ISSN No:-2456-2165

Evaluation of Proposed Treatment Process for Abattoir Wastewater

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Abstract:- The focus of this paper is to evaluate the performance of a proposed treatment process developed for treating wastewater generated from an abattoir. The flow operation for the treatment was presented in the following sequence: filtration → coagulation/flocculation → filtration → adsorption → filtration→disinfection. To achieve this objective, three samples of wastewaters were collected at designated locations within the abattoir, and were taken to the laboratory for treatment in line with the proposed process. Prior to actual treatment, a preliminary test was conducted in order to ascertain the level of pollution in the abattoir wastewater. This was followed by actual treatment as proposed: Paper filtration, bio flocculation (with chitosan), adsorption (with bentonite clay), further paper filtration and chlorine disinfection. The treated wastewater samples were intermittently subjected to physical, chemical and biological property tests so as to ascertain the performance of the treatment. The results obtained after coagulation/flocculation treatment showed: turbidity in NTU: 0.04±0.01, 0.39±0.06, 0.02±0.01; TDS in mg/l: 41.00±0.58,48.00±0.58,31.40±0.12) and TSS in mg/l: 42.30±0.17,48.40±0.23,32.20±0.00 indicating a good improvement as against the raw wastewater, while having a TSS removal efficiency of 98%.The results also complied with WHO and FEPA standards. After the adsorption treatment, BOD, COD and heavy metals concentrations (Zn, Cr, Fe, Pb, As and Cd) were also reduced significantly to acceptable levels. Chlorine disinfection of the treated wastewater caused the concentrations of Total coliform and Escherichia coli to reduce to a non-detectable level. In order to implement this treatment process at developmental scale, appropriate sizing of the filter, flocculator and adsorption units, in line with specified capacity was recommended.

Keywords:- *Wastewater, Abattoir, Treatment Process, Physical-Chemical-Biological Property, Compliance Standard.*

I. INTRODUCTION

Human activities and her quest to earn a living has generally affected the environment, without recourse to the fact that man's existence also relies on the sustainability of its own environments necessary for healthy living. Several environments within the universe are adversely suffering from environmental degradation, with over 80% of it attributed human activities.

According to Walakira (2011), Water is vital to all (or any) sorts of life, and constitutes about 50 - 97% of plants and animals' weight, and about 70% of human constituents. It is also an important resource for domestic use, production, manufacturing, agriculture, construction, transportation and other applications. Chutter (1998), reported that water remains the most poorly managed resource within the globe despite its importance and significance nature. Industrial processes like Cannery, Milk dairy, Sugar extraction, Brewing, Distillery, Meat processing etc. makes use of huge amount of water which subsequently generates huge amount of wastewater (Tchobanoglous *et al*., 1991). However, most of these wastewaters contain substantial amount of pollutants including pathogens.

The ever increasing human population in the communities, coupled with the high demand for vital protein sources, has made the number of abattoirs to have risen to be one of such industries generating large volume of wastewaters, with no effective treatment procedures, nor adequate controls from regulatory authorities. Most of these generated untreated wastewaters are often discharged or emptied into nearby community streams or creeks or rivers, thereby constituting as agents of environmental pollution to the human inhabitants around these water bodies, and to the aquatic organisms in these waters (Kundu*et al*., 2013).

Abattoirs are registered facilities for processing, butchering and preserving of meat products for consumption by humans (Alonge, 2005). However, most slaughterhouse operations are geared towards recuperating the edible parts of the animals, the eluted wastewaters aren't properly managed. This calls for serious public health concerns, because the wastewaters may contains large amount of organic and inorganic substances (such as; Paunch, grease, fat, blood, undigested foods, suspended materials, manure, grit, urine, excrements etc.), including liquid and gaseous wastes (Aniebo et al., 2009; Bazrafshan et al., 2012).

There are reported studies in the literature which emphasized efforts in treating abattoir wastewaters. Notable ones are presented as follows. Chukwu (2008), reported a possible 60 to 90 % reduction of BOD in abattoir wastewater treatment using method of anaerobic digestion. Gauri (2015), achieved a COD reduction of about 90 %, and a removal of large amounts of nutrients by dissolved air flotation and chemical methods. In addition, kundu et. al. (2013) applied method of sequencing batch reactor to reduce abattoir wastewaters COD content to 86 to 95 %.. Cornwell, (2008) also accomplished 60 % removal of suspended solids (SS) and 35 % reduction of BOD using wastewater primary treatment techniques. However, to satisfy certain safety requirements, environmental regulatory bodies (WHO, FEPA etc.) have recommended adequate treatments for abattoir wastewaters before discharging to the environment (Barrera *et al*., 2012).

