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Operation period processes of food industry machines and devices – analysis of environmental impacts

K e y w o r d s

Ecobalancing, operation period, disposal, food industry, machine.

S ł o w a k l u c z o w e

Ekobilansowanie, eksploatacja, zagospodarowanie, przemysł spożywczy, maszyna.

S u m m a r y

The review of the sparse case studies of ecobalancing analyses of the complex technical objects (machines and devices) clearly indicates the operation phase of their life cycle as causing the most harmful impacts on the environment. In the paper the example of environmental analysis of the operation period and related disposal processes of representatives of food industry machines is presented. The research ecobalancing method, one of the most commonly worldwide used and objects selected for the analysis are also described. The selected results of analysis are presented, including the total environmental indices, the environmental profiles of the regarded machines, the study of the kinetics and the main factors determining the environmental impacts of machines during the operation period.

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1. Introduction

We, as human beings, are an integral element of the natural environment and the influence of all our activities is strongly visible: the rapid development of the civilisation led to degradation of large areas, extinction of many species of animals and plants, and shook the climate balance on Earth.

In connection with this fact, regarding also the rapid industrialisation and following degradation of the terrestrial natural environment, the conceptions of sustainable development and pro-environmental sustainable consumption gain more and more adherents. These ideas result in deepen studies on the possible environmental impacts of human's products – technical objects, particularly machines and devices.

At the same time, as a result of the growing interest of questions of environmental protection there is visible a strong need of evaluation of environmental impacts of technical objects (quantitative estimation of the generated influence on the natural environment).

Some examples of the analyses of environmental impacts of different objects, particularly less complicated (packaging, food and cosmetics, very rarely machines and devices). Most of these analyses are based on the idea of life cycle. One can observe, that all these analyses point out the exploitation (operation period) phase of technical object, as generating the most of the environmental burdens. However, the most of the research focus on the analysis of manufacturing processes of machines and devices, as the easiest to gain the veritable data.

The study presented in this paper is an attempt of determination of environmental impacts generated in the phase of exploitation and related disposal processes of the selected food industry machines and devices.

2. Method

One of the most commonly used ecobalancing methods is the Environmental Live Cycle Assessment (LCA) of Products method was used [1]. It was also used during the performance of analyses described below. It was defined as the way of quantitative determination of environmental impacts, based on inventory of environmental factors in reference to the object (product or service), process or other activity, in the whole life cycle – "from the cradle to the grave" – from the capture of materials to the final disposal [2]. The procedure of assessment using this method allows determining – on the basis of indicators calculated – which of the objects analysed is less harmful for environment, and can serve the producers to rebuild or modernise the construction, as well as can help the users in the aware choice of selected constructional solutions. LCA method can be used for implementing the policy of products' trade. Can also serve as a tool helping the development of the pro-ecological products and may be an instrument for government supporting the decision making process in reduction of the environmental arduousness of the industry [3].

LCA makes possible the identification and evaluation of emissions of harmful substances and consumption of energy and materials in all the phases of objects' life cycle. It can easily serve to [4]:

- comparison of environmental impacts of different products performing the same function,
- comparison of environmental impacts in reference to the standard,
- identification of the most harmful life cycle phases,
- help the design process of the new products,
- determination of the new direction of enterprise's development.

The LCA method consists of five main stages, divided into smaller parts, called modules. The main stages are [2]:

- goal and scope definition,
- inventory,
- classification of the environmental influences,
- evaluation and interpretation,
- propositions of improvement.

As far it does not exist one, commonly admitted LCA methodology and that's because the methods applied in different countries for evaluation of the same products sometimes generate slightly different results [5]. The reason of such situation is great variety of parameters taken into consideration, which differ each others dependently on country, regions and even enterprises. These factors may be: technological process level, volume of waste and emissions, fuel consumption etc. E.g. in the case of ecobalances of packaging materials it may happen that some results prefer glass bottles, others incline to cardboard, while some determine environmental impacts of packaging as equal.

