Possible Utilizations of Physical Waste Treatment Device

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Abstract

This article presents possibilities of a unique device for industrial waste treatment using a patented process, and outlines possible future directions. This device, using different physical processes, individually or in synergy, e.g. combined effects of ultrasonic waves, focused microwave field, arc discharges, electrostatic field and the exposure to ultra-violet radiation, is intended to degrade dangerous substances in waste, reducing its hazardous properties for the environment and to prepare the waste for future applications (material or energy).

Keywords: environment, waste, waste treatment, physical waste treatment, reducing hazardous properties

In our post-modern world with plurality of voices and their certain equalization, wherever we go, we find ourselves currently in an environment in the order of millions compounds [1]. These compounds are gradually getting into all environmental compartments. We try to design and product new substances and, at the end of their lifespan, either safely reuse or dispose them.

Waste treatment is nowadays mostly a demanding technological process directed to and achieving secondary raw materials. After processing, these raw materials are reused in production, that´s why they are today already very valued commercial commodity throughout world markets.

One of the waste treatment possibilities is a range of physical methods of treatment. Researchers from T. G. Masaryk Water Research Institute, p. r. i., Prague initiated in 2007–2011 the development of waste treatment device based on physical procedures within the project for Ministry of the Environment No. VaV SP/2f2/98/07 "Research on Waste Utilization as Substitutes for Primary Mineral Resources". Device concept has been registered as a utility model – file number: Int. 21084, Industrial Property Office on July 2, 2010 [2]. European patent No. EP 2388068 was granted to the device and method for physical waste treatment on August 22, 2014 [3].

Device and Method for Physical Waste Treatment – Field of Technique/Technology

Device for physical waste treatment (especially solid waste matrices) is conceptually based on single or selected joined – combined effect of selected force fields (microwave field, ultrasound, UV radiation, spark discharge, electrostatic field – non-thermal plasma and others, if applicable).

Technology Status-Quo

Currently force field generating devices are available or description of aggregate devices for generation of individual force fields are known. Ensuring a combined effect of more force fields on a matrix examined is difficult as commercially available appliances are mostly designed for precisely pre-defined purpose which prevents their interconnection in one assembly. Compilation and tuning of the combined device for physical treatment of materials from commercially available generators – force field sources – were not possible. In such assembly, only UV radiation source could have been potentially used, as it was generally commercially available and taken over as such to be used although after a little adjustment. Other individual force field generators had to be assembled individually with respect to intended multiple-alternative application – single or combined, from appropriate electronic parts (considering the performance, operating time – total time in use, price, etc.). Ultimate aim of the device is primarily to explore combinations of physical phenomena effects caused by force fields, optimally in superposition (synergistic effect).

Basis of Technical Solution

Proposed device for physical waste treatment is built from individual generators of physical force fields placed in a transparent box with weaved grounded Faraday cage with an opening/closing cover for manipulation. On the bottom of the box there is a loosely placed stool made of an electrically non-conductive material with a plastic container – vessel for inserting investigated matrix for sample exposure. Bottom of the container is made of a thick layer of plastic with very high electric resistance. An acceptably conductive metal mesh is loosely placed on the bottom of the container during the exposure to electrostatic field. Second metal mesh is either immersed in the sample above the container or loosely suspended above the sample. Both meshes are connected by an electric wire to a generator of electrostatic field – non-thermal plasma. UV radiator and spark discharge generator are carried by a carrier bridge with the movement function. Movement of the bridge is performed by an electric drive with a possibility to adjust the speed with 2-gear shifting mechanism and driving in two directions (forward and reverse). Arriving to the end of defined track, the bridge automatically shifts the direction by

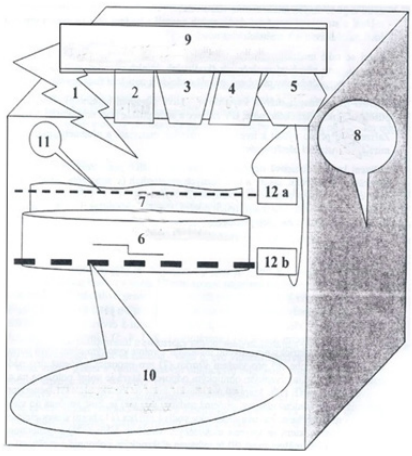

Fig. 1. Diagram of device for physical waste pre-treatment. 1,2,3,4,5- force field generators /spark discharge - high-temperature plasma, microwave field, ultrasound, UV radiation, electrostatic field - non-thermal plasma /, 6- plastic vessel (container for a sample), 7- sample investigated, 8 -Faraday cage, 9- carrier bridge, 10, 11-conductive metal mesh, 12a,b- HV supply cables

