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CHAPTER XI

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SELECTED ASPECTS OF THE SIGNIFICANCE OF EARTHWORMS IN THE CONTEXT OF SUSTAINABLE WASTE MANAGEMENT

Introduction

According to MILLENNIUM ECOSYSTEM ASSESSMENT (2005) submitted by the General Secretariat of the United Nations, the state of about 2/3 of services provided by the World's ecosystems to Man is deteriorating. It has happened as a result of over exploitation and a loss in the variety of species which would otherwise guarantee the stability of ecosystems (some of the consequences of the deterioration: the decline in fish stock, loss of soil fertility, decreased number of pollinating insects). One of the main reasons for the ecological problems of the World is the result of pollution and the presence of various toxic substances in water, soil and air. In ecosystems the concentration of some of those substances is too high due to either natural processes or high anthropogenic pressure. The changes of ecosystems are related to soil acidification, the pollution of groundwater, the eutrophication of surface water, radiation and the greenhouse effect. The depletion of resources, excessive noise and electromagnetic field have a negative effect on Man's situation which has this far been stable (ALBIŃSKA 2005, SIEMIŃSKI 2007, DOBRZAŃSKA et al. 2008).

Nowadays people have started to realise that it is no longer enough to undertake only superficial actions in order to compensate for the damage caused by the implementation of various communication, urban or industrial projects. There is a need for complex system solutions which are also important for future generations. This way of thinking is fundamental for the concept of sustainable development. Its supporters call for significant civilizational changes on an ecological, social and economic level. A wide scope of those changes gives one the right to formulate a postulate which will state that a new vision of development can reach the status of a revolution which can be compared to the revolutions so often mentioned in the history of mankind, i.e. the agricultural, scientific and industrial revolutions (Table 1).

PAWŁOWSKI (2009) suggests that a fundamental discussion about sustainable development should be enriched by ethical, technical, legal and political aspects as well as by the hierarchization of problematic groups out of which morality is considered to be a fundamental problem as without it the sustainable development revolution will not be successful.

Nowadays, at the turn of the century, we need to consider a number of local, regional and global problems that are related to a social, economic and environmental sphere. The solution to those problems is very complicated and requires the co-operation of politicians, economists, sociologists, biologists, entrepreneurs representing different countries as well as every citizen. On the other hand, SKUBAŁA (2008) thinks that the concept of sustainability has its origins in the idea that we borrowed the Earth from our grandchildren.

Table 1

Critical phases in the process of the development of mankind
(based on PAWŁOWSKI 2009 - changed)

The development phase		Period
1	Hunting and picking	Upper Palaeolithic
2	The agricultural revolution	The beginning: about 9000 years ago in Asia, in Europe about 4000 years later
3	The scientific revolution	The symbolic beginning: the publication of "On the Resolution of the Heavenly Spheres" by Nicolaus Copernicus (1543); the explication, the publication of "Mathematical Principles of Natural Philosophy" by Isaac Newton (1687)
4	The industrial revolution	The symbolic beginning: a significant modification of a steam engine by Watt (1769). The next phase (1860-1914): the beginning of using crude oil (an internal combustion engine) and electricity
5	The sustainable development revolution	Significant events: the U'Thant's speech (1969), the definition of sustainable development (Bruntland's definition) introduced by the United Nations (1987), the United Nations Conference "Earth Summit" in Rio de Janeiro (1992), the announcement of the United Nations Decade of Education for Sustainable Development (2005-2014)

In Poland, we can consider the following as some of the most important achievements in the implementation of the ideas of sustainable development: the STATE ENVIRONMENTAL POLICY (1990), the CONSTITUTION OF THE REPUBLIC OF POLAND (1997) which accepted the regulation that the ideas of sustainable development would be implemented (the article 5), the binding multidimensional strategic plan Poland 2025 (RZĄDOWE CENTRUM STUDIÓW STRATEGICZNYCH, MINISTERSTWO ŚRODOWISKA 2000) as well as constantly improved and updated environmental protection policy (GRUSZECKI 2008). The survey shows that despite the announcement of the United Nations Decade of Education for Sustainable Development, the idea of sustainable development is still under-acknowledged (KOSTECKA 2007, 2009).

