Analysis of Correlation between Waste Accumulation and Countries Welfare Level

E G Shershneva

1Department of Banking and Investment, Ural Federal University, Mira Street, 19, Ekaterinburg, 620002, Russia

E-mail: elena_sher@e1.ru

Abstract. The article considers the results of countries analysis by progressiveness degree of waste management based on the correlation between changes in the volume of waste accumulation and indicators of wealth. The author's novelty is systematization of quantitative and qualitative criteria for analysis and grouping of countries by the effectiveness of waste handling system. As a result of the comparative analysis, three groups of countries are presented: "Green" – European countries with a small population and high level of welfare, with an effective waste management system and a positive decoupling effect, but there is a problem of increasing the volume of waste per capita (Denmark, Sweden and Belgium). "Yellow" group consist of large European countries and Japan, where there is less waste per capita, a responsible approach to recycling and limiting plastic, but there is a problem of proportional growth in welfare and waste. "Red" group includes countries with a large population and problem of increasing the total waste volume, inefficient waste management and low level of recycling (China, USA and Russia). The study showed that the introduction of effective waste management (collection, recycling, waste culture) can be reduced the change index of personal waste and at the same time increase the change index of gross domestic product (per capita).

1. Introduction
The waste problem has become a global challenge: as a result of economic development, the waste volume in countries is increasing. In this regard, the theoretical and practical research direction that studies the possibility of reducing the garbage press, the development of effective waste management while maintaining a high quality of life becomes relevant. The hypothesis of this research is the assumption that as a result of the synergy of responsible management, production and consumption in the "government-business-society" system, a positive social and environmental effect can be achieved.

The purpose of this study is to develop an author's methodological approach for comparative analysis of countries by the degree of progressiveness of waste management based on the correlation between changes of waste accumulation level and indicators of welfare. The objectives of the study are identification of global problems in the field of waste accumulation and management, systematization of quantitative and qualitative criteria for characterize the intensity of waste accumulation and correlate these data with changes in gross domestic product, analyze the dynamics of change indexes in waste accumulation and domestic income (per capita) to identify the effectiveness of country waste management system (decoupling effect).
2. Waste accumulation and management: global challenge and transformational vector of consumption model of modern society

Solid domestic waste (SDW) is waste generated as a result of final consumption, as well as goods that have lost their consumer properties. In modern society, issues of collection and circulation of SDW are very acute due to the growth of urban population and spread of extended consumption model. Research of the ecological footprint of countries claims that since the 1070s, humanity has been "living in debt", spending far more resources than our planet is able to reproduce [1]. It is time to stop uncontrolled and unreasonable production and consumption. The transition to resource-saving circular economy is needed. Usage of waste as a resource for production of goods and energy is a important element of circular or "closed-cycle" economy [2]. In "closed-cycle" model, all residual materials are treated as resources and returned to the production system as much as possible. Effective waste management creates a sustainable culture of production and consumption, strengthens three directions of society development: economic, environmental and social.

On a global level, three major problems can be identified in the field of waste accumulation and management:

1. Annual increase in the World's waste volume. According to the World Bank report (2016), in the World was produced 2.01 billion tons of solid domestic waste, which is an average of 0.74 kilograms per person per day [3]. In the report predicted that waste production will increase to 3.40 billion tons in 2050 as a result of population growth, urbanization and economic development.

2. There is a high rate of waste per capita in economically developed countries and in emerging markets (figure 1). It is proved that the higher level of welfare of population, the higher share of inorganic waste (plastic, metal, glass, paper, rubber and others) [4].

3. Inefficient waste management. Most part of SDW is in landfills and dumps and only about 15% of the global waste is recycled (figure 2). The situation can be described as a "landfill crisis". In developed countries, there are more responsible waste management and progressive disposal methods. In accordance with concept of "Lansink's ladder", responsible countries go through hierarchy of waste processing methods: dump – incineration – composting – recycling – prevention of formation [5].

