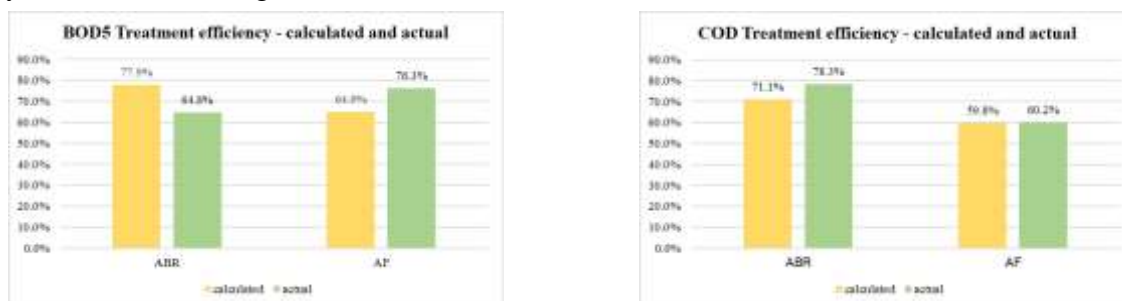


Figure 7: Comparison between calculated and actual treatment efficiency

4. CONCLUSIONS

The study results was applied in the pig farm of Mr. Tran Quoc Hoan, in Kim Lien commune, Nam Dan district, Nghe An province within the National Target Program on New Rural Construction in the 2016-2020 period for the North Central region. It can be seen that the study results are suitable with actual application.

For treatment of waste and wastewater from pig raising with a very high concentration of organic pollution, biogas digester is very necessary in the pre-treatment process to reduce the polluted load for the next treatment process components. The application of biogas digester mainly referred to theoretical calculation as well as practical

experience. Therefore, it is necessary to study deeply about the role of biogas digester in this treatment process.

In the aerobic process by Horizontal Gravel Filter (HGF) component, the treatment efficiency of smell, color and nutrients in wastewater after anaerobic treatment process is also refer to theoretically calculation as well as the selection of plants for the HGF mainly based on experience. Thus, a specific study on this issue is necessary. While the treatment of sludge in biogas digester and anaerobic chambers/reactors is inherited through the composting process from many studies and projects, so it is not necessary to conduct any further research.

REFERENCES

- [1] Ministry of Natural Resources and Environment, 2016, "National Technical Regulation on the effluent of livestock - QCVN 62-MT:2016/BTNMT", Vietnam
- [2] Vietnam Academy for Water Resources, 2019, " Report on Assessment of the current situation and propose suitable technologies for waste treatment of domestic and small and medium-scale of livestock" - Project "Research and selection of suitable technology for waste treatment (domestic, livestock) on a small and medium scale for the National Target Program on New Rural Construction in the North Central region", Vietnam.
- [3] Vietnam Academy for Water Resources, 2019, "Report on pilot site selection for building models and designing suitable technologies for waste treatment of domestic and small and medium-scale of livestock in the North Central region" - Project "Research and selection of suitable technology for waste treatment (domestic, livestock) on a small and medium scale for the National Target Program on New Rural Construction in the North Central region", Vietnam.
- [4] Vietnam Academy for Water Resources, 2020, "Report on results of monitoring the operation of the wastewater treatment model at the pig farm of Mr. Tran Quoc Hoan, Kim Lien commune, Nam Dan district, Nghe An province" - Project "Research and selection of suitable technology for waste treatment (domestic, livestock) on a small and medium scale for the National Target Program on New Rural Construction in the North Central region", Vietnam.

- [5] Adreas Ulrich, Stefan Reuter, et al., (2009), “Decentralized Wastewater Treatment System (DEWATS) and Sanitation in Developing Countries”, United Kingdom.