Sustainable development and the problem of waste management

Among the issues described above there is another problem which was noted in the last decade of the 20th century – a constant increase in the volume of municipal waste which can be explained by the rapid development of civilization and a higher standard of living (ROSIK-DULEWSKA 2007). As waste has a negative effect on the environment, rational and pro-environmental ways of waste management need to be urgently considered and implemented. Otherwise, all the elements of ecosystems, i.e. soil, water, atmosphere and consequently Man will continue to suffer (KOZŁOWSKI 2000, SIEMIŃSKI 2007). The redirection of the waste management strategy towards environmental protection must be a characteristic for the 21st century (KEMPA 2001, BARAN, DROZD 2004). It is due to the statistical data which shows that Poland alone produces 9354 tonnes of municipal waste annually (CONCISE STATISTICAL YEARBOOK 2008). However, according to the authors of the National Waste Management Plan (2010), the real amount of waste is at least 10% larger.

Every citizen should contribute to the implementation of the pro-environmental waste management. In accordance with the WASTE MANAGEMENT ACT (Journal of Laws 2001, no. 62, pos. 628) every citizen must take broad actions in order to avoid generating waste. Resulting waste will need to be sorted at recycling centres provided by appropriate authorities (in Poland, at the moment, it is only possible to sort metal, plastic, glass and paper). There should also be facilities for the separation of hazardous waste from a waste stream. Apart from the legal regulations (the WASTE MANAGEMENT ACT, art. 10 – a legal requirement to segregate waste), the difference in rates for having non-segregated and segregated waste collected might be another factor that would motivate citizens, who are not aware of ecological issues, to segregate waste. However, in order to fully implement the pro-environmental principles of waste management we need to take more responsibility for the education and the ecological culture of all citizens.

The presence and the disposal of waste has been a problem for some time. Nowadays it is far more serious as it is related to growing urbanization and over-consumption. In Poland, modern waste management was neglected for a long time both by the representatives of the central and provincial offices, and by the communal authorities responsible for environmental protection and citizens. That is why an urgent reconstruction of the waste management system towards sustainable solutions is an important issue.

In order to reduce the amount of waste, the Poles need to considerably change their attitudes and behaviour, e.g. they should gradually eliminate purchases of products whose production, exploitation and then resulting waste has a negative effect on the environment. In order to achieve this we need to constantly make customers aware and there must be cooperation between producers and those responsible for waste processing. In households we need to avoid products with unnecessary packaging or instead use returnable packaging. We also need to compost organic waste as well as some forms of packaging. The reduction of the amount of waste in industrial factories requires long-term actions. A cleaner production means not only an investment, as in many cases there would be a need for the whole technological lines to be changed (PRZYWARSKA 2005) but also, as it has been shown in the survey, changing inappropriate attitudes of people which usually accounts for 2/3 of obstacles in the implementation of the principles of environmental protection (SKALMOWSKI 2007).

Nowadays, we know that a suitable location of a well equipped dump site can considerably limit its negative effect – the pollution of surface and ground water and the pollution of soil and reduce the danger of microbiological, dust and odour contamination. However, the problem that still exists in Poland is not only the lack of acceptance of our participation in the waste management system but also the lack of acceptance of the necessity of waste segregation which makes it possible to reuse it (KOZŁOWSKI 2000, BARAN, DROZD 2004, JĘDRCZAK 2007, ROSIK-DULEWSKA 2007).

Why you should not dispose of organic waste at landfill sites and illegal dump sites

The WASTE MANAGEMENT ACT (Journal of Laws 2001, no. 62, pos. 628) formulates the principles of dealing with waste, which guarantees the protection of life and health of Man as well as environmental protection in accordance with the ideas of sustainable development. The regulations included in the act are to prevent the production of waste, force limits on its amount and its negative influence on the environment and make recycling and neutralizing easier.

The main aim of the new regulations, which meet the UE standards within the scope of waste management, is to limit the prevailing method of neutralizing waste which is its disposal at landfill sites (KEMPA 2001, GRUSZECKI 2008).

In Poland, similarly to the majority of developed countries, we can observe a constant increase in municipal waste production. According to the NATIONAL DEVELOPMENT PLAN for the period of time 2007-2013 and the STATE ENVIRONMENTAL POLICY for the period of time 2009-2012, the weight of waste produced by every citizen reaches 300 kg annually. However, it is still half as large as in the richest EU countries.