Thus, level of welfare and technological development of the country have an impact on accumulation and disposal of waste. "Garbage culture" and waste management are elements of the environmental image of countries. Changes in elements of the eco-system (increasing indicators of pollution) entail changes in the quality of life (deterioration of health, comfort of living conditions), as well as changes in economic indicators (with the growth of industry increases the volume of waste and the burden on environment) [5, 6]. From the other side, growth of gross domestic product (GDP) leads to an increase in pollution of environment [7, 8]. The growth in the volume of waste is so-called "satellite of progress" and expenditure for a high standard of living. The difference in economic development and distribution of waste in countries is object of the next step of this study.
3. Methodical approach to comparative analysis of waste accumulation and welfare level of some countries

The research purpose is to study countries on a number of indicators that characterize the intensity of waste accumulation and correlate these data with changes in GDP, the development of waste processing technologies and measures taken to minimize the harmful effects of anthropogenic waste.

The author's approach consists in systematization of quantitative and qualitative criteria for analysis and processing of statistical information (table 1). Average data for 2017-2019 years were used to fill quantitative indicators (1.1 – 1.3). The following indicators are used for country analysis:

1. Quantitative
   1.1. Average annual volume of SDW in country \( (I_1) \), millions of tons per year.
   1.2. Average annual volume of SDW per capita \( (I_2) \), kilograms per year.
   1.3. Annual GDP \( (I_3) \), billions of dollars.
   1.4. Percentage of waste incineration and recycling \( (I_4) \), %.

2. Qualitative
   2.1. Trend of annual index of SDW and GDP change for the period 2010-2020 \( (I_5) \).
   2.2. Presence of decoupling effect \( (I_6) \).
   2.3. Taking restrictive measures on the use of plastic \( (I_7) \).
   2.4. Sorting or separation by type of waste \( (I_8) \).

Table 1 shows that the USA and China have the largest GDP and waste volumes, and the share of waste recycling is near 50%. In European countries the percentage of recycling is higher, but the average volume of waste per capita is quite high. Less waste is accounted for by 1 resident of Russia and Japan. In most countries, GDP growth is accompanied by an increase in SDW.

| Country | \( I_1 \) | \( I_2 \) | \( I_3 \) | \( I_4 \) | \( I_5 \) | \( I_6 \) | \( I_7 \) | \( I_8 \) |
|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| USA     | 250     | 790     | 20 500  | 46      | ↑SDW and ↑GDP | –       | +       | +       |
| China   | 245     | 760     | 22 400  | 48      | ↑SDW and ↑GDP | –       | +       | +       |
| Russia  | 60      | 380     | 4 200   | 12      | ↑SDW and ↑GDP | –       | –       | –       |
| Germany | 55      | 630     | 4 400   | 89      | ↑SDW and ↑GDP | –       | +       | +       |
| Japan   | 46      | 352     | 5 500   | 82      | ↓SDW and ↓GDP | –       | +       | +       |
| France  | 35      | 515     | 3 100   | 70      | ↑SDW and ↓GDP | –       | +       | +       |
| Switzerland | 5,8 | 710   | 605   | 51      | ↑SDW and ↑GDP | –       | +       | +       |
| Belgium | 4,8     | 610     | 560     | 95      | ↓SDW and ↑GDP | +       | +       | +       |
| Denmark | 4,5     | 760     | 320     | 96      | ↓SDW and ↑GDP | +       | +       | +       |
| Sweden  | 4,4     | 450     | 520     | 97      | ↓SDW and ↑GDP | +       | +       | +       |

Compiled by the author based on [9, 10, 11]

It is positive that developed countries have introduced waste sorting and are moving towards introducing restrictive measures on the use of plastic. In Russia, this practice does not yet exist (red zone in table 1) and also there is a very low percentage of waste recycling. Due to the deterioration of infrastructure for collection and disposal of SDW, most of the waste is buried in open landfills and dumps that are not equipped with special means to protect the soil, water and surrounding areas from contamination. The annual growth of waste in Russia requires a systematic approach to solving the problem: the formation of a "garbage culture" of citizens, limiting the use of non-degradable materials and taking state measures to develop the waste processing industry [12]. According to analyst's forecasts, in Russia it is quite realistic to reorient the sector from stockpiling to waste processing in 10-15 years [13]. The key point is to create a high-quality institutional environment for waste management with the involvement of all stakeholders: government, business and society.
Such countries as Denmark, Sweden and Belgium show a positive environmental footprint: the highest percentage of utilization and GDP growth with waste reducing at the same time (green zone in table 1). This is decoupling effect, when economic growth takes place against the background of improved environmental indicators [14]. To identify the decoupling effect (indicator I₆), two indexes were studied: the rate of change in GDP and the rate of change in SDW over five-year intervals in the period 1995-2018. Figure 3 shows trends in countries where economic growth has been accompanied by a decrease in waste volumes (↓SDW and ↑GDP). So, in Belgium and Denmark, despite positive experience, the problem of high level of waste per capita remains, which authorities intend to solve using psychological and fiscal methods.

