

## Review Article

# Historical Development of Environmental Management Tools and Techniques: A Review Paper on Its Driving Forces

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**Abstract:** Industrial development since the past period has caused serious impacts on the natural environments. This paper, therefore, explores and discusses the various pollution control techniques employed by firms. The paper therefore, has a theoretical and analytical part. The theoretical section provides background concepts on environmental management tools. The analytical part contains case studies that denote the prospect and consequences of the approach. The various approach employed to manage industrial impacts on environments were usually grouped into passive, reactive, and proactive strategies. The initial approach had less care for environments in which industries made a profit at the cost of environments. The reactive approach is defensive and practiced to handle waste after it is generated, which is an end-of-pipe approach and waste recycling technology. Firms used them to fulfill compliance and environmental regulation criteria. Recently, cleaner production, which is a proactive approach is emerged due to the existence of pressures from regulatory bodies, stakeholders, cost factors, and competitive advantages. It helps to reduce wastes at the source by minimizing the volume of by-products and the amount of energy and raw materials used. From the existed approaches, cleaner technology is more advantageous than others for environmental and economic reasons.

**Keywords:** Cleaner Production, End-of-Pipe Technology, Environmental Tools, On-Site Recycling, Passive Approach, Reactive Approach

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## 1. Introduction

Industrial production, from 18<sup>th</sup> to half of the 20<sup>th</sup> century, was evaluated based on its productivity, costs, and time used to produce [1]. However, manufacturing industries causing serious environmental degradation, which greatly counterbalance the economic gains. Consequently, environmental issues became a global agenda and concern for all sectors. To eliminate the negative effects of industries on environments, pressures from academia, policymaker, and the public have been increasing in all industries to improve their environmental performance. As a result, environmental protection and management started to become a concern of

corporate environmental management [2-6]. Hereafter, environmental management accounting has basically been introduced to help firms manage natural resources, energy utilization, and pollution [7].

This was begun in the 1960s mainly after the publication of *Silent Spring* by Rachel Carson in 1962 and the Club of Rome that analyzed the global level and later published *Limits to Growth* in 1972 [8]. Again the 1972 Stockholm conference initiated the establishment of the United Nations Environment Program [9, 10]. The 1987 world commission conference on *Our Common Future* also gave more focus for environments and the development. The fundamental idea behind this sustainable development meaning of 1987 was that both the current and future society have an equal right to the

environment. This refers to the importance of conserving natural resources [11]. The 1992 Rio de Janeiro conference also addresses environmental issues. The meeting discloses the issue for companies to look for new techniques that are environment-friendly [12].

Although environmental management strategies have been practiced since the industrial revolution, their concern for the environment had variation. The most common groups based on their ascending order for environmental responsibility are passive, reactive, and proactive strategies [11, 13].

Reactive environmental strategies are corresponded to responding to regulatory requirements, but proactive environmental strategies incorporates environmental issues beyond the legal requirements to satisfy community and organizational stakeholders [9]. However, there is a group of scholars who grouped environmental management strategies into reactive, preventive, and proactive without including the passive stages [14-17].

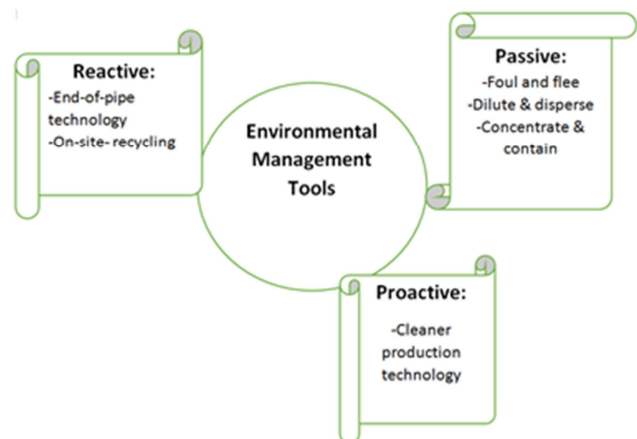
The passive approach, which was common before the 1960s, had a motive of maximizing the profits with no care for environments. This includes foul and flee, dilute and disperse, and concentrate and contain [18]. The reactive approach such as end-of-pipe technology treats industrial wastes in its outlet part using a procedure like refusing destruction and establishing chimney filters [15]. Reactive pollution prevention techniques give due emphasis on “low-hanging fruit” because industries allocated minimal budget for the conservation of the environment. Moreover, the industries seek easy and inexpensive behavioral and material changes for emission reduction [14]. The environmental performance of industries was weak and results in serious environmental pollution and contamination via the releases of toxic substances to the natural environments. The companies used such technologies mainly to fulfill legal requirements and environmental regulations [17, 19]. The approach is not adequately committed to care for the natural environment, and uses end-of-pipe technology to solve the pollution [20].