Rys. 1. Schemat urządzenia do wstępnego przetwarzania odpadów fizycznych. 1,2,3,4,5 – generatory pola siłowego /wyładowanie iskrowe – plazma wysokotemperaturowa, pole mikrofalowe, ultradźwięki, promieniowanie UV, pole elektrostatyczne - plazma nietermiczna/, 6 – pojemnik z tworzywa sztucznego (pojemnik na próbkę), 7 – badana próbka, 8 – klatka Faradaya, 9 – mostek nośny, 10, 11 – przewodząca metalowa siatka, 12a, b – kable zasilające WN

the end landing switches. Track length is mechanically adjustable. Exposure to spark discharge is performed by a spark gap which is located on the carrier bridge together with generator. Force field generators can operate simultaneously, in various sequential combinations or alone. Joint effect of electrostatic force field - non-thermal plasma plus spark discharge cannot be currently achieved (risk of damage to electronics by spark discharge). Diagram of device concept is outlined in Fig. 1.

Application

The device and method of physical waste treatment can be used separately or in an appropriate combination with other technologies and processes. Application of the device is aimed to reduce the content of less degradable, highly harmful pollutants, such as polyaromatic hydrocarbons (PAHs), persistent organic pollutants (POPs), such as PCB, xenobiotics, etc.

The device has been used in laboratory for its ability to reduce the levels of hazardous pollutants in selected types of waste to make them reusable - as a material (fertiliser or recultivation mixtures) and/or for energy (production of solid alternative multi-component composited fuels). For example, there were sludges from municipal and industrial wastewater treatment plants, paper mill sludges, plastics, wastes from coal treatment, wastes from food industry, etc.

Maximum decrease of the sum of 15 PAHs 43,92% has been shown in experiments with focused microwave field (MW), experiments with ultrasound exposure did not shown demonstrable decrease of PAHs content, with UV radiation the maximum decrease of the sum of 15 PAHs was 9,92%, with spark discharge the maximum decrease of the sum of 15 PAHs was 12,39%, with electrostatic field the maximum decrease of the sum of 15 PAHs was 45,07%. Interesting levels of degradation has been achieved also in adsorbable organic halogens (AOX), specifically persistent polychlorinated biphenyls (PCB) while using combined physical technologies of waste treatment. The level of degradation often depends on available performance of given equipment. Performance of generators of each force fields of the device was limited in funds available for the research of this area during project solution. The project has validated correctness of the concept and functionality of the device proposed by us.

Vision, designing and actual construction of the device was financially limited. Currently, optimisation and finalisation of the construction is being solved, in particular of the part designed for physical waste treatment by electrostatic field and SW concept for measurement and regulation. In this phase of device research and development, the work will include optimisation of power HV part and basic measurement with regulation, measurement of basic quality parameters of the process, measurement and regulation of additional process parameters, data transfer and visualisation. Device concept is retained; it will not be modified. The device will be only optimised in all aspects (performance, measurement, regulation, data archiving and transfer, visualisation).

During experimental work, selected generators of power field are currently used, i.e. generator of UV radiation, spark discharge, and electrostatic field – non-thermal plasma. Process of physical waste treatment is detailed in Figure 2.

If the intended final product of treated waste materials is an alternative fuel, it is necessary to create a formulation from identified, treated waste, to submit test specimens of alternative fuels to laboratory testing, and to select formulations and procedures for alternative fuel production.

In accordance with the most appropriate and prospective formulation, to prepare waste-based multicomponent composited alternative fuel. To homogenise required amount of fuel for validation combustion testing, to modify its shape for granules or pellets if needed. Minimum amount of fuel produced for combustion tests is given by its bulk density. Combustion testing for fuel certification must be always performed in an accredited laboratory. Figure 3 illustrates the preparation and testing of solid alternative multicomponent composite fuels.

