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Invited Review Article

Environmental issues in meat industry and their solutions- A review

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Abstract

When the whole world is concerned about serious environmental issues arising from natural and anthropogenic sources, concerns over the contribution of the meat industry to this problem are no exception. The activities associated with meat animal rearing, meat production and processing, and by-product handling definitely consume natural resources and produce some greenhouse gases, organic and inorganic wastes which contribute to the depletion of natural resources and environmental pollution. But these problems can be avoided or reduced by adopting some good practices at each and every step in the process chain and following the environmental management systems. All the stakeholders in the meat chain must act responsibly to ensure that the meat industry addresses environmental issues in the best possible way. The objective of this review is to compile up-to-date information related to the environmental impacts of the meat industry and various strategies available for mitigation of the impacts so that the researchers can focus on development of advanced solution and other stakeholders can adopt the effective method for mitigation of environmental pollution and protection of natural resources associated with the meat industry. The scope of this review is limited to the relevant studies conducted in the last 12 years.

Key words: By-product utilization, Environmental impact, Meat industry, Waste management

Highlights

- Environmental issues arising from the meat industry are of serious concern all over the World.
- Activities in the meat industry lead to the depletion of natural resources, environmental pollution, and climate change.
- Environmental impact of the meat industry can be mitigated by sustainable animal rearing, proper meat production and processing technology, by-product utilization, and waste management.
- Adoption of the environmental management system and compliance with the rules and regulations can ensure meat production without badly affecting the environment.

INTRODUCTION

There is no denial that hue and cry over the environmental impact of the meat industry exist all over the world, but this is not a completely unresolvable problem. A group of environmental activists and animal lovers are expressing their concerns over the environmental issues arising from the commercial production of meat animals and meat, and their concerns are not unreasonable. Like many other food industries and agricultural activities, the meat industry also requires natural resources like water and energy (fossil fuel), which leads to environmental pollution (Petrovic *et al.*, 2015). The extent of use of water and the degree of environmental pollution may be on the higher side in comparison to plant-based food groups (Poore and Nemecek, 2018; Karwowska *et al.*, 2021). Does it mean that meat production and consumption should be completely stopped to save the environment? The answer is "NO" as we cannot deny the necessity of nutrient-rich food like meat for a large section of the human population and ever-increasing demand for meat and meat products. Animal husbandry (for dairy/meat production or agricultural activities) doesn't only provide nutrient-rich food, but also contributes greatly to the national economy. Especially in the developing countries, livestock products can contribute significantly to nutrition, food security and household economy (FAO, 2011). Meat is one of the top five agricultural export products in India, and our country earned US$

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2.2 billion from the export of buffalo meat during 2021-2022 (Economic survey, 2021-22). The contribution of the livestock sector was 6.17% of total Gross Value Added in 2020-21, and India achieved 14.1% increase in 2022 over the previous year in meat industry value of output (Invest India, 2022). As per the FAO report, 2011, "meat consumption is projected to rise nearly 73% by 2050; most of this demand will be met by large-scale, intensive animal-rearing operations". The report also says that "an urgent challenge is to make intensive production more environmentally benign". So, what is the solution to the problem of the environmental impact of the meat industry? Is there any way that allows us to eat meat and still reduce environmental pollution? Yes, it is the responsibility of all the stakeholders in the meat chain to follow sustainable animal husbandry practices and meat production/ processing to keep a balance of environmental impacts and benefits of meat industry. Paying attention to each step in the meat chain starting from meat animal production to consumption of meat products through good practices like Good Animal Husbandry Practices (GAHP), Good Manufacturing Practices (GMP), Good Hygienic Practices (GHP), Good Transportation Practices (GTP) and adoption of Environmental Management System (EMS) in the meat industry helps to overcome the environmental issues (Poore and Nemecek, 2018).