3. Case study

3.1. Objects' characteristics

The main problem of the researchers performing the detailed and full-scale environmental analyses of the operation period and disposal processes is lack of the veritable data from users. Given this fact, the objects chosen for environmental analyses of the exploitation and related disposal processes were two kinds of machines for filling and closing the packaging, working in beer filling lines in one of the biggest Polish breweries. These machines are commonly called fillers or monoblocks (this second notion corresponds to the combination of the filler and closing machine). The notion of "monoblock" is met commonly in the industry practice, and it is used also in this paper.

One of the selected machines is designed to fill up 0,5 l bottles, the second one works in the 0,5 l can filling line. Their construction differ slightly, as well as work and efficiency parameters but both machines meet the same function – filling up the containers with beer – what is the procedural requirement of the LCA method.

The machines were conventionally called M1 and M2, and presented in the Fig. 1 and Fig. 2.

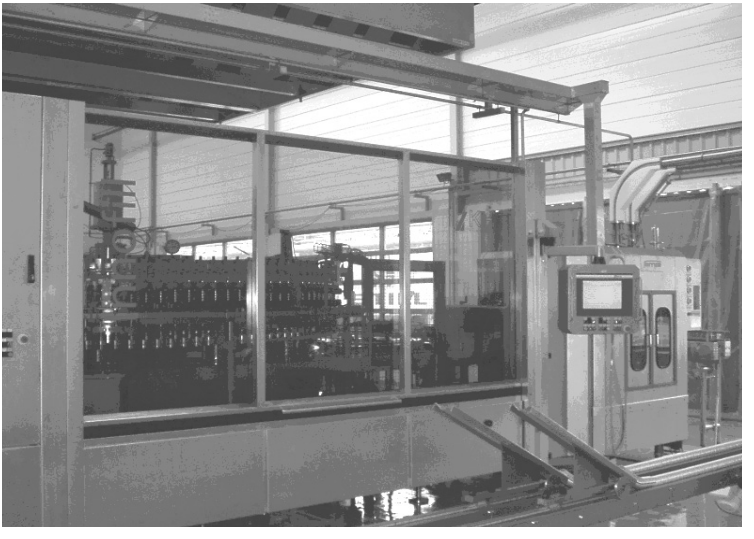

Fig. 1. Monoblock M1
Rys. 1. Monoblok M1

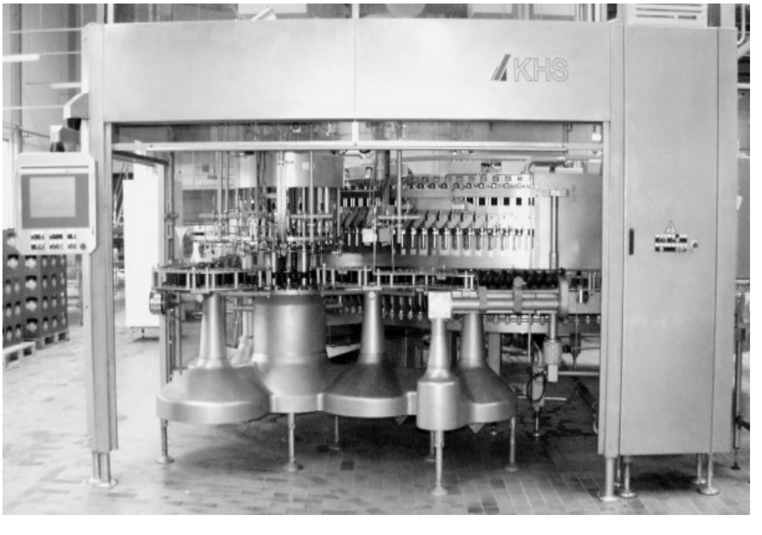

Fig. 2. Monoblock M2
Rys. 2. Monoblok M2

The main task of both monoblocks is to fill up the clean bottle or can with beer, containing precisely defined percentage of CO_2 and the slightest amount of air. Beer should not loose its properties during the process, and tight closure of the packaging should guarantee the definite best-before date (usually 6 months).