The whole process of reusing selected types of waste (material or energy) has been carefully controlled by chemical analyses under toxicological and genotoxicological monitoring Project generated two special certified methodologies: “Methodology for group determination of phenols in sludge” and

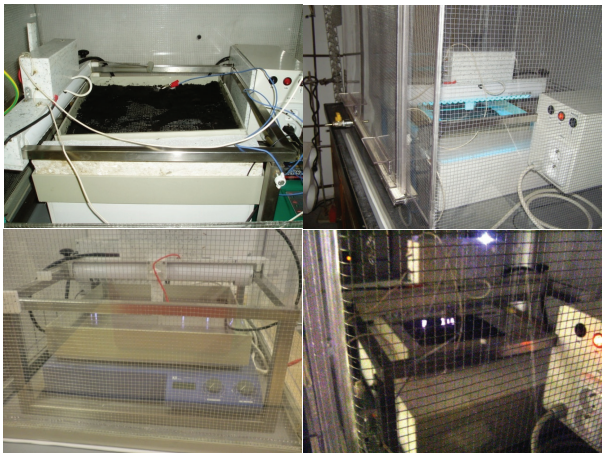

Fig. 2. Photographic evidence of the device for physical waste treatment – EP 2388068 (electrostatic field, spark discharge, UV radiation)
Rys. 2. Zdjęcia urządzenia do fizycznego przetwarzania odpadów – EP 2388068 (pole elektrostatyczne, wyładowanie iskrowe, promieniowanie UV)

Fig. 3. Photographic evidence – alternative multicomponent fuel based on fuels treated on the device for physical waste treatment as per EP 2388068 "Device for Physical Waste treatment" – homogenisation of components at the stage before granulation in cooperation with Czech Brown Coal Research Institute, Inc. (VÚHU a.s.) in Most, combustion testing on a certified testing equipment at VŠB – Technical University in Ostrava, examples of final granulated multicomponent solid alternative fuel
Rys. 3. Zdjęcia – alternatywne paliwo wieloskładnikowe na bazie paliw poddanych obróbce na urządzeniu do fizycznego przetwarzania odpadów zgodnie z patentem EP 2388068 „Urządzenie do fizycznego przetwarzania odpadów" – homogenizacja składników na etapie przed granulacją we współpracy z Czeskim Instytutem Węgla Brunatnego, Inc. (VÚHU as) w Most, testy spalania na certyfikowanym sprzęcie badawczym na VŠB – TU w Ostrawie, przykłady końcowego granulowanego wieloskładnikowego stałego paliwa alternatywnego

"Methodology for determination of genotoxic effects of substances in water treatment sludge using Ames Fluctuation Test".

Conclusions

Waste treatment leads to higher reuse, therefore new techniques and technologies are welcome and in the right time, also supported by companies, especially within their efforts at sustainable development.

Device for physical waste treatment (especially solid waste matrices) is conceptually based on single or selected joined – combined effect of selected force fields, either as an independent technology or in combination with other technologies. In this moment, the device is built as testing – laboratory equipment, with a perspective to become also industrial plant equipment after its optimisation and completion. The device can be used also as a special equipment for testing the resistance of materials to various combined effects of force fields and also as an equipment for cleaning or sanitation of newly produced compounds and materials.

Currently there is a cooperation with other research sites, in particular with deployed sites at universities, experimental testing of waste within equipment optimisation for users; negotiations are ongoing with the producers of testing laboratory and industrial technical equipment, as well as with professional waste management companies experienced in treatment of selected waste types for future use or safe disposal. We are constantly building a network of professional partners. For the patent commercialisation phase, a significant and strong strategic partner is sought - for further development, use and application of the device.

Thanks to all involved in this research and development project of waste utilisation as a substitution of primary natural sources, as well as to the Ministry of the Environment for their financial, professional and methodological support given throughout this project.

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Możliwość wykorzystania urządzeń do wzbogacania fizycznego odpadów

W artykule przedstawiono możliwości zastosowania unikalnego urządzenia do przemysłowego przetwarzania odpadów przy użyciu opatentowanego procesu oraz nakreślono możliwe przyszłe kierunki zastosowania. Przedstawione urządzenie, wykorzystuje różne procesy fizyczne, indywidualnie lub w synergii, np. połączone skutki fal ultradźwiękowych, skupionego pola mikrofalowego, wyładowań łukowych, pola elektrostatycznego i ekspozycji na promieniowanie ultrafioletowe. Celem jest degradacja zawartości niebezpiecznych substancji w odpadach, zmniejszenie ich niebezpiecznego oddziaływania na środowisko i przygotowanie odpadów do przyszłych zastosowań (odzysk materiałowy lub energetyczny).

Słowa kluczowe: środowisko, odpady, przetwarzanie odpadów, fizyczne przetwarzanie odpadów, zmniejszenie niebezpiecznych właściwości