The proactive environmental management strategy is important to address the environmental issues far from pollution control using cleaner technology. It can stretch up to innovating products, including environmental issues in each strategy of the production process and allowing the participation of stakeholders. At this level, the companies have the highest level of care for the environment and it becomes their main priority [8, 15, 17, 21, 22]. The strategy enhances resource productivity, the substitution of materials, innovating manufacturing technology that uses less energy, producing new goods which can be recyclable, and redesigning new processes [21, 23]. Therefore, the purpose of this paper is to develop a literature review aimed at first and foremost at knowing the driving forces and the trends of environmental management strategies used by firms, as well as cost-benefit comparison using case studies. Specifically, the review covers (i) to assess views of the factory and any other sectors that practiced environmental management strategies towards to the natural environment where the wastes disperse, (ii) to identify the socio-economic and ecological consequences of practicing dilute and disperse

strategy by firms and agricultural sectors in Ethiopia, (III) to discuss and identify the prospect and consequences of applying on-site recycling and end-of-pipe strategies both for the firm and the surrounding environment, and (iv) to assess the driving forces for the development of cleaner production technology and its economic and environmental advantages.

## 2. Trends in Environmental Management Strategies

Human beings are consuming more natural resources for a long period. Mainly after the establishment of industries, the rate of resource consumption and waste generation was increasing. This huge production and consumption of resources put pressure on the earth's natural resources like water, minerals, soil, animals, and plants and the generated waste resulting in environmental crisis [24]. Over time, the industries used different techniques to reduce the burden on environments which is called environmental management systems. In a broader sense, the aim of applying the environmental management system is to preserve natural resources and protecting environments from pollution and degradation [25]. The various techniques used up to now may be categorized into passive, reactive, and proactive environmental strategies (Figure 1). Thus, the next paragraphs are devoted to explaining chronologically the different environmental management strategies supporting by a case study.



**Figure 1.** The three major environmental management techniques used to reduce the burden of industries on environments.

### 2.1. Passive Environmental Management Strategies: Dilute and Disperse

This approach was common at the beginning of the industrial period and around the 1900s, and still practices in some developing countries. This dilutes and disperses strategy was used with the sense that the environment has infinite resources and also capable to absorb and dilute all wastes generated from industries. This approach has three strategies: foul and flee, dilute and disperse, and concentrate and contain [18, 26].

Dilute and disperse of waste products were common when the number of industries and their wastes was within the range of environments' capability. In other term, the amount of waste produced is small compared to the environments where it sinks. The wastes are biodegradable within a range of time and the wastes are disposed of into environments [12].

*Case study: Dilution and dispersion of wastes in River Akaki, Ethiopia*

River water has a big economic benefit for the country in terms of serving as a water source for households, hydropower, industries, and irrigation schemes. At the beginning of the industrialization period in Ethiopia, the industries located along the river had fewer impacts over the river water. This was because of the total size of wastes were small in amount and mostly biodegradable wastes. However, when the size of industries are expanded, the population number is increasing and urbanization expanded, the river water is started to be threatened [27]. Many studies [28-30], reported that the industries, urban settlers, and irrigation practices in River Akaki and largely within River Awash catchment area caused uncontrolled waste disposal into the river water. Among them, industrial wastewater is the primary pollutant for pollution of River Akaki (a tributary of River Awash). They discharge their wastes directly into the river and its tributaries without treatment because they have no on-site waste treatment technology [29, 31]. Expansion of agricultural activities along the bank of the river has also caused an increase in the size and kinds of wastes from agricultural input [29].

As a consequence River Akaki has high microbiological and chemical pollutant loads that change its physicochemical and biological nature of the water [31]. According to Taddese, Sonder [32], the concentration of heavy metals in the soils irrigated by River Akaki is high. This cause a high risk to human, animals, and plants, and the surrounding soils, air, and water resources. This impact is kept on going to the worst unless strict environmental protection action is used to force industries to treat their waste. For example, in Addis Ababa city, before 2009, more than 2,000 registered industries are found and purposively almost all of them are established along the bank of rivers. Conversely, most of them have no efficient waste treatment plants, because they are not willing to invest more in waste treatment technologies. Even those industries which established a waste treatment plant, they are not effectively treating their wastes. Therefore, they released the polluted water wastes into the river, streams, and lakes [31]. Similarly, Addis Ababa industrial park is located in Akaki sub-city where the River Akaki is flowing down [33].

The seriousness of the pollution is proved by the existence of high concentrations of heavy metals such as manganese, chromium, nickel, lead, arsenic, and zinc in vegetables and soils which irrigated water from River Akaki. Their concentration exceeds the maximum allowable limit [32, 34]. The other evidence for the continued release and dispersion of untreated wastes to a water body in the absence of aquatic life in Lake Aba Samuel. The reservoir was rich in fish population and the local inhabitants were harvesting fish, but because of eutrophication, no fish in the lake water recently and is named

as the "dead lake" [35].