The appropriate filling up operation should also guarantee the required amount of beer in the packaging (too little amount of beer is a disadvantage for the customer, while too large amount of beer can result in fractures or leak of the packaging), the sterile filling up, the minimal shock (for avoiding the foaming process), prevention of the oxygen capture from air and loss of CO_2 dissolved in beer and the protection of beer against chemicals and lubricants.

The essential work operation of the monoblock is filling up phase. During this phase the packaging (bottle, can) is filled up with beer, closed and eventually the label is stuck.

3.2. Ecobalancing analysis – assumptions and chosen results

Assumptions

For secure the correctness, usefulness and practicality of ecobalance calculations the system boundaries were specified. The following issues were excluded from analysis:

- construction and exploitation of buildings, where the selected machines work (EIA – Environmental Impact Assessment method is better for this purpose),
- transport processes, e.g. spare parts and exploitation materials delivery to the user,
- exploitation of the supply devices and machinery (carriers, transporters etc.),
- human resources utilization (particularly the staff needs satisfaction).

In the filling line M2, where monoblock M2 works, there are two filling and closing units, both with the efficiency of 50.000 cans/h, but for simplify the calculations one machine is assumed, with the total capacity of 100.000 cans/h. Due to the differences in efficiency parameters of both machines, as well as to their different workload, according to the methodological requirements, the functional (comparative) unit is introduced. It was assumed at the level of 100.000 hl of beer filled packaging. The functional unit's size corresponds with 7–9% of the annual fill up value for one filling line. The assumption of the functional unit allows the direct comparison of environmental impacts caused by both machines.

Chosen results of ecobalance

In the Fig. 3 and Fig. 4 the total environmental impacts of both monoblocks is presented, after taking into consideration the functional unit. The significant difference (30%) of the environmental effects caused by monoblock M1 is visible. The analysis of the structure of environmental effects (decomposition of particular environmental categories and groups of categories) emphasises the strong domination of impacts connected with influence on human health and natural resources depletion. Environmental impacts, which can be identified with ecosystems quality, have much lower values. Fossil fuels depletion (50% of impacts) and respiratory diseases caused by inorganic substances (43% of impacts) are the most important impact categories. This fact unambiguously illustrates the possible high participation of impacts connected with energy production and consumption in the whole of operation period impacts of both machines.

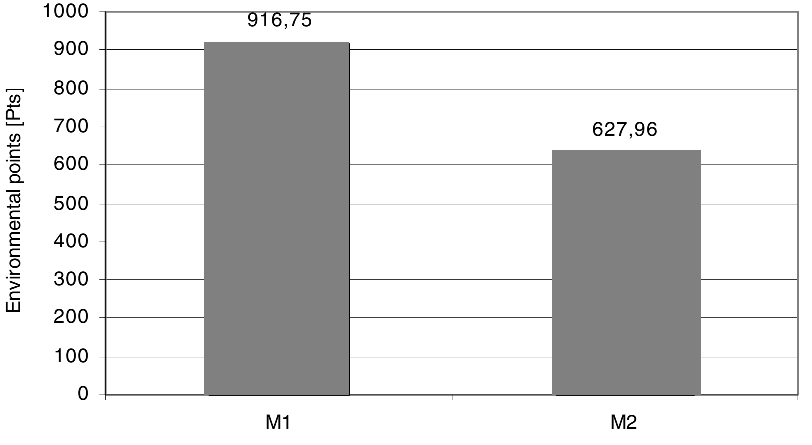

Fig. 3. Total environmental impact of both machines in the period of 2001–2004
Rys. 3. Całkowite oddziaływanie środowiskowe obu maszyn w latach 2001–2004