This study intends to develop a treatment process for an abattoir wastewater located in a sub-urban community in Rivers state, Nigeria. This process will articulate treatment procedures in a sequential manner, which applies physical, chemical and biological mechanisms. These procedures would be subjected to performance evaluation, and would be recommended as well for chemical engineering process integration.

II. MATERIALS AND METHOD

2.1 MATERIALS AND EQUIPMENT

The main materials used for this study are wastewater samples collected from designation locations around the abattoir. These samples were collected from three (3) designated points: main slaughterhouse, 5 metre away from slaughter house and by the river bank. Relevant equipment or apparatuses used in the laboratory during treatment would be mentioned at the appropriate sections.

2.2 Experimental Procedure

(A). Sample screening

Samples of wastewater from the abattoir were screened using filter mesh (1 to 5 mm pore size), which helped to remove grit, small stones, gravel, animal bones, skin and other contaminants.

(B). Coagulation and flocculation

Chitosan (isolated from chitin of crabs) was modified in the laboratory, and was used as biocoagulant/flocculant. The wastewater samples: A, B and C were separately subjected to coagulation and flocculation treatment in a 500 ml capacity column. Different dosages of chitosan (2.5, 5 and 10 g) were added to the wastewater samples, amidst frequent agitation, after which they were allowed to stand for 48h. The samples were then filtered and analysed for physiochemical properties.

(C). Adsorption treatment

50 g of bentonite clay powder was activated with 60% H_2SO_4 amidst thorough mixing. The clay was then washed with distilled water, and oven dried at 80 ^oC. An adsorption column packed with 19.6 g activated bentonite clay (having packed height of 1.3 cm) was set up, which was supported with 500ml separating funnel and 250 ml perforated beaker (for even distribution of wastewater), both were clamped on top of the column in a retort stand assembly. To prevent bentonite loss, the column base was plugged with 1.8mm sized filter paper. A 250ml beaker was then mounted beneath the set up as the collector. 150ml wastewater was then introduced into the column through the separating funnel and regulated with a tap, and the contact time recorded. This procedure was repeated for all wastewater samples A, B and C.

(D). Paper Filtration

Treated wastewaters recovered from adsorption were then filtered using Whatman filter paper of wet strength standard, with pore size 20 to 25 µm, for the purpose of removing suspended particles.

(E). Chlorination

4.44 g of chorine reagent (or sodium hypochlorite) was dissolved in 250ml distilled water and stirred for 60 seconds. 10 ml each of the treated wastewater sample was dose with 1 ml of the prepared chlorine reagent in a sample bottle and allowed to stand for 30 mins. Thereafter, 3 ml of the chlorinated water sample was taken for analysis, in order to check for microbes presence.

(F). Pre- and Post-Treatment Analysis of Abattoir Wastewater

At different stages of the treatment, the wastewater samples were subsequently subjected to analysis using standardized methods to determine parameters such as: Dissolved oxygen (DO), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), pH, Total solids, Total dissolved solids (TDS), Total suspended solids (TSS), heavy metals, microbes etc. The essence of this analysis was to ascertain the treatment performance.

(G). Treatment Flow Process

The treatment process proposed for the wastewater used for this study was developed into a flow-sheet using Microsoft visio, by articulating the different stages of the treatment in a sequential order: Screening → Coagulation/flocculation → Filtration → Adsorption → Filtration → Chlorination. The flow-sheet as presented in Figure 1 is a qualitative flow-sheet which only indicates the streams entering and coming out of each equipment or units. The flow-sheet also made use of process equipment such as pumps and collector for efficient wastewater treatment.

