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Cleaner production measures in small-scale slaughterhouse industry – case study in Bosnia and Herzegovina

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Abstract

The goal of this project was to demonstrate to Bosnian and Herzegovinian industries that significant reductions in water use, wastewater discharge and pollution load can be obtained at little or no cost and that efficient use of resources and reduction of waste generation at source are clearly preferable compared with the end-of-pipe wastewater treatment. The project was performed on a small-scale slaughterhouse industry ‘‘Sahbaz’’ using a methodology prescribed by the Regional Activity Center for Cleaner Production from Barcelona and the Ministry of Environment of Spain. Upon detailed diagnosis of the industrial process and waste flows generated, the opportunities for environmental improvement were identified and CP measures were recommended and implemented. In the first three months of project implementation the amount of water saved and BOD reduced was 32 percent while salt consumption was reduced by 40 percent. Total annual net savings resulting from the application of selected measures were 669 €/year.

Keywords: Slaughterhouse industry; Meat processing industry; Cleaner production measures; Industrial process diagnosis; MOED; Pollution prevention; Water conservation

1. Introduction

The industry in Bosnia and Herzegovina is facing requirements as per the new set of environmental laws, which are fully based on European environmental policies and practices. These laws require the application of integrated pollution prevention and control. Currently, none of the existing industries in the country have exemplary pollution prevention programs, nor do they implement substantial measures to avoid, reduce or control pollution. Furthermore, most of them are not financially capable of upgrading their processes in order to respond to these new, stricter, environmental standards based on the European policies and practices.

The main goal of this project was to demonstrate to Bosnian and Herzegovinan industries that significant reductions in water use, wastewater discharge and pollution load can be obtained at little, or no cost, and that the efficient use of resources and reduction of waste generation at source are clearly preferable compared to the end-of-pipe treatment. By introducing the Cleaner Production (CP) concept among the industries, the project demonstrated the advantages of CP and disseminated the results to other people coming from the industry, in order to persuade them to apply the same concept.

2. Working methodology

The environmental and economic benefits of CP were demonstrated on small-scale slaughterhouse industry ‘‘Sahbaz’’ located in Semizovac near Sarajevo. The research was based on the methodology prescribed by the Regional Activity Center for Cleaner Production (RAC/CP) in Barcelona and the Ministry of Environment of Spain that involves carrying out an MOED (Minimization Opportunities Environmental Diagnosis) study. An MOED is used as a tool for assessing industrial

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activity aiming at detecting potential opportunities for prevention and reduction of pollution at source. It also provides sufficient data to the industry helping to direct its policy towards cleaner practices through technically and economically viable practices and technologies. An MOED specifically analyses production processes and waste flows, identifying the opportunities for environmental improvement connected with these processes [1].

The project was carried out in nine steps as follows:

Step 1: Initial visit and meeting with the industry. The consultant visited the company to establish initial contact with the management. The meeting was held in order to present the potential benefits from cleaner production and clearly define the objective and scope of work to be carried out based on information on environmental issues the company is facing.

Step 2: Definition of basic guidelines. Based on the information obtained from the company at the beginning of the project, the consultant prepared the work proposal including the scope of the study; list of significant areas and processes to be diagnosed; key questions to be addressed; list of persons to be interviewed; and data collection methods.

Step 3: Presentation of the work proposal. The consultant presented the work proposal to the management explaining the steps to be carried out, degree of expected participation from the company and anticipated results. The management designated one in-house representative to help the consultants in carrying out MOED and to be responsible for later implementation and monitoring of proposed CP measures.

Step 4: Acceptance of MOED. Implementation of the project started following the formal acceptance of the work proposal by the company.

Step 5: Working visits. Visits were arranged in order to collect information on the company, its production process, consumption of raw and auxiliary materials, including water and energy, and generated waste flows. An assessment was carried out, including the processes, equipment and premises, and working procedures. The entire industrial process was analysed in order to detect the potential places where CP measures could be applied.

Information was gathered by the Consultant through interviews with personnel in all production areas (manager, process engineer, workers and accountants) assuming that work procedures may vary depending on the person, as well as that ideas for improvement can come from the employees themselves.