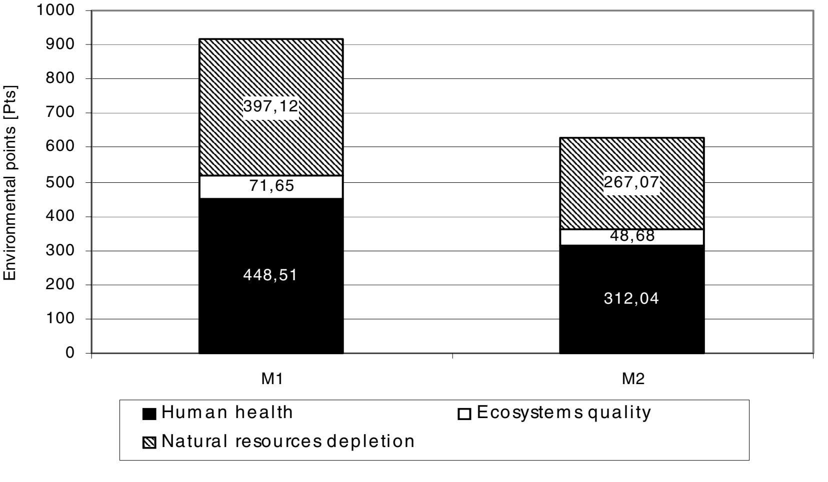

Fig. 4. Environmental impact of both machines regarding the groups of impact categories in the period of 2001–2004
Rys. 4. Oddziaływanie środowiskowe obu maszyn z podziałem na grupy kategorii oddziaływań środowiskowych w latach 2001–2004

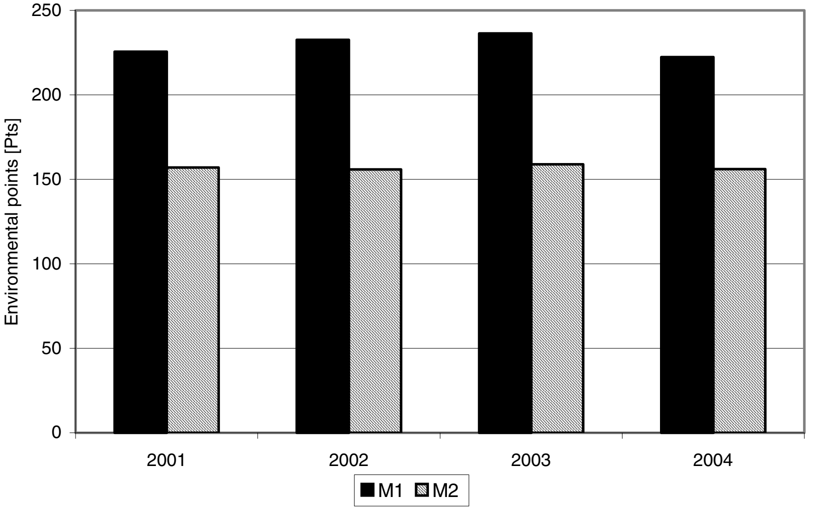

Fig. 5. Comparison of changes of environmental impacts level of selected machines in the considered period
Rys. 5. Porównanie zmian poziomu oddziaływań środowiskowych analizowanych maszyn w rozpatrywanym czasie

The environmental influence of both machines in respective years is presented in Fig. 5. It follows, that the fluctuations of the level of environmental impacts in the whole considered period amounted to less than 10% and one can assume, that the production of 100.000 hl of beer as such caused the similar environmental influence every year. In common with the total environmental impact of both machines, the strong influence of categories connected with fossil fuels depletion and respiratory diseases caused by inorganic substances is strongly visible in respective years. Once again the production and large consumption of electric energy is the reason.