Therefore, the River Awash and its tributaries are polluted by the dispersion of wastes from industries, households, and farming practices. The use of this polluted river water has serious health impacts on farmers, society, and the environment. The farmers are affected when they are contacting the water during farming practices. The public has big health impacts by consuming vegetables and fruits grown using the polluted river water. It has also impacts on the environments by polluting the soil, vegetation, and ground waters [30].

## 2.2. Reactive Environmental Strategies: End-of-Pipe Approaches

End-of-pipe is defined as a practice of treating polluting substances at the end of the production process when all products and waste products have been made and the waste products are being released (through a pipe, smokestack, or another release point) [36]. This approach is implemented to minimize the volume of pollutants released from industries to environments to avoid compliance and fulfill the environmental regulations [19, 37, 38].

This technology is used to remove or transforming wastes at the end of the production process. It is not influencing the main chemical reactions during the manufacturing processes and the chemical composition of the main products is not altered [39]. One of the main distinguishing features is that they do not affect the production process rather used to take care of and treat the wastes after generated by firms. The technology helps to minimize/eliminate the impacts on the environment, prevent the spread of the waste, and measure the level of pollution [37, 40]. Some of the common end-of-pipe technologies are incineration for waste disposal, wastewater treatment plants to keep water resources, sound absorbers for noise abatement, and application of exhaust-gas cleaning technology to keep the air quality. Most of the time, the technique is not efficient and effective to avoid environmental problems, because it does not solve the causal factors. Rather it leads transmitting of pollutants from one medium to another medium in the environments. Therefore, end-of-pipe technology is temporarily delaying pollutants from causing environmental risks and the approach may cause either serious environmental problems or it may be an indirect source of pollution to the same medium (Glavič and Lukman, 2007).

*Case study 1. Almeda textile factory in Ethiopia by [41].*

The firm is found in Tigray in Adwa town. The firm is one of the biggest textile factories in the country. The firm has a large water requirement during the production phases and in the end, the volume of wastewater is too large. To reduce its impacts on the environment, the company established a treatment plant which is end-of-pipe technology. The treatment has preliminary and secondary treatment phases. The preliminary treatment includes separation sieve, primary sedimentation, neutralization, precipitation, and flocculation. The secondary treatment includes secondary sedimentation, active sludge, and disinfection. This shows that industrial effluents are passing different stages to minimize their toxicity

level and reduce the side effects on the ecosystem when the treated water joins the river water [41].

However, the wastewater has no efficient chemical treatment techniques. The factory has no adequate chemical utilization for pollution treatments. This is related to the high cost of the chemicals. For instance, Sulphuric acid is needed to neutralize the wastewater, but the effluent discharged at the end has alkaline nature. There is also sodium hypochlorinate chemical requirement to free the wastewater from pathogenic organisms. But, the actual yearly consumption of these two chemicals is near zero. Besides, when the industry is working in its full potential of textile production, the volume of effluent will be more and caused overflow beyond the canal. As a result, the wastewater joins the nearby river and surrounding environment without any treatment step [41].

Therefore, the factor has less care and a small investment for environmental management. The local people are facing health problems because, they are using river water for

domestic and agricultural activities [41]. The best solution is practicing cleaner production technology mainly in fabric processing (wet processing).

*Case study 2: Evaluation of food waste disposal options by life cycle cost analysis from the perspective of global warming: Jungnang, South Korea [42].*

The case study was conducted in South Korea, Jungnang district. The objective was to evaluate and compare different food disposal systems from the time of generation to final disposal. Life cycle cost analysis was analyzed for each stage and monetary value for environmental benefits is calculated using market prices of by-products and carbon prices for greenhouse gas reduction in the perspective of global warming.

The study used eight techniques of food waste disposal and each technique is evaluated based on their separate discharge, separate collection, transportation, treatment, and disposal (Table 1).

**Table 1.** Cost of the different food waste treatment techniques (\$/Ton).

Treatment techniques	Discharge	Collection	Transportation	Treatment/disposal	Total Cost
Dry feeding	0	60.79	1.35	72.14	134.29
Wet feeding	0	60.79	2.58	59.31	122.69
Composting	0	60.79	2.80	70.06	133.63
Aerobic digestion	0	60.79	0.23	63.74	124.74
Co-digestion with sludge	0	60.79	0.18	17.10	78.05
Food waste disposal	176.18	4.26	0.03	0.10	180.56
Dryer incineration	99.59	10.33	2.23	7.69	119.84
Landfill	0	60.79	2.29	14.19	77.24

Source: Kim, Song [42].