The vast majority of municipal waste (in 2007 – 9609 tonnes) (STATE ENVIRONMENTAL POLICY …) is still disposed of in landfill sites. A significant part of that mass (at least 30% on average) is biodegradable which, in the form of waste, is a serious threat to all the elements of the environment. On the other hand however, it is a potential material for the production of compost which increases soil fertility.

We need to remember that landfill sites which contain organic substance have perfect conditions for all living organisms – especially for those traditionally regarded as pests to Man: rodents, insects and some species of birds. As bioton gets heated, such animals not only find food but also warm hiding places all year round. Their large populations are very mobile, they move long distances from a place to place spreading pathogenic elements.

In the situation where Poland, as well as other EU countries, has a duty to obey the LANDFILL DIRECTIVE 99/31/EC, which requires the gradual reduction of organic waste mass stored at landfill sites until 2025, every idea of neutralizing such kinds of waste (including in places where they are produced) should be recognized, widespread and constantly improved.

As numerous studies show, one of the successful methods of neutralizing organic waste is vermicomposting. The use of vermiculture biotechnology in relation to selected biowaste makes it possible not only to reduce the volume of organic waste disposed of at landfill sites but also to gain two important products: organic fertilizer – vermicompost and earthworm body walls whose nutritional value is high. Vermicomposting is a widely used method and it is still multidimensionally examined all over the world including the search for the importance of the use of various species of earthworms (EDWARDS 1998, DOMINGUEZ et al. 2001, BORGES et al. 2003, DICKERSON 2004, KOSTECKA 1994; 2004A, PARVARESH et al. 2004, SELDEN et al. 2005, SHARMA et al. 2005; GARG et al. 2006, KOSTECKA, PĄCZKA 2006).

From the facts presented above we can tell that actions towards the organic waste segregation and the pro-environmental neutralization of waste should become more important in the future strategy for sustainable waste management. According to the LANDFILL DIRECTIVE UE 99/31/UE, it must be a common responsibility of all citizens and communal authorities. However, as studies show, not even all decision makers are aware of it (KOSTECKA et al. 2007).

After segregating biowaste from a waste stream, the most justifiable way of its neutralization is anaerobic fermentation with biogas recovery, aerobic composting (or vermicomposting) and, when it is required, combustion with energy recovery. Neutralizing segregated organic waste can take place on various scales: at an appropriate installation, at a municipal, communal compost sites or household compost areas (KOSTECKA 1998, 2000, KASPRZAK 2001, JĘDRCZAK 2007).

In a situation where waste is stored as the disposal of bioton at communal installations or having compost areas in a garden or an allotment is not possible, some citizens could be convinced to use a specific (unconventional) form of the organic waste management. "Earthworm ecological boxes" would allow the management of wastes in a place where they are generated (as vermiculture on a small scale, in boxes in a "handy" place e.g. a balcony, a kitchen or a basement) (APPELHOF 1982, 1993, KOSTECKA 2000). It is also possible to vermicompost office wastes (KOSTECKA 2003).

The conditions of a study

The study of earthworm ecology and the use of earthworms in the neutralization of organic waste have been conducted at the centre in Rzeszów since 1986 (previously the branch of University of Agriculture in Kraków and nowadays the University of Rzeszów). The aim of the publication is to present those parts which refer to the sustainable waste management against the background of the selected studies conducted in Poland and abroad.

In the individual study (conducted in a laboratory as well as on a semi-technical and technical scale) of the neutralization of organic waste in vermiculture, we included agricultural wastes (cattle and horse manure as well as post-harvest residues), sewage sludge from several municipal sewage treatment plants, cellulose, office and household wastes. A concentrated population of earthworm *Eisenia fetida fetida* (Sav.) has been used in the study. Their life functions, observed in substrate which contained the above mentioned wastes, made it possible for coprolitic fertilizer, also known as vermicompost, to form. The results of the study have also been used in broad educational actions.

