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Industrial Waste Disposal: Development of New Technologies and Economic Mechanisms of Management

Ibragim Musaevich Bamatov, Evgeny Valerevich Alekseev, Anna Alexandrovna Silaeva, Aigul Linarovna Faizrakhmanova, Alexander Vasilyevich Melnichuk, Tatiana Ivanovna Zvorykina

Abstract*: The purpose of this paper is to analyse the methods and instruments of funding and taxation in the waste disposal sector in countries with different levels of economic development, budget decentralisation, population density and cultural traditions. The paper covers the issues of industrial waste disposal and international practice in addressing this problem. The condition, problems and ways of waste disposal are discussed, with a focus on the role of the state and tax mechanisms in different countries. Based on an expert survey, an optimum strategy is proposed to bring down waste in industrial production by implementing new technology. The strategy is designed to prevent and minimise waste generation, to reuse and recycle waste, recover or dispose of waste materials, treat and destruct waste.

***Keywords*: environmental taxes and levies, environmental taxation, industrial waste, recycling, recovery, treated waste.**

I. INTRODUCTION

The problem of waste accumulation has grown to a critical level not only in Russia but globally. Production processes generate leftovers that are not suitable for further use. The rate of industrial waste accumulation is continuously growing, which may lead to a global catastrophe. The problem first emerged in the countries with high income levels and high population density, primarily the advanced West European economies. Now, they have well-developed technologies to recycle industrial waste, as well as a balanced regulatory system in this sector of the economy.

In 2015, the United Nations Sustainable Development Summit adopted the Global Sustainable Development Goals for 2016-2030. One of the global challenges cited was unsustainable resource consumption. The proposed goals to address the problem included the reduction of waste accumulation through prevention, reduction, recycling and reuse of waste and encouraging companies, especially large and transnational companies, to adopt sustainable practices and to integrate sustainability information into their reporting cycle [1].

Unsustainable consumption of raw materials and reluctance to adopt new technology cause the depletion of resource potential in any country and put environmental safety at risk. The rate of industrial waste accumulation keeps growing year after year, while disposal technologies are almost not developing in many countries. Industrial waste is transferred to landfills, which degrades the surrounding environment and threatens the resident populations. The latest trends show there is an urgent problem on the global scale calling for immediate response and prevention of further waste generation.

Major waste accumulation in the environment as a result of increased engagement of resources in production cycles and low rate of their useful exploitation poses a call to the society to balance its environmental and economic interests with the interests of economic subjects.

A major step in this direction could be the development of a system of tax regulation incentivising adoption of optimised waste reduction strategies in production based on the use and development of new technologies.

II. LITERATURE REVIEW

According to Meadows' concept of system dynamics, the factors that influenced further human development included environmental pollution and the depletion of nonrenewable natural resources [2].

The American economist S. Kuznets established a relationship between the growth of prosperity and environmental degradation that tends to get worse with growing per capita income until a certain point and then declines [3].

K. Boulding coined the term "cowboy economy" describing an economy of limitless resources and proposed that the risk of natural degradation should be taken into account in decision-making [4]. D. Wilson, C. Velis and L. Rodic stress that economic performance is primarily dependent on the methods and tools of disposal; therefore, opting for an optimum solution is of utmost importance [5].

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* Correspondence Author
Ibragim Musaevich Bamatov*, Chechen State University, Grozny, Russia.
Evgeny Valerevich Alekseev, Moscow State University of Civil Engineering (National Research University), Moscow, Russia.
Anna Alexandrovna Silaeva, Russian State University of Tourism and Service, Moscow, Russia.
Aigul Linarovna Faizrakhmanova, Kazan Federal University, Elabuga, Russia.
Alexander Vasilyevich Melnichuk, Russian state social University, Moscow, Russia.
Tatiana Ivanovna Zvorykina, Institute of Business Technologies, Russian New University, Institute for Regional Economic Research, Moscow, Russia

In Russia, many researchers have also addressed the issues of waste and resource conservation. S.M. Naiman points out that waste reuse as recycled material resources by enterprises would be helpful in addressing issues such as resource-saving, prevention of water, soil and air pollution, increasing component and product output and developing the production of new competitive products [6]. Iu.V. Nikulichev in his works indicates the importance of the economic efficiency of disposal, which depends on the conditions and level of development of each country [7]. D.A. Barabanshchikov and A.F. Serdiukova believe that there is no way to develop an environmentally-friendly society without a management system and state support [8].