The consultant prepared structured working tables for data collection including the following information:

- *General description of the company* (name, contact details, main activity, number of employees, etc.)
- *Information on the process:* raw and auxiliary materials including water and energy consumption, as well as end products (name, supplier, annual consumption, consumption per unit produced, purchase price, method of storage, and method of transfer). Raw materials were defined as those with volume contribution exceeding 10% of total consumption and those which easily became a part of the waste flow. Information on consumption quantities and costs of raw and auxiliary materials, including information on water and energy consumption, were obtained through the accounting department analysing purchases and archived bills. Since the company has single water and a single electrical meter at the entrance of the facility, the breakdown of water and energy consumption was not available and had to be estimated based on the worker's experiences. This information was additionally compared to the survey data of Australian and Danish abattoirs [2]. Likewise, the quantity of wastewater generated was not measured. The amount of wastewater was estimated based on figures recommended by UNEP DTIE [2].

  For water and energy consumption, the consultant identified the water supply source, type of energy used, total amounts consumed annually, estimated breakdown of water consumption inside the facility, and calculated annual cost of each resource. For the total amount of water and energy consumed as well as the associated costs, the consultant used the monthly bills received from the water supply and the energy distribution companies. No attempt was made to separately quantify the water use from each step of the slaughtering process.
- *Information on the waste flows*, where each flow was identified, source of generation identified, annually generated amounts determined, as well as existing type of management or treatment and accompanying cost. Every section of the plant was surveyed for losses and wastes, including pens, receiving area, kill floor and products processing area. Every process and operation was surveyed for activities that allowed materials to escape to the floor or drain contributing to the water pollution. In order to determine the total amount of solid waste generated, the consultant used the bills for solid waste collection where monthly amount collected and cost of collection were stated. The wastewater pollution load was obtained by analysing wastewater samples taken at the single discharge point to the river Bosna. The samples were analysed for COD, BOD, pH, suspended matter and toxicity in order to calculate population equivalent[1] which is the measure of pollution load generated by the industry. The analysis was carried out in accordance with the methods prescribed by Standard Methods for the Examination of Water and Wastewater [3] while the calculation of population equivalent was made according to the standard method prescribed by national legislation [4]. No attempt was made to separately quantify the pollution load from each step of slaughtering process.

[1] One population equivalent (PE) represents the organic biodegradable load having a five-day biochemical oxygen demand (BOD_5) of 60 g of oxygen per day.

- *Information processing*. The information was processed in a form of process diagrams with material balance, showing the input–output of raw materials, including water and energy and waste flows, in each stage of the process. This method helped to clearly define the types of wastes generated and the place of their occurrence in the production process. The information about raw material consumption, including water and energy, and waste generation were expressed as per unit of production (i.e. per head slaughtered) that is an indicative measurement of environmental efficiency of the business. This information is used to benchmark the environmental efficiency of "Sahbaz" slaughterhouse against best available practices recommended by UNEP [2], and to detect the sources of waste where savings are possible.

Step 6: Assessment of minimization opportunities to identify the options for improvement. In order to identify the specific options for improvement, quantities generated, process where it is generated, environmental impact and the treatment cost were studied for each waste flow. Environmental indicators used to benchmark performance were: water consumption, energy consumption and the organic load in the effluent, expressed as value per unit of production.

Step 7: Study of specific options with descriptions of the different proposed alternatives. Based on the environmental indicators assessed in Step 6, the consultant determined specific points in the production process where CP could be implemented at source. The specific CP measures were selected from different guiding publications recommending pollution prevention opportunities for each step of the slaughtering process [2,5–7].

Step 8: Preparation and presentation of the final document. The final document contained information obtained during the project, conclusions drawn and pollution minimization alternatives recommended in the previous steps. The document was delivered to the company and a meeting was organised in order to discuss the results obtained and to suggest a program for implementation of the alternatives identified.

3. Process diagnosis

3.1. Description of industrial facility and raw materials consumed

The industry's main activity is slaughtering of beef, calf and lamb with average 65 heads being slaughtered every month. A total of six workers are working in the industry, of which four are involved in the slaughtering process, one in meat processing and one in cleaning activities. The slaughtering procedure is semi-automated. All carcasses are cut and boned at the plant and the boneless meat is sold at the company's three retail locations. "Sahbaz" also performs further processing, as in steaks, roasts, ground beef, smoked meat, "cevapcici" (traditional meat balls), sausages, etc. The flow diagram for the slaughtering and processing of cattle used in Sahbaz slaughterhouse industrial facility along with generated waste flows is given in Fig. 1.

Sahbaz slaughterhouse industry obtains its water from the city grid. Water is used for numerous purposes, including truck washing (occasionally), livestock watering, washing of casings, offal and carcasses, cleaning and sterilizing of knives and equipment, cleaning floors, work surfaces, equipment, and workers' personal hygiene. Cleaning, in particular, is a major area of water use. The industry has only a single water meter at the entrance that documents cumulative water consumption for the whole plant. Based on monthly water consumption bills that state the amount of water consumed and the associated costs, and knowing the number of head slaughtered per day, the average water consumption was estimated at about 7 m^3/day or 0.7 m^3 per head slaughtered.