Thus, the study found out that the cost of using food disposal treatment was highest from the rest option, but landfill (which is the less recommended option of waste disposal) has a small cost. Sequentially the next highest food waste treatment is dry feeding, composting anaerobic digestion, wet feeding, and dryer incineration. This result shows that treating food wastes using various techniques

demands more financial resources (Table 1).

The reuse of waste food has many tangible and intangible benefits for health and environments. It helps to reduce CO<sub>2</sub> emission and the amount of virgin material required for production. However, in monetary value, benefits secured at the end from the sale of by-products and environmental benefit is too small (Table 2).

**Table 2.** Benefits from by-products and environmental benefits from GHG reduction.

Techniques	By-products/tonne			CO <sub>2</sub> reduction/tonne		Total benefits (\$)
	By-products	Amount	Benefits (\$/ton)	CO <sub>2</sub> reduction (kg/ton)	Environmental benefits (\$/ton)	
Dry feeding	Dry feed	130kg	33.41	104	1.17	34.58
Wet feeding	Wet feed	430kg	47.36	345	3.81	51.17
Composting	Compost	250kg	27.53	212	2.35	29.88
Anaerobic digestion	Electricity	174kg	10.94	180	1.98	14.17
Co-digestion	NA	NA	NA	NA	NA	NA
Food waste disposer	NA	NA	NA	AN	NA	NA
Dryer incineration	Waste heat	2.16Gcal	23.72	657	7.34	31.06
Landfill	Electricity	30kwh	1.91	96	1.03	2.94

Source: Kim, Song [42].

The net benefit value of each waste treatment technique infers that the cost of treatment outweighs the revenues that are generated from the sale of by-products and environmental benefits (Table 3).

**Table 3.** Cost-benefit comparison of food waste reuse.

Reuse techniques	Total cost	Total benefits	Net benefits
Dry feeding	134.29	34.58	-99.71
Wet feeding	122.69	51.17	-71.52

Reuse techniques	Total cost	Total benefits	Net benefits
Composting	133.63	29.88	-103.75
Anaerobic digestion	124.74	14.17	-110.57
Co-digestion	78.05	NA	-
Food waste disposer	180.56	NA	-
Dryer incineration	119.84	31.06	-88.78
Landfill	77.24	2.94	-74.30

Source: Table 1 and Table 2.

Similarly, in Dutch plastic waste recycling, the cost for collection, separation, sorting, and recycling of household plastic waste was larger than the revenues collected at the end of the sale of recycled plastic [43]. Therefore, end-of-pipe technology is very costly to control wastes and economically unsustainable approaches for such waste types [44].

### 2.3. Reactive Environmental Strategies: On-site Recycling

Sustainable development and promotion of environmental management system have forced the firms to utilize proper ways to protect the environments from pollution/wastes [45]. End-of-pipe line approach encountered with challenge and failed to achieve to protect the environments, but incur costs on industries. Following this, in the 1980s on-site recycling and recovery of waste emerged intending to reduce the volume of waste by returning in to reuse and reprocessing [26]. According to Peng, Scorpio [46], the disposal option is six, which from low to high environmental risk, namely, reduce, reuse, recycle, compost, incinerate, and landfill. Of the listed disposal option, recycling is environmentally more appropriate than landfilling and incineration for solid waste management. Recycling has three benefits: (1) reduces the need for new resources, (2) help to cut down transport and production costs of materials, and (3) reduces the number of wastes going to landfills [23, 45-47]. Moreover, in the construction industry, recycling has two more advantages: preserving land for future city expansion and development; and improving the general condition of the environment [47]. Recycling promotes reproducing new raw materials from the wastes and this process helps to secure economic advantage in turn [46, 48].

*Case study: On-site recycling practice for construction waste management in Malaysia* from [48].

Construction waste is one of the main challenges for environments in the developed world. It is also a pressing

problem in Malaysia. Construction and demolition waste constitute 10-30% in the world and 28% in Malaysia from the total wastes disposed of in landfills. The main problems are increases cost of waste removal in terms of the land site for disposal, transport cost and time, and demanding extra construction materials. To reduce the environmental and economic loss of the waste, the practices of reuse and recycling is promoted recently in the world. The benefits of recycling and reuse of construction wastes are prolonging the lifespan of landfill sites, minimizing new resource requirements, avoiding health risks, and reduces costs for construction of new landfill sites. The section below proves the various economic and environmental benefits of reuse and recycling of construction wastes. The composition of construction wastes is soil, and sand, bricks, and blocks, concretes, and aggregate, wood, metal products, roofing materials, plastic materials, and packaging of products [48].

The project site is in Beni Selangor in Malaysia and building an institution that covers 49,662 m<sup>2</sup> areas of floor space. (The exchange rate of currency was in 2006 \$1= between 3-4 RM).