Even despite certain findings and topical relevance [9-11], the stimulating role of environmental levies in bringing down industrial waste is not well-researched; Russian waste reduction system based on the adoption and development of new technology is not sufficiently efficient.

Research hypothesis: an optimum waste reduction strategy should be based on the use of new technology and designed to meet the following criteria: prevention and minimisation of waste generation; reuse, recycling, recovery and disposal of waste materials; waste treatment and destruction.

III. PROPOSED METHODOLOGY

A. General description

For the set problem, the methods of statistical analysis and literature review were used to describe the international practice of environmental taxation influencing waste reduction in the industrial sector of the economy. The method of expert discussion was also employed to identify and profile an optimum strategy of waste reduction at industrial enterprises in Russia.

The statistical, factual and analytical data were sourced from Eurostat and reviewed environment-related research works in academic publications over the past decade.

The officers of the regional administration of Rosprirodnadzor (11 experts) and executives of regional industrial enterprises (13 experts) took part in the expert survey to discuss the research results (online).

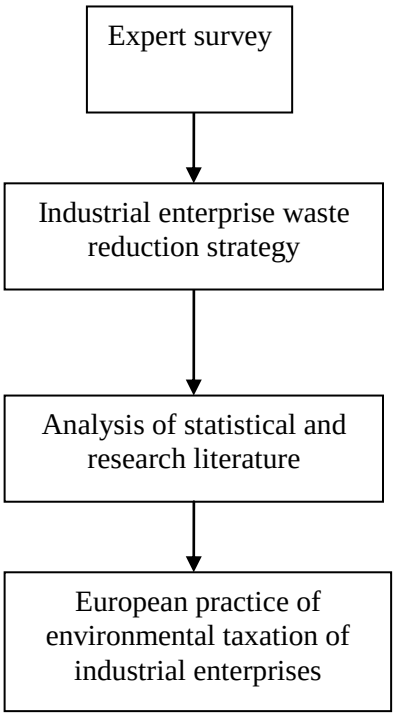
The experts were asked to propose and describe their vision of a waste reduction strategy at industrial enterprises.

B. Algorithm

The first stage of the research involved the experts determining key references of a waste reduction strategy.

The second stage included the analysis of literature and statistical data of Eurostat concerning the issue of taxation of industrial waste and the resulting effects for waste reduction.

C. Flow Chart



IV. RESULT ANSLYSIS

A. Results

To confirm the research hypothesis and determine an optimum strategy of waste reduction, an expert survey was conducted. In the respondents' view, the development of an optimum strategy, predictably, should be based on the following criteria:

- prevention and minimisation of waste generation;
- reusing, recycling, recovery or disposal of waste;
- treatment or destruction of waste, i.e. physical destruction, chemical detoxication or other methods of waste neutralisation.

According to the experts, the introduction of waste minimisation measures can provide considerable short- and long-term advantages in the following two dimensions: regulatory compliance and improved profitability. The responding experts believe that the risk of fines for non-compliance drives many waste generators to install treatment units. However, insufficient knowledge and technical expertise in waste minimisation prevent businesses from committing to waste reduction.

According to the experts, waste minimisation can open up the potential to improve profitability: through the realisation of specific economic benefits, reduction of liabilities, shaping a positive public image, health and safety improvements for employees, improved operational safety and, consequently, lower production costs.

The implementation of waste minimisation programs requires technical assistance and time and/or capital input. Such inputs, however, should be balanced with the potential advantages of waste minimisation/prevention for the industry (Table 1).

Table 1. Potential advantages of waste minimisation/prevention for the industry.

Advantages	% of references
reduction of spending on monitoring, control and treatment	83.3%
smaller waste storage requirements and increased operational space	75%
lower analytical costs for identification and determination of waste flows	70.8%
lower risks in handling hazardous materials and, consequently, improvements in health and safety for employees	62.5%
improved operational efficiency and process reliability	62.5%
lower costs of handling, pre-treatment, transportation and dumping off-site	58.3%
lower administrative spending on waste dumping	58.3%
lower production costs, including material, energy and utility requirements	54.2%
lower environmental risks resulting in elimination or minimisation of fines	54.2%
improved company image perception by shareholders/stakeholders, employees and society	50%

The responding experts stress that not all advantages are achievable in the short term, primarily due to the fact that applicable regulations, compliance levels/fines and the state of infrastructure for waste treatment indicate that business is more prepared for fines than waste reduction. However, with rising overall costs of compliance relating to waste monitoring, treatment and dumping, more and more businesses would focus on finding methods to bring down operational costs.