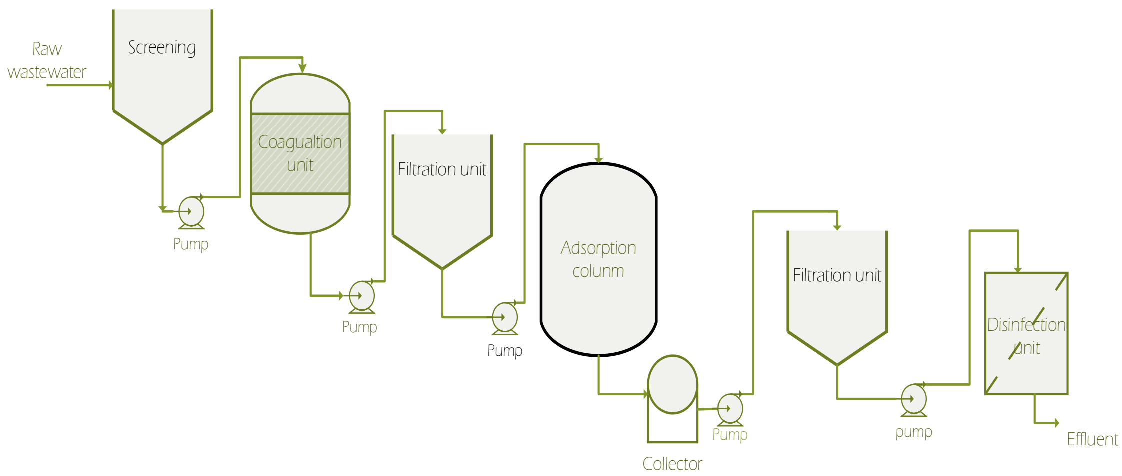

Figure 1: Abattoir wastewater treatment flow-sheet.

III. RESULTS AND DISCUSSION

(A). Abattoir wastewater pre-treatment analysis

Slaughterhouses are well known for the high quantity of waste they produce, which in most cases, not treated before discharged. The various activities of slaughterhouses produce wastewater and solid wastes, which are usually mixed with wastewater and released into any nearby stream, lake and river. Wastewater samples from the slaughterhouse were obtained very early in the morning from three (3) designated points. Physical examination of the sampled wastewater revealed large concentration of animal faeces, blood, fat and other contaminants. These results corroborate with those of Tamenech and Tamirat, (2017), who also reported presence of urine, blood animal faeces in wastewater from a related slaughterhouse, and also stated that odours and emissions are considered as gaseous wastes. Table 1 shows the effects of the physicochemical parameters of the analysed wastewater from the slaughterhouse before treatment. The table also compares it to the wastewater discharge standard of the Federal Environmental Protection Agency (FEPA) and the World Health Organization (WHO). This result revealed that the slaughterhouse wastewater is heavily polluted. The samples had pH values ranging from 5.99±0.01 to 6.02±0.01. The pH of the samples is within the discharge requirements set aside by WHO and FEPA. The wastewater pH according to Aniyikaiye (2019), is critical for the efficient removal of organic compounds and heavy metals and this adds to the stability of its carbon dioxide content, corrosiveness and coagulation potential. The sample's biochemical oxygen demand (BOD) in mg/l ranges from 198.27±0.01 to 283.52±0.01. Both levels are much greater than the WHO's recommended limit of 60 mg/l and FEPA's recommended limit of 50mg/l. This large value denotes that the water is severely contaminated. High BOD encourages the growth of bacteria in the river, which depletes the oxygen supply, endangering the lives of the fish and other marine species that live there. The study wastewater's chemical oxygen demand (COD) was 845.03 mg/L, 1416.13mg/L and 1305.64mg/L respectively. This is also higher than the stipulated standard, indicating a high concentration of organic pollutants in the abattoir. The Total Dissolved solids (TDS) of the analysed samples ranges from 1720±1.73 to 3420±1.16 (mg/l). The value for sample 1 lies within the set aside discharge standard by FEPA (2000mg/L) but it's greater than that of WHO (1500) mg/L. That of sample 2 and 3 are far above the stipulated standard of both WHO and FEPA. According to Walakira (2011), discharging wastewater with a high TDS value will damage aquatic life and make the water at the receiving end unfit for drinking and domestic use. It will also restrict crop yield if used for irrigation. Phosphate, Nitrates, Calcium, Sodium, Magnesium, Chloride and Potassium all contributes to an increase in TDS, indicating hard water. Total suspended solids (TSS) detected in the samples ranges from 1563±1.73 to 3174±2.31 in mg/l. Eze and Eze (2018) has earlier reported that high TSS increases turbidity in the water, which causes a strong demand for oxygen, and this affects aquatic life. Suspended solids absorb sunlight and prevent heat from reaching water bodies, increasing water temperature and lowering dissolved oxygen levels in the process. Furthermore, these solids, along with a decrease in growth rate, limit the mobility of marine organisms (Aniyikaiye, 2019). Phosphate concentrations range from 24.71±0.01 to 26.70±0.12 (mg/l). These values are greater than the stipulated standards. In polluted water, high Phosphate values are essential because they act as reservoirs of algae, which causes the death of marine species. (Walakira 2011). The heavy metal concentrations as shown in table 2 were all discovered to be higher than the guidelines given by WHO and FEPA. Since heavy metals are not biodegradable, they have significant impact on organisms even in trace amount. (Uyigue et.al, 2020). Heavy metals are major pollutants of the environment, and their toxicity is becoming more of a concern for ecological, evolutionary, nutritional and environmental factors. (Uyigue et.al, 2020). Lead alters membrane permeability, inhibits enzyme activities and causes water imbalance, mineral nutrition fluctuations and alters hormonal status. According to Akpor et.al, 2014, lead has harmful effect on the CNS (central nervous system), liver, kidneys, reproductive system. The toxicity of lead in water can be ascribed to its free ionic content and organism availability. Cd has no known beneficial effects and, as concentration rises above fixed levels, it may become detrimental to living organisms (primarily humans and animals) and less toxic to plants (Malwina, 2019). They are moderately poisonous to all species, with accumulated toxin in humans and other mammals concentrating in the liver, lung, pancreas, and thyroid (EPA, 1971). Cadmium accumulates and reaches the food chain as it enters the top soils and is ultimately washed through waterways by surface waters, posing a severe danger to human lives and aquatic species. It enters the body via the gastrointestinal tract through ingested food products grown on polluted soil, while smokers may receive a substantial portion of their cadmium intake by inhaling cigarette smoke. (Walakira, 2011). Cadmium is poisonous even though it is absorbed slowly through the digestive tract; a heavy intake of Cd in food combined with long-term exposure triggers bone defects such as osteoporosis and osteomalacia (Oghenerobor et.al, 2014). Chromium toxicity impart on plant growth and development include suppression of germination, decline of plant growth and biomass, and potential respiratory effects such as wheezing, coughing, and other symptoms after exposure (Akpor et.al,2014).