![Figure 3. Positive environmental effect (decoupling): growth of GDP and reduction of waste.](image)

- Change index of GDP per capita
- Change index of SDW per capita

The following graphs show countries where GDP and waste growth are observed simultaneously (figure 4). This is a problematic situation that is typical for most countries. It should be noted that in countries with a large population, there is no downward trend in the rate of waste reduction. Regarding this situation, the World Bank review says that "… unmanaged and improperly managed waste from decades of economic growth requires urgent action at all levels of society" [3]. Public authorities, producers and consumers should actually make the transition to model of reasonable economic growth based on the principles of a circular economy [15].

![Figure 4. Negative environmental effect: simultaneous growth of GDP and waste.](image)

- Change index of GDP per capita
- Change index of SDW per capita

Thus, developed countries view waste as a valuable resource, processing up to 90 % of SDW and keeping in mind the expression of our great chemist D. I. Mendeleev: "Waste utilization is the transformation of useless goods into valuable resources, and this is one of the important achievements of modern technology" [16]. Such progressive technologies are high-temperature pyrolysis, gasification, air and electric separation, bio-thermal composting and digital waste management technologies [17]. But there is a practice that wealthy states export their waste to other countries and
continents. The use of underdeveloped countries as a cheap channel for the disposal of rich countries from toxic waste, sometimes called "garbage or toxic colonialism" [18].

4. Discussion of research results
As a result of a comparative analysis of accumulation and disposal of waste, in table 2 presented three groups of countries by the degree of progress in waste management: green (progressive), yellow (fairly effective) and red (requiring the introduction of more serious measures).

Table 2. Types of countries by degree of progress in waste management.

| Country type | Characteristics of waste accumulation and management | Examples |
|--------------|-----------------------------------------------------|----------|
| Green        | Sustainable reducing the growth rate of waste generation; decoupling effect; percentage of waste incineration and recycling is more than 90%; strict waste sorting system; restriction measures on the use of plastic. Low level of total SDW – high level of SDW per person. Low population. | Belgium, Denmark, Sweden |
| Yellow       | Periodic reducing the growth rate of waste generation; short-term decoupling effect; percentage of waste incineration and recycling is 50-90%; strict waste sorting system; restriction measures on the use of plastic. Middle level of total SDW – high /middle level of SDW per person. Middle / large population. | Germany, Japan, France, Switzerland |
| Red          | There is no reducing the growth rate of waste generation; percentage of waste processing and recycling < 50 %; weak waste sorting system; not everywhere introduced restriction measures on the use of plastic. High level of total SDW – low/middle level of SDW per person. Large population. | USA, China, Russia |

Urbanization in countries from "yellow" and "red" groups will be serious challenge, requiring a transition to a model of reasonable economic growth and setting up effective waste management. Thus, when planning new cities and eco-transformation of old territories, waste infrastructure is a fundamental element of a comfortable and sustainable residential environment [19]. One of the measures to reduce hard-to-recycle waste can be considered the use of light emitting diode (LED) in home and public lighting [20]. In sphere of tourism and hospitality as sources of economic growth it is necessary to minimize the use of disposable plastic dishes, sort waste in restaurants, hotels and shopping organizations [21]. There is already a practice when shops and cafe accept plastic dishes back or provide discounts when handing over plastic containers.

Global challenges require a balance between economic success and burden on the ecosystem, reasonable welfare and concern for future generations. The study showed that there is a socio-economic contradiction: preventing the formation of SDW contradicts the goals and interests of financial elite, business and corrupt authorities. Business owners are not ready to reduce production and lose revenue because people switch to a model of reasonable consumption. Modern managers need to understand that today's unjustified benefits reduce tomorrow's opportunities and quality of life.