**Table 4.** Amount of construction waste generated and reused and recycled.

Construction waste Materials	Amount of waste generated		Amount of waste reused and recycled	
	Tonnage	%	Tonnage	%
Concrete and aggregate	17,820	65.80	13,365	67.04
Soil and sand	7,290	27	5,400	27.33
Wood	1,350	5	810	4.0
Brick and blocks	315	1.16	126	0.64
Metal products	225	1	54	0.27
Roofing materials	54	0.20	5.4	0.03
Plastic materials and Packaging products	14.4	0.005	-	-
Total	27,068.4	100	19,760.4	100

Source: Begum, Siwar [48].

From a total of 27,068.4 tons of construction wastes, about 19,760.4 tons are reused and recycled on the construction site, which is 73% of the total wastes. Concrete and aggregate is the largest waste generated in the site followed by soil and sand and wood-based materials. They are also the highest wastes reused and recycled in the site (Table 4).

**Table 5.** Total benefit estimation of on-site recycled construction waste materials.

Beneficial items		Benefits in monetary value (RM)
1	Cost savings from purchasing new by reusing and recycling of construction waste materials	939,874.00
2	Revenue from the selling of scrap construction waste materials	27,000.00
3	Waste transportation cost savings by reusing and recycling of construction waste materials	39,520.80
4	Cost savings from landfill charge by reusing and recycling of construction waste materials	49,401.00
Intangible benefits (A)		
1) Save landfill space		
2) Reduced liability which including for environmental problems and workplace safely		A
3) Less chance of soil and groundwater contamination Improved public image and environmental concern		
6	Total benefits of reusing and recycling of construction waste materials on the site	1,055,796.00 + A

Source: Begum, Siwar [48].

Table 5 confirms that the reuse and recycling of construction waste have significant economic and environmental advantages. Therefore, according to this case study report, reuse and on-site recycling of the construction waste has total benefits of 1,055,796 RM and many other intangible benefits. The total cost incurred during the conversion of construction wastes by reuse and recycling practice is estimated to be 198,754 RM and some other intangible costs (Table 6).

**Table 6.** Total cost estimation for reuse and recycling of construction wastes.

	List of items	The cost in monetary value (RM)
1	Collection and separation costs of construction waste materials	185,254.00
2	Equipment purchasing cost	13,500.00
3	Storage cost	-
4	Transportation cost	-
	Intangible costs ( $A^*$ )	
5	1) Worker's health risk cost 2) Cost of negative externality i.e. noising, bad smell	$A^*$
6	Total costs of reusing and recycling of construction waste materials on the site	$198,754.00 + A^*$

Source: Begum, Siwar [48].

Thus, the net benefits of reusing and on-site recycling has a significant economic return (Table 7). Therefore, the project has a net benefit of 857,042 RM and many intangible benefits from construction waste. In general, this case study supports that reuse and on-site recycling of construction waste have feasible benefits both in its economic and environmental benefits.

**Table 7.** Net benefits of reuse and recycling of construction wastes.

	Description	Value in RM
1	Total benefits	$1,055,796 + A$
2	Total cost	$198,754 + A^*$
	Net benefits	$857,042 + A^*$

Source: Begum, Siwar [48].

N. B:  $A^*$  implied the existence of more intangible benefits than the costs from the conversion of construction wastes using reuse and on-site recycling strategies.

#### 2.4. Proactive Environmental Strategies: Cleaner Production

Since the 1990s and the beginning of the 21<sup>st</sup> century, scholars, consultants, and most firms located in developed countries are aware that existed environmental regulation is not effective for the observed environmental problems. They seek a new approach-which collectively called proactive environmental strategies. This new strategy has a voluntary initiative to improve environmental performance than the predecessor approaches. Firms that apply proactive environmental strategies deal with environmental wastes at sources and the strategy is viewed as the most recent and modern technique for firms [14, 15, 25, 49].

Over the last three decades, different environmental management approaches have been developed to minimize

environmental risks. The proactive environmental strategy is defined as a pattern of corporate practices beyond the requirements of environmental regulations and standard actions aiming to reduce the environmental impact of operations [50]. The approach go beyond fulfilling regulatory requirements such as waste reduction, minimization of water and energy consumption as well as practicing to prevent pollution [51]. According to Dong, Tong [5], cleaner production has been viewed as an effective measure to alleviate the conflicts between environmental protection and economic development, and the best approach to achieve sustainable development. The approach is developed as a response to end-of-pipe technology and help firms to improve their environmental and organizational performance without jeopardizing the economic returns [22].

*What forces drive manufacturing industries from reactive to proactive approach?*

According to Berry and Rondinelli [52] and other scholars, corporate manufacturing industries since the 1990s become proactive instead of complying with government regulation. The driving forces are:

(i) *Regulatory demands*- industrial environmental accountability has grown in the past and it forced the governments to apply environmental regulations and legal restrictions to solve waste problems [2, 52]. For example, in the USA in 1970 there were about 2,000 environmental rules and regulation and it advances to more than 100,000 in the late 1990s. The existence of such a regulatory process from federal to local level initiated industries to switch off their reactive approach and advanced to cleaner technology [52].