Environmental issues in the meat industry

The meat industry significantly influences the environment in terms of climate change, depletion of natural resources, and environmental pollution (Djekic, 2015). In the slaughterhouse, significant environmental issues are associated with consumption of water and energy, and emissions of high organic strength effluent (CPCB, 2017). The extent of environmental impacts varies depending on the scale of operation (small, medium, large meat industry); types of processes (meat animal rearing, slaughter and dressing of meat animals, processing of meat products, by-product processing); and the types of meat animals involved (cattle, buffalo, pig, sheep, goat, poultry, etc) (Djekic, 2015; CPCB 2017). Like many other countries, India is also witnessing considerable environmental issues arising from the meat industry. The CPCB documented a report in 2017 on "characterization, waste management practices and best available pollution control technologies in slaughterhouses" and mentioned that India has numerous small, medium and large slaughterhouses, and many of them are not having adequate basic facilities for scientific and hygienic handling of meat, by-products and wastes. In India, sanitation standard in the majority of slaughterhouses is very low; and unsatisfactory waste disposal and discharge of contaminated effluents are leading to environmental threats. A study conducted by Singh *et al.*, 2014 revealed that many slaughterhouses in and around Aligarh, Uttar Pradesh, India did not have proper waste treatment or disposal systems; solid wastes were either sold or dumped in fields or burnt; liquid waste was discharged in drains without treatment, and all these were contributing to environmental pollution. The environmental issues have become so serious that the Supreme court directed the CPCB vide order dated 23.08.2012 to take initiative against the slaughterhouses which are not following the environmental norms and implementing slaughterhouse rules (CPCB, 2019). Following are few important environmental issues arising from the meat industries.

Green House Gas (GHG) emission: Meat production and processing do not produce much GHG, but the rearing of meat animals considerably contributes to GHG production, which may result in climate change (Petrovic *et al.*, 2015). Some environmental activists claim that the meat industry is one of the major contributors to GHG, but it is not true. As per the United States Environmental Protection Agency (USEPA) data, the GHG emission in the US in 2020 from different sources were 27% from transportation, 25% from electric power, 24% from industry, 13% from commercial and residential and 11% from agriculture; and out

of this 11% share of agriculture, only 4.4% is from animals (USEPA, 2020). This GHG emission is either directly from enteric fermentation (in ruminants) and manure or indirectly from animal feed production activities (Gao *et al.*, 2014). As per the Life- Cycle Assessment (LCA) approach, beef cattle contribute 41 percent of total livestock sector emissions (Gerber *et al.*, 2015). Reckmann *et al.* (2012) reported that LCA on pork production resulted in 3.6 kg CO_2 equivalent global warming potential per kg of pork on an average.

Depletion of natural resources: As the meat industry is water intensive, all the operations involved in meat production including meat animal rearing and processing require a huge quantity of water (Gerbens-Leenes *et al.*, 2013). The activities like slaughtering and dressing of animals, cleaning of equipment and premises, washing of transport vehicles and meat handlers, and processing of by-products require water. The meat industry also requires energy (fossil fuel or any other source) for operating slaughtering and processing equipment, transport vehicle, chilling, freezing, boiling, cooking, pasteurization, steam production, smoking, drying, lighting, etc. Therefore, it is said that the meat industry leads to the depletion of natural resources like water and energy (Gerbens-Leenes *et al.*, 2013; Petrovic *et al.*, 2015).

Environmental pollution: All the water consuming activities in the animal farm, slaughterhouse, and meat processing plant generate huge quantities of wastewater. The quantity of water used in a slaughterhouse greatly depends on its layout, degree of mechanization, size of animal slaughtered, method of slaughter and dressing, and cooling of carcass etc.; and large quantity of water used in cleaning, washing and evisceration (CPCB, 2017). Wastewater gets mixed with various organic and inorganic materials like manure, urine, blood, hair, fat, stomach and intestinal contents, feathers (poultry), cleaning agent, chemicals, packaging material etc. from different areas (CPCB, 2017; Ramirez, 2021). This wastewater/effluent is a great source of water pollution if discharged into the natural water stream without proper treatment (Kharat, 2019). The key indicators of wastewater quality are the quantity of solid waste, Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Suspended Solids (TSS) and to some extent nitrogen and phosphorus (CPCB, 2017). The quality and quantity of effluent vary widely depending upon the scale and types of operation, types of animals, the efficiency of by-product recovery and cleaning processes etc (CPCB, 2017). As per the United Nations Environment Programme (UNEP, 2000) and Integrated Pollution Prevention and Control Integrated Pollution Prevention and Control (IPPC, 2006), the important environmental performance indicators in the meat industry are meat yield, solid output (manure, by-products), water and energy consumption, wastewater load (BOD and COD), and discharge. The huge quantity of effluent generated in the meat industry has high protein, fat and grease with a BOD level of 1500-2000 mg/L (Irshad *et al.*, 2016). Blood has a high potential to increase the BOD level in the effluent, and the mixing of stomach and intestine contents in wastewater leads to a high level of TSS (Kharat, 2019). As per the CPCB, 2017, sources of liquid and solid wastes and the typical characteristics of slaughterhouse effluent are presented in Table 1 and 2 respectively.