Selected aspects of issues concerning modern vermiculture and its importance

The conditions of Northern Europe and Poland are ideal for a concentrated population of the above mentioned earthworm *Eisenia fetida fetida* (Sav.) to be used in the vermicomposting of organic waste (KOTOWSKI 1989, KOSTECKA 1994, KASPRZAK 1998). We can find this geopolitical species in a soil surface layer where organic waste accumulates. It was bred on the American continent in the 1950s (BOUCHE 1987; EDWARDS, BOHLEN 1996). Nowadays, we can breed it on a technical scale (EDWARDS, BOHLEN 1996, KASPRZAK 1998, KOSTECKA 2000) or in households (APPELHOF 1982, 1993, KOSTECKA 1994, ŻYGADŁO 2002, JĘDRCZAK 2007, ROSIK-DULEWSKA 2007). In some countries the whole system solutions for the organic waste management with the use of vermiculture are created (FREDERICKSON, HOWELL 2003, BLOUIN et al. 2006, GARCIA-ORTEGA, OLIVARES-GONZALES 2006, FREDERICKSON et al. 2007).

In the process of vermicomposting other species of earthworms are potentially suitable; in a temperate climate: *Eisenia fetida andrei*, *Dendrobena veneta, Dendrobena rubida* and *Lumbricus rubellus*, in a tropical climate: *Eudrilus eugeniae*, *Perionyx excavatus* and *Pheretima elongata* (EDWARDS 1988, 1998, DOMINGUEZ 2004, SINGH et al. 2004).

Vermiculture is relatively new biotechnology (EDWARDS, BOHLEN 1996) which takes place in controlled conditions and comprises of the breeding of concentrated populations of earthworms in various organic waste. In order for a process to be called vermiculture there should be over 100 specimens of earthworms per 1 dm^3 (LAC 1991, KOSTECKA 2000, 2004A, ZHENJUN 2003, GARG et al. 2006). Thanks to its life functions such a concentrated population very quickly and successfully transforms various organic wastes into a fertilizer (vermicompost) of excellent quality (KALEMBASA 1998, ZABŁOCKI, KIEPAS-KOKOT 1998, KOSTECKA 1999A, SZCZECH, SMOLIŃSKA 2001, ARANCON et al. 2003, 2004, EDWARDS et al. 2004, HURY 2008, ALI et al. 2007, ZALLER 2006, 2007, GUTIERREZ-MICELI et al. 2007). In the situation where soil in Europe is low in humus and where organic waste is a threat to the environment, the vermiculture biotechnology makes it possible to neutralize biowaste in a pro-environmental way.

One of the requirements for a vermiculture technique is feeding earthworms with thin layers, providing the next ones only after earthworms have finished eating the previous layers (GADDIE, DOUGLAS 1977). For the proper vermicomposting of organic waste with the presence of *Eisenia fetida*, pH of soil in breeding beds needs to be kept within 6.7-7.5 and, as far as possible, the temperature should be regulated (the ideal soil temperature for the life functions of *E. fetida* is 12-28^{o} C). Humidity (about 70%) as well as aeration is also very important. Currently the main directions of the use of vermiculture are considered to be:

- Neutralizing segregated organic waste; through the production of vermicompost which results in the possibility of supplementing the lack of nutrients in plants and making microorganisms in soil more active,
- The production of earthworms body biomass which is rich in protein (about 58-71% of dry mass); biomass can be used as a food supplement for fish, poultry, pigs and other animal e.g. zoo animals,
- Gaining additional populations of earthworms whose introduction to soil will improve the process of reclamation,
- Using enzymes and other substances included in lymph in cosmetic, wine, beer, textile and medical industry (ZHENJUN 2003; DOMINGUES 2004; DOMINGUES, EDWARDS 2004, EDWARDS et al. 2004).

In the process of vermicomposting it is possible to neutralize various organic wastes e.g. sewage sludge, post-production wastes of agricultural processing industry, post-harvest residues, green wastes, cotton wastes, wastes generated during coffee production, kitchen wastes, wastes from supermarkets and restaurants, wastes from slaughterhouse, bones and feathers from poultry slaughterhouse, excrement (poultry, pig, cattle, sheep and horse), excrement of fur-bearing animals (foxes, minks and rabbits), post-champignon wastes, wastes from beer and paper factories (EDWARDS 1988, BUTT 1993; OROZCO et al. 1996, KASPRZAK 1998, KOSTECKA 1999A, 2000, 2004B, BENITEZ et al. 2002, ZAJĄC 2002, FREDERICKSON, HOWELL 2003, DOMINGUEZ 2004, DOMINGUEZ, EDWARDS 2004, LOH et al. 2005, GAJALAKSHMI et al. 2005, GUPTA et al. 2005, NOGALES et al. 2005, GARG et al. 2006, HUERTA et al. 2006, AIRA, DOMINGUEZ 2007, SUTHAR 2007, BRANDON et al. 2008).