(ii) *Cost factors*- governments' enforcement of environmental regulations has increased and it helps to reduce pollution and toxic waste. However, the existence of complex and many regulations charged companies more cost [52]. Annually most firms spent billions of dollars for activities linked with environmental management systems like securing environmental permission, use recommended technologies to control wastes, and preparing to report on environmental impacts of their firms [53]. For example in the USA, before 2000 the total cost for complying with environmental laws was exceeding \$1 trillion and from this, nearly \$120 billion allocated to control air pollution.

(iii) *Stakeholder forces*- Stakeholders forced firms to practices proactive environmental strategies to improve their environmental performances to increases their internal and external performances. With this, the firms can secure their competitive advantage and profit-making [54]. On the other way, firms see proactive strategies as the best mechanism to satisfy the needs of diverse groups of stake holds because the approach demands simple modification of government policies. Some of the strategies may include define the new mission, expand education and training for the employee, search new ways to handle changes, modify behavior throughout the company and rearrange the company value system [52].

(iv) *Competitive requirements*- International standards for

environmental quality protection is formulated by the expansion of the global market and international trade agreements. As a result, in 1996 from 93 countries about 127,000 companies certified of quality management under ISO 9000 series guidelines. Environmental protection becomes concerns and interpreted as an opportunity for manufacturing industries to secure their competitive advantage in the international arena [13, 52].

The proactive environmental management strategy has a dynamic capability that helps firms to become familiar with the changing business environment. The approach will lead to positive impacts and improves firms' competitive advantage [13, 50], and have resulted in considerable cost savings for many firms [9].

Besides, many scholars are using cleaner production and pollution prevention interchangeably. However, according to Hilson [11], they have a clear variation mainly in their scope and geographic sites as well. In their scope, cleaner production covers changes in the wider range of environmental management techniques, but pollution prevention is referring to environmental improvements from the technological dimension only. Geographically cleaner production is commonly used in Europe, Asia, and Australia whereas pollution prevention is very common in North America [11, 12]. Therefore, cleaner production is broader in its scope and encompasses pollution prevention as its "subset" [11].

Cleaner production is a strategy used to reduce the impact of pollution on environments using source reduction unlike end-of-pipe [12, 55]. According to Okwiet [25], cleaner production includes a preventive environmental strategy that allows improvement in efficiency on processes, products, and services. In the process, cleaner production refers to conserving raw materials, and energy, eradicating any toxic raw substance, and minimizing wastes and emission. For the products, cleaner production covers avoiding any unwanted impacts throughout its lifetime. For services, cleaner production takes into consideration environmental issues in the design and service delivery ways. It includes any action which helps to eliminate or reduce the generation of waste

both in its quantity and toxicity level at the source. It can also cover the conservation of raw materials, and energy and minimizes wastes and emission. Cleaner production is a systematic and dynamic process that can be employed at each stage of the production process in a continuum fashion [25, 44, 55].

Similarly, cleaner technology includes the recirculation of materials, the use of environmentally friendly materials like replacing organic solvents with water, and the modification of the design of the combustion chamber [23, 37]. Therefore, the main benefits of cleaner technologies are minimizing the cost of production, decreases the size of wastes, improve productivity, increase energy efficiency, recover raw material from wastes, and minimize waste disposal problems [12, 23, 37]. Likewise, Hilson [11], stated that cleaner production has benefits during the "production process" and "products". In the production process, cleaner production has the advantage of conserving raw materials, minimize both water and energy usage, avoid toxic and dangerous inputs, reduces emissions, and wastes both in amount and toxicity at the source. Concerning the final products, cleaner production pursues to minimize its environmental, health, and safety impacts ranging from its raw material production to the manufacturing process, final uses, and up to its disposal [11].

*Case study: Benefits of cleaner practices in a piece of medium-size gold-plated jewelry in Brazil* by Giannetti, Bonilla [56].

The company is situated in Sao Paulo, Brazil, and is producing gold-plated jewelry since 1986. The firm has always in compliance with environmental regulation, treat effluents, and control the gaseous emission which incurs costs. The company thus needs to reduce and in the first year, they identified waste generation by sector, its composition, and characteristics. In the following year, they evaluated the economic and environmental benefits of the intervention of cleaner production technology. After the application of cleaner production techniques, the company recorded a decline in the size of waste generated and saved more money (see Table 8).