Since the breakdown of energy consumption was not available, it was estimated based on the values recommended by UNEP [2], i.e., 80–85 percent of the slaughterhouse's total energy requirement is consumed as thermal energy in the form of hot water. The 200 l pots full of water are heated on wood burning stoves located outside the slaughtering area. The hot water is used for cleaning oily floors. The remaining 15–20 percent of slaughterhouse's energy need is supplied by electricity. The electricity is used for boiler water heating, refrigeration, by-product processing, slaughter area, etc. Based on monthly energy consumption bills that state the amount of

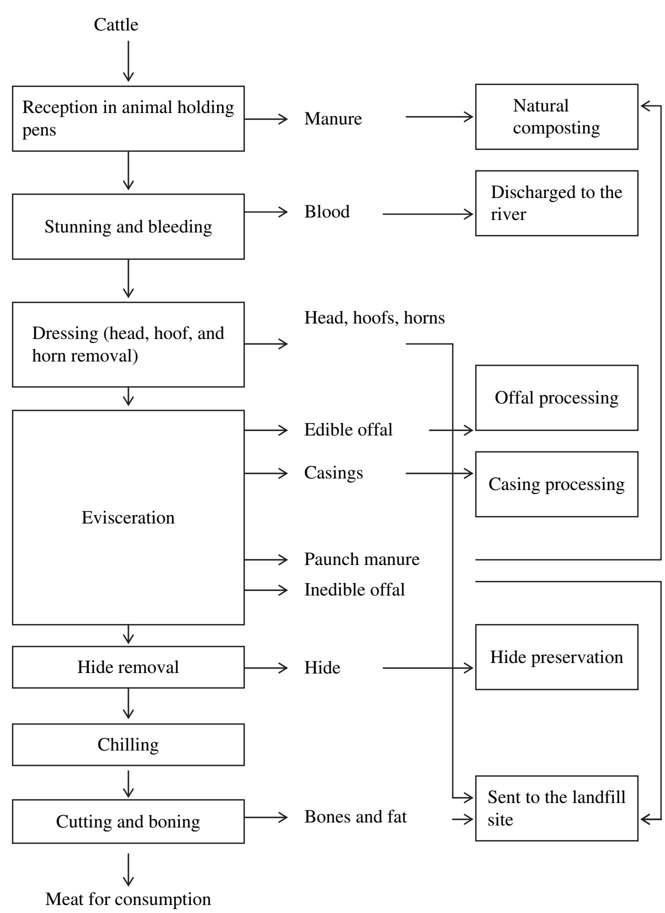

Fig. 1. Flow diagram of cattle slaughtering.

electricity consumed and associated cost, and knowing the number of head slaughtered per day, the average energy consumption in Sahbaz slaughterhouse industry was estimated to be 61 kWh per head killed.

The hides removed in the slaughtering process are conveyed to the hide processing area, where they are preserved by salting. The salt is consumed irrationally and while the exact consumption of salt per ton of hides is unknown, it is known that the company purchases approximately 3 tons of salt per year.

Different pollutants generated by each stage of the process are given in Table 1.

3.2. Description of waste flows generated

The main environmental issue associated with meat processing in Sahbaz slaughterhouse industry is discharge of high-strength effluent. Water is consumed in all stages of the process, starting from the first step where the live animal enters the facility up to the last step, where disassembled parts of the animal leave the plant. Since the breakdown of water use within the facility was not available, based on the values recommended by UNEP [2] it was estimated that about 80–95 percent of water used is discharged as wastewater, while the remaining part is held up with by-products and wastes or lost through evaporation. Wastewater is generated in several stages of the process including truck washing (occasional), washing of holding pens, washing of casings, offal and carcasses, cleaning and sterilizing of knives and equipment, cleaning floors, work surfaces, equipment, and personal hygiene. It is occasionally practiced to dry clean the floors prior to washing them with water. Employees wash their hands in a sink using automatic press-to-open valves designed to release 1.5 l of water during every washing. Based on the information obtained from accounting books, the annual quantity of detergent used for cleaning floors and equipment in the plant is approximately 80 l.