Table 1: Physicochemical parameters of abattoir wastewater before treatment

SAMPLE	pH	TDS (mg/l)	TSS (mg/l)	BOD5 (mg/l)	COD (mg/l)	Total coliform	E. coli
Sample 1	5.99±0.01[a]	1720±1.73[a]	1563±1.73[a]	198.27±0.01[a]	845.03±0.02 [a]	45±0.58[a]	28±0.06[a]
Sample 2	6.02±0.01[b]	3420±1.16[a]	3174±2.31[a]	283.52±0.01[a]	1416.13±0.02[a]	70±0.12[a]	51±0.58[a]
Sample 3	5.99±0.01[c]	2260±1.16[a]	2043±0.00[a]	249.16±0.01[a]	1305.64±0.02[a]	30±0.58[a]	22±1.16[a]
WHO (2006)	6.0-9.0	1500	60.0	60.0	150.0	N. A	N. A
FEPA	6.0-9.	2,000	30.0	50.0	N. A	N. A	N. A

Note: Samples 1, 2 and 3 are respectively wastewaters from slaughter house, 5meters away from slaughter house and from the river bank

Table 2: Heavy metal contents before treatment

SAMPLE	Pb(mg/l)	Cd (mg/l)	Cr (mg/l)	As (mg/l)	Zn (mg/l)	Fe (mg/l)
Sample1	13.20±0.12[a]	1.58±0.01 [a]	25.03±0.02[a]	3.74±0.01 [a]	19.14±0.01 [a]	5.02±0.00 [a]
Sample2	10.41±0.01[a]	2.04±0.02 [a]	33.48±0.01[a]	5.18±0.01 [a]	11.95±0.02 [a]	2.69±0.01 [a]
Sample 3	17.26±0.02[a]	1.83±0.02 [a]	29.27±0.12[a]	5.70±0.06 [a]	13.35±0.17 [a]	2.14±0.02 [a]
WHO, 2006	0.2	0.01	0.02	0.05	5.0	5.0
FEPA	<0.1	<1.0	<1.0	0.1	<1.0	20.0