The experts' proposed waste minimisation strategies include:

- new process (clean production/clean technologies): the ultimate goal is the adoption of clean production processes/technologies to prevent or minimise waste generation;

- waste reduction at enterprises: such methods are focused on cutting waste through proper business practices and engineering and maintenance, technology adjustments, changed inputs and/or product.

That said, the experts indicate that the choice of a specific method would depend on the type and quantities of waste generated by a business and its technical/financial potential to adjust operational processes. The methods may vary, spanning from high technology and expensive solutions to easily adaptable practices and procedures, such as inventory management, training and technical maintenance programs.

According to one of the respondents, "the priority at the current stage of industrial development is to stimulate waste minimisation in practice, both at currently operational enterprises and future facilities". Therefore, a waste reduction strategy should involve measures to control the urgent production waste generation problem and open the way for adopting clean technologies in the future.

According to the experts, the options in waste minimisation/prevention should meet the following criteria: simple, realistic and economically viable in the short term; suitable for operational and new enterprises (potential waste generators); sufficiently flexible to support long-term waste minimisation programs; based on the available knowledge base.

Based on the above criteria, the experts propose the following technical options to promote industrial waste minimisation (Table 2).

Table 2. Technical options to promote industrial waste minimisation.

Efforts	Description	% of references
Encouraged approach or direct requirement		
waste minimisation audits	audit completion with a commitment to introduce a waste minimisation program	75%
environment protection management system (EPMS)	introduction of management systems to mitigate risks and liabilities	70.8%
monthly waste exchange reporting	aligned with the establishment of a waste exchange system	58.3%
other steps		
waste exchange	involves the establishment of a waste exchange system to reuse and thus reduce waste	70.8%
pilot/demo projects	involve the implementation of industrial waste reduction program through the use of eco-friendly methods of production, etc.	62.5%

Table 3 lays out qualitative expert assessments of each of the proposed prevention and minimisation options above.

Table 3. Selected strategic steps recommended for waste prevention and minimisation.

Efforts	Advantages	Disadvantages
Encouraged approach or direct requirement		
Waste minimisation audits	May be focused on major sources of industrial waste. Applicable for existing and new enterprises. Focused on industrial waste reduction. Demo projects may be used to adopt audit methods. Audits provide the basis for refining waste minimisation programs.	Audit methodology is unclear and considerable preparation is required both for regulators and waste generators. Small businesses may lack expertise or skills to conduct audits, so the practice may be limited to only large enterprises.
EPMS	Brings down liabilities and risks of waste generators. EPMS is a proven method to improve environmental record and management.	Risk and liability management is a new concept for a majority of large businesses. Not applicable in the short- and mid-term perspective; a long-term measure for a majority of businesses.

Monthly waste exchange reporting (see below for waste exchange)	Expands recycling potential and prevents illegal discharge or dumping.	A central waste trade and exchange system should be introduced. Waste collection poses a logistics problem.
Other steps		
Waste exchange	May be based on the strong recycling traditions in the industry and may produce income or at least come at zero cost for businesses. May be the only available option for some industrial waste generators to cut waste channelled for dumping.	Industrial waste identification is required; may be applicable only in the long-term perspective and for large businesses. May not be efficient without a central body/organisation coordinating the waste collection and trade for further use as resources. Applicable only for a limited scope of relatively clean materials.
Pilot and demo schemes	May be adopted in the short-term perspective to raise awareness on relatively simple methods of waste minimisation. May be linked to pollution costs and profitability improvement. Applicable for SMEs and large businesses. There may be sector-specific or general benefits for all sectors. Industrial waste minimisation schemes may engage the results of other industrial pollution prevention programs.	A relatively new concept for the industry in hazardous waste minimisation. Complex issues have to be addressed regarding engagement, sponsorship, funding, etc. The current dumping method means there is no commercial driver for change. For now, the stance in the industry is that waste minimisation requires cleaner technology and, consequently, additional costs.

Compiled based on the expert survey.

As to waste reuse, recycling and recovery, the responding experts mentioned that these options are applicable for industrial waste in many cases. However, there are considerable existing and potential obstacles, including:

- lack of separation of hazardous and non-hazardous industrial waste;
- lack of separation of different types of hazardous industrial waste;
- use of waste as a resource replacement considerably depends on waste purity;
- inability to isolate waste suitable for reuse, recycling and recovery often means there is no such reuse/recycle option for such waste;
- uncontrollable malpractices in handling cheap or free waste prevent reuse/recycling operations.