Table 1
Pollutants generated in industrial process

Stage of the process	Pollutant(s) generated	Destination of pollutant(s)
Reception of animals	■ Manure	■ Composting, effluent to the river
Stunning and bleeding	■ Blood	■ City landfill
Dressing	■ Heads, hoofs, and horns	■ City landfill
Evisceration	■ Edible offal	■ Processed for the market
	■ Casings	■ Processed for the market
	■ Paunch manure	■ Composting
	■ Inedible offal	■ City landfill
	■ Trimmings	■ City landfill or river Bosna
Hide removal	■ Hides	■ Processed for the market
	■ Salt	■ River Bosna
Cutting and boning	■ Bones	■ City landfill
	■ Fat	■ Reused, excess discharged to effluent and then to river Bosna
Cleaning	■ Detergents	■ River Bosna

Since the material release into the wastewater stream is not well prevented, wastewater contains excess pollutants. The pollutants include: blood, fat, manure, undigested stomach contents, meat and meat extracts, dirt and cleaning agents. Of all the components present in abattoir effluent, blood is the single largest contributor to the pollution load. Blood has a very high organic content, with its organic load equivalent estimated to be 0.14–0.18 kg BOD_5/kg [2]. Blood is also the main contributor to nitrogen loads in the effluent which can cause eutrophication problems downstream of the effluent discharge point. Laboratory results of wastewater quality analysis revealed that wastewater load from the slaughterhouse, expressed as population equivalent (PE), is 362. The Sahbaz slaughterhouse industry pays an annual water management fee of 308 €, especially established for slaughterhouses based on average pollution parameters, while the official price for all industries wanting to have their PE determined is 1.02 €/PE. This PE analyses confirmed that the established fee was correct.

Sahbaz slaughterhouse industry discharges all its wastewater into the Bosna River. A three-stage septic tank of 10 l/s capacity was constructed inside the plant with the aim of separating fat and trimmings from the wastewater prior to discharge into the river. The trimmings from septic tanks are removed manually as need arises, while the septic tanks are emptied and cleaned once every two months by the local water utility. However, the laboratory analysis of wastewater discharged revealed that the treatment effect is negligible and that the septic tanks do not function properly so the quality of wastewater has not improved significantly. The reason for this may be poor design or construction of the septic tanks.

Knowing that the sewer system is not constructed in the Sahbaz slaughterhouse surrounding area, discharging wastewater into the river was seen as a temporary solution. A permanent solution would be to discharge the wastewater into a city sewer, its construction being planned for the near future, and to treat the waters in city wastewater treatment plant or to install packaged wastewater treatment plant, treat the water inside the slaughterhouse area and discharge it into the river. However, the second option is not economically feasible given the high price of a package wastewater treatment plant for such a small industry and due to the high operational costs. Furthermore, the wastewater treatment plant will generate residuals which must be disposed off in environmentally friendly manner generating additional costs to the industry. Therefore, the recommendations were made for reducing wastewater pollution at source, that is, before its discharge into the river. These measures consist of economically feasible actions that will improve the quality of discharged wastewater.

Solid waste is produced in almost all stages of the process (stunning and bleeding, dressing, evisceration, and cutting and boning). Inedible products from the slaughtering process such as bone, fat, heads, hair and offal are all disposed into a 5 m^3 solid waste bin (skip), located inside the plant. Blood is also partially collected in a plastic vessel and discharged into the bin. The bin is not covered which results in unpleasant odour. The local solid waste utility empties the waste bin once a week. Based on monthly solid waste collection and disposal bills stating the amount of solid waste collected and associated cost, Sahbaz slaughterhouse produces approximately 20 m^3 of solid waste per month.

The manure is disposed in the manure disposal area, adjacent to the riverbed. The manure is spread directly on the soil which is then exposed to natural composting, resulting in unpleasant odour. The location designated for manure disposal and method of disposal are considered unfavourable since the produced leachate can easily percolate through the pile and flow to the river causing organic pollution. In order to eliminate the above impacts on the environment, the Sahbaz slaughterhouse industry had considered sending the manure to the municipal disposal site. However, disposal on a municipal site would increase the frequency and amount of waste disposed at the landfill, while also increasing the associated costs. Therefore, it is recommended that the manure disposal area should be redesigned in an environmentally acceptable way, while considering the application of a controlled composting process.

4. Recommended cleaner production measures

The process modification and good housekeeping measures are two minimization alternatives considered for the Sahbaz slaughterhouse industry. The modifications recommended are mainly directed at eliminating organic pollution from wastewater and reducing water consumption. While selecting measures to be applied, best available practices recommended by several authors were considered [2,5–7].