**Table 8.** Annual savings by the firm using cleaner technology intervention.

Area of interventions	Action	Reduction in (%)	Energy, raw material, and money savings			
			(kWh/year)	(L/year)	(kg/year)	(US\$/year)
Paper	Reduction & Substitution	47			2664	?
Plastic	Reuse	52			929	4,273.70
Safety pins	Reuse	80			360	2,398.90
Degreasing solution	Reduction	86			2232	8,262.00
Rinsing water	Reduction	35		2304		4,941.80
Final-color electrolyte	Reduction	100		13		86,280.30
Electricity	Reduction	36	30			9,841.20
Total money						115,881.70

Source: Giannetti, Bonilla [56].

N. B: The authors did not calculate the financial gain from paper reduction.

According to Giannetti, Bonilla [56], their study finding shows the firm recorded the following main benefits after cleaner production is used.

i. Waste reduction

For example, the ratio of waste paper generation is reduced

by 47% compared to the mass of pieces produced in weight. The remarkable achievement is recorded in plastic package bags reduction. This is achieved by reusing the bags most of them several times and "code labeled" bags twice. Metal scrap waste is reduced by 42% due to the reuse process.



#### ii. Reducing the cost of the degreasing solution

The raw pieces come with coated oil and need degreasing substance of caustic soda, cyanides, and hypophosphite. These degreasing solutions need to be replaced after 15 days and empty to the effluent treatment plant. This request more money, time, and labor. But, with joint work with degreasing supplier, the baths changes were connected to the mass of pieces degreased. The replacement period is improved from 15 days to 2 months and 5 days. This leads to money-saving (UD\$ 8,000.00 per year) from the reduction of chemical consumption, energy, and effluent treatment cost. This cleaner production helps the company to reduce the quantity of generated toxic wastes.

#### iii. Reduction in rinsing water consumption

The industry demands more water for cleaning and preparation, for bath make-up and maintenance and, especially, for rinsing and it shares 64% of the entire firm water consumption. The practices they used were conserving and reducing water usage by 35%. They controlled each ten rinsing tanks manually and opened when they showed certain turbidity.

#### iv. Extending useful lifetime of electrolytes

Before cleaner technology application, the process baths used in metal finishing are periodically discarded when their chemical activity is below the level recommended for production purposes. This caused the generation of voluminous wastes. Later, among the various electrolytes used for gold-plated jewelry production, the final-color was selected to practice cleaner techniques. When the electrolyte is reached the limit value given by the supplier, rather than replacing the electrolytes, by adding 15% of the final-color bath in the tank, they able to extend its useful life to about 60% in volume. This intervention in the final-color electrolyte help to save about 40% of the material, 90% of the energy, and 80% of the money.

#### v. Reduction of electricity demands

The electric energy cost of the company is very large. To be more efficient, without compromising the production process, they used simple techniques. (i) The four baths are operated 24 hours a day with a temperature range from 65°C to 90°C. To reduce the energy wastage, they turned off the power resistance for 90 minutes three times a day. This brings a reduction of energy consumption by 18%. (ii) Polyvinyl chloride balls are used in each bath to reduce evaporation and heat losses. This technique again resulted in an 18% reduction in energy consumption. In sum, these two approaches reduced the energy demands by 36%.

### 3. Discussion

Environmental management system has been recognized as an effective tool to achieve social, environmental, and economic goals [57].

Dilute and disperse environmental management approaches, which is “not caring for the waste” principle, is applicable in areas where the population number is too small and when they are not also the main consumer of non-biodegradable or toxic products. The approach, however, is challenged when there is

an increment in human population size, the complexity of chemical and industrial products, and the production of more dangerous and non-biodegradable wastes. These all caused the environment to be unable to absorb the generated industrial waste rather created various environmental crises. Therefore, practicing “out of sight out of mind” was challenged and resulted in the development of a reactive approach [12]. For instance, at the beginning of the industrial period in Ethiopia, industries were located deliberately along the bank of rivers to get adequate water supply and to discharge their wastes easily. They had fewer impacts on the environment because the total size of wastes was small in amount and mostly biodegradable in nature. However, when the size of industries is expanding, the population number is increasing and urbanization expanded, the river water is started to be threatened and the approach is challenged [27].

The reactive approach is known by its defensive character. It has no role to reduce the amount of industrial waste. For instance, end-of-pipe technology is employed at the end of the industrial process and is trying to minimize the impact level of wastes on the environment and society. The approach has no remarkable result to the firms in terms of improved efficiency on raw materials, water, and energy utilization, but its cost of establishment and maintenance is high [58, 59].

As an example, the Almeda textile factory in Ethiopia implements end-of-pipe technology for wastewater treatment. However, the treatment plant is not effectively treating industrial effluents. The factory managers believe that the cost of treating industrial waste incurs the industry to the extra cost. Because the treatment plant needs more labor power and expensive chemicals. The cost of chemicals to treat the waste needs about 2-3 million Ethiopian birrs per month (which is equal to 110,500 - 165,753 USD). This proves that end-of-pipe technology requires a high amount of finance.