Note: Samples 1, 2 and 3 are respectively wastewaters from slaughter house, 5 meters away from Slaughter house and from the river bank

(B). Coagulation/Flocculation and Adsorption treatment performance

The results of the physicochemical and heavy metal parameters of sampled wastewater after coagulation and adsorption treatment obtained from notable slaughterhouse before and after treatment are shown in Tables 2 to Table 5. The result shows that TDS (mg/l) in the untreated water Range: (1720±1.73 to 3420±1.16) was reduced significantly to (24.90±0.55 to 27.80±0.06), which is quite lower than the USEPA recommended standard of 1200 mg/l, TSS (mg/l) was reduced from (1563±1.73 to 3174±2.31) in untreated water to (29.20±0.12 to 30.6±0.35) in the treated sample with USEPA bench mark as 100mg/L. The study revealed that coagulation/flocculation treatment was best achieved at 10g mass of chitosan as against the 2.5g and 5g masses with about 98% efficiency. The obtained TSS and TDS values at 10g gave TSS in mg/l 42.30±0.17, 48.40±0.23, 32.20±0.00 and TDS in mg/l 41.00±0.58, 48.00±0.58, 31.40±0.12 levels in samples 1, 2 and 3 respectively. BOD (mg/l) was reduced from range of (198.27±0.01 to 283.52±0.01) in untreated wastewater to (11.98±0.01 to 15.47±0.06) in treated water with USEPA bench mark being 50mg/l. COD (mg/l) was notably high in untreated wastewater at range (845.03±0.02 to 1416.13±0.02) this however was reduced significantly to (278.59±0.06 to 310.73±0.02). COD results are always higher than BOD. However, the higher the relative Oxygen content of a waste, the higher the COD and polluting capacity of the waste. (Sincero and Sincero, 2003). Despite the decrease in other factors, the COD values obtained indicates that the effluent also has possible pollution potentials to be considered. Total coliform was reduced from range (30±0.58 to 70±0.12) in the wastewater to a non-detectable level after chlorination. E.coli was also reduced to below detectable limit from range (22±1.16 to 51±0.58) to a non-detectable limit after chlorination with average maximal levels seen in the samples in the order; sample 2 > sample 1 > sample 3. Adsorption on the other hand, has little effect on total coliform or E-coli levels, according to the report. The appearance of coliforms and E-coli in untreated wastewater indicates the presence of a disease-causing pathogen, which is consistent with previous reports that such illnesses are transmitted by insects and animals that come into contact with wastewater. (Fall, 1997). Table 4 show the effects of heavy metal concentrations in the sampled wastewater after adsorption treatment. The adsorption treatment however gave a significant decrease in the concentration of the heavy metals at $p>0.05$ with about 96% efficiency in performance. With these level of concentrations, the wastewater is safe for discharge. The overall heavy metal levels after treatment were seen in the order Zn>Cr>Fe>Pb>As>Cd. This shows that the adsorption procedure however reduced Cr more than Zn, as Zinc was shown to climb from position two to one while Fe climbed from position four to three. While with average maximal levels seen in the samples in the order; sample 1 > sample 2 > sample 3. It is worthy to note that adsorption treatment has little or no effect on the pathogenic concentration of the wastewater, hence Chlorination treatment and this reduced the Total coliform and Escherichia coli concentration to a non-detectable level with about 99% efficiency.

Table 3: Wastewater Characteristics after coagulation/flocculation treatment

SAMPLE	Treatment level	Turbidity (NTU)	TSS (mg/l)	TDS (mg/l)
Sample 1	2.5g	0.31±0.00[a]	53.1±0.06[a]	52.80±0.17[a]
	5g	0.12±0.01[a]	46.9±0.06[a]	46.60±0.12[a]
	10g	0.04±0.01[a]	42.30±0.17[a]	41.00±0.58[a]
Sample 2	2.5g	1.29±0.01[a]	71.40±0.12[a]	69.60±0.23[a]
	5g	0.58±0.02[a]	57.90±0.23[a]	56.40±0.06[a]
	10g	0.39±0.06[b]	48.40±0.23[a]	48.00±0.58[a]
Sample 3	2.5g	0.25±0.03[c]	48.80 ±0.06[a]	48.60±0.17[a]
	5g	0.06±0.01[a]	37.50±0.12[a]	37.20±0.12[a]
	10g	0.02±0.01[a]	32.20±0.00[a]	31.40±0.12[a]