Table 1. Sources of liquid and solid wastes in a slaughterhouse

Source	Liquid wastes	Solid wastes
Animal holding	Floor washing, urine	Fodder waste, dung
Slaughter hall	Blood, floor, and machine washing	Blood clots
Hide / skin removal	-	Hair and dirt
Internal organ cleaning	Wash liquor	Stomach and intestinal content
Carcass dressing	Blood, floor, and machine washing	Meat trimmings, fat, grease
By-product plant	Floor, machine washing, glue water	Grease and offal

Table 2. Typical characteristics of slaughterhouse effluent

Parameters	Raw effluent
pH	7.6-8.2
BOD	1200-4000 mg/L
COD	3000-7000 mg/L
TSS	1500-4500 mg/L

Apart from the target product (meat), the meat industry generates various edible and inedible by-products like organs, bone, blood, meat trimmings, skin, hair, feather, head, feet, horn, stomach and intestinal content, manure etc. (Ockerman and Hansen, 2000; Jayathilakan *et al.*, 2012; CPCB, 2017). These are rich in organic matter; if these are not utilized properly and disposed of without any treatment, they create environmental pollution and spread of diseases (Jayathilakan *et al.*, 2012).

Various gases (CO_2, CO, NO_2, SO_2, CFCs, NH_3, etc) are also emitted from different activities in the meat industry, like, heating of water for hot water and steam, evaporation of chilling liquid, stripping of freezing machine, smoking of meat products, singeing of pig hair or poultry feathers etc (CPCB, 2017; Kharat, 2019). All these lead to air pollution and obnoxious odour. Decomposition of highly perishable offals also results in foul smell.

Solutions to environmental issues in the meat industry

The natural resources can be saved, and the GHG emission and environmental pollution can be mitigated with the adoption of a proper animal farming system (GAHP), efficient meat production and processing technology (GMP and GHP), efficient utilization of animal by-products and effective solid and liquid waste management (GMP and GHP) (CPCB, 2017; Bandaw and Herago, 2019). The old slaughterhouses need to be modernized to enhance sanitation and hygienic condition and ultimately ensuring the reduction in environmental pollution (CPCB, 2017). The National Green Tribunal (NGT) in India has been giving directions to the meat industries through CPCB and State Pollution Control Board (SPCB) from time to time to follow the environmental norms. Most of the states have constituted State Level Committee for monitoring the slaughterhouses, and SPCBs are to take necessary actions if the slaughterhouses do not comply with the environmental norms. SPCBs need to send the status of the slaughterhouses, effluent treatment and action taken against the illegal slaughterhouses or defaulters to the CPCB (CPCB, 2019).

Addressing the environmental issues in the meat industries through various interventions are discussed here.

Mitigation of GHG emission: Though it is not easy to completely mitigate the GHG emission from meat animal production, but modified farming practices (GAHP) like improved herd management, feeding, and manure management considerably reduce the GHG emission (Nguyen *et al.*, 2012). Mixing manure with soil also helps in carbon sequestration, thereby increasing soil fertility and mitigating CO_2 emissions (Nguyen *et al.*, 2012). The use of the net energy system in pig feed formulation in China was an effective strategy to mitigate the GHG and reduce land use (Hu *et al.*, 2022). Beauchemin *et al.* (2011) studied the effect of combination of GHG mitigation strategies like changed levels of forage use and improved forage quality, feed supplementation with polyunsaturated lipids, feeding of corn distillers dried grains, improved reproductive performance and longevity of the herd etc. in a beef cattle herd for 8 years. They found that cow calf system resulted in 80% of the total emission, whereas feedlot system produced only 20%. They also observed that 63% of the total GHG was from enteric CH_4. In LCA, they reported that the combination of these mitigation strategies significantly reduced total farm GHG emission up to 17% and the effect was more in cow calf herd than the feedlot herd.