5. Conclusion
The study showed that the introduction of effective waste management (strict collection and sorting, recycling, waste culture of producers and consumers) can be reduced the change index of personal waste and at the same time increase the change index of gross domestic product (per capita). In countries with a small population and a high level of welfare, there is an effective waste management system and a positive decoupling effect, but there is a problem of growing waste per capita and a high fraction of inorganic garbage (Denmark, Sweden and Belgium). In larger European countries and
Japan, there is less waste per capita, responsible approach to utilization and a plastic restriction, but there is a problem of proportional growth in welfare and waste. In countries with a large population (USA, China and Russia) there is a problem of increasing the total amount of waste, inefficient waste management and low level of recycling.

6. References
[1] Sausheva O S 2017 Ecological footprint as an indicator of economic growth at the present stage of development Russian J. of Resources, Conservation and Recycling (online) 4(4) Available at: https://resources.today/PDF/13RRO417.pdf
[2] Alexandrova V D 2019 Actual concept of circular economy Int. J. of Humanities and Natural Sci. 5-1 pp 87–93
[3] What a Waste 2.0: a global snapshot of solid waste management to 2050 by the World Bank (available at: https://worldbank.org/bitstream/handle/10986/30317/211329ov.pdf)
[4] Shilkina S V 2020 Global trends in waste management and analysis of the situation in Russia Russian J. of Resources, Conservation and Recycling (online) 1(7) Available at: https://resources.today/PDF/05ECOR120.pdf
[5] Ermolaeva Yu V 2017 Global waste management models: a sociological approach Scientific Result. Sociology and Management 3(3) pp 61–76
[6] Kasabutskaya M S 2017 Social ecology and research ecological consciousness in sociology: theoretical aspects Society. Environment. Development 4 pp 124–8
[7] Shkiperova G T, Lukashova I V and Druzhinin V P 2015 The impact of economy on the environment in countries with different level of development: a comparative analysis Economic Analysis: Theory and Practice 25 pp 20–31
[8] Knight K and Rosa E A 2011 The environmental efficiency of well-being: a cross-national analysis Social Sci. Research 40(3) pp 931–49
[9] https://www.imf.org/external/russian/index.htm
[10] World Data Atlas https://knoema.ru/atlas
[11] Recycling Around the World https://www.recyclingexpert.co.uk
[12] Shershneva E G 2021 Plastic waste: global impact and ways to reduce environmental harm IOP Conf. Ser.: Mater. Sci. Eng. 1079 062047
[13] IFC Report: Waste in Russia: garbage or a valuable resource? Scenarios for the development of the circulation sector with solid municipal waste (available at: http://biotech2030.ru/wp-content/uploads/2018/04/Othody-y-RF.pdf)
[14] Shershneva E G and Kondyukova E S 2020 Green banking as a progressive format of financial activity in transition to sustainable economy IOP Conf. Ser.: Mater. Sci. Eng. 753 072003
[15] Pakhomova N V, Richter K K and Vetrova M A 2017 Transition to circular economy and closedloop supply chains as driver of sustainable development St Petersburg University J. of Economic Studies 33(2) pp 244–68
[16] Astrapova G V and Frolova N Yu 2018 To the question of the modern market waste formation from the packaging of consumer goods Russian J. of Resources, Conservation and Recycling (online) 1(5) Available at: https://resources.today/PDF/04NZOR118.pdf
[17] Shershneva E G 2021 Progressive technologies of waste utilization as drivers of sustainable development IOP Conf. Ser.: Mater. Sci. Eng. 1079 062044
[18] World Waste Facts https://www.theworldcounts.com/challenges/planet-earth/state
[19] Shershneva E G 2021 Architectural and technological dialogue: development of "New City" generation IOP Conf. Ser.: Mater. Sci. Eng. 1079 022001
[20] Shershneva E G and Alpatova E S 2021 Current trends in design of street lights IOP Conf. Ser.: Mater. Sci. Eng. 1079 032006
[21] Kondyukova E and Shershneva E 2018 Diversification of the Middle Urals multi-touristic potential Worldwide Hospitality and Tourism Themes 10 (4) pp 478–86