Table 4: Heavy metals contents after adsorption

SAMPLE	Pb(mg/l)	Cd (mg/l)	Cr (mg/l)	As (mg/l)	Zn (mg/l)	Fe (mg/l)
Sample1	0.48±0.05[a]	0.002±0.00[a]	0.81±0.01[a]	0.04±0.01[a]	2.02±0.01[a]	1.14±0.06[a]
Sample2	0.08±0.02[a]	0.005±0.00[b]	1.53±0.02[a]	0.03±0.01[b]	1.53±0.02[a]	1.05±0.00[a]
Sample 3	0.03±0.01[a]	0.002±0.00[c]	2.41±0.01[a]	0.01±0.00[c]	2.41±0.01[a]	0.83±0.02[a]

Table 5: Wastewater characteristics after chlorination

SAMPLE		Total Coliform(cfu/ml)	E. coli (cfu/ml)
Sample 1	15 mins	15.00±0.29	10.00±0.23
	30 mins	0.00±0.00	0.00±0.00
Sample 2	15 mins	30.00±0.40	20.00±0.58
	30 mins	0.00±0.00	0.00±0.00
Sample 3	15 mins	10.00±0.06	0.00±0.00
	30 mins	0.00±0.00	0.00±0.00

(C). Basic Requirements for upgrading the abattoir wastewater treatment process

The need to upgrade an abattoir wastewater treatment process to an industrial scale is very important, because it would save the environment and human inhabitants from pollution. So far, the treatment process carried out for this study is on a laboratory scale, but would require upgrading, first to a pilot scale, and then to an industrial scale. At the pilot scale treatment, the quantity of wastewater treated would increase from 500 ml capacity to about 20 to 500 litre capacities. Basic equipment required at this stage, would mainly be the coagulator/flocculator unit, adsorption column, chlorine dosing basin and cartridge filter units. However, pump units may not be required, because the flow system can easily utilize gravity force.

To upgrade the abattoir wastewater treatment process to industrial scale (i.e. ≥ 1000 liter capacities), appropriate process engineering design considerations must be carried out in line with the treatment capacity. This would include treatment process flow-sheet development, material and energy balances, equipment sizing and specifications, and cost evaluation and analysis. This would be followed by actual fabrication of equipment or by procurement based on specifications. Also, based on the layout plan for the treatment plant, actual installations would be done, followed by test run and physical commissioning.

3.1 Feasibility of Developed Treatment process

Several factors can be adduced to the constraints and limitations often faced while trying to develop a treatment process for wastewater. These factors are named as follows: (1. Cost of developing the plant (includes design, fabrication and installation); availability of technology (includes Equipment and material access); regulatory constraints, Government policy and Economic instability. A treatment plant with high cost of design and installation would require a long-term break even, while lack of access to equipment and supplies could lengthen the project's completion time, resulting in time and cost over-runs. Tough regulatory regulations could impede the realisation of the treatment plant while poor government policy and an unstable economy may put the treatment process on hold.

The proposed treatment plan made use of locally available raw materials and locally fabricated equipment, resulting in a modest operating cost. It was unaffected by regulatory constraints since the government and the regulatory authorities are working together to ensure that the environment is pollution free. The simplicity of this process is also showcased in its cost effectiveness and handy adsorbents used. This therefore shows that the developed process remains; cost effective and reliable in the treatment process suitable for slaughterhouse wastewater management.

IV. CONCLUSIONS

The developed treatment process was of the sequence: wastewater collection → Screening→ Coagulation/flocculation→ Filtration → Adsorption → Filtration → Chlorination → Filtration, was shown to be efficient in the treatment and decontamination of the slaughterhouse wastewater. This was showcased in the highly significant decrease in the level of the identified contaminant and or pollutant as well as the zero tolerance of this process to the heavy microbial load obtained from the untreated wastewater. However, this process was capable of making the water reusable in the slaughterhouse, for washing and any other activity that could only involve dermal contact with the water and for safe disposal but not fit for drinking because there exist still some traces of heavy metals not good for human health.

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