Application of novel technologies and alternative approaches in meat industry: Care

should be taken during meat production and processing to use less energy-intensive technology, less water consuming and less waste generating process. Novel technologies like high pressure processing (HPP) of meat, ohmic heating, pulsed electric field (PEF) etc. are energy efficient and environment friendly, and can improve the sustainability of meat industry (Smetana *et al*., 2019). Pardo and Zufia (2012) mentioned that HPP is more beneficial than conventional pasteurization process and is an environment-friendly technology for packaged ready-to-eat products. The PEF does not require water for meat tenderization, and therefore waste water is not generated; and it also does not release particulate matter, gases and chemicals like conventional cooking and heating processes (Smetana *et al*., 2019). All these novel technologies have shown promising results in the laboratory and pilot scale. But the meat industries are not applying these technologies widely because of their certain limitations like their high installation and processing cost, application in batch-based process and in small scale. To harness the advantages of these eco-friendly energy efficient technologies, further research is needed in the designing of the advanced equipment suitable for large scale industrial application.

Conventional methods used for meat production, meat cooling, cleaning etc. can be replaced with alternative methods to reduce the water consumption in the meat industry. Few examples of such alternative methods include gas stunning or dry electronarcosis of poultry instead of electronarcosis stunning by immersion in water; hot water spray or steam scalding instead of hot water immersion scalding of pig and poultry; air-refrigeration of poultry carcass for pre-cooling instead of immersion in chilled water; use of mechanical or dry cleaning of solid wastes followed by final rinsing instead of only wet cleaning in the transport vehicle, lairage, meat production and processing areas; use of ammonia refrigeration system for maintaining cold temperature etc. (Bailone *et al*., 2022). Application of simple step like fasting of animals before slaughter reduces the chances of visceral rupture and results in less water use for cleaning of carcass or slaughter hall. Likewise, water waste can be reduced by using automatically closing water taps in the hand washing and shower area for the meat handlers; spray nozzles or high-pressure hose for plant and equipment cleaning; and also by using water waste control system with automatic eviscerator and other equipment which require continuous flow of water (Bailone *et al*., 2022).

Efficient by-product utilization: The by-products available from the slaughterhouse make 52-68% of the live weight of the animals, depending on the species of the animals (Jayathilakan *et al.*, 2012). If these are not utilized properly, they not only lead to economic loss for the meat processor but also result in environmental pollution (Jayathilakan *et al.*, 2012). With sincere efforts of the stakeholders, the pollution can be mitigated, and the high-value products can be prepared from these incredible resources of protein, fat, minerals, vitamins, enzymes, hormones, etc. The uses of meat industry by-products are presented in Table 3 (Ockerman and Hansen, 2000).

Researches are going on for improved utilization of animal by-products. Here are some findings of such studies. Hydrolysis of protein-rich by-products like blood and collagen results in high valued bioactive peptides, which can be used in pharmaceuticals and cosmetics (Toldrá *et al.*, 2016). Bioplastic having polyhydroxyalkanoates can be made from low-quality animal fats, and the use of petroleum-based plastic can be reduced (Riedel *et al.*, 2015). A recent study showed that biodiesel production can be improved by using trans-esterification of animal fat assisted with ultrasounds (Adewale *et al.*, 2016). Bioelectricity can also be produced by using goat rumen fluid in microbial fuel cells (Meignanalakshmi and Vinoth Kumar, 2016).

Effective waste management: As we know that the main principles of waste management are reuse, recycle and reduce; these 3Rs are also

Table 3. Uses of meat industry by-products

Primary by-product	Uses
Hide/skin	Leather, collagen
Bone	Bone meal, gelatine
Blood	Food ingredients, blood meal, serum, plasma, gelatine, bioactive peptide
Fat	Cooking fat, lubricant, soap, cosmetics, biodiesel
Stomach and intestine	Casing, tripes
Organs like glands, lungs, brain	Food ingredients, pet food, pharmaceutical uses like hormones, enzymes
Horn, hoof/feet	Keratin, horn/hoof meal, artefacts
Feather	Artefacts, feather meal
Hair, bristles, wool	Brush, carpet, garments
Inedible carcass or parts	Carcass meal, animal feed, fertilizer
Stomach and intestinal content	Animal feed, fertilizer, biogas

applicable to the management of solid wastes and effluent of the meat industry. The basic steps for limiting the pollution from meat industry include minimization, segregation and processing of waste to recover maximum by-products and finally proper waste disposal (Kharat, 2019).