The environmental influence of both machines, resulting from the use of exploitation media, materials and spare parts in the considered period, is presented in the Fig. 6 and Fig. 7. First tendency is twenty, thirty times larger impact of exploitation media and materials, than the impact caused by spare parts. The environmental influence of media and materials appears quite stable; however the impacts connected with the use of spare parts vary a lot, depending on time. The biggest difference in the case of monoblock M1 is between the years 2002 and 2004 (six times). In case of monoblock M2 the difference is on the level of 230%, for the same years. This fact is caused by a steady consumption of exploitation media (energy, water), depending only from the capacity of production. But from the other side – the demand for spare parts is highly irregular, and bound up with the different assumed durability of elements and assemblies.

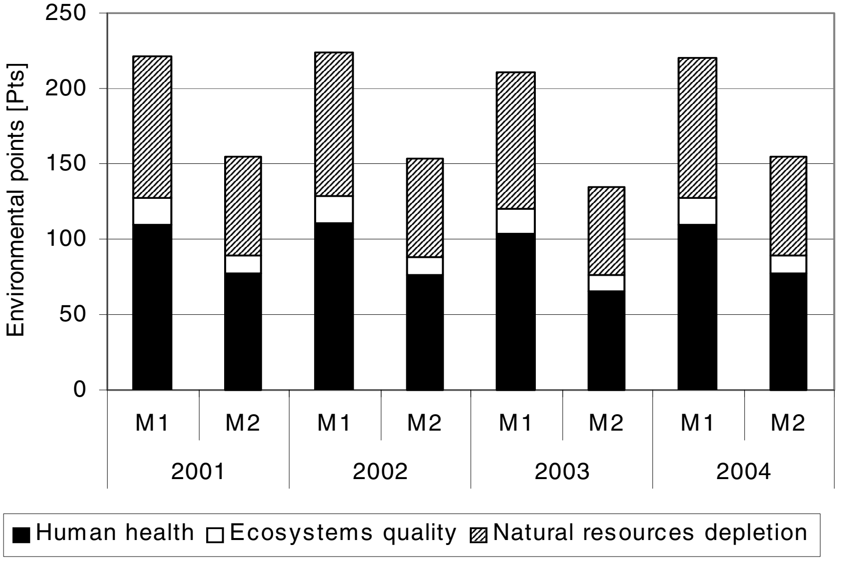

Fig. 6. Environmental influence of exploitation media and materials of both machines
Rys. 6. Oddziaływania środowiskowe materiałów i mediów eksploatacyjnych obu maszyn

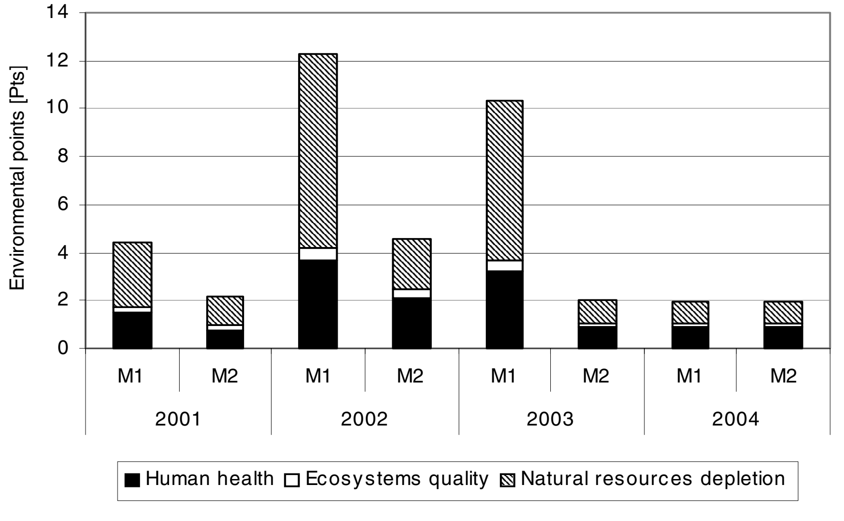

Fig. 7. Environmental influence of spare parts of both machines
Rys. 7. Oddziaływania środowiskowe materiałów części zamiennych obu maszyn

The total environmental impacts of exploitation-related disposal processes of spare parts and exploitation materials of both machines are presented in the Fig. 8 and Fig. 9, after considering the functional unit, in division into different environmental categories and different disposal variants. It is visible, than the total environmental index of the disposal processes has a negative value in both cases. It is caused by strong participation of the recycling processes in the final variant of disposal of the considered materials.