One of the experts specifically pointed at the latter obstacle. According to the expert, "recovery or recycling processes are often relatively expensive and such recycled or recovered material may cost as much as new materials. Therefore, they are nearly no financial incentives to use recovered or recycled materials unless the cost of proper waste disposal is taken into account".

Waste types to be approached, in the Russian context, as the primary group for reuse, recycling and recovery are laid out in Table 4.

Table 4. Categories of waste suitable for reuse, recycling and recovery.

Waste type	Industry type	Technology
Acids and alkali	Metallurgy Production equipment Electricity/electronics	Down-gradient reuse, i.e. applications with lower purity requirements
Solvents	Paint production Pharmaceuticals Electronics	Down-gradient reuse, i.e. applications with lower purity requirements Solvent recovery (for example, paint waste elimination from the paint-scraper surface) Solvent distillation Fractional distillation of solvent mixtures
Oils	Production equipment Electrical equipment Petrochemical products Vehicle maintenance	Down-gradient reuse, i.e. applications with lower purity requirements Recycling Application as low-grade fuels
Heavy metals	Primary metals Metalworking	Recovery by solution precipitation methods and recycling Electrolytic metal recovery from solutions, e.g. galvanic solutions
Precious metals	Photography Electricity/electronics	Recovery by solution precipitation methods and recycling Electrolytic metal recovery from solutions, e.g. galvanic solutions
Etching agents	Electricity/electronics	Recovery of heavy metal content, e.g. Cu from copper etching agents Recovery of etching agents

Compiled based on the expert survey.

According to the respondents, a major reason for the low profile of waste reuse, recycling and recovery in Russia (except for waste oils) is the nearly complete refraining from waste separation practices. Thus, short-term commitment should be the identification and separation of industrial waste. The next step, according to an expert, is the "elimination of malpractices, e.g. when solvents are left to evaporate, which causes air pollution".

The experts believe reuse, recovery and recycling may be fostered along the lines of similar practices of the EU where there is, firstly, an established waste exchange system to bring together the generators of waste suitable for reuse, recycling or recovery with businesses capable to dispose of such waste; secondly, waste exchanges (electronic databases) operated by regulators, trade associations or private entities in some cases.

Even amid the primary importance of waste prevention and minimisation, reuse, recycling and recovery, experts believe there will always be the need for proper treatment and disposal of waste by the businesses themselves.

Overall, the available on-site treatment processes may be grouped as follows: mechanical treatment and physical/chemical treatment processes. The experts also point that physical/chemical treatment processes (Table 5) are the most common approach for inorganic industrial waste, e.g. oxidation/reduction, neutralisation/precipitation and stabilisation.

Table 5. Treatment processes and treated waste.

Process	Treated waste
Oxidation/reduction	Oxidation of cyanide waste using sodium hypochloride or chloride Volume reduction of hexavalent chromium waste using ferrous metal waste or sodium sulfite
Neutralisation/precipitation	Precipitation of heavy metals from solutions as hydroxide or sulphides Neutralisation of acidic and alkaline waste
Hydrolysis	Alkaline hydrolysis of organophosphorus pesticides
Flocculation, coagulation and filtration	Used for dehydration of partially treated slimes
Electrolysis, electroreduction, etc.	Used for the recovery of heavy metals and precious metals from solutions, e.g. gold from galvanic solutions
Stabilisation/consolidation	Treatment of residual solids/sediments for chemical "stabilisation" of residual potentially hazardous components of the inorganic matrix

Compiled based on the expert survey.

According to the experts, the main role in fostering the adoption of waste reduction strategies by enterprises lies with differential environmental taxation, which is most developed in the EU countries.

V. DISCUSSION

Literature review on the topic showed that tax on producers in the global practice is approached as an ecotax, is determined by the environmental footprint (emission quantity and structure) and called a pollution tax [12]. It is a separate levy payable independently from other taxes.