It must be stressed that this pro-environmental biotechnology is only common to a lesser extent. Its rare occurrence is usually associated with the fact that people breed earthworms for their own use and that earthworms are used to escalate the process of organic matter breakdown only on a small scale (ROŚCISZEWSKA et al. 1998), whereas in other countries such as Germany, France (ŻYGADŁO 2002), Spain, Canada, Sweden and the USA the process takes place far more often and is far more common (GADDIE, DOUGLAS 1977, KOSTECKA 2004A).

As it has been mentioned before, the breeding of earthworms can take place on various scales: small and „handy" or large , e.g. at sewage treatment plants. KOSTECKA (2000) conducted a positive trial of vermicomposting of sewage sludge at a sewage treatment plant in Brzesko, Poland. After the preliminary trial in a laboratory and the preparation of a station for vermiculture at the plant, earthworms were introduced onto 6-month sludge of stabilized parameters which was also modified with sawdust. After 3 months earthworms transformed the sludge into a fertilizer of tubercular structure.

We can vermicompost organic material in solid beds e.g. made of concrete (an optimum size: 2 m wide, 10 m long and 0.5 m high, which is equivalent to 10 beds according to the US norms) (GADDIE, DOUGLAS 1977). On the other hand, earthworms can also transform organic waste in beds made from waste materials (e.g. wood, brick, rubber transmission belts) (KOSTECKA 2000). We can also organize systems of a high technical level (BOUCHE 1987, RIGGLE, HOLMES 1994, BLOUIN et al. 2006, GARCIA-ORTEGA, OLIVARES-GONZALES 2006, FREDERICKSON et al. 2007).

Vermiculture and agricultural households

Providing permanent access to organic fertilizers and feed and, at the same time, reducing their purchase cost is known to be an important issue in the agricultural sector. Which is why neutralizing animal excrement, post-harvest residues as well as home organic wastes through vermiculture can be of paramount significance (Figure 1). The drawing shows that in vermiculture we can use any segregated organic wastes (household wastes, wastes generated by herbivorous and omnivorous animals as well as any post-harvest residues). Vermicompost (which can used e.g. for vegetables, orchards or field cultivation) and the protein of an earthworm body wall (which can be used as a feed supplement for omnivorous animals and fish) are the products of vermiculture.

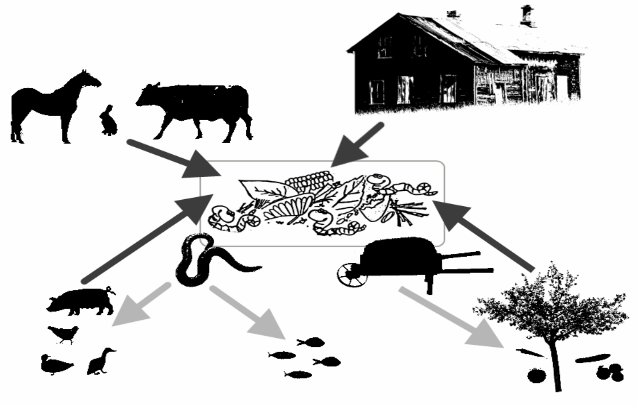
Presently, in some parts of Poland, there is a growing interest in vermiculture but mainly on a small scale in order to produce vermicompost. Vermicompost derived from cattle manure has good fertilizing qualities. Experiments on the use of vermicompost have been conducted for many years now (JARECKI, MAKOWSKI 1992, MURAWSKA et al. 1992, KOSTECKA, KOŁODZIEJ 1995, SŁAWIŃSKI, SONGIN 2001, HURRY 2008).