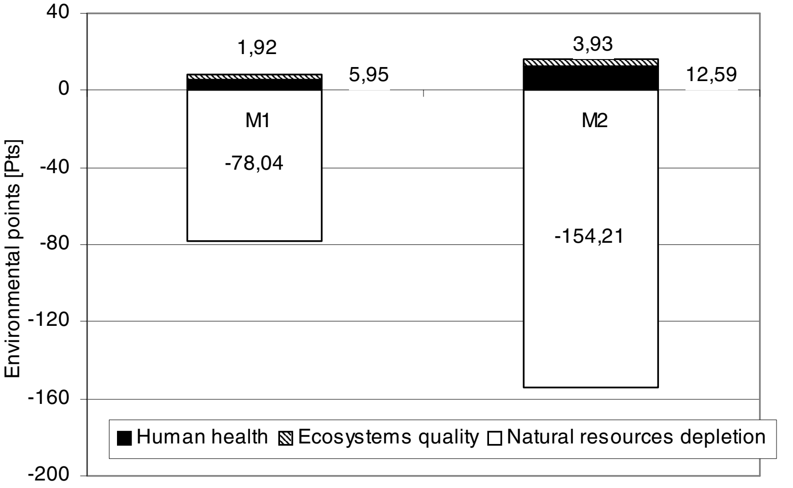

Fig. 8. Environmental influence of the disposal processes of both machines in the considered period, in division into three groups of categories
Rys. 8. Oddziaływania środowiskowe procesów zagospodarowania części zamiennych obu maszyn w ujęciu trzech grup kategorii oddziaływań środowiskowych

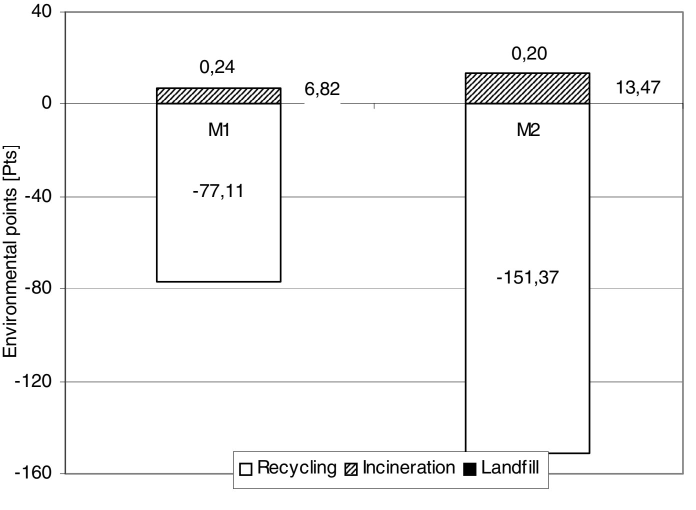

Fig. 9. Environmental influence of both machines in the considered period, regarding the spare parts disposal scenario
Rys. 9. Oddziaływanie środowiskowe obu maszyn w analizowanym okresie ze względu na scenariusz zagospodarowania części zamiennych

During the disposal of spare parts and exploitation materials of monoblock M2 twice bigger environmental influence is generated, than in case of monoblock M1. It means that the potential profits for the environment, regarding the assumed disposal scenario of exploitation materials and spare parts, are also twice bigger in case of machine M2.