Effluent can be treated in three different steps, i.e., primary, secondary and tertiary treatment (Irshad *et al*., 2016; CPCB, 2017; Kharat, 2019). In the preliminary step, by-products, fat and grease, and coarse solids are removed by screening, skimming, and settling to reduce the pollutant burden in the effluent (CPCB, 2017; Kharat, 2019). It is better to collect by-products and solid waste as close as possible to the source so that these do not contaminate the effluent, and reuse of the by-products is possible. Care should be taken at each step of meat production and processing to minimize or avoid the use of water, and that would ensure the reduction of liquid waste. Primary treatments of effluent remove the suspended solids, odour and colour by screening, neutralization (adding acid or alkali), equalization (stabilizing pH and BOD), sedimentation (suspended solid particles by gravity), dissolved air floatation (injecting of air bubbles in the effluent to bring the light particles to the surface as scum) and coagulation (colloidal impurities by chemical coagulants or electrical charge) (Irshad *et al.*, 2016; CPCB, 2017; Kharat, 2019).

After the primary treatments, the effluent is subjected to secondary treatments, which include aerobic and anaerobic biological treatment to remove the organic pollutants. Anaerobic treatment is employed when the organic load in the effluent is very high, and aerobic treatment is done when the effluent has a low organic load. Instead of applying a single method, a combination of anaerobic and aerobic treatment efficiently removes the BOD up to the level of 99% (Irshad *et al.*, 2016). Secondary treatment includes the use of a trickling filter, anaerobic digestion, activated sludge process (ASP), oxidation ditch, aerated lagoon, and oxidation pond (Irshad *et al.*, 2016; CPCB, 2017; Kharat, 2019). In the trickling filter method, a biofilm is produced over the trickling filter bed to treat the effluent aerobically. Anaerobic digestion is carried out in a closed container where methane and ammonia gases are produced. In the activated sludge method, organic components of the effluent are biologically degraded by microbes in the presence of oxygen and after settling down of the effluent, a portion of sludge is added back to the reaction tank. Organic materials in the effluent are microbially oxidized in different

shapes and sizes of oxidation ditch, aerated lagoon, and oxidation pond.

Tertiary treatment is carried out to remove bacteria present in the effluent and inorganic matter like nitrogen, phosphorus, metals, metal oxides, sulfates, etc. (CPCB, 2017; Kharat, 2019). This treatment employs different physical or chemical methods like reverse osmosis, chemical precipitation, evaporation, dialysis, removal by algae, activated carbon, chlorination, UV or gamma rays, etc. (CPCB, 2017; Kharat, 2019). After the tertiary treatment, the effluent achieves a quality worthy of being reutilized and it can also be discharged in the fresh water stream or for land irrigation.

Odour control devices like biofilters, wet scrubbers, and activated carbon are used in slaughter house or by-product processing plants to remove odour from exhaust air, especially from the rendering unit (Kharat, 2019). Regenerative thermal oxidiser can remove 99% of volatile organic compounds to purify the exhaust gases and waste airflow (Geng *et al.*, 2018).

All these treatment methods are utilized by the slaughterhouse and the meat processing units as per the availability of the effluent treatment plant (ETP), category of the unit, types and quantity of wastes (CPCB, 2017; Kharat, 2019). Small slaughterhouse generally removes solid wastes in a settling tank and discharges the effluent in the sewer; medium size slaughterhouse adopts biological treatments; and large size mechanized and export-oriented slaughterhouse follows various primary, secondary and tertiary treatments in a proper ETP (CPCB, 2017). Bandaw and Herago (2019) mentioned that GMP, GHP, and proper waste management practices (solid, liquid and gas) in an abattoir can reduce the potential threats to the environment. Many experiments are being conducted to improve the efficiency of the removal of BOD, COD, TSS, and inorganic components. Many researchers are working on the application of a combination of different methods or modification of traditional methods to devise more effective and best-suited effluent treatment for various meat industries.