Although the harvest of potatoes grown on vermicompost is smaller (JARECKI, MAKOWSKI 1992) or the same (SADOWSKI, NOWAK 1990) in comparison to the harvest of potatoes grown on manure, the conducted experiments also show a positive influence of vermicompost on harvest. It transpires that the proportion of potato tubers that can be consumed is higher (KOSTECKA et al. 1996, SADOWSKI, NOWAK 1990) and the health of plants is considerably better. In the study conducted by KOSTECKA and co-authors (1996), tubers grown on vermicompost were sporadically affected by *Phytohthora infestans* during harvest as well as after 7 months of storage. It is confirmed by SZCZECH i BRZESKI (1994) who consider that vermicompost functions as a plant protection agent.

The content of nitrate and heavy metals has been determined in vegetables grown on vermicompost (KOSTECKA, BŁAŻEJ 2000). They have higher nutritional value (the content of nitrate, lead and cadmium was lower) in comparison to vegetables fertilized with minerals. Favourable properties of vermicompost as an organic fertilizer have been scientifically proven which is also confirmed by allotment owners who notice that plants are healthier and crops yields are higher.

Vermicompost has a positive influence on soil fertility (EDWARDS et al. 2004), however, some authors are of the opinion that soil fertility is stimulated more by the growth of a microorganism population rather than vermicompost (DOMINGUEZ 2004, TOGNETTI et al. 2005). Other authors also proved that vegetables (potatoes, cabbage, lettuce, tomatoes) and e.g. strawberries grown of that organic fertilizer (of examined content, produced from cattle manure) grew faster (ATIEYH et al. 2002, ARANCON et al. 2003, 2004; HASHEMIMAJD et al. 2004, GUTIÉRREZ-MICELI et al. 2007) and were healthier (SZCZECH, SMOLIŃSKA 2001, SZCZECH et al. 2002; BŁAŻEJ, KOSTECKA 1998) than those fertilised with minerals or compost.

Vegetables (potatoes, tomatoes, cucumbers) fertilized with vermicompost absorbed less amount of nitrate and heavy metals in comparison to those fertilised with minerals (KOSTECKA, BŁAŻEJ 2000). In the study conducted by EDWARD et al. (2004) it was shown that vermicompost significantly slowed down the growth of pathogenic fungi such as *Pythium*, *Rhizoctonia* i *Verticillium* and vegetables contained smaller amount of heavy metals. Agricultural use of vermicompost escalated the growth of a root and the absorption of nutrient (PADMAVATHAMMA et al. 2008).



Source: author's own work

Dark arrows show organic wastes which are feed for earthworms, light arrows identify the possibilities of using the products of vermiculture: vermicompost (right) and earthworm biomass (left)

Fig. 1. Vermiculture in an agricultural household

Taking into consideration the multifunctional development of rural areas and the need to create additional sources of income for country dwellers, the importance of another project – earthworm mass – needs to be emphasised. Not only can earthworms be a feed supplement but also mature specimens can be sold e.g. to fishermen or as a pedigree material for other vermicultures.

As mentioned earlier, the existence of vermiculture in agricultural households creates the possibility to use the protein of an earthworm body. For many years, several publications have shown (MC INROY 1971, SABINE 1983) that earthworm biomass is an attractive feed due to its high levels of aminoacids such as lysine, methionine, cystine, tryptophan and threonine. In periods of long-lasting drought, during winter and when it becomes cold, the possibilities of finding biomass by birds bred in yards are limited. In such cases, earthworm biomass derived from vermiculture can be a cheap source of valuable protein reserves. Many authors have conducted the analysis of the content, nutritional value and the vitamins of earthworms which demonstrated that earthworms are an attractive feed for fish, poultry, pigs and zoo animals (ZHENJUN 2003; VIEIRA et al. 2004; SOGBESAN et al. 2007A i B).

In an individual study (KOSTECKA, DEJNEKA 1998), it was proved that poultry using a free yard (French white ducks and hens of a general use were fed) had an interest in the biomass of earthworm *E. fetida.* According to KORELESKI et al. (1994), we can introduce earthworms into mixed fertilizer in the form of powder or granulate. The need of constant rejuvenation of an earthworm population favours the idea of the removal of earthworm biomass from breeding stations on a regular basis. It results in the possibility of starting new stations or using earthworms as feed.
Earthworms used in household vermiculture need to be protected from scratching birds (e.g. with plastic net) to prevent parasitic diseases of poultry from spreading. Feeding scratching birds with biomass must take place in controlled conditions.