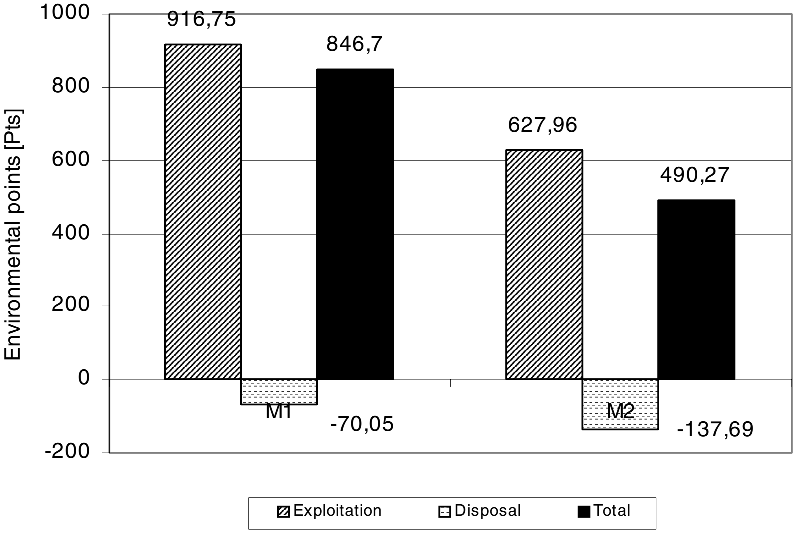

Fig. 10. Comparison of total environmental indexes for both analysed machines
Rys. 10. Porównanie całkowitych wskaźników oddziaływań środowiskowych obu maszyn

3.3. Total environmental influence of operation period and exploitation-related disposal processes of analysed objects

The comparison of the basic environmental indexes of both analysed machines, for the operation period and related disposal processes, is presented in the Fig. 10.

Analysing the reciprocal relations of impacts of exploitation and disposal processes one can say, that monoblock M2 is more environment-friendly, that monoblock M1. The exploitation research proved, that despite the similar size of production for both filling lines, the environmental impacts generated by monoblock M1 are 1/3 smaller, than those caused by the second one, simultaneously reaching two times bigger negative index of environmental influence caused by disposal processes. Taking into consideration all these facts, one can say, that monoblock M2 results in 40% smaller environmental influence, than the monoblock M1. So it is more environment-friendly and from this point of view for the consumer aware of the problems of impacts of technical objects on environment it is better to buy the beer in multiple use glass bottles than in the aluminium cans.

4. Summary

The analysis presented in this paper is one of the parts of the comprehensive environmental study of the selected objects, regarding their whole life cycle. The results were selected for showing the necessity and importance of the environmental evaluation of the exploitation and related disposal processes of technical objects. The analysis presented was made on the basis of the veritable and real data coming directly from users of considered filling machines. The 2nd stage of the study concerns years 2005–2008, but the project is still not finished yet.

5. References

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Procesy eksploatacyjne maszyn i urządzeń przemysłu spożywczego – analiza oddziaływania na środowisko

S t r e s z c z e n i e

Analiza nielicznych spotykanych w literaturze studiów przypadku dotyczących analiz ekobilansowych złożonych obiektów technicznych (maszyn i urządzeń) jednoznacznie wskazują fazę eksploatacji jako powodującą najpoważniejsze oddziaływania środowiskowe. W artykule przedstawiono przykład analizy środowiskowej procesów eksploatacyjnych i związanych z nimi procesów zagospodarowania wybranych reprezentantów maszyn i urządzeń przemysłu spożywczego. Opisano wykorzystaną metodę ekobilansową, jedną z najpowszechniej wykorzystywanych na świecie do tego typu badań, jak również obiekty badawcze. Zaprezentowano wybrane wyniki badań, zawierające wskaźniki środowiskowe, profile oddziaływań środowiskowych, studium zmienności oddziaływań w czasie, jak również główne czynniki determinujące poziom oddziaływań środowiskowych wybranych maszyn podczas eksploatacji.