A study of an ETP in a typical slaughterhouse showed that ETP having two-stage ASP followed by an activated carbon filter removed 98.62% Total Dissolved Solids (TDS), 99.48% BOD, and 99.08% COD (Kharat and Akolkar, 2014). The application of direct current electrocoagulation can remove 87% COD of meat processing effluents, and COD removal is better when aluminium plates are used as electrodes (Ali, 2015). AL-Saadi and Gabriel (2019) reported that anaerobic treatment (5 days of fermentation) of meat effluent followed by an aerobic process (sludge activation for 24 hours) with membrane bioreactor system (MBR) resulted in excellent removal of 98.3% of TSS, 94.53% of BOD5 and 95.56% of COD. An improved Sequential Batch Reactor (SBR) process (a variation of ASP) is the Attached Growth Batch Reactor (AGBR) technology that combines all the steps in a single basin and allows microbial degradation of effluent using enzymes. Samuel and Srinivas (2019) used this AGBR technology to reduce 90% of effluent parameters and they also studied the benefits of combination of AGBR and biogas digester. A study on the effect of chemical coagulation and electro-Fenton process for the treatment of slaughterhouse waste water using different levels of polyaluminium chloride (PAC), hydrogen peroxide, pH, reaction time, and voltage indicated that 75 mg/L PAC and 2500 mg/L hydrogen peroxide at 20V voltage, pH 3 and 75 minutes effectively removed 89.55% COD, 88.88% BOD, 91.27% TSS and 100% faecal coliform (Bazrafshan *et al.*, 2022). The nanomaterials like carbon nanotubes, zinc oxide, titanium oxide etc. can also efficiently eliminate biological and metal contaminants from the wastewater (Amin *et al.*, 2014).

Instead of dumping the slaughterhouse solid wastes, which may cause environmental pollution and spread diseases, these wastes can be utilized profitably and this is the core concept of "wastes to profits" (Ramirez *et al.*, 2021). These can be treated by composting, bio-methanation, rendering, and incineration depending on the quantity and quality of the

wastes, but incineration should be the last option (CPCB, 2017; Kharat, 2019). All the fodder residues, dung, meat trimmings, hair, feather, stomach and intestinal content, etc can be composted or utilized for biogas production (bio-methanation). The use of biosynthesized iron nanoparticles for anaerobic digestion of slaughterhouse waste improves biogas production and also reduces the COD (Yazdani *et al*., 2019). By application of appropriate scientific methodology (pre-treatment, optimum reactor conditions and additives), wastes from slaughter house can be converted into sustainable energy i.e., biodiesel which is of almost conventional fuel quality, and also hydrogen. For example, 4.068 million L of biodiesel can be produced from 4.785 million L of chicken fat (Chowdhury *et al*., 2022).

Rules, Regulations, Standards and Environmental Management System (EMS) for the meat industry: One way to address the environmental issues in the meat industry is the adoption of a holistic approach focusing on the environmental management system (Djekic, 2015). Several acts, rules and regulations have been framed which the Indian meat industries need to follow to take care of the environmental issues. The slaughterhouses and meat processing plants should be licensed by or registered with the Food Safety and Standards Authority of India (FSSAI) and also should have the approval of the CPCB/SPCB or local authority. For the meat industry, FSSAI has mandatory standards i.e., Food Safety and Standards (for licensing and registration of Food Business Operators) Regulation, 2011 for following the minimum hygienic condition including cleaning, pest control and waste management (FSSR, 2011). Other applicable rules and regulations include Environment (Protection) Act, 1986; Environment (Protection) Amendment Rules, 2015; Water (Prevention and Control of Pollution) Act, 1974; Water (Prevention and Control of Pollution) Rules, 1975; Air (Prevention and Control of Pollution) Act, 1981; Municipal Solid Wastes (Management & Handling) Rules, 2000; National Green Tribunal Act, 2010; and Prevention of Cruelty to Animals (Slaughterhouse) Rules, 2010 etc. The CPCB has guidelines for the discharge of effluents from slaughterhouse, meat processing plants, and animal by-product processing plants. There are Bureau of Indian Standards for handling of slaughterhouse by-products (IS: 8895:2015) and basic requirement of an abattoir (IS 4393: 2016).

The USEPA, European Environment Agency (EEA), Australian Environment Agency, etc. also have their environment management guidelines and standards for effluent discharge for the meat sector. The standards for the discharge of slaughterhouse effluents in different countries are presented in Table 4.