Vermiculture and individual households and public institutions

Food leftovers are generated not only in the kitchen – we produce them in great amounts at schools, universities, offices, canteens, street markets. It has been shown that vermicompost derived from home and office wastes is very rich in nutrients, however, its salinity may be high (KIEPAS-KOKOT, SZCZECH 1998, KOSTECKA 2000). Vermiculture which takes place in small boxes (at home, school, hospitals, canteens, work places) makes recycling of organic waste of high quality possible (selected organic wastes) in places where they are produced. In order to draw attention towards pro-environmental actions of those who decide to start vermicomposting, such a solution has been called "an ecological earthworm box" (KOSTECKA 1999B, 2000).

„An ecological earthworm box" (at home, school, work place etc.) makes it possible for anyone to contribute to the sustainable waste management; it reduces the ecological footprint (BEST FOOT…) which is associated with transport of waste to landfill sites and it prevents negative consequences of biowaste deposits at landfill sites as well as illegal dump sites.
We need to follow the following rules in order for ecological boxes to function properly:

- A feed layer should be no thicker than 10 cm every time a new one is added. We should not include too much meat waste, we need to add acid waste very carefully bearing in mind that earthworms in small boxes are not able to retreat to a remote and safe place. The practice showed that feed should not cover the whole surface of a breeding box. The observation of earthworm behaviour and their gathering in new waste can indicate the acceptance of new conditions,
- We need to thin an earthworm population on regular basis by taking away of about 25% of specimens several times during a vegetation season,
- The humidity in boxes should be kept on a permanent level of 70% and other soil parameters should also be taken considered ,
- As a box is being filled up, we need to gradually remove the resulting vermicompost (KOSTECKA 1994, 2000).

Oxygen is also an important factor for the proper functioning of the earthworm biology. Soil bed should be loose and porous. An important aspect of the functioning of ecological boxes can be the presence of additional fauna e.g. the population of

Enchytraeidae (white worms). Their large populations can slow down the growth of *E. fetida* because of the excretion of substances that are toxic to earthworms. That is why, despite large amounts of waste, earthworms can starve and consequently die when white worms are present in boxes (MAKULEC 1996). Earthworms prefer feed without the excretions of white worms. The number of earthworms was three times larger in waste without *Enchytraeidae's* excretion (KOSTECKA, ZABOROWSKA-SZARPAK 2001).

A serious problem of ecological boxes with a small volume of soil bed is the concentration of a breeding population which is too high. When this happens specimens have a negative effect on one another (the worsening of the conditions of earthworms and the lack of copulation) (KOSTECKA 2000). In such conditions the life strategy of earthworms means moving energy distribution from procreation towards growth (AIRA et al. 2007). Too high a concentration can lead to the predominance of male specimens which do not produce ova (*anisopary effect*) (MEYER, BOUWMAN 1997). Consequently such a process leads to the slowing down of the growth of a population as earthworms do not reproduce. Such an unfavorable process can be slowed down by reducing the amount of waste containing cellulose in the ratio 1:1/2 (KOSTECKA 2000).

Vermiculture and businesses

According to the principle of constant development, the knowledge of the environmental impact assessment (EIA) needs be considered as one of the most fundamental issues that should be known to owners and managers of large as well as small businesses. EIA refers to the localization of businesses, the realization of their aims, the exploitation of equipment and installation together with the functioning of the product or service provided. The pro-environmental management of businesses leads to the assessment of the impact that production/service processes have on the environment and then taking action in order to gradually reduce negative effects (e.g. reducing the volume of produced waste; putting less pressure on the environment owing to smaller electric and thermal energy consumption, using less water and producing less sewage; which reduce the emission of hazardous substances to the atmosphere and surface water).

The redirection of businesses towards pro-environmentalism often requires only small investment. Moreover, as far as waste management is concerned, businesses can reduce their ecological footprint by using vermiculture (Table 2).