In some countries (France, UK, Belgium), it depends on the method of disposal, e.g. for landfill disposals, the maximum rate is EUR 150 per ton and, depending on the environmental burden, the figure comes down to EUR 20 per ton [13]. The tax revenues are mostly transferred to the national budget and then redistributed between environmental agencies and used to improve the ecological situation. The funds are also used for waste disposal activities. Such tax is a stimulus for maintaining more prudent and environmentally-friendly production, so it is often subject to changes. Thus, where waste generation is growing, more toxic substances are used or accidents occur causing increased environmental burdens, fines are applied as regulated by applicable laws and, vice versa, smaller environmental footprint and adoption of new eco-friendly and safe technology would lead to tax reduction [14, 15].

Pollution taxes in the EU countries account for much smaller revenues compared to those generated from the energy and transport taxes. Together with resource taxes, they only account for 5% of the total ecotaxes [16].

Analysing the statistics of revenues generated from ecotaxes in the EU countries for 2015, one should note the high levels of France (EUR 2,563 million), Spain (EUR 732 million) and Italy (EUR 582 million). Figures are lower for Iceland (EUR 22.82 million) and Portugal (EUR 1.2 million) where the environmental profile and environmental safety are relatively high [17].

Most of the times, the ecotax is calculated based on the quantitative and qualitative pattern of the environmental footprint (sometimes only the carbon, sulfur and nitrogen compound tax). Data show that developed countries have higher taxes and, accordingly, higher financial outlays for improvement of the environmental situation. In some countries, there are tables of rates applied in differential taxation of waste disposal depending on the level of hazard and the price of emissions of a substance or pollution materials per 1 ton [18].

In many countries (USA, Canada, New Zealand), producers arrange the disposal of consumed goods on their own by collecting such goods from consumers in designated centres. The largest corporations and enterprises operate their own disposal lines and make money, while others cooperate with waste disposal companies. A typical feature of this method of financing is the absence of engagement with the state, as producers fully undertake to dispose of their goods. A mix of financial approaches is also applied in the USA. For instance, in 2012, the American company Johnson & Johnson Services spent USD 6.4 million to pay for disposal of its products with a specialist company. Companies such as Hewlett-Packard Development Company, Apple and Ford Motor operate their own disposal lines, so they recycle used products on their own. The goods are collected at designated disposal centres. The HP company operates its own recycling systems in countries with high use rates for its products and it cooperates with specialist waste-treatment companies in other places. The loan price instrument is used in the USA for collecting used products [19].

The waste handling practice of the EU countries supports the main propositions of the above strategy pointing out that the industrial waste management policy should reflect the hierarchical principles of managing waste operations based on their priority. The hierarchical scheme involves the following main principles:

- waste generation prevention or reduction at the source, which is ensured by changes of the technological procedure, raw material or product quality or quite often by improved management of processes and operation of equipment;
- waste separation as close as possible to the source of generation operates as differentiation of waste flows with different useful content;
- waste reuse takes place at the source of generation (the producer), e.g. reengaging waste as part of the production cycle being the source of its generation;
- waste recycling to recover useful components, e.g. recovery of non-ferrous metals from metallurgical waste, treatment of waste from related sectors in high-temperature metallurgical units;

such approach may require the establishment of an exchange network for recycled materials across industries;

- waste neutralisation helps to bring down the degree or class of hazard and may involve different methods: incineration of combustible waste, physical and chemical treatment to neutralise toxic compounds, etc.

- dumping waste on the surface or deep in the ground is the least viable waste management option, as it leads to numerous dangerous environmental problems, such as air, soil, surface and groundwater pollution, damaging natural ecosystems, which have to be mitigated and, in the long run, eliminated [20].

VI. CONCLUSION

The findings confirmed the hypothesis that an optimum strategy of industrial waste reduction should be based on the utilisation of new technology and should take into account the following criteria: prevention and minimisation of waste generation; reuse, recycling, recovery and disposal of waste materials; waste treatment and destruction.

Successful implementation of waste reduction strategies at domestic enterprises would help to promote the adoption of systematic improvement of technological, economic and environmental activities with a view to a more eco-friendly production; improvement of organisational measures and establishment of environmental management systems; development of modern environmental protection management systems; implementation of sustainable development principles.

Thus, the introduction of a waste reduction strategy by Russian enterprises would ensure the optimisation of economic and environmental interests of businesses fully accommodating the principles of the environmental-economic management approach, capable of promoting innovation development and improving competitiveness in both internal and external markets.

For now, the introduction of such strategies requires initiative from regional governments, particularly, spreading information concerning the efficiency of adopting such strategies; the initiative of engaging advanced businesses to adopt waste reduction strategies; stimulating the enterprises implementing such strategies; arrangement of training at such enterprises.

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