In addition to the mandatory standards, there is also a voluntary International Standard (IS 14001) for environmental management systems (EMS) which can be adopted by the industries to ensure that they minimize their environmental impact on water, air, land, etc. EMS is a proactive approach by which a meat industry can review its environmental goals, analyze

Table 4. Standards for discharge of slaughterhouses effluents in different countries (CPCB, 2017)

Parameters	Standards (maximum concentration)					
	India	USA	China	Ireland	Australia	Ethiopia
pH	6.5 to 8.5	6.0-9.0	6.0-9.0	6.0-9.0	6.0-9.0	6.0-9.0
BOD (mg/L)	30	50	20	20-40	300	80
COD (mg/L)	250	250	100	125-250	900	250
Suspended solids (mg/L)	50	50	70	60	<1500	-
Oil and grease (mg/L)	10	10	-	10-15	<200	15

impacts and legal or other compliance obligations, set environmental objectives and targets, establish programs to meet the objectives, monitor the progress in achieving its objectives, review the progress of EMS and ensure environmental awareness and competence of employees (USEPA, 2022). With the assistance of the World Bank, Govt. of India has developed the Environment Management Framework for the food industry (MOFPI, 2022). In Australia, a national EMS has been implemented for the red meat and chicken meat industry. "The red meat industry is reducing greenhouse gas emissions, and it has taken the initiative to be carbon neutral by 2030" (Meat and Livestock Australia, 2022).

Challenges and solutions for complying with hygienic and environmental norms by Indian meat industry: In spite of having so many afore mentioned rules and regulations in place, the reality is that the present Indian meat sector is still in the nascent stage of their compliance. Though several state-of-art modern abattoirs and processing units (mostly in private sector) are complying with the rules and regulations and exporting good quantity of meat, but majority of the meat production and processing is in unorganized sector. Meat is still produced in some places in the make-shift arrangements and poorly maintained slaughter places where the environmental and hygienic norms get little or no attention at all. Municipal slaughter houses are mostly not self- sustaining as they don't generate enough revenue to maintain the unit (CPCB, 2017). Majority of the small slaughter houses are controlled by the lease holders who do not give adequate attention to the environmental issues (CPCB, 2017). Small slaughter houses and the meat shop owners do not have the infrastructure, funds and awareness for complying with all the rules and regulations. So, what is the way forward? The setting up of rural slaughter houses has the potential of reducing the unorganized and clandestine slaughter; and also better utilization of by-product and waste management. The small meat shop owners in rural areas can get their animals slaughtered in the slaughter house on the payment basis without investing money for waste management. It is not economically feasible for the small slaughter houses/meat shops to process the by-products. Therefore, aggregation of the by-products from such places and processing them at a centralized facility can be a better option for better utilization and lesser waste generation. The wastes in the small slaughterhouses do not require big ETP as only primary treatment of the wastes and disposal of treated solid and liquid wastes separately may serve the purpose (CPCB, 2017). The Govt. of India has taken several initiatives to provide financial assistance to the meat sector through different schemes like scheme for establishing and modernization of slaughterhouses, hygienic slaughter of animals, application of modern technologies for waste management, better by-product utilizations, cold chain management etc. The central and few state governments are also encouraging establishment of meat production and processing units in public private partnership model. The FSSAI has also been creating awareness among the meat producers and processors and building capacity for successful implementation of the Food Safety and Standard Regulations in the meat sector. The number of registered slaughter houses and meat processing units are increasing gradually. This gives the hope that environmental issues in the meat sector will be effectively managed by the active participation of all the stakeholders in future.

Conclusion

It is evident from the above discussion that there are considerable environmental issues in the meat industry. But with a holistic approach for sustainable animal production, good practices in meat production and processing, efficient utilization of slaughterhouse by-products, and effective waste management, it is possible to reduce the environmental impact to an acceptable level. All countries need to

have their environmental management policy and strict guidelines for the meat industry, and all the stakeholders should be motivated enough to adopt appropriate measures to ensure the mitigation of environmental pollution and the protection of natural resources. Indian meat industry has a long way to go to reach the golden standard of environmental parameters. Future research should be focussed on the innovation of advanced scientific and affordable solutions to improve the management of natural resources and wastes and to augment the sustainability of the meat sector.

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