Spreading the information about so many potential advantages of an ecological earthworm box may increase an interest in possessing one. The questionnaire conducted among random workers of Huta Stalowa Wola shows (KOSTECKA et al. 2007) that 63% of those questioned would agree to have an ecological box in their surroundings. Their preferences, as far as the location of a box is concerned, are presented in the Figure 2.

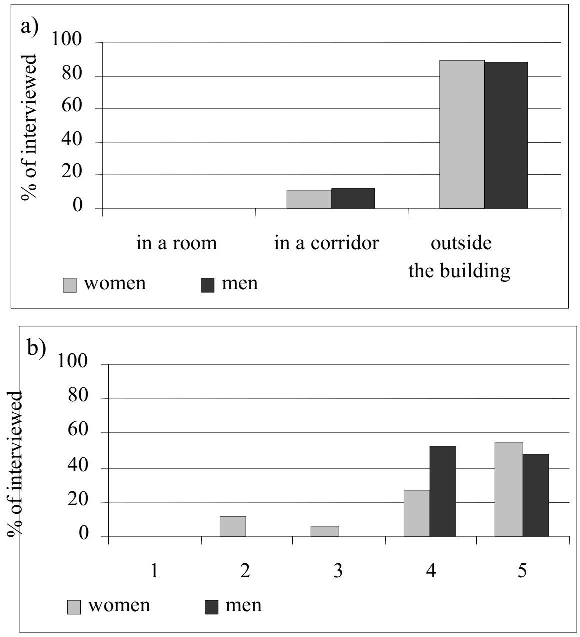
Those willing to have an ecological box would probably have to face a serious problem – the difficulties in finding a pedigree population. Nowadays the number of earthworm breeders has drastically decreased. The last inventory of vermiculture was conducted in the period of 1995-1997 and showed the disappearance of the vast majority of 209 farms (ROŚCISZEWSKA et al. 1998). Nowadays we know of only a few breeders with sizeable vermicultures. It seems, however, that they are able to expand their farms if interest in purchasing pedigree populations increases.

Table 2

Examples of actions that lead to the reduction of anthropogenic impact of businesses within the scope of waste management (including organic waste management) (based on KOSTECKA, KOSTECKI 2006, changed)

Sector	Actions which lead to the reduction of anthropogenic impact and to financial savings
WASTE mana-gement	-defining areas where it is possible to limit the production of waste, analyzing its amount and content in order to determine purchase policy (e.g. cleaning, office and food products), -the purchase of products (company supplies) in big or returnable packaging, -conducting the analysis of costs of packaging, -preparing a waste (materials) recycling programme, -reducing packaging of toilet articles, introducing soap dispensers, -reducing the amount of informative leaflets for clients and printing on recycled paper, -composting of organic wastes in a place where they are generated in „an ecological earthworm box"[a] (reducing the costs of having waste collected, producing vermicompost), -using electronic mail (the reduction of paper use).

a - based on Kostecka, 1999a, 2003



a) at a work place:
b) in household conditions: (1) at home (2) on a balcony (3) in a basement (4) at an allotment (5) in the garden
Source: KOSTECKA et al. 2007

Fig. 2. The preferences of the location of boxes with earthworms

Summary

Vermicomposting is one of the solutions to the problem of neutralizing organic waste. It can reduce the volume of waste at landfill sites and its negative impact on the environment due to the possibility of producing biowaste in places where waste is generated. Vermicomposting can also promote the idea of getting closer to nature. It also favours the sustainable waste management which results in economic savings on a home, local, regional, national continental and even World scale.

Vermiculture can be popularised in rural areas. It offers a successful transformation of household organic waste into fertilizer. Using vermicompost for vegetable crops allows the achievement of high biochemical value. It is also possible to use earthworms for biomass.

The topic of vermiculture should be included in education within the scope of ideas and problems concerning environmental engineering, the formation of the environment, environmental protection or sanitary engineering. It can also be useful in other courses. As the United Nations Decade of Education for Sustainable Development (2005-2014) has been announced, scientists should promote access to the aspects discussed above among a large number of students within the scope of a general subject or the humanities.

It also needs to be highlighted that due to the growing interest in pro-environmental actions and the popularization of the results of studies on vermiculture, taking further actions e.g. the economics of the vermiculture phenomenon, which is understood in broad terms, is justified and even required.

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