4.1. Process modifications

The following process modifications were recommended:

- Time required for effective bleeding is generally not less than 7 min. Therefore, it was recommended to extend the time of bleeding to at least 7 min which will maximize the proportion of blood collected, significantly contributing to the reduction of pollution load in the effluent. Combined with other measures to prevent material release into wastewater, it can help the industry to improve effluent quality and reduce water management fee.
- Since blood is a single largest contributor to pollution load, it is necessary to efficiently separate blood from wastewater. Therefore, it was recommended that a two-way blood drain system with two drain outlets be constructed, one to the blood collection drum and the other to the septic tanks. During slaughtering, the outlet to the septic tanks would be closed so that all blood is drained to the blood collection drum. When slaughtering is completed and blood fully swept out to the collection drum, the outlet to the blood collection drum would be closed while the outlet to the effluent system would be opened so that cleaning wastewaters are directed to the septic tanks. Removable plugs or valves can be used to close the outlets to these drains. Control of valves should be the responsibility of a designated operator who also gives the go-ahead to start cleaning the area. Combined with other proposed measures, the wastewater quantity collected in septic tanks would also decrease, contributing to the reduction of septic tank emptying frequency and cost. The collected materials would be disposed at the sanitary landfill site that is currently the only available option for materials with least environmental impacts.
- Introduction of controlled manure composting to replace the current practice of manure disposal inside the slaughterhouse area on the riverbank.

4.2. Equipment modification

The following equipment modifications were recommended:

- For cleaning surfaces a pressurised spray is far more effective and therefore uses less water. Fit hoses for surface cleaning with spray nozzles. A pressure of 25–30 bar is recommended by UNEP [2];
- In animal holding pens, install a 20–35 mm diameter hose fitted with a 9–10 mm nozzle to maximize cleaning efficiency;
- For washing carcasses use cool water to reduce the removal of fat from the surface of carcass;
- Fit drains with screens and/or traps to prevent solid materials from entering the effluent.

4.3. Good housekeeping measures

The following good housekeeping measures were recommended:

1. Keeping work areas tidy and uncluttered to avoid accidents;
2. Improving inventory control and record keeping of consumables, such as cleaning chemicals agents, salt, etc. to avoid waste;
3. Training employees in blood collection, good cleaning practices and water conservation. A training program is necessary to train employees to use two-way blood drain system and to use minimum required amount of water needed for job and cleaning practices;
4. In cattle reception process:
   - Avoiding feeding of animals prior to slaughter in order to reduce the quantity of stomach contents, thereby making the cleaning of the intestines easier;
   - Reusing relatively clean wastewater from cooling systems for washing pens' floors and trucks. However, the use of cold water for greasy floors is not always a good practice;
   - Dry clean holding pens prior to washing with water;
5. In hide removal and dressing process, control the consumption of salt.

6. Good cleaning practices:
   - Always undertake dry cleaning before washing with water;
   - Changing washing practices by washing the floors with angles up to 60° and by rinsing with cold water first;
   - Regularly monitoring spray nozzles;
   - Install pressure reducers and shut off valves to reduce water consumption;
   - Have management routinely measure water use through the meter on a daily basis and track water use per annual;
   - Have management occasionally run wastewater tests such as COD on discharge to quantify the waste load and track on a per head basis.

5. Conclusions

The balance of raw materials and associated costs before and three months after implementation of CP measures is given in Table 2. It is important to note that at the time of analysis of the results, a recommended blood collection system had not been constructed yet. The values given in the table are based on results of analysis of water consumption and wastewater discharge bills issued by the water utility, as well as the information on consumption of salt gathered from company's accounting books. The values obtained are expressed on an annual basis.

In the first three months of project implementation the amount of water saved was 32 percent or 45 m^3 per month. If the same trend would continue throughout the year, it would result in annual financial savings of approximately 317 €. The new wastewater analysis carried out after the three months of project implementation revealed that BOD and population equivalent measurements were reduced by 32 percent, while further reduction was expected with continuation of application of all proposed measures. Moreover, the salt consumption was reduced by 1.8 tons bringing additional savings of 146 €/year. Total annual savings resulting from the application of selected measures were 669 €/year.

Based on the results obtained, the project achieved its goals and demonstrated the environmental and economic advantages of CP.

Table 2
Balance of raw materials and costs

	Before	After
Water consumption (m^3/year)	1831	1557
Salt consumption (tons/year)	3	1.2
Wastewater load	$BOD_5 = 3520$ mg O_2/l, PE = 362	$BOD_5 = 2052$ mg O_2/l, PE = 240
Water costs (€/year)	2117	1800
Salt consumption costs (€/year)	306	160
Septic tank emptying cost (€/year)	281	143
Wastewater fee (€/year)	232	194
Total cost (€/year)	2936	
Annual savings (€/year)		669
Investments (€/year)		43
Pay-back period		Less than one month

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