Therefore, the industry is not effectively treating the wastes and causes different socio-economic and ecological impacts on the site. River water and land pollutions are common. This again complicated the health condition of the local inhabitants who are using the polluted river water for domestic and agricultural activities [41]. Similarly, the application of end-of-pipe technology in South Korea for food waste disposal treatment [42] and plastic waste recycling in Dutch [43] demands more financial resources. These justified the cost of waste treatment after the generation is very high.

The other reactive technology is the three R's (Reduce, Reuse, and Recycling). The two central ideas of the approach are minimizing the resource requirements and reducing environmental pollution [60]. Among them, recycling is the least preferred approach for waste management. Recycling promotes reproducing new raw materials from the wastes and this, in turn, helps to secure an economic advantage [46, 48]. According to Lauritzen [61], recycling is preferable when there is a shortage of raw material for the production of goods and has no proper and suitable site for waste disposal. On-site recycling in construction site help to sort out the wastes into different groups based on their nature and components on the construction site. Therefore, it has more importance by



minimizing the volume of waste generated and improve the rate of reusing and recycling of construction materials [62]. The great concern for the natural environment forced firms to adopt a proactive approach to improve their corporate sustainability performance [57].

Over the last three decades, different environmental management approaches have been developed to minimize environmental risks. The strategy has various names of cleaner production, waste minimization, eco-design, and design for sustainability, pollution prevention, toxic-use reduction, and soon. These all are proactive strategy and they also known as source reduction [63]. The main purpose is to prevent pollution from being generated rather than designing a mechanism to control pollution or manage the waste after it has already been produced. When industries are proactive, they implement new strategies to prevent industrial wastes, redesigning the existed process, and securing competitive advantage. The firm can secure an economic advantage by introducing new products and decreases the costs of production [4, 21]. According to Sharma and Vredenburg [16], a firm's environmental strategy is proactive if it displays environmental management practices regularly in their all working dimension rather than using them as a criterion to fulfill the legal requirement of environmental regulation. Therefore, such changes have benefits to the firm and the environment. It allows the industry to substantial savings in reduced raw materials, pollution control, and liability costs. It also helps the industry to lower costs used for inspection, regulatory sanction, emission charges, and third-party lobbying and litigation. The new approach can also protect the environment from pollution and can reduce risks to worker health and safety. Collectively, the proactive approach has a more economic gain for firms and can reduce environmental crises [53], which is proofed by the cleaner practices in medium-size gold-plated jewelry in Brazil. In sum, the various cleaner production steps that are used by the factory collectively bring a financial gain of US\$ 115,581.70, without including the benefit obtained from paper reduction. The highest money saving is from final-color electrolyte intervention. Apart from these money-saving benefits, the company reduced its impacts on the environments (see Table 8). Therefore, cleaner production minimized the cost of production and waste overload which helps to reduce the level of impacts on environments and improved firms' productivity.

## 4. Conclusion

Rapid industrialization and urbanization are the main polluters of the environment. They are sources of pollution for water, air, and soils/lands. As industries expanded and getting complex, their pollution rate is intensified and has caused a high toxicity level. Since the distant past period, the awareness level and dissemination of environmental issues are grown in scholars, the public, and governments. These initiated the industries to practice environmental protection techniques.

The initial strategy was the passive approach, which

includes diluting and disperse, and concentrates and contain. They have no significant effort to care for the environment. Later reactive strategy has emerged which is called end-of-pipe and recycling approaches which are reacting to pollution after it is generated, and they demand more cost for treating industrial wastes. Comparatively, end-of-pipe technology is very expensive and the cost of maintenance is large.

Since the 1990s proactive strategies emerge and firms reduce industrial pollution at source using cleaner products and production methods. Compared to end-of-pipe technology-which curb pollution emissions using add-on measure, cleaner production techniques reduces resource use like raw materials, energy, water, and reducing industrial wastes and emissions at the source. Firms that apply preventive technologies are securing more benefits. They can reduce the amount of waste generation, reduces waste disposal costs, improve the working condition of workers, improve production level, minimize the number of raw materials to be purchase, and reduce long-term liability. Thus, cleaner products and production technologies are usually seen as being superior to end-of-pipe technologies for both environmental and economic reasons.

Although cleaner production is promoted in the world, the industries in Ethiopia are still practicing passive and reactive approaches that have less relevance for the sustainability of the environment. Therefore, the manufacturing industries in Ethiopia should switch to cleaner production technology.

In sum, industrialization and urbanization are the main polluters of the environment; passive approach has no significant effort to care for the environment; reactive approaches are demanding more cost for treating industrial wastes, and proactive strategies are used to reduce industrial pollution at source using cleaner products and production methods.

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